Chandrayaan-2
Solar X-ray Monitor (XSM)

Data Products and Archive
Software Interface Specification

Version 1.1
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Document Data Sheet

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Abstract	:	This document provides the definition of XSM data products, PDS4 archive organization. It is meant to be a reference document for users of XSM data
Keywords	:	XSM, FITS, PDS4

Revision History

Version 0.5	10 Aug 2020	Initial version
Version 0.6	05 Oct 2020	Updated the data file formats, added CALDB file formats and some minor changes in PDS4 archive structure
Version 1.0	10 Dec 2020	First release version
Version 1.1	28 Jun 2021	Updated with details of xml label associated with zip file

Contents

1 Introduction

This Data Product and Archive Software Interface Specification for the Solar X-ray Monitor (XSM) instrument on-board the orbiter of Chandrayaan-2 mission describes the XSM data products, product file definition, generation of data products, and PDS4 archive organization. It provides the details of XSM data archived and disseminated from ISRO Science Data Archive (ISDA) at Indian Space Science Data Center (ISSDC). This document serves as a reference for scientists who intend to utilize the XSM data by providing them an overview of the instrument, data product definitions, etc. Some acronyms used in the document and a list of reference documents are given below.

Rest of this document is organized as follows. Section 2 provides a description of the XSM instrument, observation plan, and calibration. The data product definition and generation of products with XSM Data Analysis Software (XSMDAS) are described in section 3 and section 4 provides the organization of the XSM PDS4 archive and file nomenclature. Formats of the data products and sample XML label are provided in appendix.

1.1 Acronyms

XSM	Solar X-ray Monitor
FITS	Flexible Image Transport System
GTI	Good Time Interval
PHA	Pulse Height Analysis
XSMDAS	XSM Data Analysis Software
PDS	Planetary Data System
ISRO	Indian Space Research Organization
PRL	Physical Research Laboratory
POC	Payload Operations Centre
ISSDC	Indian Space Science Data Centre
ISDA	ISRO Science Data Archive
LID	Logical Identifier
VID	Version Identifier
SPICE	Spacecraft, Planet, Instrument, C-matrix, Events
UTC	Coordinated Universal Time
XML	Extensible Markup Language

1.2 Reference Documents

1. M. Shanmugam *et al.*, "Solar X-ray Monitor Onboard Chandrayaan-2 Orbiter", Current Science, 2020. DOI: 10.18520/cs/v118/i1/45-52 arXiv:1910.09231
2. N. P. S. Mithun *et al.*, "Solar X-ray Monitor On Board the Chandrayaan-2 Orbiter: In-flight Performance and Science Prospects", Solar Physics, 295 (139), 2020, DOI: 10.1007/s11207-020-01712-1 arXiv:2009.09759.
3. N. P. S. Mithun *et al.*, "Ground Calibration of Solar X-ray Monitor On Board the Chandrayaan-2 Orbiter", Experimental Astronomy, 2020, DOI: 10.1007/s10686-020-09686-5 arXiv:2007.07326.
4. N. P. S. Mithun *et al.*,"Data Processing Software for Chandrayaan-2 Solar X-ray Monitor", Astronomy and Computing (under review), 2020, arXiv:2007.11371.
5. Chandrayaan-2 Preliminary Design Review Data Products, Processing and Dissemination Plan - Volume 3C, June 2017.
6. XSM Data Analysis Software Software Requirement Specifications and Software Design Document, PRL/CH2/XSM/DAS/L12-SRS-SDD-V1.2, October 30, 2018.
7. Chandrayaan-2 Solar X-ray Monitor (XSM) Level-1, Level-2 Data Products Interface Control Document, PRL/CH2/XSM/DAS/L12ICD-V1.1, December 31, 2018.
8. Chandrayaan-2 Science data management and Archive plan, HRDPD, SAC, July 2018.
9. Planetary Data System Standards Reference, version 1.11.0, October 1, 2018.
10. Data Providers Handbook, Archiving Guide to the PDS4 Data Standards, version 1.11.0, October 1, 2018.
11. PDS4 Data Dictionary Document, Abridged, version 1.11.0.0, September 23, 2018.

2 Chandrayaan-2 Solar X-ray Monitor (XSM)

The orbiter of Chandrayaan-2, the second Indian lunar mission, includes a remote X-ray fluorescence spectroscopy experiment to obtain quantitative estimates of the elemental abundances on the lunar surface. This experiment has been realized with two instruments onboard the Chandrayaan-2 orbiter viz. (i) the *Chandrayaan-2 Large Area Soft X-ray Spectrometer* (CLASS), which measures the X-ray fluorescence from the elements on the lunar surface; and (ii) the *Solar X-ray Monitor* (XSM), which measures the spectrum of solar X-rays responsible for excitation of the elements on the lunar surface. From the strength of elemental lines obtained from the CLASS spectrum together with the incident solar spectrum inferred from the XSM, the quantitative estimates of abundances of constituent elements on the lunar surface can be derived. Apart from this, with unique characteristics such as the highest spectral resolution for a solar broadband soft X-ray spectrometer and the full resolution spectral measurement

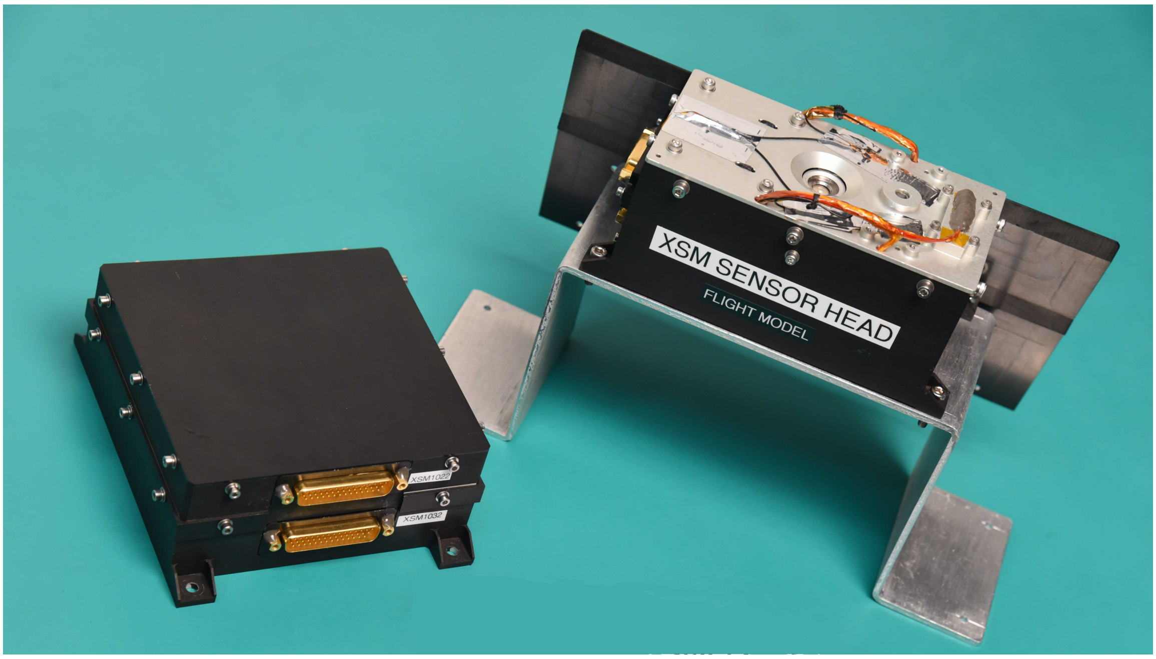

Figure 2.1: A photograph of the Chandrayaan-2 XSM instrument packages: (i) sensor package that houses the detector, front-end electronics, and filter wheel mechanism (right) ; (ii) processing electronics package that houses the FPGA based data acquisition system, power electronics, and spacecraft interfaces (left).

at every second, the XSM is also expected to provide significant contributions to enhance our understanding of the corona, the outer atmosphere of the Sun.

The Chandrayaan-2 spacecraft was launched by the GSLV MkIII-M1, on 22 July 2019. It reached its nominal circular orbit around the Moon in early September after several orbit maneuvers and the XSM began its nominal operations in lunar orbit from 12 September 2019. The detailed instrument description, ground calibration, observation plan, and in-flight performance of XSM are given in references 1 to 4 mentioned in the previous section. Relevant details from these are reproduced in this section.

2.1 Instrument Description

The XSM carries out spectral measurements of the Sun in soft X-rays with an energy resolution better than 180 eV (typically 175eV) at 5.9 keV. Major specifications of the XSM instrument are given in table 2.1, and a detailed description of the instrument design can be seen in Shanmugam *et al.*, 2020. Figure 2.1 shows a photograph of the XSM instrument which is configured as two packages: (i) a sensor package that houses the detector, front-end electronics, and a filter wheel mechanism; (ii) a processing electronics package that houses the FPGA based data acquisition system, power electronics, and spacecraft interfaces. The instrument is fix-mounted on the Chandrayaan-2 orbiter such that the spacecraft structures do not obstruct the instrument field of view (FOV). Figure 2.2 shows the mounting of XSM packages on the spacecraft and definitions of the spacecraft and instrument reference axes.

At the heart of the instrument is a Silicon Drift Detector (SDD). Its unique configuration of electrodes provides very low detector capacitance and, thereby, higher spectral resolution compared to other silicon-based detectors that work in a similar energy range. The SDD also

Table 2.1: Specifications of XSM

Parameter	Specification
Energy Range	1 – 15 keV (up to ~M5 class)
	2 – 15 keV (above ~M5 class)
Energy Resolution	< 180 eV @ 5.9 keV
Time cadence	1 second
Aperture area	0.367 mm^2
Field of view	±40 degree
Filter wheel mechanism properties	
Positions	3 (Open, Be-filter, Cal)
Filter wheel movement modes	Automated and Manual
Be-filter thickness	250 μm
Automated Be-filter movement threshold	80,000 $counts\ s^{-1}$ (~M5 class)
Calibration source	Fe-55 with Ti foil
Detector properties	
Type	Silicon Drift Detector (SDD)
Area	30 mm^2
Thickness	450 μm
Entrance Window	8μm thick Be
Operating temperature	-35° C
Electronics parameters	
Pulse shaping time	1 μs
Dead time	5 μs
Number of channels in the spectrum	1024
Mass	1.35 kg
Power	6 W

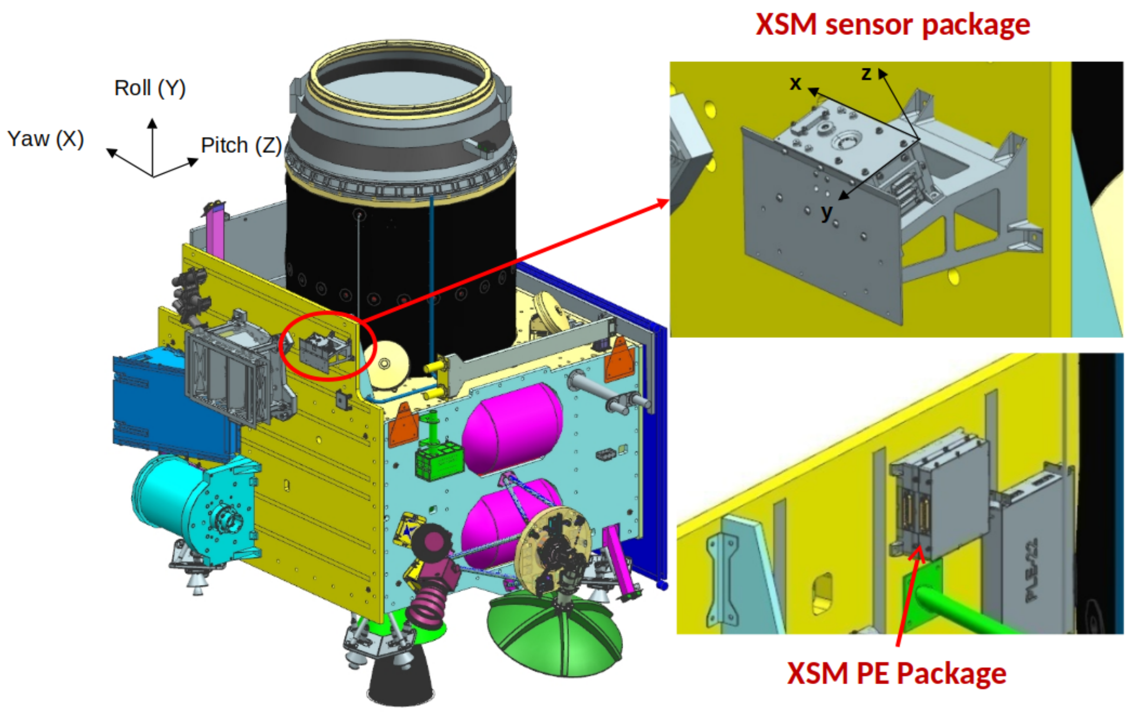

Figure 2.2: Schematic representation of Chandrayaan-2 orbiter showing the mounting location of the XSM sensor and processing electronics (PE) packages. The spacecraft reference frame axes, Yaw(X), Roll(Y), and Pitch(Z), are marked in the figure. The sensor package is mounted on the -pitch panel of the spacecraft with a canted bracket (20° from roll axis towards -pitch direction) to avoid any spacecraft structures obstructing its field of view. The PE package is mounted on the inner side of the -pitch panel. Axis definitions for the XSM instrument reference frame are marked on the sensor package. The XSM reference frame is obtained by a rotation of $-110°$ about the X-axis of the spacecraft frame.

has the ability to handle relatively higher incident flux. The detector, procured from KETEK GmbH, Germany, is available in the form of an encapsulated module containing a thermo-electric cooler (TEC), a FET, a temperature diode, and an 8 μm thick Beryllium entrance window. The detector has an active area of $\sim 30\ mm^2$ and a thickness of 450 μm.

X-ray photons incident on the SDD generate a charge cloud proportional to the deposited photon energy, which is collected at the anode of the detector. The front-end electronics that include a charge sensitive preamplifier and shaping amplifiers convert this charge to a voltage signal in the form of a semi-Gaussian pulse. The peak of this pulse is then detected by a peak detector and digitized by a 12-bit analog to digital converter (ADC). Histograms of the 10-bit ADC channels (ignoring the two least significant bits), where each channel is $\sim 16.5\ eV$ wide, are generated at an interval of one second and is recorded on-board. Apart from the complete spectrum with one-second cadence, the XSM also records light curves in three pre-defined, but adjustable (by ground command), energy intervals with a 100 ms time resolution. XSM processing electronics packetizes the spectral data every second along with the health parameters of the instrument, such as the detector temperature, current drawn by the TEC, and various voltage levels. These packets are sent to the spacecraft data handling system that records it after tagging it with the onboard clock time. Absolute time is assigned to each data packet during ground processing by the correlation between onboard clock time and Coordinated Universal Time (UTC) from the available real-time telemetry.

The spectral performance of the detector, defined by the energy resolution, depends on its temperature. In order to achieve the targeted resolution of better than 180 eV, the SDD temperature needs to be maintained at $\sim -35^oC$. Since the ambient temperature during the lunar orbit is expected to vary over a wide range between -30^oC to $+20^oC$, the XSM employs a closed-loop temperature control using the TEC that is part of the detector module, to maintain the detector at -35^oC. The hot end of the TEC is interfaced with a thermal radiator to radiate away the heat. There is also a provision to vary the set point of the detector temperature by ground command, in case such a requirement arises.

It is well known that the solar X-ray intensities vary over several orders of magnitude between quiet and active phases of a solar cycle. In the classification of solar flares based on the flux measured by the GOES 1–8 $\AA$ channel, the highest intensity X-class flares have five orders of magnitude higher flux than the lowest intensity A-class flares. A single X-ray spectroscopic detector cannot be sensitive enough to detect flares below A-class and, at the same time, does not saturate during large flares. Hence, the XSM includes a filter wheel mechanism mounted on the top cover of the sensor package that brings a 250 μm Beryllium filter in front of the detector during high-intensity flares. This additional Be filter increases the low energy cutoff and thereby reduces the incident rate. An onboard algorithm moves the filter wheel to the Be-filter position when the count rate is higher than the specified threshold for five consecutive intervals of 100 ms. A similar automated logic decides the movement of the filter wheel mechanism back to its open position. The threshold rate for movement to Be-filter position is nominally set to be 80,000 $counts\ s^{-1}$ (adjustable by ground command), which corresponds to ∼M5 class flare as discussed later.

The filter wheel also has an additional position where a calibration source is mounted. The calibration source used is 100 mCi activity Fe-55 nuclide covered with a 3 μm thick titanium foil. This source generates four mono-energetic lines: Mn-Kα and Mn-Kβ lines with energies of 5.9 keV and 6.49 keV, respectively, as well as Ti-Kα and Ti-Kβ lines of energies 4.5 and 4.93 keV, respectively. Spectral response and gain of the instrument can be monitored by acquiring the spectrum of this calibration source. The filter wheel mechanism can be brought to the calibration position by ground command for in-flight calibration as and when required.

As the spacecraft attitude configuration is dictated by the requirement of observation of the Moon by other instruments and other mission operation constraints, the Sun's position varies with respect to the bore-sight of the XSM. Hence, in order to maximize the duration of observation of the Sun, the XSM is designed with a large field of view of 40° half cone angle. An aluminium collimator (or detector cap) with a thickness of 0.5 mm placed over the detector provides this wide field of view and, at the same time, restricts the aperture area such that the count rate remains within the instrument capability over a wide range of incident solar X-ray intensities. The collimator aperture of $\sim 0.7\ mm$, much smaller in comparison to the detector diameter of $\sim 6.18\ mm$, defines the instrument's geometric entrance area. As aluminium with thickness 0.5 mm is transparent to X-rays above $\sim 8\ keV$, the collimator is coated with 50 μm of silver on both sides to block X-rays up to 15 keV arriving from outside the XSM FOV. The coating on the bottom of the cap also ensures that the aluminium fluorescence lines from the cap do not reach the detector.

2.2 Observation Plan

During the nominal operation phase, the attitude of the Chandrayaan-2 spacecraft is such that the yaw direction always points to the Moon (see figure 2.2 for the axis definition). All Moon-viewing instruments are mounted with their bore-sights in the yaw direction. Thus the spacecraft attitude is not fixed in the inertial reference frame. However, the orbital plane is fixed with respect to the inertial reference frame, and this results in different orientation of the orbital plane with respect to the Sun giving rise to the orbital seasons: 'dawn-dusk' (D-D) and 'noon-midnight' (N-M), as shown in figure 2.3. The attitude of the spacecraft (other than yaw axis) is maintained according to these orbital seasons to optimize power generation. During the three months of D-D season surrounding the day when the orbital plane is perpendicular to the Moon-Sun vector, the spacecraft attitude is such that Sun is maintained in a yaw-roll plane. In this season, continuous observations of the Sun with XSM are possible. In the N-M season covering three months around the day when the Sun vector lies in the orbital plane of the spacecraft, the spacecraft attitude follows the orbital reference frame, and the Sun does not remain within the FOV of XSM for the entire orbit. Nominally, the XSM is expected to operate at all times when the Sun is within the FOV of the instrument.

During the three months of the 'dawn-dusk' season (D-D), XSM observes the Sun almost continuously. At the beginning and the end of this season, there are short durations ($\sim 20 - 30$ minutes per ~ 120 minute orbit) of occultation of the Sun by Moon, which vanishes as the D-D day approaches. During the ~ 30 day period around the D-D day, XSM has almost uninterrupted observations of the Sun. Apart from the occultation period, there can be very short periods (~ 10 minutes per orbit, a couple of times a day) of operation of other instruments on the spacecraft during which Sun is out of the field of view of XSM. During the 'noon-midnight' season (N-M), XSM has a much lower cadence of observations. In the initial and last $\sim$20 days of the season, the attitude definition is such that the Sun is completely out of the field of view of XSM, and hence no observations are available during this time. After the initial $\sim$20 days, the Sun enters into the FOV of XSM with an exposure time of few minutes that increases up to ~ 25 minutes per orbit until the N-M day. After the N-M day, exposure per orbit starts decreasing, and the Sun is not in FOV for the last $\sim$20 days of the season.

2.3 Ground and In-flight Calibration

In order to infer the incident solar spectrum from the XSM observations, the instrument's spectral response needs to be calibrated. This spectral response matrix is then to be used in the analysis procedure along with the observed spectrum. Several dedicated ground calibration experiments were carried out to determine the gain parameters of the XSM under various observing conditions of ambient temperature and Sun angle, the spectral redistribution function of the detector, and the effective area as a function of incident angle. These measurements were used to derive the on-ground estimate of the response matrix. A detailed description of ground calibration aspects of XSM is presented in Mithun *et al.* (2020, *Exp. Astr.*). The parameters

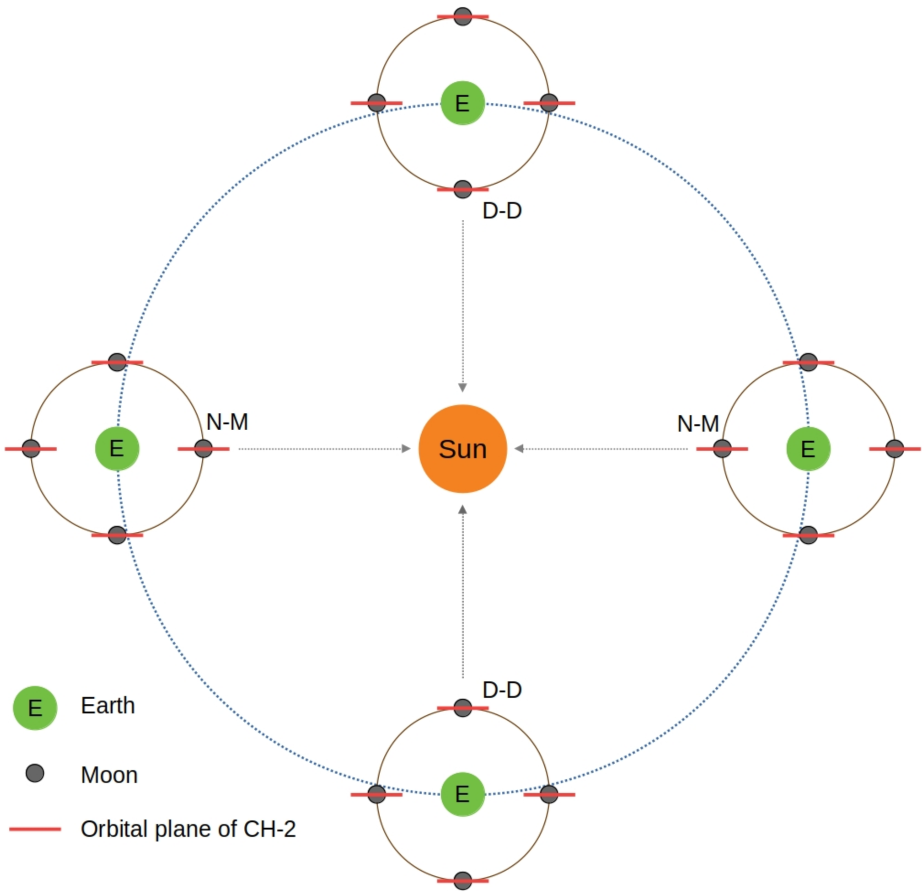

Figure 2.3: Orbital seasons for Chandrayaan-2 spacecraft: 'dawn-dusk' (D-D) and 'noon-midnight' (N-M). On 'dawn-dusk' day, the orbital plane is perpendicular to the Moon-Sun vector, and on 'noon-midnight' day, it is parallel. The attitude of the spacecraft is defined differently during the three month seasons around both these days, as described in the text.

derived from calibration experiments are included in the form a calibration database, which is utilized by the XSM Data Analysis Software.

Further, the ground calibration gain and spectral redistribution parameters were validated with the in-flight observations of the calibration source. The on-ground estimate of the effective area was refined using the in-flight observations of the quiet Sun at different incidence angles. Details on the aspects of in-flight performance and calibration of XSM are provided in Mithun *et al.* (2020, *Sol. Phy.*).

3 XSM Data Products

In this section, the data products of XSM included in the archive are defined. Processing level and content of the XSM data archive as well an overview of the generation of these data products with XSM Data Analysis Software (XSMDAS) at the Payload Operations Center (POC) are described here. More details on the data analysis software and POC processing is available in

Mithun *et al.* (2020, *Astronomy & Computing*).

3.1 Data Processing Level Definition

XSM archive includes two levels of data: designated as raw and calibrated as per the PDS4 nomenclature. The raw data include the files with raw instrument data frames and auxiliary information and calibrated data files include standard science level products. Both the levels of data are organized into files for each day of observation. The raw and calibrated data are also designated with level numbers of 1 and 2, respectively. The data product level definition is summarized in the table below.

PDS4 level	XSM level	Description
Raw	1	Raw payload data with aux organized day-wise
Calibrated	2	Calibrated day-wise standard products

Table 3.1: XSM data processing level definitions

3.2 XSM Data Products

The daily data set of the XSM includes a maximum of six data product files with three each of raw and calibrated files. If, on a particular day of observation, there were no periods when the XSM observed the Sun, there will be no calibrated data for that day and there will be only the science data, hk, and sun angle files under raw directory.

All products of XSM are in FITS format and each product file is associated with an PDS4 XML label file which contain the metadata. These XML labels include details such as a unique logical identifier to the data set, observation details, the revision history of the data set, and the structure of the respective FITS data file. This allows tools like PDS4viewer[1] to parse, display, and plot the data from the FITS files.

The contents of raw and calibrated data files of XSM are briefly described below. Format of the raw and calibrated FITS files are given in appendix-B and appendix-C, respectively.

3.2.1 Raw Data

Raw data of XSM includes three files as listed below:

(i) Science data file (*.fits): It tabulates the raw XSM data frames and the respective UTC, Mission Elapsed Time (MET), DH clock time, and XSM clock time.

(ii) HK parameter file (*.hk): Various housekeeping parameters and instrument settings decoded from the data are provided as a function of time.

(iii) Sun angle file (*.sa): This file includes various geometry parameters for the observation duration, such as the polar and azimuthal angles of the Sun, the FOV and occult flags, and the projected radial position of the Sun on the XSM detector.

[1] `http://sbndev.astro.umd.edu/wiki/PDS4_Viewer`

3.2.2 Calibrated Data

Calibrated data of XSM includes three files as listed below:

(i) GTI file (*.gti): This file provides the good time intervals from the default processing that excludes durations when Sun is out of FOV or occulted, any of the instrument parameters not within the desired range, and the times when data is not available. Each GTI is recorded as a row in the two-column table listing start and end time of the interval in MET.

(ii) Spectrum file (*.pha): Standard spectrum file included in the XSM archive contains time-series spectra (in type-II PHA format) with a time bin size of one second, where the counts are scaled to on-axis observations. Each row of the binary table records the start and end times, the spectrum, statistical and systematic errors.

(iii) Light curve file (*.lc): The standard light curve provided is for a time bin size of one second integrating counts over the full energy range of XSM (excluding the ULD events). Count rate corrected for the instantaneous effective area as a function of time is tabulated in this file.

3.3 Data Flow and Processing Overview

XSM data from the Chandrayaan-2 spacecraft downloaded to the ground stations undergo pre-processing at ISSDC. The raw frames downloaded from the spacecraft at the ground stations contain data from all instruments that were operated during that session. The data from different instruments are segregated during the first stage of ground pre-processing. In the next step of level-0 processing at ISSDC, each of the segregated XSM data packets with the Data Handling (DH) system header is assigned the corresponding UTC stamp based on the DH clock time. Correlation between DH clock time and UTC is derived from real-time telemetry samples correcting for the transmission delay and other factors.

Analysis and interpretation of the instrument science data require other auxiliary information like the orbit and attitude of the spacecraft during the observation. This auxiliary information derived from the spacecraft telemetry data and orbit determination are provided in the form of SPICE kernels of orbit, attitude, and clock information for the duration of the instrument data. The instrument data packets with the UTC stamps in a binary (.pld) file along with this auxiliary information as SPICE kernels constitute the 'level-0' data files of XSM for each download session. It may be noted that the successive downloads, in general, will have an overlap of data in order to ensure continuity.

Higher levels of processing to generate the raw and calibrated data products of XSM for archival from this level-0 data set is carried out at the XSM Payload Operations Center (POC) at PRL. The level-0 data is downloaded at the POC and subsequent processing is done with the XSM Data Analysis Software (XSMDAS). The XSMDAS generates raw and calibrated data files organized as files corresponding to each day of observation from all the available level-0 data sets for the given day. After the generation of data products (both raw and calibrated) and validation, they are sent to ISSDC for dissemination to the users.

3.4 XSMDAS: XSM Data Analysis Software

The XSM Data Analysis Software (XSMDAS) is designed to process the level-0 data to level-1 (raw) and level-2 (calibrated) data products. It is composed of individual modules that cater to specific functionality and is meant to be used by the scientific users for the analysis of XSM data. All calibration information of the XSM required for the analysis are included in a calibration database (CALDB) described in the next section, which is used by the XSMDAS modules.

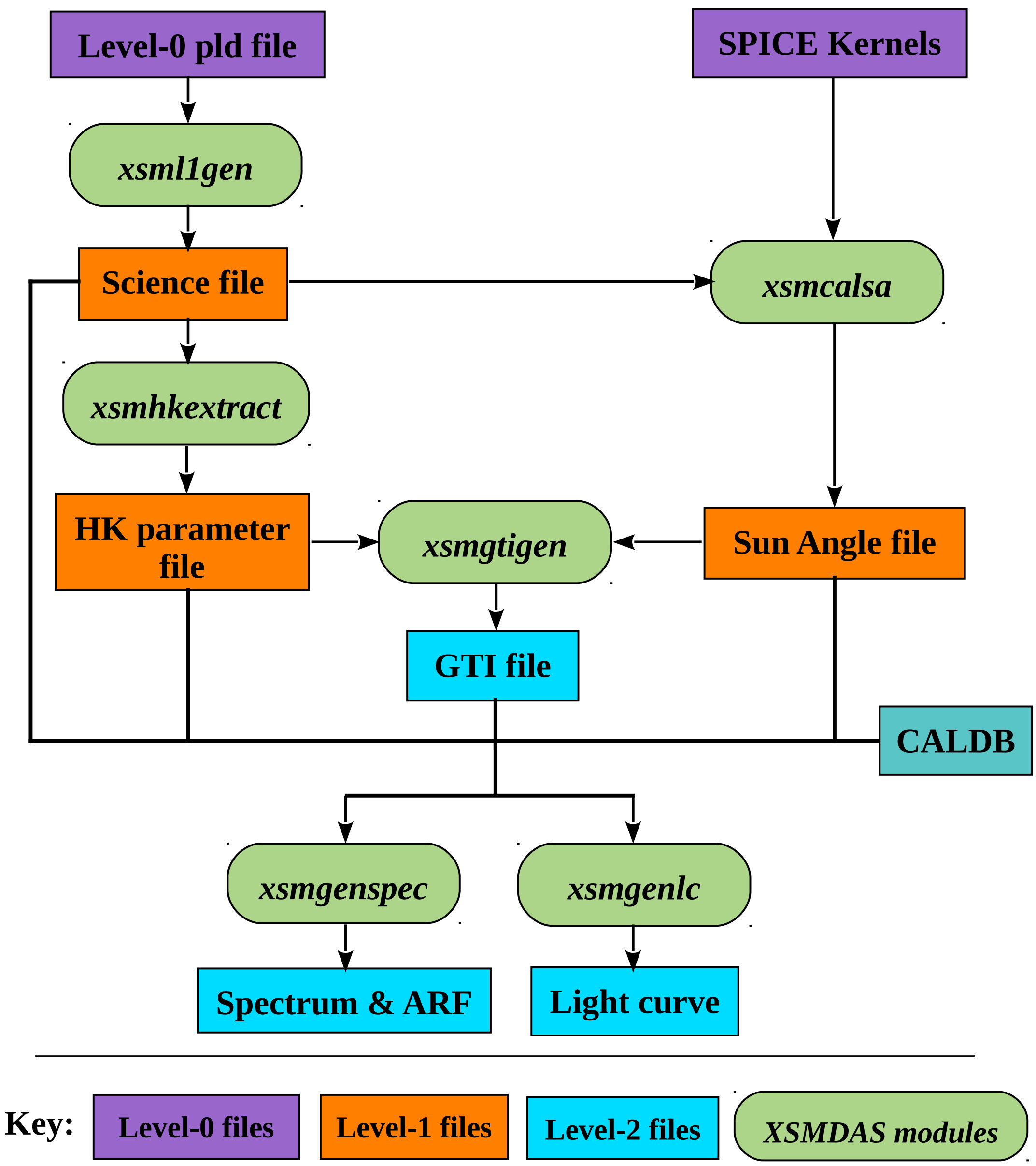

Figure 3.1: Work flow of the XSM Data Analysis Software (XSMDAS) showing its modules and their input and output files.

Figure 3.1 shows the flowchart of the XSMDAS where individual modules and their input and output files are shown. The modules that generate level-1 files do not have any user-configurable parameters and also do not use any calibration information. Hence, these are executed only at the POC to generate level-1 data files, which are to be made available to the users. On the other hand, the modules for generating level-2 science products require various user inputs as well as the calibration data and hence the users may need to execute these modules with specific inputs to meet their requirements. Thus, these modules of XSMDAS are made available, along with the first release of data sets from ISDA. Subsequent revisions of the software, if necessary, will also be provided from time to time.

XSMDAS is composed of eight modules; three each for the generation of level-1 and level-2 data products and two additional modules for adding spectra and generating XML labels corresponding to the data product files. A brief description of the algorithm employed and the available options for all the modules are given below. A complete list of user input parameters is given in the user guide distributed along with the software. Help files can also be accessed with the *xsmhelp* command.

A. Modules for level-0 to level-1 processing

1. *xsml1gen*: Combines raw payload data frames corresponding to one day of observation from multiple level-0 files and generates a single FITS file, ignoring corrupted frames, if any.

2. *xsmhkextract*: Extracts the house keeping parameters of XSM from the header of the data frames and creates a table with these parameters.

3. *xsmcalsa*: Using SPICE kernels with the orbit, attitude, and clock information of the spacecraft and other auxiliary information, computes the instantaneous angle subtended by the Sun vector with respect to the instrument bore-sight for the time stamps correponding to level-1 science file generated by *xsml1gen*. It utilizes user-level application program interfaces provided with the SPICE toolkit. A FITS table with the polar (θ) and azimuthal (ϕ) angles of the Sun with respect to XSM instrument reference frame (see figure 2.2) is the output of this module.

B. Modules for level-1 to level-2 processing

1. *xsmgtigen*: Creates good time intervals (GTI) during which the observations are useful for scientific analysis based on the house keeping parameters and the Sun angle parameters. This module also provides a provision to incorporate additional user-defined GTIs.

2. *xsmgenlc*: Generates the light curve from the level-1 data for a specified energy range, correcting for the effective area variation with angle. The generated light curves gives count rates for on-axis observations with XSM. There is an option to generate a light curve for any energy range with a time bin size as multiples of one second and to generate a light curve for the three pre-defined coarse energy ranges with a time bin size in multiples of 100 ms.

3. *xsmgenspec*: Generates the gain corrected 512 channel PI spectrum from the raw 1024 channel PHA spectral data for the required duration. The output can be either a time-integrated spectrum (type-I PHA file) or a time series of spectra (type-II PHA file) with

a specified time bin size. For each PI channel, apart from the counts, statistical errors computed from Poisson distribution and systematic errors from the ground calibration are also recorded in the spectrum file. Ancillary response file (ARF) corresponding to the spectrum incorporating the effective area is also generated along with the spectrum.

C. Additional modules

1. *xsmpds4gen*: This module generated the PDS4 XML label associated with each data product file. It reads the FITS product file and generates the respective XML label using the appropriate template XML file. The attributes that had placeholder values are replaced with the actual values based on the contents of the FITS file.

2. *xsmaddspec*: This tool provides the facility to add together multiple spectrum files generated by *xsmgenspec* to create a single spectrum output. The module takes care of the propagation of statistical and systematic errors of the channel-wise counts while adding the spectra together. It also combines the ancillary response files that correspond to the individual spectra and provide an output ARF file to be used with the added spectrum.

3.5 XSM Calibration Database (CALDB)

Various calibration parameters such as gain, spectral redistribution, and effective area, which are required for the analysis of XSM data, are derived from extensive ground calibration experiments. These data are stored in a set of FITS files that form the calibration database (CALDB) of XSM, which is accessed by the XSMDAS modules to generate the products. The XSM CALDB design follows a philosophy similar to the HEASARC's CALDB system[2] meant for X-ray astronomy missions. Each aspect of calibration data is stored in individual FITS file BINTABLE extensions with appropriate structure. In case of any update in a particular calibration data, a new file with the same format as the previous one is included in the new release while retaining the old versions. A calibration index file (FITS format) included in each CALDB release keeps a record of the file names with the latest calibration data of each type and includes the names of older versions of the same data with their quality flag marked as bad. The index file also defines the validity start and end time for each file, thus allowing multiple good files of the same type valid over a different range of times. This is particularly useful if some of the calibration parameters (e.g., gain) varies over the mission duration and different set of values are to be used for observations at different times.

With such a design of the CALDB system, the calibration file names are not hard-coded in the software. XSMDAS accesses the index file of the CALDB and identifies the appropriate calibration data file based on the observation time of the data being processed. This allows updates of the CALDB without any updates in the data analysis software unless there is a change in format or addition of new types of calibration files. The XSM CALDB includes six types of calibration files other than the calibration index file, the contents of which are briefly described below.

[2] `https://heasarc.gsfc.nasa.gov/docs/heasarc/caldb/caldb_intro.html`

(i) Gain: This file includes the gain and offset of the XSM over a grid of TEC current and interaction position in the detector.

(ii) Effareapar: This file includes the parameters required for the computation of effective area, defined over an x-y grid of position of the Sun in the field of view of XSM.

(iii) RMF: Redistribution Matrix File defining the spectral redistribution function in Pulse Invariant (PI) channels over a grid of incident energies.

(iv) RSP: Response files including redistribution and on-axis effective area for use with area scaled spectra. Two such files where one correponds to without Be filter and the other with Be filter.

(v) Syserror: Channel-wise systematic errors to be included in the spectrum are recorded in this file.

(vi) Ebounds: This file defines the nominal energy range for the PI channel definition.

(vii) Abscoef: This file includes the X-ray absorption coefficients of materials that form the entrance window (Be), dead layer (SiO_2), and the detector (Si) obtained from NIST.

The XSM CALDB is also made available during the data release. Further updates in the calibration if any would also be released as subsequent versions of the CALDB.

4 XSM PDS4 Archive Organization

The archival of data from payloads of Chandrayaan-2 follow PDS4 standard. PDS4 information model 1.11.0.0 is adopted for generation of archive of all instrument data sets including XSM. For XSM, the POC will create instrument archive bundle in PDS4 compliant format, which will be uploaded to ISSDC for archival. In this section, the mission level archive organization, XSM bundle structure and collections, nomenclature, and dissemination plan are discussed.

4.1 Mission Level Archive Organization

Figure 4.1 shows the mission level archive organization. Under isda archive, mission (ch2), and instrument host orbiter (cho) directories are included. Under the orbiter directory, context products and applicable xml schema files are stored. The instrument bundles are organized under the respective mission operation phase, primarily the normal operation phase (nop). Like xsm, directories of other instruments with the respective bundle are placed under nop directory.

The context directory includes the context products as defined in the PDS4 data provider's manual. Context products for the mission, instrument host or the orbiter, and all instruments are included. Each of them is an XML file with a unique LID which includes description of the respective component like mission or instrument. Data and other products in the archive are referenced to these context products by referring to their LIDs in the product labels. LIDs for the context products of Chandrayaan-2 mission, Chandrayaan-2 orbiter, and XSM are listed below:

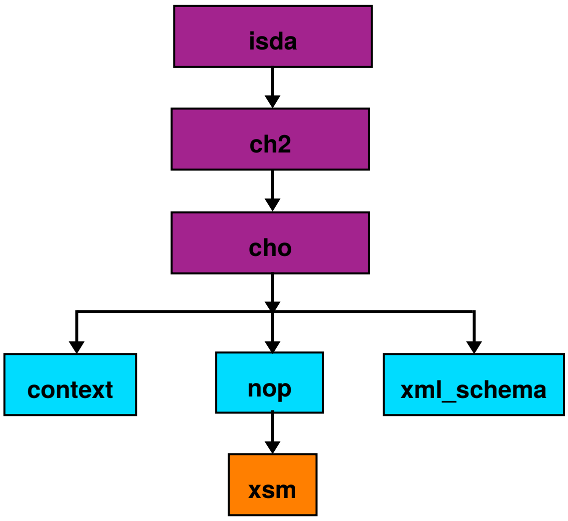

Figure 4.1: Mission level archive organization

- urn:isro:isda:context:investigation:mission.chandrayaan2
- urn:isro:isda:context:instrument_host:spacecraft.ch2orbiter
- urn:isro:isda:context:instrument:xsm.ch2orbiter

The XML schema directory includes the applicable XML schemas for the PDS4 labels in the archive.

4.2 XSM Instrument Bundle

All data products and other products such as documents related to XSM are included in an instrument bundle. The XSM instrument bundle then includes multiple collections for each type of products like data, document, calibration, and miscellaneous. Figure 4.2 shows the organization of individual collections under the xsm instrument bundle.

The data collection includes day-wise raw and calibrated data products and labels of XSM. Documents related to XSM data are included as document collection and calibration collection has the required calibration information. The XSMDAS is included under the miscellaneous collection. The instrument level bundle and association to collections are defined in the bundle_xsm.xml file under the main instrument directory. For easy reference, a readme file with the bundle organization is also included there. Details of the contents under each collection is given in the next section.

4.2.1 LID Definition

Every product in a PDS archive is assigned with a unique logical identifier (LID). The products also have a version identifier (VID) so that multiple versions of the same product can be uniquely identified. LIDs are defined following the standards defined in the PDS4 data provider's handbook and the Chandrayaan-2 archive conventions.

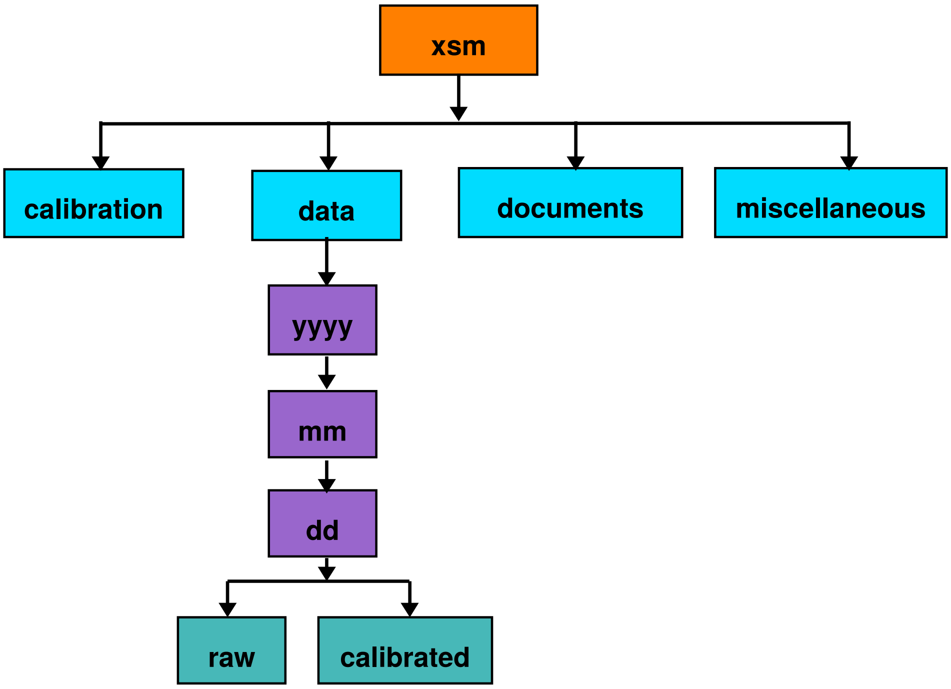

Figure 4.2: XSM instrument bundle organization

In the case of XSM, the LIDs for the instrument bundle, collections, and basic products are defined as per the below convention:

- **Bundle LID:** The bundle LID for XSM is defined as
  `urn:isro:isda:ch2_cho.xsm`
  where `ch2_cho.xsm` is the unique bundle id.
- **Collection LID:** These are formed by appending the collection id to the bundle LID defined above. Each collection under the XSM bundle has a unique id and is defined in table 4.1.
- **Product LID:** LIDs for basic products are formed by appending the unique product id to the collection's LID as:
  urn:isro:isda:ch2_cho.xsm:<collection_id>:<product_id>
  The <product_id> for each type of products in the collections are defined in the next section.

4.3 XSM Bundle Collections

This section provides the details of contents in each of the collections in the XSM bundle. Apart from the products and labels, each collection directory also include one inventory csv file with the LIDs of all products present in the collection and an XML file that defines

Collection	LID	Contents
data	urn:isro:isda:ch2_cho.xsm:data	Raw and calibrated data products
document	urn:isro:isda:ch2_cho.xsm:document	Documents associated with XSM data products
calibration	urn:isro:isda:ch2_cho.xsm:calibration	XSM calibration database
miscellaneous	urn:isro:isda:ch2_cho.xsm:miscellaneous	XSM Data Analysis Software

Table 4.1: LID definition for XSM bundle collections

the collection. These files are named as collection_<collection_id>_inventory.csv and collection_<collection_id>_inventory.xml, respectively.

4.3.1 Data collection

Figure 4.3 shows the product files which are included in the data collection. Apart from the FITS product files (formats in appendix), each of them will have an associated PDS4 label file and each product is assigned with a unique product ID. Nomenclature of these files, label files, and product ID definition is given below.

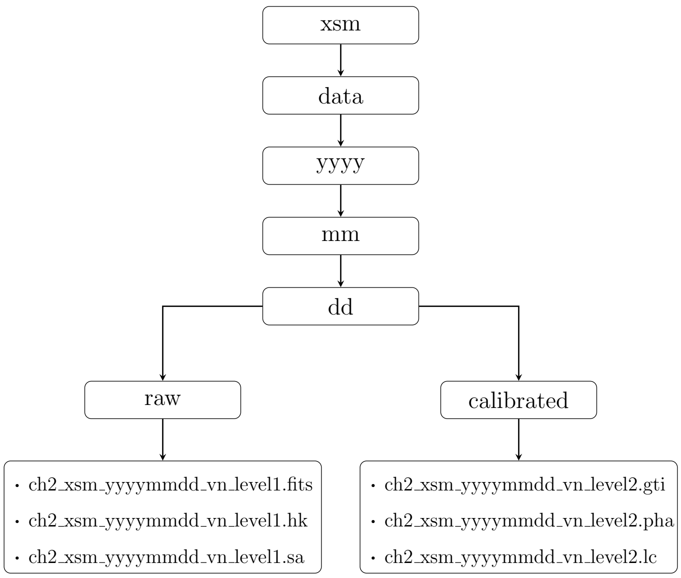

Figure 4.3: XSM data collection contents

Nomenclature of product files and labels and product ID

XSM raw (level-1) and calibrated (level-2) products have the following scheme of nomenclature:

ch2_xsm_yyyymmdd_vx_leveln.extn

Field	Description
yyyymmdd	Date of observation (only one set of files per day, hence no time field)
x	Version number of the file starting from 1. It will increment on successive reprocessing (if required)
n	Denotes level of data product - either 1 or 2
extn	Extension denoting the type of product as defined in table 4.3

Table 4.2: Definition of fields in XSM file nomenclature

File type	Data level	extn	<product_id>
Science data file	raw	fits	raw_ch2_xsm_yyyymmdd_level1_fits
HK parameter file	raw	hk	raw_ch2_xsm_yyyymmdd_level1_hk
Sun angle file	raw	sa	raw_ch2_xsm_yyyymmdd_level1_sa
GTI file	calibrated	gti	calibrated_ch2_xsm_yyyymmdd_level2_gti
Spectrum file	calibrated	pha	calibrated_ch2_xsm_yyyymmdd_level2_pha
Light curve file	calibrated	lc	calibrated_ch2_xsm_yyyymmdd_level2_lc

Table 4.3: Definition of extensions and product id for each product file types defined in previous section.

with the fields defined in table 4.2.

As the archive follows PDS4 standard, each data product file mentioned above require an associated PDS4 XML label which provides information of the data product including the organization of data in the file. Names of these XML files follows below scheme:

Label file Name: `ch2_xsm_yyyymmdd_vx_leveln_extn.xml`

which will be the label file for product named `ch2_xsm_yyyymmdd_vx_leveln.extn`. Each product also has a unique product ID which is used in the generation of LID for the product as defined in previous section. These product ID definitions are given in table 4.3.

4.3.2 Document Collection

The document collection includes relevant documents related to the XSM data products and analysis. At present, the directory includes XSM data products and archive software interface specifications, this document, and a user guide to XSM Data Analysis Software. Both the documents are in PDF format and have an associated XML label file with the same base name. The product IDs are same as the base name of the document files.

4.3.3 Calibration Collection

Calibration collection includes the XSM Calibration Database (CALDB) as a compressed zip file. The zip file contains calibration data files in FITS format as explained in a previous section. This CALDB is required for analysis of XSM data with XSMDAS. There is also an XML label file associated with the zip file.

4.3.4 Miscellaneous Collection

Under this collection, presently, a zip package of the XSM Data Analysis Software (XSMDAS) and the respective label file are included. It is the source code distribution of the software for users. Installation instructions and usage details are present within the package in form of readme files and help files. These details are also given in the user guide present in the document collection.

4.4 Data Dissemination and Utilization

XSM data will be archived at ISSDC along with data of other instrument of the Chandrayaan-2 mission. XSM data will be disseminated using a web interface named PRADAN at the following link:

`https://pradan.issdc.gov.in/pradan/`

Users will have to create account in this web portal to view and download the publicly available data sets. There will be provision to select available XSM data for any day of observation and download the zip file of the day-wise archive of the data collection.

The zip file for daily archive of XSM data collection has the following name where symbols have the same meaning as that for names of product files:

Name: **ch2_xsm_yyyymmdd_vx.zip**

When uzipped, this file generates the following directory structure with root directory being xsm.

```
xsm/
   data/
       yyyy/
           mm/
             dd/
               raw/
                     Raw data products and labels
               calibrated/
                     Calibrated data products and labels
```

Associated with each zip file, an xml file is also provided, which can be viewed by clicking on the corresponding column in the data products given in PRADAN. Important details from the XML label such as the total exposure time and sun exposure time are given as separate columns in PRADAN. In addition, the file also provides details on the level-0 data files used to generate the particular daywise level-1 and level-2 product. The version numbers at the end of the level-0 file names signify whether they were generated with pre-OD or post-OD orbit data. Generally, all the data sets use post-OD level-0 data which will have M.1 version numbers with

M=1,2,3, etc. However, if the post-OD data is not available for a given data dump, pre-OD file is used which has a version number of 0.1. It may be noted that as the geometry parameters relevant to the scientific analysis of XSM are found to be not at all affected by whether pre-OD or post-OD orbit is used, this has no impact on the scientific analysis of XSM data. These details are provided only for the sake of completeness and unformity as the differences between pre and post OD products may be more signficant for other payloads on Chandrayaan-2 that are observing the Moon.

Rest of the XSM bundle collections: calibration, document, and miscellaneous will be hosted separately on PRADAN as compressed files for the users under other downloads section.

All the XSM data files can be read by using the FITS libraries available with most of the programming languages like IDL and python for visualization or to carry out further analysis. Spectrum and response files of XSM are compatible with the X-ray astronomy spectral fitting software tools XSPEC[1] and ISIS[2]. The spectra can be directly loaded into them following the standard procedures to carry out spectral fitting with physical or empirical models. OSPEX[3] is another software that is widely used in the solar physics community for X-ray spectral fitting. It is an IDL-based package available as part of Solarsoft. The calibrated spectrum product file provided in the archive can be loaded in OSPEX with an IDL routine `ch2xsm_read_data.pro` provided along with the XSM Data Analysis Software. Refer the XSM Data Analysis Guide for more details.

[1] https://heasarc.gsfc.nasa.gov/xanadu/xspec/
[2] https://space.mit.edu/cxc/isis/
[3] https://hesperia.gsfc.nasa.gov/ssw/packages/spex/doc/ospex_explanation.htm

Appendix

A Contact Information

For any queries related to XSM data products please contact XSM Payload Operations Center (POC) at xsmpoc@prl.res.in.

Name	Address	Email
Prof. Santosh Vadawale	Principal Investigator XSM, PRL Ahmedabad	santoshv@prl.res.in
Dr. M. Shanmugam	Deputy Project Director XSM, PRL Ahmedabad	shansm@prl.res.in
Mr. Mithun N. P. S.	XSM Payload Operations Center, PRL Ahmedabad	mithun@prl.res.in

For queries related to download of XSM data, please contact ISSDC team at issdc@istrac.gov.in.

B Raw Data File Format

As mentioned earlier all raw data products of XSM are in FITS file format, and are binary tables. The format of each of the raw data files are provided here. Note that, in archive each of these product file will be accompanied by a PDS4 XML label file.

B.1 Science file

Name

BASENAME_level1.fits

File format

```
SIMPLE  =                    T / file does conform to FITS standard
BITPIX  =                   16 / number of bits per data pixel
NAXIS   =                    0 / number of data axes
EXTEND  =                    T / FITS dataset may contain extensions
COMMENT   FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT   and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH-2_ORBITER'       / Name of mission/satellite
INSTRUME= 'CH2_XSM '           / Name of Instrument/detector
ORIGIN  = 'PRLPOC  '           / Source of FITS file
```

```
CREATOR = 'xsml1gen '          / Creator of file
FILENAME= 'ch2_xsm_20190917_v0_level1.fits' / Name of file
CONTENT = 'L1 Science file'    / File content
DATE    = '2020-08-19T12:41:12' / Creation Date
XSMDASVE= '1.06    '           / Version of XSMDAS that created this file
END

XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                 2108 / width of table in bytes
NAXIS2  =                86400 / number of rows in table
PCOUNT  =                    0 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                    7 / number of fields in each row
TTYPE1  = 'Time    '           / MET Since 2017-01-01 00:00:00 UTC
TFORM1  = 'D       '           / data format of field: 8-byte DOUBLE
TTYPE2  = 'UTCString'          / UTC String
TFORM2  = '30A       '         / data format of field: String
TTYPE3  = 'FrameNumber'        / label for field
TFORM3  = 'J       '           / data format of field: 4-byte INTEGER
TTYPE4  = 'BDHTime '           / label for field
TFORM4  = 'D       '           / data format of field: Double
TTYPE5  = 'XSMTime '           / label for field
TFORM5  = 'D       '           / data format of field: Double
TTYPE6  = 'DataArray'          / label for field
TFORM6  = '2048B       '       / data format of field: BYTE ARRAY
TTYPE7  = 'DecodingStatusFlag' / label for field
TFORM7  = 'I       '           / data format of field: 2-byte INTEGER
TUNIT1  = 's       '           / physical unit of field 1
EXTNAME = 'DATA    '           / name of this binary table extension
DATE-OBS= '2019-09-17 00:00:00.864800000' / Date observation start
DATE-END= '2019-09-17 23:59:59.650700000' / Date observation end
TSTART  =        85449600.8648 / Start Time
TSTOP   =        85535999.6507 / Stop Time
TIMESYS = 'UTC     '           / Time system
MJDREF  =               57754. / MJD reference
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH-2_ORBITER'       / Name of mission/satellite
INSTRUME= 'CH2_XSM '           / Name of Instrument/detector
ORIGIN  = 'PRLPOC  '           / Source of FITS file
CREATOR = 'xsml1gen '          / Creator of file
XSMDASVE= '1.06    '           / Version of XSMDAS that created this file
```

```
EXTVER  =                    1 / auto assigned by template parser
FILENAME= 'ch2_xsm_20190917_v0_level1.fits'
DATE    = '2020-08-19T12:41:12'
TELAPSE =     86398.7858999968
```

B.2 House Keeping (HK) Parameter file

Name

BASENAME_level1.hk

File format

```
SIMPLE  =                    T / file does conform to FITS standard
BITPIX  =                   16 / number of bits per data pixel
NAXIS   =                    0 / number of data axes
EXTEND  =                    T / FITS dataset may contain extensions
COMMENT   FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT   and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH-2_ORBITER'       / Name of mission/satellite
INSTRUME= 'CH2_XSM '           / Name of Instrument/detector
ORIGIN  = 'PRLPOC  '           / Source of FITS file
CREATOR = 'xsmhkextract '      / Creator of file
FILENAME= 'ch2_xsm_20190917_v0_level1.hk' / Name of file
CONTENT = 'HK data '           / File content
DATE    = '2020-08-19T12:41:14' / Creation Date
XSMDASVE= '1.06    '           / Version of XSMDAS that created this file
END

XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                  140 / width of table in bytes
NAXIS2  =                86400 / number of rows in table
PCOUNT  =                    0 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                   38 / number of fields in each row
TTYPE1  = 'Time    '           / label for field   1
TFORM1  = '1D      '           / data format of field: Double
TTYPE2  = 'UTCString'          / UTC String
TFORM2  = '30A      '          / data format of field: String
TTYPE3  = 'FPGATime'           / XSM PE FPGA Clock time
TFORM3  = '1D      '           / data format of field
```

```
TTYPE4  = 'FrameNo  '           / Frame Number
TFORM4  = '1J       '           / data format of field
TTYPE5  = 'SyncLW   '           / Sync Word LW
TFORM5  = '1J       '           / data format of field
TTYPE6  = 'SyncUW   '           / Sync Word UW
TFORM6  = '1J       '           / data format of field
TTYPE7  = 'EventCounter'        / Event trigger count
TFORM7  = '1J       '           / data format of field
TTYPE8  = 'EventDetected'       / Event detected count
TFORM8  = '1J       '           / data format of field
TTYPE9  = 'RampCounter'         / Ramp counter
TFORM9  = '1I       '           / data format of field
TTYPE10 = 'HVMonitor'           / HV Monitor
TFORM10 = '1E       '           / data format of field
TTYPE11 = 'DetTemperature'      / Detector Temperature
TFORM11 = '1E       '           / data format of field
TTYPE12 = 'TECCurrent'          /  TEC Current monitor
TFORM12 = '1E       '           / data format of field
TTYPE13 = 'LV1Monitor'          /  LV1 (+3.3V) Monitor
TFORM13 = '1E       '           / data format of field
TTYPE14 = 'LV2Monitor'          /  LV2 (+1.5V) Monitor
TFORM14 = '1E       '           / data format of field
TTYPE15 = 'LLDRefVoltage'       /  LLD Reference Voltage
TFORM15 = '1E       '           / data format of field
TTYPE16 = 'TECRefVoltage'       /  TEC Reference Voltage
TFORM16 = '1E       '           / data format of field
TTYPE17 = 'MotorControlMode'    / 0-Auto;1-Manual;2-ForceStep
TFORM17 = '1B       '           / data format of field
TTYPE18 = 'MotorOperationMode'  / 0-IR;1-Counter;2-Step
TFORM18 = '1B       '           / data format of field
TTYPE19 = 'MotorSetPos'         / 0-Open;1-Cal;2-Be
TFORM19 = '1B       '           / data format of field
TTYPE20 = 'MotorIRPos'          / 0-Open;1-Cal;2-Be
TFORM20 = '1B       '           / data format of field
TTYPE21 = 'IRPowerStatus'       / 0-ON; 1-OFF
TFORM21 = '1B       '           / data format of field
TTYPE22 = 'FrameDiscardFlag'    / 1- Motor moving
TFORM22 = '1B       '           / data format of field
TTYPE23 = 'MotorAutoTime'       / Autmovement sampling time(ms)
TFORM23 = '1B       '           / data format of field
TTYPE24 = 'StepModeDir'         / Direction 0-clock;1-anticlock
TFORM24 = '1B       '           / data format of field
TTYPE25 = 'WindowLowerThresh'   / Lower threshold for movement
```

```
TFORM25 = '1J      '           / data format of field
TTYPE26 = 'WindowUpperThresh'  / Upper threshold for movement
TFORM26 = '1J      '           / data format of field
TTYPE27 = 'PileupRejMode'      / 0-OFF; 1-ON (default)
TFORM27 = '1B      '           / data format of field
TTYPE28 = 'PileupRejTime'      / 5us/10us
TFORM28 = '1B      '           / data format of field
TTYPE29 = 'GuardBits'          / Guardbits should be zero
TFORM29 = '1I      '           / data format of field
TTYPE30 = 'Ch1Start'           / Coarse channel 1 start
TFORM30 = '1I      '           / data format of field
TTYPE31 = 'Ch1Stop '           / Coarse channel 1 stop
TFORM31 = '1I      '           / data format of field
TTYPE32 = 'Ch2Start'           / Coarse channel 2 start
TFORM32 = '1I      '           / data format of field
TTYPE33 = 'Ch2Stop '           / Coarse channel 2 stop
TFORM33 = '1I      '           / data format of field
TTYPE34 = 'Ch3Start'           / Coarse channel 3 start
TFORM34 = '1I      '           / data format of field
TTYPE35 = 'Ch3Stop '           / Coarse channel 3 stop
TFORM35 = '1I      '           / data format of field
TTYPE36 = 'CoarseChEvents'     / Total events in Coarse Ch LC
TFORM36 = '1J      '           / data format of field
TTYPE37 = 'SpecEvents'         / Total events in spectrum
TFORM37 = '1J      '           / data format of field
TTYPE38 = 'ULDEvents'          / Events in last channel
TFORM38 = '1J      '           / data format of field
TUNIT1  = 's       '           / physical unit of field
TUNIT3  = 's       '           / physical unit of field
TUNIT10 = 'V       '           / physical unit of field
TUNIT11 = 'V       '           / physical unit of field
TUNIT12 = 'V       '           / physical unit of field
TUNIT13 = 'V       '           / physical unit of field
TUNIT14 = 'V       '           / physical unit of field
TUNIT15 = 'mV       '          / physical unit of field
TUNIT16 = 'mV       '          / physical unit of field
TUNIT23 = 'ms       '          / physical unit of field
TUNIT28 = 'us       '          / physical unit of field
EXTNAME = 'HKPARAM  '          / name of this binary table extension
DATE-OBS= '2019-09-17 00:00:00.864800000' / Date observation start
DATE-END= '2019-09-17 23:59:59.650700000' / Date observation end
TSTART  =        85449600.8648 / Start Time
TSTOP   =        85535999.6507 / Stop Time
```

```
TIMESYS = 'UTC     '           / Time system
MJDREF  =               57754. / MJD reference
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH-2_ORBITER'       / Name of mission/satellite
INSTRUME= 'CH2_XSM '           / Name of Instrument/detector
ORIGIN  = 'PRLPOC  '           / Source of FITS file
CREATOR = 'xsmhkextract '      / Creator of file
XSMDASVE= '1.06    '           / Version of XSMDAS that created this file
EXTVER  =                    1 / auto assigned by template parser
FILENAME= 'ch2_xsm_20190917_v0_level1.hk'
DATE    = '2020-08-19T12:41:14'
TELAPSE =     86398.7858999968
```

B.3 Sun Angle (SA) file

Name

BASENAME_level1.sa

File format

```
SIMPLE  =                    T / file does conform to FITS standard
BITPIX  =                   16 / number of bits per data pixel
NAXIS   =                    0 / number of data axes
EXTEND  =                    T / FITS dataset may contain extensions
COMMENT   FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT   and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH-2_ORBITER'       / Name of mission/satellite
INSTRUME= 'CH2_XSM '           / Name of Instrument/detector
ORIGIN  = 'PRLPOC  '           / Source of FITS file
CREATOR = 'xsmcalsa     '      / Creator of file
FILENAME= 'ch2_xsm_20190917_v0_level1.sa' / Name of file
CONTENT = 'Sun Angle'          / File content
DATE    = '2020-08-19T12:41:22' / Creation Date
XSMDASVE= '1.06    '           / Version of XSMDAS that created this file
END

XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                   38 / width of table in bytes
NAXIS2  =                86400 / number of rows in table
PCOUNT  =                    0 / size of special data area
```

```
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                   10 / number of fields in each row
TTYPE1  = 'Time    '           / label for field   1
TFORM1  = '1D      '           / data format of field: Double
TTYPE2  = 'Theta   '           / Polar Angle of Sun wrt XSM
TFORM2  = '1E      '           / data format of field
TTYPE3  = 'Phi     '           / Azimuthal Angle of Sun wrt XSM
TFORM3  = '1E      '           / data format of field
TTYPE4  = 'FovFlag '           / 0-Out of FOV ;1- In FOV
TFORM4  = '1B      '           / data format of field
TTYPE5  = 'OccultFlag'         / 0-Not occult ;1- Occult
TFORM5  = '1B      '           / data format of field
TTYPE6  = 'DetPosR '           / Radial Position of Sun in SDD
TFORM6  = '1E      '           / data format of field
TTYPE7  = 'RamAngle'           / Ram angle b/w velocity & boresight
TFORM7  = '1E      '           / data format of field
TTYPE8  = 'RA      '           / RA of boresight
TFORM8  = '1E      '           / data format of field
TTYPE9  = 'DEC     '           / DEC of boresight
TFORM9  = '1E      '           / data format of field
TTYPE10 = 'AngRate '           / Rate of change of theta
TFORM10 = '1E      '           / data format of field
TUNIT1  = 's       '           / physical unit of field
TUNIT2  = 'degree  '           / physical unit of field
TUNIT3  = 'degree  '           / physical unit of field
TUNIT6  = 'mm      '           / physical unit of field
TUNIT7  = 'degree  '           / physical unit of field
TUNIT8  = 'degree  '           / physical unit of field
TUNIT9  = 'degree  '           / physical unit of field
TUNIT10 = 'degree/s'           / physical unit of field
EXTNAME = 'SUNANG  '           / name of this binary table extension
DATE-OBS= '2019-09-17 00:00:00.864800000' / Date observation start
DATE-END= '2019-09-17 23:59:59.650700000' / Date observation end
TSTART  =        85449600.8648 / Start Time
TSTOP   =        85535999.6507 / Stop Time
TIMESYS = 'UTC     '           / Time system
MJDREF  =               57754. / MJD reference
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH-2_ORBITER'       / Name of mission/satellite
INSTRUME= 'CH2_XSM '           / Name of Instrument/detector
ORIGIN  = 'PRLPOC  '           / Source of FITS file
CREATOR = 'xsmcalsa '          / Creator of file
XSMDASVE= '1.06    '           / Version of XSMDAS that created this file
```

```
EXTVER  =                    1 / auto assigned by template parser
FILENAME= 'ch2_xsm_20190917_v0_level1.sa'
DATE    = '2020-08-19T12:41:22'
TELAPSE =     86398.7858999968
```

C Calibrated Data File Format

Similar to raw files, calibrated products are also FITS binary tables. The format of each of the calibrated data files are provided here. Note that, in archive each of these product file will be accompanied by a PDS4 XML label file as discussed earlier.

C.1 Good Time Interval (GTI) file

Name

BASENAME_level2.gti

File format

```
SIMPLE  =                    T / file does conform to FITS standard
BITPIX  =                   16 / number of bits per data pixel
NAXIS   =                    0 / number of data axes
EXTEND  =                    T / FITS dataset may contain extensions
COMMENT   FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT   and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH-2_ORBITER'       / Name of mission/satellite
INSTRUME= 'CH2_XSM '           / Name of Instrument/detector
ORIGIN  = 'PRLPOC  '           / Source of FITS file
CREATOR = 'xsmgtigen '         / Creator of file
FILENAME= 'ch2_xsm_20190917_v0_level2.gti' / Name of file
CONTENT = '        '           / File content
DATE    = '2020-08-19T12:41:26' / Creation Date
XSMDASVE= '1.06    '           / Version of XSMDAS that created this file
END

XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                   16 / width of table in bytes
NAXIS2  =                   15 / number of rows in table
PCOUNT  =                    0 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
```

```
TFIELDS =                    2 / number of fields in each row
TTYPE1  = 'START   '           / label for field   1
TFORM1  = 'D       '           / data format of field: 8-byte DOUBLE
TTYPE2  = 'STOP    '           / label for field   2
TFORM2  = 'D       '           / data format of field: 8-byte DOUBLE
TUNIT1  = 's       '           / physical unit of field
TUNIT2  = 's       '           / physical unit of field
EXTNAME = 'GTI     '           / name of this binary table extension
DATE-OBS= '2019-09-17 00:00:00.864800000' / Date observation start
DATE-END= '2019-09-17 23:59:59.650700000' / Date observation end
TSTART  =        85449600.8548 / Start Time
TSTOP   =        85536000.6407 / Stop Time
TIMESYS = 'UTC     '           / Time system
MJDREF  =               57754. / MJD reference
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH-2_ORBITER'       / Name of mission/satellite
INSTRUME= 'CH2_XSM '           / Name of Instrument/detector
ORIGIN  = 'PRLPOC  '           / Source of FITS file
CREATOR = 'xsmgtigen '         / Creator of file
XSMDASVE= '1.06    '           / Version of XSMDAS that created this file
EXTVER  =                    1 / auto assigned by template parser
FILENAME= 'ch2_xsm_20190917_v0_level2.gti'
DATE    = '2020-08-19T12:41:26'
TELAPSE =     86399.7858999968
EXPOSURE=     86385.7862000018
OBSEXP  =               86400.
```

C.2 Spectrum file

Name

BASENAME_level2.pha

File format

```
SIMPLE  =                    T / file does conform to FITS standard
BITPIX  =                   16 / number of bits per data pixel
NAXIS   =                    0 / number of data axes
EXTEND  =                    T / FITS dataset may contain extensions
COMMENT   FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT   and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH-2_ORBITER'       / Name of mission/satellite
INSTRUME= 'CH2_XSM '           / Name of Instrument/detector
```

```
ORIGIN  = 'PRLPOC  '           / Source of FITS file
CREATOR = 'xsmgenspec '        / Creator of file
FILENAME= 'ch2_xsm_20190917_v0_level2.pha' / Name of file
CONTENT = 'Type II PHA file'   / File content
DATE    = '2020-08-19T12:41:32' / Creation Date
XSMDASVE= '1.06    '           / Version of XSMDAS that created this file
END

XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                 8221 / width of table in bytes
NAXIS2  =                86246 / number of rows in table
PCOUNT  =                    0 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                    9 / number of fields in each row
TTYPE1  = 'SPEC_NUM'           / PI Channel
TFORM1  = '1J      '           / format of field: int
TTYPE2  = 'CHANNEL '           / Vector of spectral bin numbers.
TFORM2  = '512J    '           / format of field
TTYPE3  = 'COUNTS  '           / Counts array (a spectrum)
TFORM3  = '512E    '           / format of field
TTYPE4  = 'STAT_ERR'           / Statistical uncertainty (error) on counts colum
TFORM4  = '512E    '           / format of field
TTYPE5  = 'SYS_ERR '           / Systematic Error (Fractional)
TFORM5  = '512E      '         / data format of field
TTYPE6  = 'EXPOSURE'           / Statistical uncertainty (error) on counts colum
TFORM6  = '1D      '           / format of field
TTYPE7  = 'TSTART  '           / Start time of spectrum
TFORM7  = '1D      '           / format of field
TTYPE8  = 'TSTOP   '           / Stop time of spectrum
TFORM8  = '1D      '           / format of field
TTYPE9  = 'FILT_STATUS'        / Filter status
TFORM9  = '1B      '           / format of field
EXTNAME = 'SPECTRUM'           / name of this binary table extension
DATE-OBS= '2019-09-17 00:00:00.864800000' / Date observation start
DATE-END= '2019-09-17 23:59:59.650700000' / Date observation end
TSTART  =        85449600.8647 / Start Time
TSTOP   =        85535999.8647 / Stop Time
TIMESYS = 'UTC     '           / Time system
MJDREF  =               57754. / MJD reference
CONTENT = 'SPECTRUM'
HDUCLASS= 'OGIP    '
```

```
HDUCLAS1= 'SPECTRUM'
HDUCLAS2= 'TOTAL   '
HDUCLAS3= 'COUNT   '
HDUCLAS4= 'TYPE:II '
HDUCLAS5= 'TG      '
HDUVERS = '1.2.0   '
HDUVERS1= '1.2.0   '
LONGSTRN= 'OGIP 1.0'           / The OGIP Longstring convention may be used
AREASCAL=                   1.
BACKSCAL=                   1.
CORRSCAL=                   1.
BACKFILE= 'none    '           / Background file
RESPFILE= 'CH2xsmrspwitharea_open20191214v01.rsp' / RMF file
ANCRFILE= '        '           / Ancillary response file
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH-2_ORBITER'       / Name of mission/satellite
INSTRUME= 'CH2_XSM '           / Name of Instrument/detector
ORIGIN  = 'PRLPOC  '           / Source of FITS file
CREATOR = 'xsmgenspec '        / Creator of file
DETCHANS=                  512
POISSERR=                    F / Error in stat_err column
TLMIN1  =                    0
TLMAX1  =                  511
XSMDASVE= '1.06    '           / Version of XSMDAS that created this file
EXTVER  =                    1 / auto assigned by template parser
FILENAME= 'ch2_xsm_20190917_v0_level2.pha'
DATE    = '2020-08-19T12:41:32'
CHANTYPE= 'PI      '
TELAPSE =               86399.
```

C.3 Light curve file

Name

BASENAME_level2.lc

File format

```
SIMPLE  =                    T / file does conform to FITS standard
BITPIX  =                   16 / number of bits per data pixel
NAXIS   =                    0 / number of data axes
EXTEND  =                    T / FITS dataset may contain extensions
COMMENT   FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT   and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
```

```
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH-2_ORBITER'       / Name of mission/satellite
INSTRUME= 'CH2_XSM '           / Name of Instrument/detector
ORIGIN  = 'PRLPOC  '           / Source of FITS file
CREATOR = 'xsmgenlc '          / Creator of file
FILENAME= 'ch2_xsm_20190917_v0_level2.lc' / Name of file
CONTENT = 'Light curve'        / File content
DATE    = '2020-08-19T12:41:43' / Creation Date
XSMDASVE= '1.06    '           / Version of XSMDAS that created this file
END

XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                   20 / width of table in bytes
NAXIS2  =                86329 / number of rows in table
PCOUNT  =                    0 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                    4 / number of fields in each row
TTYPE1  = 'TIME    '           / label for field   1
TFORM1  = 'D       '           / data format of field: 8-byte DOUBLE
TTYPE2  = 'RATE    '           / label for field   2
TFORM2  = 'E       '           / data format of field: 4-byte REAL
TTYPE3  = 'ERROR   '           / label for field   3
TFORM3  = 'E       '           / data format of field: 4-byte REAL
TTYPE4  = 'FRACEXP '           / label for field   4
TFORM4  = 'E       '           / data format of field: 4-byte REAL
TUNIT1  = 's       '           / physical unit of field
TUNIT2  = 'count/s '           / physical unit of field
TUNIT3  = 'counts/s'           / physical unit of field
EXTNAME = 'RATE    '           / name of this binary table extension
DATE-OBS= '2019-09-17 00:00:00.864800000' / Date observation start
DATE-END= '2019-09-17 23:59:59.650700000' / Date observation end
TSTART  =        85449600.8638 / Start Time
TSTOP   =        85536000.6497 / Stop Time
TIMESYS = 'UTC     '           / Time system
MJDREF  =               57754. / MJD reference
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH-2_ORBITER'       / Name of mission/satellite
INSTRUME= 'CH2_XSM '           / Name of Instrument/detector
ORIGIN  = 'PRLPOC  '           / Source of FITS file
CREATOR = 'xsmgenlc '          / Creator of file
HDUCLASS= 'OGIP    '           / OGIP Standard
```

```
HDUCLAS1= 'LIGHTCURVE'
HDUCLAS2= 'TOTAL   '           / total lc
TIMESYS = 'UTC      '          / Time measured from
TIMEREF = 'LOCAL   '           / reference time
TIMEUNIT= 's       '           / unit for time keywords
TELAPSE =     86399.7858999968 / elapsed time
TIMEDEL =                   1. / delta time
CHSTART =                    0 / PHA channel start
CHSTOP  =                    0 / PHA channel stop
XSMDASVE= '1.06    '           / Version of XSMDAS that created this file
EXTVER  =                    1 / auto assigned by template parser
FILENAME= 'ch2_xsm_20190917_v0_level2.lc'
DATE    = '2020-08-19T12:41:43'
```

D CALDB File Format

D.1 Index file

```
SIMPLE  =                    T / file does conform to FITS standard
BITPIX  =                   16 / number of bits per data pixel
NAXIS   =                    0 / number of data axes
EXTEND  =                    T / FITS dataset may contain extensions
COMMENT   FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT   and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH-2_ORBITER'       / Name of mission/satellite
INSTRUME= 'CH2_XSM '           / Name of Instrument/detector
CHECKSUM= '4nB951B941B941B9'   / HDU checksum updated 2020-08-19T07:01:28
DATASUM = '         0'         / data unit checksum updated 2020-08-19T07:01:28
END

XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                  140 / width of table in bytes
NAXIS2  =                    8 / number of rows in table
PCOUNT  =                    0 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                    5 / number of fields in each row
TTYPE1  = 'CAL_CNAM'           / label for field   1
TFORM1  = '20A     '           / data format of field: ASCII Character
TTYPE2  = 'CAL_FILE'           / label for field   2
```

```
TFORM2  = '40A     '           / data format of field: ASCII Character
TTYPE3  = 'REF_TIME'           / label for field   3
TFORM3  = 'D       '           / data format of field: 8-byte DOUBLE
TTYPE4  = 'CAL_QUAL'           / label for field   4
TFORM4  = 'I       '           / data format of field: 2-byte INTEGER
TTYPE5  = 'CAL_DESC'           / label for field   5
TFORM5  = '70A     '           / data format of field: ASCII Character
EXTNAME = 'CIF     '           / name of this binary table extension
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH2_ORBITER'        / Name of mission/satellite
INSTRUME= 'XSM     '           / Name of Instrument/detector
HDUCLASS= 'OGIP    '           / OGIP Standard
LONGSTRN= 'OGIP 1.0'           / The OGIP Long String Convention may be used
ORIGIN  = 'PRL     '           / Origin of FITS file
CREATOR = 'xsmcaldbgen'        / Software that created the FITS file
VERSION = '1       '           / Version number
FILENAME= 'xsmcaldb.indx'      / File name
CONTENT = 'CIF FILE'           / File content
```

D.2 Gain file

```
SIMPLE  =                    T / file does conform to FITS standard
BITPIX  =                   16 / number of bits per data pixel
NAXIS   =                    0 / number of data axes
EXTEND  =                    T / FITS dataset may contain extensions
COMMENT   FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT   and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH-2_ORBITER'       / Name of mission/satellite
INSTRUME= 'CH2_XSM '           / Name of Instrument/detector
CHECKSUM= '3rBA5oA83oAA3oA7'   / HDU checksum updated 2020-04-03T05:18:41
DATASUM = '         0'         / data unit checksum updated 2020-04-03T05:18:41
END

XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                   16 / width of table in bytes
NAXIS2  =                 3910 / number of rows in table
PCOUNT  =                    0 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                    4 / number of fields in each row
TTYPE1  = 'TEC_CURRENT'        / label for field   1
```

```
TFORM1  = 'E       '           / data format of field: 4-byte REAL
TTYPE2  = 'DETPOSR '           / label for field   2
TFORM2  = 'E       '           / data format of field: 4-byte REAL
TTYPE3  = 'GAIN    '           / label for field   3
TFORM3  = 'E       '           / data format of field: 4-byte REAL
TTYPE4  = 'OFFSET  '           / label for field   4
TFORM4  = 'E       '           / data format of field: 4-byte REAL
EXTNAME = 'GAIN    '           / name of this binary table extension
NTEC    =                  115
NRAD    =                   34
HIERARCH TECBINSIZE =     0.02
HIERARCH RADBINSIZE =      0.1
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH2_ORBITER'        / Name of mission/satellite
INSTRUME= 'XSM     '           / Name of Instrument/detector
HDUCLASS= 'OGIP    '           / OGIP Standard
LONGSTRN= 'OGIP 1.0'           / The OGIP Long String Convention may be used
ORIGIN  = 'PRL     '           / Origin of FITS file
CREATOR = 'xsmcaldbgen'        / Software that created the FITS file
VERSION = '1       '           / Version number
FILENAME= 'CH2xsmgain20200330v02.fits' / File name
CONTENT = 'XSM Gain'           / File content
CCNM0001= 'GAIN    '           / CALDB Code:Gain
CCLS0001= 'BCF     '           / CALDB Class: Basic Calibration File
CDTP0001= 'DATA    '           / CALDB Type: File contains DATA
CBD10001= 'TEC("0.0-2.5")V'    / CALDB Boundary: TEC Current range
CBD20001= 'DETPOSR("0-3.2")mm' / CALDB Boundary: Det position
CVSD0001= '2017-01-01'         / CALDB Validity Start date (dd/mm/yy)
CVST0001= '00:00:00'           / CALDB Validity Start Time (hh:mm:ss)
CDES0001= 'Gain and offset of detector' / CALDB Description
COMMENT = ''
COMMENT = 'Gain and offset of detector'
COMMENT = ''
CHECKSUM= '9ANNJ8LM9ALMG5LM'   / HDU checksum updated 2020-04-03T05:18:41
DATASUM = '1360568999'         / data unit checksum updated 2020-04-03T05:18:41
END

XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                   16 / width of table in bytes
NAXIS2  =                  115 / number of rows in table
PCOUNT  =                    0 / size of special data area
```

```
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                    4 / number of fields in each row
TTYPE1  = 'TEC_CURRENT'        / label for field   1
TFORM1  = 'E       '           / data format of field: 4-byte REAL
TTYPE2  = 'DETPOSR '           / label for field   2
TFORM2  = 'E       '           / data format of field: 4-byte REAL
TTYPE3  = 'GAIN    '           / label for field   3
TFORM3  = 'E       '           / data format of field: 4-byte REAL
TTYPE4  = 'OFFSET  '           / label for field   4
TFORM4  = 'E       '           / data format of field: 4-byte REAL
EXTNAME = 'CALGAIN '           / name of this binary table extension
NTEC    =                  115
NRAD    =                    1
HIERARCH TECBINSIZE =     0.02
HIERARCH RADBINSIZE =      3.3
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH2_ORBITER'        / Name of mission/satellite
INSTRUME= 'XSM     '           / Name of Instrument/detector
HDUCLASS= 'OGIP    '           / OGIP Standard
LONGSTRN= 'OGIP 1.0'           / The OGIP Long String Convention may be used
ORIGIN  = 'PRL     '           / Origin of FITS file
CREATOR = 'xsmcaldbgen'        / Software that created the FITS file
VERSION = '1       '           / Version number
FILENAME= 'CH2xsmgain20200330v02.fits' / File name
CONTENT = 'XSM CAL Gain'       / File content
CCNM0001= 'GAIN    '           / CALDB Code:Gain
CCLS0001= 'BCF     '           / CALDB Class: Basic Calibration File
CDTP0001= 'DATA    '           / CALDB Type: File contains DATA
CBD10001= 'TEC("0.0-2.5")V'    / CALDB Boundary: TEC Current range
CBD20001= 'DETPOSR("0-3.2")mm' / CALDB Boundary: Det position
CVSD0001= '2017-01-01'         / CALDB Validity Start date (dd/mm/yy)
CVST0001= '00:00:00'           / CALDB Validity Start Time (hh:mm:ss)
CDES0001= 'Gain and offset of detector' / CALDB Description
COMMENT = ''
COMMENT = 'Gain and offset of detector for CAL src'
COMMENT = ''
```

D.3 Effareapar file

```
SIMPLE  =                    T / file does conform to FITS standard
BITPIX  =                   16 / number of bits per data pixel
NAXIS   =                    0 / number of data axes
EXTEND  =                    T / FITS dataset may contain extensions
```

```
COMMENT   FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT   and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH-2_ORBITER'       / Name of mission/satellite
INSTRUME= 'CH2_XSM '           / Name of Instrument/detector
CHECKSUM= '4qCA6oB74oBA4oB7'   / HDU checksum updated 2020-06-15T10:12:34
DATASUM = '         0'         / data unit checksum updated 2020-06-15T10:12:34
END

XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                   28 / width of table in bytes
NAXIS2  =                 9800 / number of rows in table
PCOUNT  =                    0 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                    7 / number of fields in each row
TTYPE1  = 'DETX    '           / label for field   1
TFORM1  = 'E       '           / data format of field: 4-byte REAL
TTYPE2  = 'DETY    '           / label for field   2
TFORM2  = 'E       '           / data format of field: 4-byte REAL
TTYPE3  = 'Alpha   '           / label for field   3
TFORM3  = 'E       '           / data format of field: 4-byte REAL
TTYPE4  = 'Be_thick'           / label for field   4
TFORM4  = 'E       '           / data format of field: 4-byte REAL
TTYPE5  = 'DeadSi_thick'       / label for field   5
TFORM5  = 'E       '           / data format of field: 4-byte REAL
TTYPE6  = 'DeadSiO2_thick'     / label for field   6
TFORM6  = 'E       '           / data format of field: 4-byte REAL
TTYPE7  = 'DetSi_thick'        / label for field   7
TFORM7  = 'E       '           / data format of field: 4-byte REAL
EXTNAME = 'EFFAREAPAR'         / name of this binary table extension
DX      =                 0.05
DY      =                 0.05
NXBINS  =                  140
NYBINS  =                   70
XMIN    =                 -3.5
YMIN    =                 -3.5
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH2_ORBITER'        / Name of mission/satellite
INSTRUME= 'XSM     '           / Name of Instrument/detector
HDUCLASS= 'OGIP    '           / OGIP Standard
LONGSTRN= 'OGIP 1.0'           / The OGIP Long String Convention may be used
```

```
ORIGIN  = 'PRL     '           / Origin of FITS file
CREATOR = 'xsmcaldbgen'        / Software that created the FITS file
VERSION = '1       '           / Version number
FILENAME= 'CH2xsmeffareapar20200410v01.fits' / File name
CONTENT = 'XSM EffectiveArea'  / File content
CCNM0001= 'EFFAREAPAR'         / CALDB Code:Effareapar
CCLS0001= 'BCF     '           / CALDB Class: Basic Calibration File
CDTP0001= 'DATA    '           / CALDB Type: File contains DATA
CBD10001= 'DETX("-3.5 to 3.5") DETY(-3.5 to 0)' / CALDB Boundary: X,Y range
CVSD0001= '2017-01-01'         / CALDB Validity Start date (dd/mm/yy)
CVST0001= '00:00:00'           / CALDB Validity Start Time (hh:mm:ss)
CDES0001= 'Effective area parameters' / CALDB Description
COMMENT = ''
COMMENT = 'Effective area parameters for XSM'
COMMENT = ''
```

D.4 RMF file

```
SIMPLE  =                    T / file does conform to FITS standard
BITPIX  =                    8 / number of bits per data pixel
NAXIS   =                    0 / number of data axes
EXTEND  =                    T / FITS dataset may contain extensions
COMMENT   FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT   and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
COMMENT   FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT   and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH-2_ORBITER'       / Name of mission/satellite
INSTRUME= 'CH2_XSM '           / Name of Instrument/detector
ORIGIN  = 'PRLPOC  '           / Source of FITS file
CREATOR = 'xsmgenresp '        / Creator of file
FILENAME= '20200423xsmresponse.rmf' / Name of file
CONTENT = 'Response File'      / File content
DATE    = '2020-04-26T23:11:37' / Creation Date
END

XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                   10 / width of table in bytes
NAXIS2  =                  512 / number of rows in table
PCOUNT  =                    0 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
```

```
TFIELDS =                    3 / number of fields in each row
TTYPE1  = 'CHANNEL '           / label for field   1
TFORM1  = 'I       '           / data format of field: 2-byte INTEGER
TTYPE2  = 'E_MIN   '           / label for field   2
TFORM2  = 'E       '           / data format of field: 4-byte REAL
TTYPE3  = 'E_MAX   '           / label for field   3
TFORM3  = 'E       '           / data format of field: 4-byte REAL
TUNIT1  = '        '           / physical unit of field
TUNIT2  = 'keV     '           / physical unit of field
TUNIT3  = 'keV     '           / physical unit of field
EXTNAME = 'EBOUNDS '           / name of this binary table extension
HDUCLASS= 'OGIP    '
HDUCLAS1= 'RESPONSE'
HDUCLAS2= 'EBOUNDS '
CHANTYPE= 'PI      '           / Channel type
HDUVERS = '1.2.0   '           / OGIP version number
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH-2_ORBITER'       / Name of mission/satellite
INSTRUME= 'CH2_XSM '           / Name of Instrument/detector
ORIGIN  = 'PRL     '           / Source of FITS file
CREATOR = 'xsmgenresp '        / Creator of file
DETNAM  = '        '
FILTER  = '        '
DETCHANS=                  512 / Number of channels in ebd
EXTVER  =                    1 / auto assigned by template parser
END

XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                   26 / width of table in bytes
NAXIS2  =                 3000 / number of rows in table
PCOUNT  =              6144000 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                    6 / number of fields in each row
TTYPE1  = 'ENERG_LO'           / label for field   1
TFORM1  = 'E       '           / data format of field: 4-byte REAL
TTYPE2  = 'ENERG_HI'           / label for field   2
TFORM2  = 'E       '           / data format of field: 4-byte REAL
TTYPE3  = 'N_GRP   '           / label for field   3
TFORM3  = 'I       '           / data format of field: 2-byte INTEGER
TTYPE4  = 'F_CHAN  '           / label for field   4
TFORM4  = 'J       '           / data format of field: 4-byte INTEGER
```

```
TTYPE5  = 'N_CHAN  '           / label for field   5
TFORM5  = 'J       '           / data format of field: 4-byte INTEGER
TTYPE6  = 'MATRIX  '           / label for field   7
TFORM6  = 'PE(512) '           / data format of field: variable length array
TUNIT1  = 'keV     '           / physical unit of field
TUNIT2  = 'keV     '           / physical unit of field
TUNIT3  = '        '           / physical unit of field
TUNIT4  = '        '           / physical unit of field
TUNIT5  = '        '           / physical unit of field
TUNIT6  = 'cm^2    '           / physical unit of field
EXTNAME = 'MATRIX  '           / name of this binary table extension
HDUCLASS= 'OGIP    '
HDUCLAS1= 'RESPONSE'
HDUCLAS2= 'RSP_MATRIX'
HDUCLAS3= 'REDIST  '
CHANTYPE= 'PI      '           / Channel type
HDUVERS = '1.3.0   '           / OGIP version number
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH-2_ORBITER'       / Name of mission/satellite
INSTRUME= 'CH2_XSM '           / Name of Instrument/detector
ORIGIN  = 'PRLPOC  '           / Source of FITS file
CREATOR = 'xsmgenresp '        / Creator of file
DETNAM  = '        '
FILTER  = '        '
EFFAREA =                   1.
LO_THRES=                   0.
DETCHANS=                  512 / Number of channels in rmf
NUMGRP  =                 4096 / Total number of response groups
NUMELT  =                      / Total number of response elements
TLMIN4  =                    0 / First channel number
EXTVER  =                    1 / auto assigned by template parser
```

D.5 RSP file

```
SIMPLE  =                    T / file does conform to FITS standard
BITPIX  =                    8 / number of bits per data pixel
NAXIS   =                    0 / number of data axes
EXTEND  =                    T / FITS dataset may contain extensions
COMMENT   FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT   and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
COMMENT   FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT   and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
```

```
TELESCOP= 'CH-2_ORBITER'       / Name of mission/satellite
INSTRUME= 'CH2_XSM '           / Name of Instrument/detector
ORIGIN  = 'PRLPOC  '           / Source of FITS file
CREATOR = 'xsmgenresp '        / Creator of file
FILENAME= 'CH2xsmrspwitharea_befilt20191214v01.rsp' / Name of file
CONTENT = 'Response File'      / File content
DATE    = '2020-08-19T12:23:18' / Creation Date
XSMDASVE= '1.06    '           / Version of XSMDAS that created this file
END

XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                   10 / width of table in bytes
NAXIS2  =                  512 / number of rows in table
PCOUNT  =                    0 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                    3 / number of fields in each row
TTYPE1  = 'CHANNEL '           / label for field   1
TFORM1  = 'I       '           / data format of field: 2-byte INTEGER
TTYPE2  = 'E_MIN   '           / label for field   2
TFORM2  = 'E       '           / data format of field: 4-byte REAL
TTYPE3  = 'E_MAX   '           / label for field   3
TFORM3  = 'E       '           / data format of field: 4-byte REAL
TUNIT1  = '        '           / physical unit of field
TUNIT2  = 'keV     '           / physical unit of field
TUNIT3  = 'keV     '           / physical unit of field
EXTNAME = 'EBOUNDS '           / name of this binary table extension
HDUCLASS= 'OGIP    '
HDUCLAS1= 'RESPONSE'
HDUCLAS2= 'EBOUNDS '
CHANTYPE= 'PI      '           / Channel type
HDUVERS = '1.2.0   '           / OGIP version number
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH-2_ORBITER'       / Name of mission/satellite
INSTRUME= 'CH2_XSM '           / Name of Instrument/detector
ORIGIN  = 'PRL     '           / Source of FITS file
CREATOR = 'xsmgenresp '        / Creator of file
DETNAM  = '        '
FILTER  = '        '
DETCHANS=                  512 / Number of channels in ebd
XSMDASVE= '1.06    '           / Version of XSMDAS that created this file
EXTVER  =                    1 / auto assigned by template parser
```

```
FILENAME= 'CH2xsmrspwitharea_befilt20191214v01.rsp'
DATE    = '2020-08-19T12:23:18'
END

XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                   26 / width of table in bytes
NAXIS2  =                 3000 / number of rows in table
PCOUNT  =              6144000 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                    6 / number of fields in each row
TTYPE1  = 'ENERG_LO'           / label for field   1
TFORM1  = 'E       '           / data format of field: 4-byte REAL
TTYPE2  = 'ENERG_HI'           / label for field   2
TFORM2  = 'E       '           / data format of field: 4-byte REAL
TTYPE3  = 'N_GRP   '           / label for field   3
TFORM3  = 'I       '           / data format of field: 2-byte INTEGER
TTYPE4  = 'F_CHAN  '           / label for field   4
TFORM4  = 'J       '           / data format of field: 4-byte INTEGER
TTYPE5  = 'N_CHAN  '           / label for field   5
TFORM5  = 'J       '           / data format of field: 4-byte INTEGER
TTYPE6  = 'MATRIX  '           / label for field   7
TFORM6  = 'PE(512) '           / data format of field: variable length array
TUNIT1  = 'keV     '           / physical unit of field
TUNIT2  = 'keV     '           / physical unit of field
TUNIT3  = '        '           / physical unit of field
TUNIT4  = '        '           / physical unit of field
TUNIT5  = '        '           / physical unit of field
TUNIT6  = 'cm^2    '           / physical unit of field
EXTNAME = 'MATRIX  '           / name of this binary table extension
HDUCLASS= 'OGIP    '
HDUCLAS1= 'RESPONSE'
HDUCLAS2= 'RSP_MATRIX'
HDUCLAS3= 'FULL    '
CHANTYPE= 'PI      '           / Channel type
HDUVERS = '1.3.0   '           / OGIP version number
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH-2_ORBITER'       / Name of mission/satellite
INSTRUME= 'CH2_XSM '           / Name of Instrument/detector
ORIGIN  = 'PRLPOC  '           / Source of FITS file
CREATOR = 'xsmgenresp '        / Creator of file
DETNAM  = '        '
```

```
FILTER  = '        '
EFFAREA =                   1.
LO_THRES=                   0.
DETCHANS=                  512 / Number of channels in rmf
NUMGRP  =                 4096 / Total number of response groups
NUMELT  =                      / Total number of response elements
TLMIN4  =                    0 / First channel number
XSMDASVE=                      / Version of XSMDAS that created this file
EXTVER  =                    1 / auto assigned by template parser
```

D.6 Syserr file

```
SIMPLE  =                    T / file does conform to FITS standard
BITPIX  =                   16 / number of bits per data pixel
NAXIS   =                    0 / number of data axes
EXTEND  =                    T / FITS dataset may contain extensions
COMMENT   FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT   and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH-2_ORBITER'       / Name of mission/satellite
INSTRUME= 'CH2_XSM '           / Name of Instrument/detector
CHECKSUM= '4nD97kB84kB84kB8'   / HDU checksum updated 2020-08-18T08:40:26
DATASUM = '         0'         / data unit checksum updated 2020-08-18T08:40:26
END

XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                    6 / width of table in bytes
NAXIS2  =                  512 / number of rows in table
PCOUNT  =                    0 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                    2 / number of fields in each row
TTYPE1  = 'Channel '           / label for field   1
TFORM1  = 'I       '           / data format of field: 2-byte INTEGER
TTYPE2  = 'SysErr  '           / label for field   2
TFORM2  = 'E       '           / data format of field: 4-byte REAL
EXTNAME = 'SYSERR  '           / name of this binary table extension
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH2_ORBITER'        / Name of mission/satellite
INSTRUME= 'XSM     '           / Name of Instrument/detector
HDUCLASS= 'OGIP    '           / OGIP Standard
LONGSTRN= 'OGIP 1.0'           / The OGIP Long String Convention may be used
```

```
ORIGIN  = 'PRL     '           / Origin of FITS file
CREATOR = 'xsmcaldbgen'        / Software that created the FITS file
VERSION = '1       '           / Version number
CONTENT = 'XSM Systematic errors' / File content
CCNM0001= 'SYSERR  '           / CALDB Code:syserr
CCLS0001= 'BCF     '           / CALDB Class: Basic Calibration File
CDTP0001= 'DATA    '           / CALDB Type: File contains DATA
CBD10001= 'CHANNEL("0-511")'   / CALDB Boundary: channel range
CVSD0001= '2017-01-01'         / CALDB Validity Start date (dd/mm/yy)
CVST0001= '00:00:00'           / CALDB Validity Start Time (hh:mm:ss)
CDES0001= 'Systematic errors on 9bit PHA channels' / CALDB Description
COMMENT = ''
COMMENT = 'Systematic errors to be included in the spectrum output'
COMMENT = ''
```

D.7 Ebounds file

```
SIMPLE  =                    T / file does conform to FITS standard
BITPIX  =                   16 / number of bits per data pixel
NAXIS   =                    0 / number of data axes
EXTEND  =                    T / FITS dataset may contain extensions
COMMENT   FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT   and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH-2_ORBITER'       / Name of mission/satellite
INSTRUME= 'CH2_XSM '           / Name of Instrument/detector
CHECKSUM= '0pCA1o980oCA0o95'   / HDU checksum updated 2019-12-14T10:28:59
DATASUM = '         0'         / data unit checksum updated 2019-12-14T10:28:59
END

XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                   10 / width of table in bytes
NAXIS2  =                  512 / number of rows in table
PCOUNT  =                    0 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                    3 / number of fields in each row
TTYPE1  = 'CHANNEL '           / label for field   1
TFORM1  = 'I       '           / data format of field: 2-byte INTEGER
TTYPE2  = 'E_MIN   '           / label for field   2
TFORM2  = 'E       '           / data format of field: 4-byte REAL
TTYPE3  = 'E_MAX   '           / label for field   3
```

```
TFORM3  = 'E       '           / data format of field: 4-byte REAL
EXTNAME = 'EBOUNDS '           / name of this binary table extension
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH2_ORBITER'        / Name of mission/satellite
INSTRUME= 'XSM     '           / Name of Instrument/detector
HDUCLASS= 'OGIP    '           / OGIP Standard
LONGSTRN= 'OGIP 1.0'           / The OGIP Long String Convention may be used
ORIGIN  = 'PRL     '           / Origin of FITS file
CREATOR = 'xsmcaldbgen'        / Software that created the FITS file
VERSION = '1       '           / Version number
FILENAME= 'CH2xsmebounds20191214v01.fits' / File name
CONTENT = 'XSM Ebounds'        / File content
CCNM0001= 'EBOUNDS '           / CALDB Code:Ebounds
CCLS0001= 'BCF     '           / CALDB Class: Basic Calibration File
CDTP0001= 'DATA    '           / CALDB Type: File contains DATA
CBD10001= 'ENERG("0.5-17.396")keV' / CALDB Boundary: Energy range
CBD20001= 'PICH("1-512")'      / CALDB Boundary: PI Channels
CVSD0001= '2017-01-01'         / CALDB Validity Start date (dd/mm/yy)
CVST0001= '00:00:00'           / CALDB Validity Start Time (hh:mm:ss)
CDES0001= 'Nomial min and max energy of PI bins' / CALDB Description
COMMENT = ''
COMMENT = 'Nominal energy of PI bins'
COMMENT = 'Energy range: 0.5-17.396 keV. Binsize: 33.0 eV'
COMMENT = ''
```

D.8 Abscoef file

```
SIMPLE  =                    T / file does conform to FITS standard
BITPIX  =                   16 / number of bits per data pixel
NAXIS   =                    0 / number of data axes
EXTEND  =                    T / FITS dataset may contain extensions
COMMENT   FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT   and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH-2_ORBITER'       / Name of mission/satellite
INSTRUME= 'CH2_XSM '           / Name of Instrument/detector
CHECKSUM= '2nHA4n952nGA2n93'   / HDU checksum updated 2020-04-09T21:46:29
DATASUM = '         0'         / data unit checksum updated 2020-04-09T21:46:29
END

XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
```

```
NAXIS1  =                   28 / width of table in bytes
NAXIS2  =                  512 / number of rows in table
PCOUNT  =                    0 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                    4 / number of fields in each row
TTYPE1  = 'Energy  '           / label for field   1
TFORM1  = 'E       '           / data format of field: 4-byte REAL
TTYPE2  = 'BE      '           / label for field   2
TFORM2  = 'D       '           / data format of field: 8-byte DOUBLE
TTYPE3  = 'SI      '           / label for field   3
TFORM3  = 'D       '           / data format of field: 8-byte DOUBLE
TTYPE4  = 'SIO2    '           / label for field   4
TFORM4  = 'D       '           / data format of field: 8-byte DOUBLE
EXTNAME = 'PI_ENE  '           / name of this binary table extension
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH2_ORBITER'        / Name of mission/satellite
INSTRUME= 'XSM     '           / Name of Instrument/detector
HDUCLASS= 'OGIP    '           / OGIP Standard
LONGSTRN= 'OGIP 1.0'           / The OGIP Long String Convention may be used
ORIGIN  = 'PRL     '           / Origin of FITS file
CREATOR = 'xsmcaldbgen'        / Software that created the FITS file
VERSION = '1       '           / Version number
CONTENT = 'XSM Absorption Coefficients' / File content
CCNM0001= 'ABSCOEF '           / CALDB Code:Abscoef
CCLS0001= 'BCF     '           / CALDB Class: Basic Calibration File
CDTP0001= 'DATA    '           / CALDB Type: File contains DATA
CBD10001= 'ENERGY("1-15.0")degrees' / CALDB Boundary: energy range
CVSD0001= '2017-01-01'         / CALDB Validity Start date (dd/mm/yy)
CVST0001= '00:00:00'           / CALDB Validity Start Time (hh:mm:ss)
CDES0001= 'Absorption coefficients' / CALDB Description
COMMENT = ''
COMMENT = 'Absorption coefficients for XSM effective area calculation'
COMMENT = ''
CHECKSUM= 'aXircXZoaXfoaXZo'   / HDU checksum updated 2020-04-09T21:46:29
DATASUM = '1022128181'         / data unit checksum updated 2020-04-09T21:46:29
END

XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                   28 / width of table in bytes
NAXIS2  =                 1024 / number of rows in table
PCOUNT  =                    0 / size of special data area
```

```
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                    4 / number of fields in each row
TTYPE1  = 'Energy  '           / label for field   1
TFORM1  = 'E       '           / data format of field: 4-byte REAL
TTYPE2  = 'BE      '           / label for field   2
TFORM2  = 'D       '           / data format of field: 8-byte DOUBLE
TTYPE3  = 'SI      '           / label for field   3
TFORM3  = 'D       '           / data format of field: 8-byte DOUBLE
TTYPE4  = 'SIO2    '           / label for field   4
TFORM4  = 'D       '           / data format of field: 8-byte DOUBLE
EXTNAME = 'PHA_ENE '           / name of this binary table extension
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH2_ORBITER'        / Name of mission/satellite
INSTRUME= 'XSM     '           / Name of Instrument/detector
HDUCLASS= 'OGIP    '           / OGIP Standard
LONGSTRN= 'OGIP 1.0'           / The OGIP Long String Convention may be used
ORIGIN  = 'PRL     '           / Origin of FITS file
CREATOR = 'xsmcaldbgen'        / Software that created the FITS file
VERSION = '1       '           / Version number
CONTENT = 'XSM Absorption Coefficients' / File content
CCNM0001= 'ABSCOEF '           / CALDB Code:Abscoef
CCLS0001= 'BCF     '           / CALDB Class: Basic Calibration File
CDTP0001= 'DATA    '           / CALDB Type: File contains DATA
CBD10001= 'ENERGY("1-15.0")degrees' / CALDB Boundary: energy range
CVSD0001= '2017-01-01'         / CALDB Validity Start date (dd/mm/yy)
CVST0001= '00:00:00'           / CALDB Validity Start Time (hh:mm:ss)
CDES0001= 'Absorption coefficients' / CALDB Description
COMMENT = ''
COMMENT = 'Absorption coefficients for XSM effective area calculation'
COMMENT = ''
CHECKSUM= 'U66ca56bV56ba56b'   / HDU checksum updated 2020-04-09T21:46:29
DATASUM = '2878174298'         / data unit checksum updated 2020-04-09T21:46:29
END

XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                   28 / width of table in bytes
NAXIS2  =                 3000 / number of rows in table
PCOUNT  =                    0 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                    4 / number of fields in each row
TTYPE1  = 'Energy  '           / label for field   1
```

```
TFORM1  = 'E       '           / data format of field: 4-byte REAL
TTYPE2  = 'BE      '           / label for field   2
TFORM2  = 'D       '           / data format of field: 8-byte DOUBLE
TTYPE3  = 'SI      '           / label for field   3
TFORM3  = 'D       '           / data format of field: 8-byte DOUBLE
TTYPE4  = 'SIO2    '           / label for field   4
TFORM4  = 'D       '           / data format of field: 8-byte DOUBLE
EXTNAME = 'RSP_ENE '           / name of this binary table extension
MISSION = 'CHANDRAYAAN-2'      / Name of mission/satellite
TELESCOP= 'CH2_ORBITER'        / Name of mission/satellite
INSTRUME= 'XSM     '           / Name of Instrument/detector
HDUCLASS= 'OGIP    '           / OGIP Standard
LONGSTRN= 'OGIP 1.0'           / The OGIP Long String Convention may be used
ORIGIN  = 'PRL     '           / Origin of FITS file
CREATOR = 'xsmcaldbgen'        / Software that created the FITS file
VERSION = '1       '           / Version number
CONTENT = 'XSM Absorption Coefficients' / File content
CCNM0001= 'ABSCOEF '           / CALDB Code:Abscoef
CCLS0001= 'BCF     '           / CALDB Class: Basic Calibration File
CDTP0001= 'DATA    '           / CALDB Type: File contains DATA
CBD10001= 'ENERGY("1-15.0")degrees' / CALDB Boundary: energy range
CVSD0001= '2017-01-01'         / CALDB Validity Start date (dd/mm/yy)
CVST0001= '00:00:00'           / CALDB Validity Start Time (hh:mm:ss)
CDES0001= 'Absorption coefficients' / CALDB Description
COMMENT = ''
COMMENT = 'Absorption coefficients for XSM effective area calculation'
COMMENT = ''
```

E Example PDS Label for XSM Data Product

Each of the data product of XSM has an associated PDS4 XML label file. An example of the XML label associated with a raw house keeping parameter file of XSM is given here. All other product labels also have a similar structure.

```
<?xml version="1.0" encoding="UTF-8"?>
<?xml-model href="https://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1B00.sch"
  schematypens="http://purl.oclc.org/dsdl/schematron"?>
<Product_Observational xmlns="http://pds.nasa.gov/pds4/pds/v1"
xmlns:pds="http://pds.nasa.gov/pds4/pds/v1"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://pds.nasa.gov/pds4/pds/v1
https://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1B00.xsd">
    <Identification_Area>
        <logical_identifier>
          urn:isro:isda:ch2_cho:xsm_raw:ch2_xsm_20190917_level1_hk
```

```
    </logical_identifier>
    <version_id>0.0</version_id>
    <title>Chandrayaan-2 Orbiter XSM Experiment</title>
    <information_model_version>1.11.0.0</information_model_version>
    <product_class>Product_Observational</product_class>
    <Modification_History>
        <Modification_Detail>
            <modification_date>2020-08-19</modification_date>
            <version_id>1.0</version_id>
            <description>Created by XSM POC PRL</description>
        </Modification_Detail>
    </Modification_History>
</Identification_Area>
<Observation_Area>
    <Time_Coordinates>
        <start_date_time>2019-09-17T00:00:00.864Z</start_date_time>
        <stop_date_time>2019-09-17T23:59:59.650Z</stop_date_time>
    </Time_Coordinates>
    <Primary_Result_Summary>
        <purpose>Science</purpose>
        <processing_level>Raw</processing_level>
        <description>
    A series of multiply defined digital objects.
  </description>
    </Primary_Result_Summary>
    <Investigation_Area>
        <name>Chandrayaan-2</name>
        <type>Mission</type>
        <Internal_Reference>
            <lidvid_reference>
            urn:isro:isda:context:investigation:mission.chandrayaan2::1.0
            </lidvid_reference>
            <reference_type>data_to_investigation</reference_type>
        </Internal_Reference>
    </Investigation_Area>
    <Observing_System>
        <name>Observing System</name>
        <Observing_System_Component>
            <name>Chandrayaan-2 Orbiter</name>
            <type>Spacecraft</type>
            <description>
     Chandrayaan-2 Orbiter is the orbitercraft of the mission which is placed in polar orbit
     around Moon, carrying a suite of scientific instruments.
    </description>
        </Observing_System_Component>
        <Observing_System_Component>
            <name>Solar X-ray Monitor</name>
            <type>Instrument</type>
            <description>
    Solar X-ray Monitor (abbreviated as XSM) is a scientific instrument on-board
    the Chandrayaan-2 orbiter with an objective of performing X-ray spectroscopy
    of the Sun. The instrument employs Silicon Drift Detector (SDD) to cover the
    X-ray energy range of 1-15 keV with a spectral resolution better than 180 eV
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    at 5.9 keV. XSM also incorporates an innovative moving mechanism in order to
    cover the wide range of intensities of Solar X-ray flares. XSM provides
    measurement of Solar X-ray spectrum with a time cadence of one second.
    </description>
        </Observing_System_Component>
    </Observing_System>
    <Target_Identification>
        <name>Sun</name>
        <type>Sun</type>
        <description>
  Sun is the star at the center of Solar system.
  </description>
    </Target_Identification>
    <!--

     Mission specific attributes. Will be defined in local data dictionary schema
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    <Mission_Area>
        <level0_dir_name>XSM01G26CH0002830301501926008455345 4_00_V1.0</level0_dir_name>
        <level0_dir_name>XSM01CNBCH000285030150192601320561 64_00_V1.0</level0_dir_name>
        <level0_dir_name>XSM01G26CH000296030150192611032374 72_00_V1.0</level0_dir_name>
        <level0_dir_name>XSM01D18CH000300030150192611829500 47_00_V1.0</level0_dir_name>
    </Mission_Area>
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    -->
</Observation_Area>
<File_Area_Observational>
    <File>
        <file_name>ch2_xsm_20190917_v0_level1.hk</file_name>
        <local_identifier>file</local_identifier>
        <creation_date_time>2020-08-19T12:41:14</creation_date_time>
        <file_size unit="byte">12110400</file_size>
        <records>86400</records>
        <md5_checksum>1bbe40c658e9acdc82469b46d86f1cab</md5_checksum>
    </File>
    <Header>
        <local_identifier>header_Primary</local_identifier>
        <offset unit="byte">0</offset>
        <object_length unit="byte">2880</object_length>
        <parsing_standard_id>FITS 3.0</parsing_standard_id>
    </Header>
    <Header>
        <local_identifier>header_HKParam</local_identifier>
        <offset unit="byte">2880</offset>
        <object_length unit="byte">11520</object_length>
        <parsing_standard_id>FITS 3.0</parsing_standard_id>
    </Header>
    <Table_Binary>
        <local_identifier>data_HKParam</local_identifier>
        <offset unit="byte">14400</offset>
        <records>86400</records>
        <description>The records count is the number of rows in this table</description>
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    <fields>38</fields>
    <groups>0</groups>
    <record_length unit="byte">140</record_length>
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        <data_type>IEEE754MSBDouble</data_type>
        <field_length unit="byte">8</field_length>
        <unit>Sec</unit>
        <description>UTC Seconds since 2017-01-01 00:00:00 </description>
    </Field_Binary>
    <Field_Binary>
        <name>UTCSTRING</name>
        <field_location unit="byte">9</field_location>
        <data_type>ASCII_String</data_type>
        <field_length unit="byte">30</field_length>
        <description>UTC Time String</description>
    </Field_Binary>
    <Field_Binary>
        <name>FPGATIME</name>
        <field_location unit="byte">39</field_location>
        <data_type>IEEE754MSBDouble</data_type>
        <field_length unit="byte">8</field_length>
        <unit>Sec</unit>
        <description>XSM clock time</description>
    </Field_Binary>
    <Field_Binary>
        <name>FRAMENO</name>
        <field_location unit="byte">47</field_location>
        <data_type>SignedMSB4</data_type>
        <field_length unit="byte">4</field_length>
        <description>Frame Number</description>
    </Field_Binary>
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        <name>SyncLW</name>
        <field_location unit="byte">51</field_location>
        <data_type>SignedMSB4</data_type>
        <field_length unit="byte">4</field_length>
        <description>Sync bytes LW</description>
    </Field_Binary>
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        <name>SyncUW</name>
        <field_location unit="byte">55</field_location>
        <data_type>SignedMSB4</data_type>
        <field_length unit="byte">4</field_length>
        <description>Sync bytes UW</description>
    </Field_Binary>
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        <name>EventCounter</name>
        <field_location unit="byte">59</field_location>
        <data_type>SignedMSB4</data_type>
        <field_length unit="byte">4</field_length>
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        <description>Event Triggers</description>
    </Field_Binary>
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        <name>EventDetected</name>
        <field_location unit="byte">63</field_location>
        <data_type>SignedMSB4</data_type>
        <field_length unit="byte">4</field_length>
        <description>Number of detected events</description>
    </Field_Binary>
    <Field_Binary>
        <name>RampCounter</name>
        <field_location unit="byte">67</field_location>
        <data_type>SignedMSB2</data_type>
        <field_length unit="byte">2</field_length>
        <description>Ramp frequency of reset CSPA</description>
    </Field_Binary>
    <Field_Binary>
        <name>HVMonitor</name>
        <field_location unit="byte">69</field_location>
        <data_type>IEEE754MSBSingle</data_type>
        <field_length unit="byte">4</field_length>
        <unit>Volts</unit>
        <description>High Voltage monitor</description>
    </Field_Binary>
    <Field_Binary>
        <name>Detector Temperature</name>
        <field_location unit="byte">73</field_location>
        <data_type>IEEE754MSBSingle</data_type>
        <field_length unit="byte">4</field_length>
        <unit>Volts</unit>
        <description>SDD Temperature monitor in volts</description>
    </Field_Binary>
    <Field_Binary>
        <name>TECCurrent</name>
        <field_location unit="byte">77</field_location>
        <data_type>IEEE754MSBSingle</data_type>
        <field_length unit="byte">4</field_length>
        <unit>Volts</unit>
        <description>SDD Peltier current monitor in volts</description>
    </Field_Binary>
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        <name>LV1Monitor</name>
        <field_location unit="byte">81</field_location>
        <data_type>IEEE754MSBSingle</data_type>
        <field_length unit="byte">4</field_length>
        <unit>Volts</unit>
        <description>3.3V LV monitor</description>
    </Field_Binary>
    <Field_Binary>
        <name>LV2Monitor</name>
        <field_location unit="byte">85</field_location>
        <data_type>IEEE754MSBSingle</data_type>
        <field_length unit="byte">4</field_length>
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        <unit>Volts</unit>
        <description>1.5V LV monitor</description>
    </Field_Binary>
    <Field_Binary>
        <name>LLDRefVoltage</name>
        <field_location unit="byte">89</field_location>
        <data_type>IEEE754MSBSingle</data_type>
        <field_length unit="byte">4</field_length>
        <unit>Volts</unit>
        <description>Low Level Discriminator Voltage level</description>
    </Field_Binary>
    <Field_Binary>
        <name>TECRefVoltage</name>
        <field_location unit="byte">93</field_location>
        <data_type>IEEE754MSBSingle</data_type>
        <field_length unit="byte">4</field_length>
        <unit>Volts</unit>
        <description>Reference Voltage level for Peltier of SDD</description>
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    <Field_Binary>
        <name>MotorControlMode</name>
        <field_location unit="byte">97</field_location>
        <data_type>UnsignedByte</data_type>
        <field_length unit="byte">1</field_length>
        <description>Mode of Control 0-Auto;1-Manual;2-ForceStep</description>
    </Field_Binary>
    <Field_Binary>
        <name>MotorOperationMode</name>
        <field_location unit="byte">98</field_location>
        <data_type>UnsignedByte</data_type>
        <field_length unit="byte">1</field_length>
        <description>Mode of Operation 0-IR;1-Counter;2-Step</description>
    </Field_Binary>
    <Field_Binary>
        <name>MotorSetPos</name>
        <field_location unit="byte">99</field_location>
        <data_type>UnsignedByte</data_type>
        <field_length unit="byte">1</field_length>
        <description>Set Position of mechanism 0-Open;1-Cal;2-Be</description>
    </Field_Binary>
    <Field_Binary>
        <name>MotorIRPos</name>
        <field_location unit="byte">100</field_location>
        <data_type>UnsignedByte</data_type>
        <field_length unit="byte">1</field_length>
        <description>
        Actual Position of mechanism from IR 0-Open;1-Cal;2-Be
        </description>
    </Field_Binary>
    <Field_Binary>
        <name>IRPowerStatus</name>
        <field_location unit="byte">101</field_location>
        <data_type>UnsignedByte</data_type>
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    <field_length unit="byte">1</field_length>
    <description>Power Status of IR 0-ON; 1-OFF</description>
</Field_Binary>
<Field_Binary>
    <name>FrameDiscardFlag</name>
    <field_location unit="byte">102</field_location>
    <data_type>UnsignedByte</data_type>
    <field_length unit="byte">1</field_length>
    <description>1-Mechanism moving, discard frame</description>
</Field_Binary>
<Field_Binary>
    <name>MotorAutoTime</name>
    <field_location unit="byte">103</field_location>
    <data_type>UnsignedByte</data_type>
    <field_length unit="byte">1</field_length>
    <description>Autmovement sampling time(ms)</description>
</Field_Binary>
<Field_Binary>
    <name>StepModeDir</name>
    <field_location unit="byte">104</field_location>
    <data_type>UnsignedByte</data_type>
    <field_length unit="byte">1</field_length>
    <description> Direction 0-clock;1-anticlock</description>
</Field_Binary>
<Field_Binary>
    <name>WindowLowerThresh</name>
    <field_location unit="byte">105</field_location>
    <data_type>SignedMSB4</data_type>
    <field_length unit="byte">4</field_length>
    <description>Lower threshold for movement to Open from Be</description>
</Field_Binary>
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    <name>WindowUpperThresh</name>
    <field_location unit="byte">109</field_location>
    <data_type>SignedMSB4</data_type>
    <field_length unit="byte">4</field_length>
    <description>Upper threshold for movement to Be from Open</description>
</Field_Binary>
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    <name>PileupRejMode</name>
    <field_location unit="byte">113</field_location>
    <data_type>UnsignedByte</data_type>
    <field_length unit="byte">1</field_length>
    <description> 0-OFF; 1-ON(default)</description>
</Field_Binary>
<Field_Binary>
    <name>PileupRejTime</name>
    <field_location unit="byte">114</field_location>
    <data_type>UnsignedByte</data_type>
    <field_length unit="byte">1</field_length>
    <description> Dead time - 5us/10us</description>
</Field_Binary>
<Field_Binary>
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            <name>GuardBits</name>
            <field_location unit="byte">115</field_location>
            <data_type>SignedMSB2</data_type>
            <field_length unit="byte">2</field_length>
            <description>Guardbits should be zero</description>
        </Field_Binary>
        <Field_Binary>
            <name>Ch1Start</name>
            <field_location unit="byte">117</field_location>
            <data_type>SignedMSB2</data_type>
            <field_length unit="byte">2</field_length>
            <description>Coarse channel 1 start</description>
        </Field_Binary>
        <Field_Binary>
            <name>Ch1Stop</name>
            <field_location unit="byte">119</field_location>
            <data_type>SignedMSB2</data_type>
            <field_length unit="byte">2</field_length>
            <description>Coarse channel 1 stop</description>
        </Field_Binary>
        <Field_Binary>
            <name>Ch2Start</name>
            <field_location unit="byte">121</field_location>
            <data_type>SignedMSB2</data_type>
            <field_length unit="byte">2</field_length>
            <description>Coarse channel 2 start</description>
        </Field_Binary>
        <Field_Binary>
            <name>Ch2Stop</name>
            <field_location unit="byte">123</field_location>
            <data_type>SignedMSB2</data_type>
            <field_length unit="byte">2</field_length>
            <description>Coarse channel 2 stop</description>
        </Field_Binary>
        <Field_Binary>
            <name>Ch3Start</name>
            <field_location unit="byte">125</field_location>
            <data_type>SignedMSB2</data_type>
            <field_length unit="byte">2</field_length>
            <description>Coarse channel 3 start</description>
        </Field_Binary>
        <Field_Binary>
            <name>Ch3Stop</name>
            <field_location unit="byte">127</field_location>
            <data_type>SignedMSB2</data_type>
            <field_length unit="byte">2</field_length>
            <description>Coarse channel 3 stop</description>
        </Field_Binary>
        <Field_Binary>
            <name>CoarseChEvents</name>
            <field_location unit="byte">129</field_location>
            <data_type>SignedMSB4</data_type>
            <field_length unit="byte">4</field_length>
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```
                <description> Total events in Coarse Ch LC</description>
            </Field_Binary>
            <Field_Binary>
                <name>SpecEvents</name>
                <field_location unit="byte">133</field_location>
                <data_type>SignedMSB4</data_type>
                <field_length unit="byte">4</field_length>
                <description> Total events in spectrum</description>
            </Field_Binary>
            <Field_Binary>
                <name>ULDEvents</name>
                <field_location unit="byte">137</field_location>
                <data_type>SignedMSB4</data_type>
                <field_length unit="byte">4</field_length>
                <description> Events in last channel</description>
            </Field_Binary>
        </Record_Binary>
    </Table_Binary>
  </File_Area_Observational>
</Product_Observational>
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