MANUAL

DCIXS/XSM User Manual

		Name	Signature
Prepared by		S. Dunkin/R.Browning	
Approved by		R.Browning	

RUTHERFORD APPLETON LABORATORY
Chilton, Didcot, Oxfordshire
UK OX11 0QX

DISTRIBUTION

Name	Iss/Rev Date	Iss/Rev Date	Iss/Rev Date	Iss/Rev Date	Iss/Rev Date	Iss/Rev Date	Iss/Rev Date	Iss/Rev Date
		2 10.9.02	3 18.9.02	4 27.9.02	5 30.9.02	6 16.10.0 2		
RAL Server		x	x	x	x			
ESTEC - PMIS		x		x	x			

CHANGE RECORD

Date	Iss/Rev	Section	Comments
10.6.01	1		
10.9.02	2		Document duplication removed Full document issued only in PDF form
18.9.02	3	5.2.9.4.3	Parameters 36… included
27.9.02	4		Parameter Table 6 word 2 bit 12
30.9.02	5	5.2.7.5.2	Launch-lock flow chart inludes high rate HK data check
16.10.02	6		

CONTENTS

1. SECTION 1

2. SECTION 2

3. SECTION 3

4. SECTION 4

5. SECTION 5

5.1 Section 5.1

5.2 Section 5.2

5.2.1 INSTRUMENT DESCRIPTION

5.2.1.1 Science and Technology objectives

5.2.1.1.1 Lunar Science (Moon observation phase)

The D-CIXS instrument will provide the first global map of the Moon in X-rays, with <50km spatial resolution at perilune (300km). It will map the absolute abundances of key elements across the Moon, such as Si, Mg, Al and Fe, and others in favourable (i.e. flare) conditions. It will provide far better energy resolution than that obtained with the Apollo 15/16 missions. Observations of these elements will help to constrain theories of lunar origin and evolution. Of fundamental importance is to determine the magnesium number [Mg/(Mg + Fe)] across the Moon which to date has not been achieved. We will also probe the geochemistry of the larger impact basins, one of which (the South Pole-Aitken basin) may contain exposed mantle material, and which exhibited unusual spectral signatures within the Clementine data. Vertical variations in crustal composition can be revealed by examination of impact crater ejecta and central peaks (as demonstrated by Clementine), which represent exhumed or exposed crustal material. We will be able to examine the deeper layers of the crust by studying the central peaks of the largest impact craters, and the central regions of the large impact basins. The time series of lava flows can reveal petrological evolution, and large scale observations of elemental variation across different lava flows in the maria will contribute to our understanding of this evolution. These results will have direct relevance to lunar resource evaluation, as a precursor to future exploitation of the Moon as a base for space exploration

5.2.1.1.2 Lunar plasma interaction (Moon Observation Phase)

Recent Japanese X-ray observations of the Moon suggest that X-ray production on the night side due to the impact of energetic particles, while measurements by GGS/Wind and Lunar Prospector show that the energetic electrons of the solar wind are not shielded by the shadow, and that 1keV energy electrons are on occasion accelerated towards the surface. D-CIXS with its large effective area will provide the high-quality spectroscopy necessary to identify the processes.

5.2.1.1.3 The Earth's X-ray aurora: Argon line and N-S Conjugacy (Earth Spiralling Phase).

Recent results from the X-ray emission of the aurora suggest that a significant portion of the X-ray flux it detects is due to the Argon line at 2.957 keV. This contaminates their efforts to deconvolute the incident electron spectrum and hence understand the global energetics. Spectra taken by DCIXS would clearly resolve this line, and hence remove the ambiguity. At distances up to about 18 Earth radii, DCIXS will be able to make measurements of the conjugacy of the northern and southern hemisphere X-ray aurora. These will be the first such measurements , and should again be of importance in understanding global auroral energy budgets.

5.2.1.1.4 The Earth's Magnetotail (Earth Spiralling Phase).

DCIXS is shielded against electrons of energy up to 6 keV. Electrons more energetic than this are extremely rare in the solar wind. They do however occur in the magnetotail. While the increased background may degrade the X-ray performance of the instrument on the occasions when it enters the tail, there is interesting science to be done in mapping the structure of the tail. As the orbit is slowly increased from geostationary to lunar radius, the instrument will perform a detailed map of the width of the tail.

5.2.1.1.5 Astronomical Cruise Science with D-CIXS (Earth spiralling phase)

There is scope for making important astronomical observations with D-CIXS. The one important area that D-CIXS can explore that is unlikely to be done by the current observatory-class X-ray missions (e.g. Chandra and XMM-Newton) is long duration monitoring campaigns. D-CIXS can monitor up to 15 or 20 sources for periods of up to 5 months (with daily observations) and can therefore alert the astronomical community to unusual or rare outburst phenomena on superluminal jet sources in AGN or other similar objects. D-CIXS can also monitor the much brighter galactic sources for spectral and time variability and again look for longer term variability in these sources. This includes some of the brightest X-ray binary sources known which are now essentially beyond the limit of the very sensitive X-ray observatories (because they are too bright in X-rays). The proposed targets have been selected with the capabilities and limitations of the D-CIXS and SMART-1 in mind, and simulations have been made to be able to predict the observing times. Due to the large FOV without spatial resolution, the background contribution is estimated and the fields are checked for possible target confusion. All selected targets are significantly brighter than other targets in the 8x8 degree field.

5.2.1.1.6 XSM Solar Monitoring (Earth Spiralling Phase)

Important cruise science will also be undertaken by the X-ray Solar monitor. The XSM spectral range is very sensitive to solar flare activity. During a flare the measured total spectrum will be largely dominated by the flux from the event, and the contribution from the solar network can be neglected, especially in the higher energies above about 3 keV. Thus we will be able to monitor the long term evolution of flares, with the added dimension of good energy resolution (not possible with the current generation of GOES-type solar X-ray monitors). Such monitoring will complement the SOHO data very well. Long term monitoring of the X-ray spectral variability of the Sun excluding the flare events is also significant, especially in comparison with similar studies for other active stars.

5.2.1.1.7 Targets of Opportunity (Earth spiralling phase)

It is very likely that during the course of the SMART-1 cruise phase, a bright X-ray transient (sometimes referred to as X-ray Nova) will go off. Historically, such events occur about once per year. D-CIXS will then be able to provide the long term monitor of such an event and provide detailed spectral evolution of the decline in X-rays. Again, these sources can be extremely bright close to maximum light and thus may be unobservable with other current X-ray instruments.

Another possible important but unpredictable type of X-ray source would be a bright or near-Earth comet (such as comet Hyakutake in 1996 or Hale-Bopp in 1997). We know already that such sources are extremely erratic and variable and respond very quickly in changes to the solar wind and/or internal gas/dust outbursts. In these events, the X-rays are boosted and D-CIXS will have the opportunity to make detailed spectral observations of the comet/outburst. The spectrum is certainly the vital "missing" ingredient that will allow the correct model for the X-ray production mechanism to be determined.

5.2.1.1.8 Technology Objectives

The capability of these X-ray detectors, based on Swept Charged Devices, to withstand the space environment whilst maintaining good sensitivity will be proven by this mission.

An in-flight calibration of the detectors will be provided by the escape phase observations of well-.known astronomical X-ray sources. The measurements made of the low flux levels from the lunar surface against the background of the solar wind electrons will demonstrate the design possibilities of the micro-collimation techniques.

Table 5-1: Summary of Scientific Objectives

Observation	Physical parameter	Specific Performance Requirement	Special Requirements
Escape Phase			
Earth's X-ray aurora: Argon line and N-S Conjugacy.	Auroral X-ray emissions	Resolution of Argon Line	Pointing of spacecraft required
Earth's Magnetotail.	Electron flux	Detection of high background levels of electrons by detectors	
Astronomical objects	X-ray spectral time dependence	Nominal D-CIXS performance	Pointing of spacecraft required
XSM Solar Monitoring	Flare temporal evolution and X-ray spectral variation	Nominal XSM performance	
Targets of Opportunity	X-ray spectra	Nominal D-CIXS performance	Pointing of spacecraft required
Lunar Observation Phase			
Lunar geochemistry	Spatial distribution of the major lunar rock types	Nominal D-CIXS & XSM performance	
Lunar plasma interaction	X-ray emission from impact of solar wind electrons on night side of moon	Nominal D-CIXS performance	

5.2.1.2 Science and Technology performance summary

Table 5-2: Performance Summary

Observation	Physical parameter	Specific Performance Requirement	Performance Achieved?
Escape Phase			
Earth's X-ray aurora: Argon line and N-S Conjugacy.	Auroral X-ray emissions	Resolution of Argon Line	
Earth's Magnetotail.	Electron flux	Detection of high background levels of electrons by detectors	
Astronomical objects	X-ray spectral time dependence	Nominal D-CIXS performance	
XSM Solar Monitoring	Flare temporal evolution and X-ray spectral variation	Nominal XSM performance	
Targets of Opportunity	X-ray spectra	Nominal D-CIXS performance	

Lunar Observation Phase			
Lunar geochemistry	Spatial distribution of the major lunar rock types	Nominal D-CIXS & XSM performance	
Lunar plasma interaction	X-ray emission from impact of solar wind electrons on night side of moon	Nominal D-CIXS performance	

5.2.1.3 Instrument Description

5.2.1.3.1 Functional description

The x-rays from the sun are absorbed by the lunar surface which in turn is stimulated to emit flourescence X-rays characteristic of the elements which comprise the surface.

The instrument will simultaneously measure the solar X-ray flux and the emissions from the moon and will therefore able to produce a quantitative survey of the lunar surface materials as the spacecraft orbits the moon.

5.2.1.3.2 Hardware description

The *DCIXS* instrument comprises:

The main ***DCIXS*** instrument detector head, consists of a matrix of 40 X-ray sensitive Swept Charge Devices (SCDs), integrated microstructure collimators to define and limit the field of view (FOV), and filters to inhibit background UV and solar wind ions and electrons.

The ***XSM*** Solar Monitor calibration unit is intended to provide direct observation of the Sun over a full range of phase angles and solar luminosities. The XSM has a wide spectral range (0.8 up to 20 keV) and good spectral resolution (about 200 eV at 6 keV obtainable).

The instrument consists of two units:

DCIXS unit – The electronics unit including the DCIXS detectors
XSM – X-ray Solar Monitor on +X panel

The system configuration is shown in Figure 5-1

Measurement of low fluxes requires a large sensitive area detector. The incident fluorescence X-rays are detected by means of an array of 24 X-ray sensitive Swept Charge Devices (SCDs). The X-rays create electron-hole pairs and charge packets within the substrate in exactly the same way as in an X-ray sensitive CCD. The SCD is a newly developed large area ($100mm^2$) single-pixel silicon X-ray detector. It has the same readout noise, and thus energy resolution characteristics of the very best customized X-ray CCD detectors.

These devices can meet the performance requirements at 'near room' temperatures , 0° to -10°C.

BUT when operating in a proton radiation environment protective measures have to be taken.

The trapped and solar protons can generate vacancies in the silicon detector which act as charge trapping sites which degrade the performance in particular the energy resolution. The low energy protons which actually stop in the silicon cause the most damage and therefore a sliding shield to absorb them will be moved over the detectors each time the trapped proton belts are entered. The energy resolution can be restored to a certain extent by increasing the signal readout integration period. The increased integration time also increases the system noise which has been offset by reducing the nominal operating temperature to ≤-20°C.

The angular/spatial resolution is provided by a low profile(~3mm) collimator mounted directly above the SCDs.

The energy of individual X-rays will be recorded and the event time-tagged. Depending on the telemetry capacity available the individual event data will be transmitted to ground or a spectrum will be accumulated on board and then transmitted.

The Solar X-ray monitor, which provides the measurement of the flourescence excitation radiation, will measure the spectrum continusously with a 16s integration time.

The data will be time tagged and transmitted as it becomes ready.

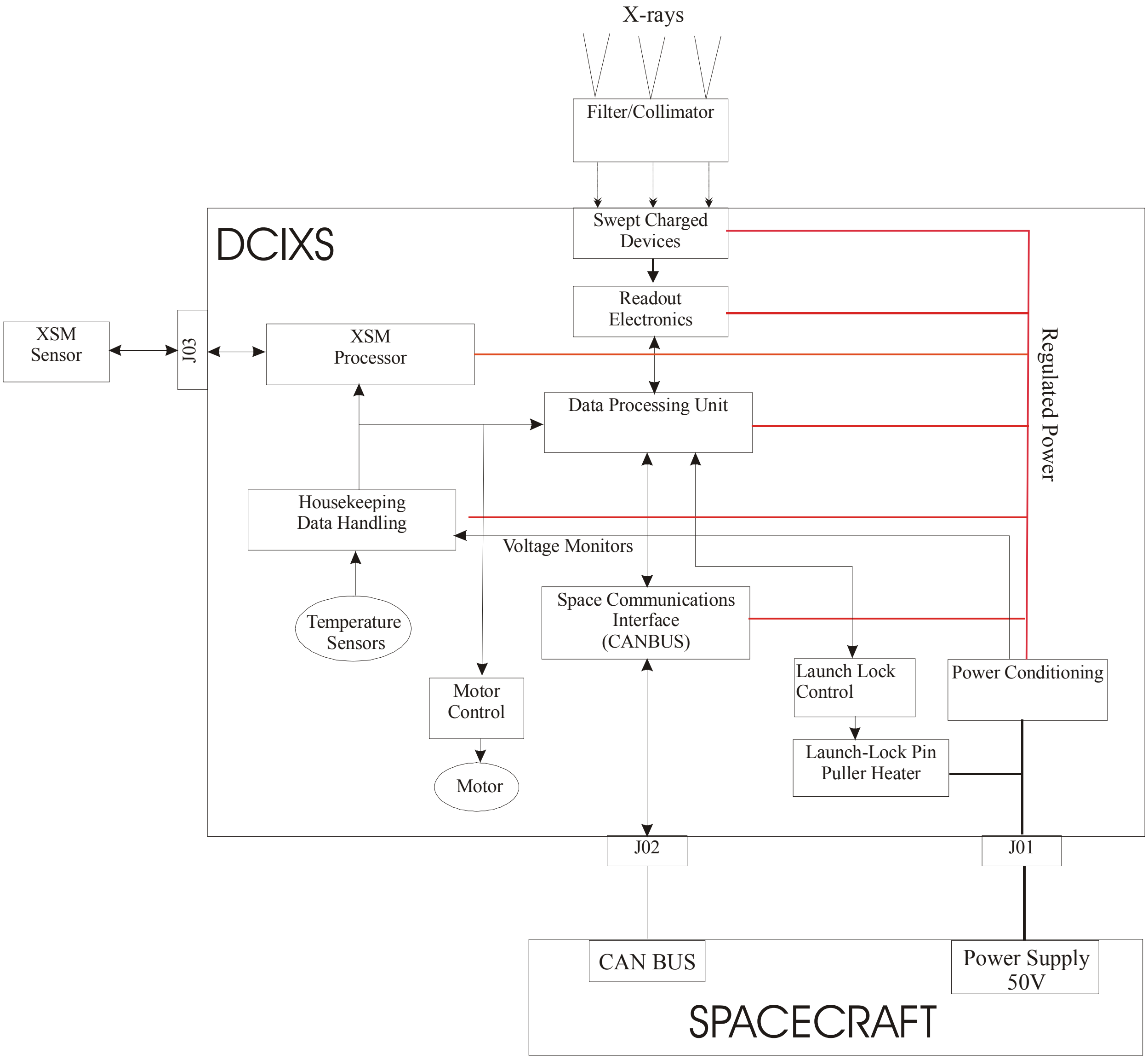


Figure 5-1 DCIXS/XSM System

5.2.1.3.2.1 Detector Assembly

A schematic of the detector assembly is shown in Figure 5-2.

The detectors are mounted in a housing which acts as a heatsink and provides attenuation using gold plating shielding for the X-ray background generated as secondary products in local structure from primary cosmic ray flux. High-energy events depositing large amounts of charge within the detector are discriminated by threshold detection, so that although contributing to a detector dead time they do not produce background signal.

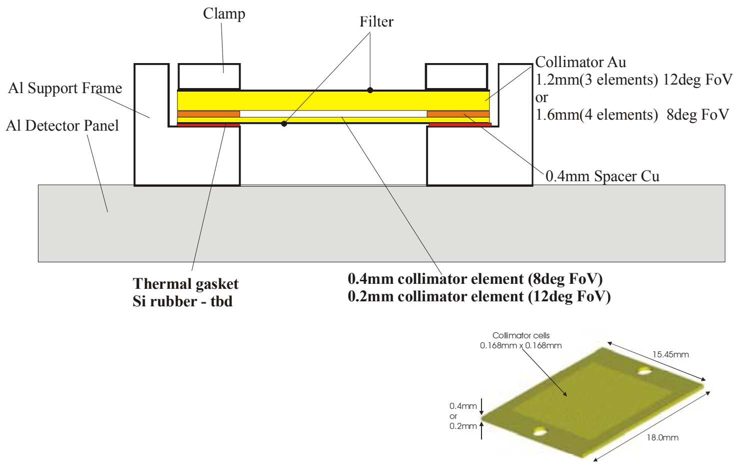


Figure 5-2 Detector Assembly

5.2.1.3.2.2 Detectors

Four SCDs are mounted on a ceramic substrate with the clocks and signal lines available on pins.
See Figure 5-3.

The detectors are mounted in small groups of four for ease of handling.

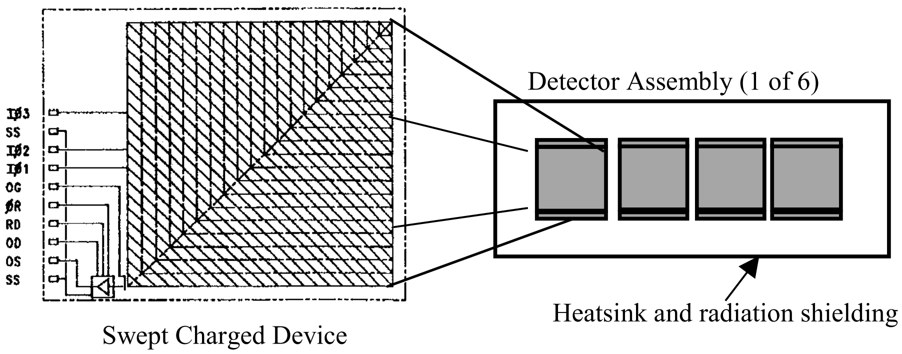


Figure 5-3 Detector Configuration

A summary of the SCD's characteristics is given in Table 5-3

SCD electrodes are arranged in a design that, upon clocking, will 'sweep' any charge towards a low capacitance sense amplifier located in one corner of the detector (the bottom left-hand corner as shown in Figure 5-3). The design of the sense amplifier is again based upon that used in CCD technology, consisting of a very low capacitance sense amplifier and reset transistor, and again operates in exactly the same way as in a CCD. Readout noise as low as 3 electrons rms. at 100KHz readout rate can be anticipated as this has already been demonstrated in EEV's latest CCD designs.

Table 5-3 Swept Charge Device Characteristics

Sensitive area:	10 x 10 mm
Max. Count rate:	30,000 counts/sec
Output noise:	3 (typ.) to 5 (max.) electrons rms. (with 100KHz Correlated Double Sampling)
Energy Resolution:	140eV
Detector Efficiency:	>30% at 280eV >30% at 10keV
Operating temperature:	-10°C to 0°C -20°C in proton radiation environment

5.2.1.3.2.2.1 Collimator Assembly

The assembly consists of the low profile collimator layers interleaved with aluminium thin film filters which act as a visible light blocking filter preventing reflected solar light from entering the detector and also functions to absorb the background solar electrons. These are present at the collimator entrance at a flux of ~100 s^{-1}

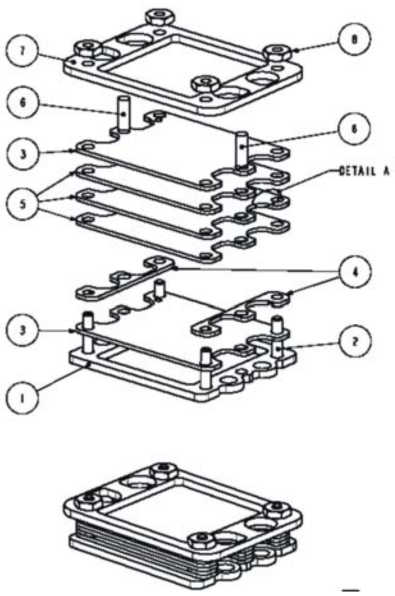


Figure 5-4 Collimator/Filter Configuration

A total of 4000Å of aluminium filter reduces the electron flux to essentially zero whilst allowing the transmission of 1-10keV fluorescence X-rays. For maximum electron suppression and immunity to pinholes, the filter is realised as two separate foils. Free standing filters of this thickness would be far too fragile to survive launch thus a suitable mesh support is required. The collimators themselves make ideal filter support structures.

5.2.1.3.2.3 SCD Readout Electronics

A block diagram of the front-end readout electronics is given in Figure 5-5. The SCD detectors are all operated in parallel under the control of a master waveform generator ASIC. This ASIC provides all the timing signals for driving the SCD electrodes, output amplifiers, the external correlated double sampling (CDS) signal processing electronics and analogue-to-digital converter (ADC).

Digital control signals from the ASIC are level-shifted and buffered for driving the SCD's electrodes, again using circuitry already developed for CCD applications. The video signal from each SCD is taken to a CCD Signal

Processor integrated circuit via a preamplifier. The signal processor performs the correlated double sampling and A/D conversion.

The digitised data is fed through an ACTEL FPGA which performs data thresholding in the digital domain, and thus provides the first stage of data reduction by only passing on those data that are above a predefined, but programmable threshold. From the ACTEL, the data are passed to the Data Processor Unit (DPU). See Figure 5-1.

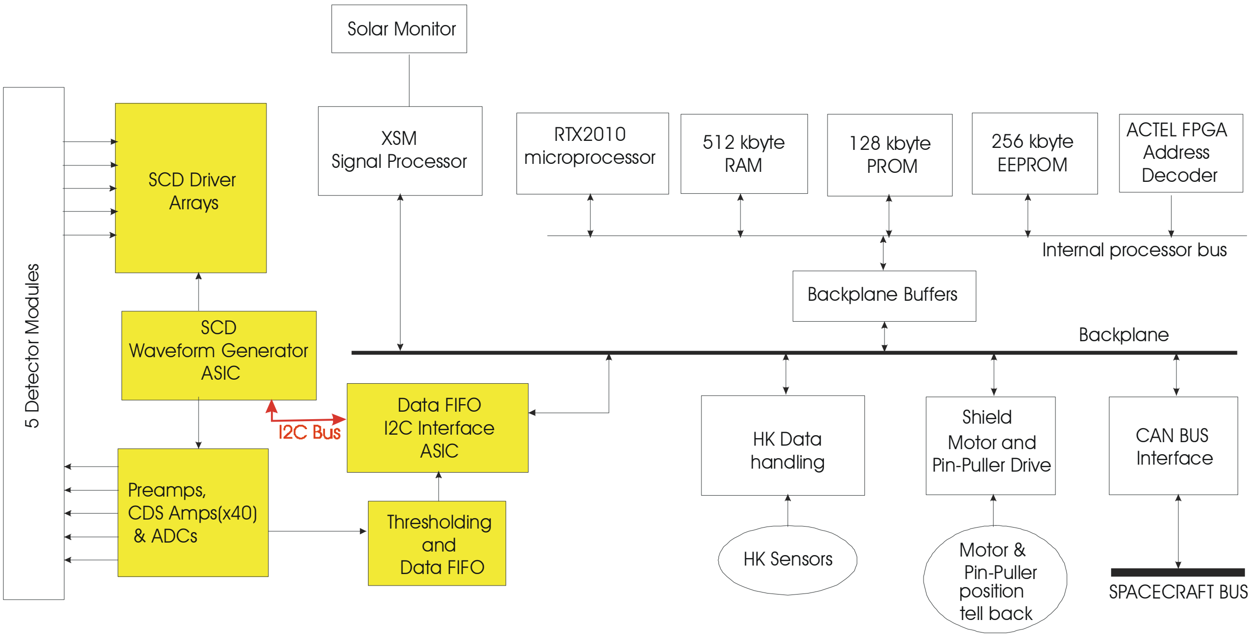


Figure 5-5 Swept Charged Device Readout System

5.2.1.3.2.4 Data Processing Unit

The Data Processor Unit (DPU) has design heritage from the ROSETTA MODULUS experiments. A block diagram of the DPU is given in Figure 5-6. It consists of an RTX2010 microprocessor with RAM, PROM, and EEPROM memory. The main functions of the unit are:

- to receive commands from the spacecraft OBDH,
- to provide control and timing synchronisation between the DCIXS detectors and the Solar Monitor,
- to receive data from both the DCIXS detector array and the Solar Monitor, and in software to provide a software histogram data compression and time tagging,
- to monitor the status and health of the instrument, and to provide housekeeping telemetry data,
- to pass data from the instrument to the main spacecraft OBDH.

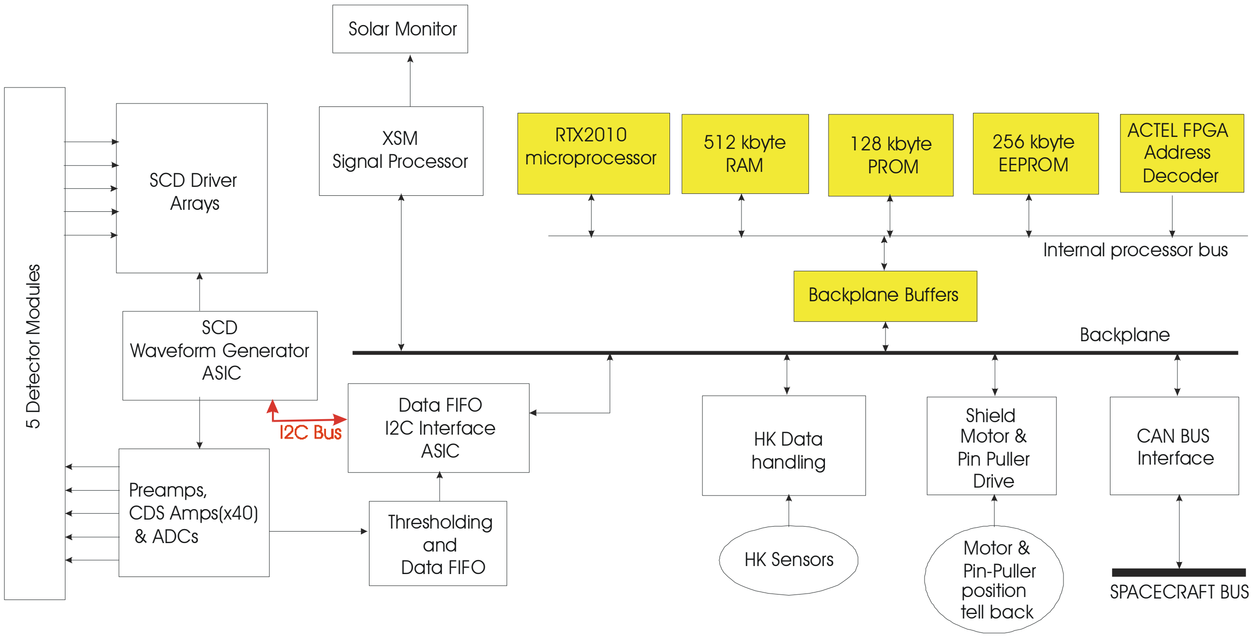


Figure 5-6 Data Processor System

5.2.1.3.2.5 Spacecraft Communications Interface

The interface between the processor bus and the spacecraft CAN Bus will be implemented in a FPGA supplied by ESA.

5.2.1.3.2.6 Housekeeping Data Handling

Temperature sensors and voltage monitors and Spacecraft Power Supply Current monitor will be conditioned and digitised on demand from the DPU via the internal backplane bus.

The housekeeping parameters are given in *S1-CIX-ICD-3002 Data Handling ICD*

5.2.1.3.2.7 Radiation Shield and Controller

The detectors will be protected from the lower energy protons, which will cause the most damage to the silicon detector material, by moving a 3mm thick tungsten shield in front as the trapped radiation belts are approached. It will be opened again on leaving the belts. See Figure 5-7

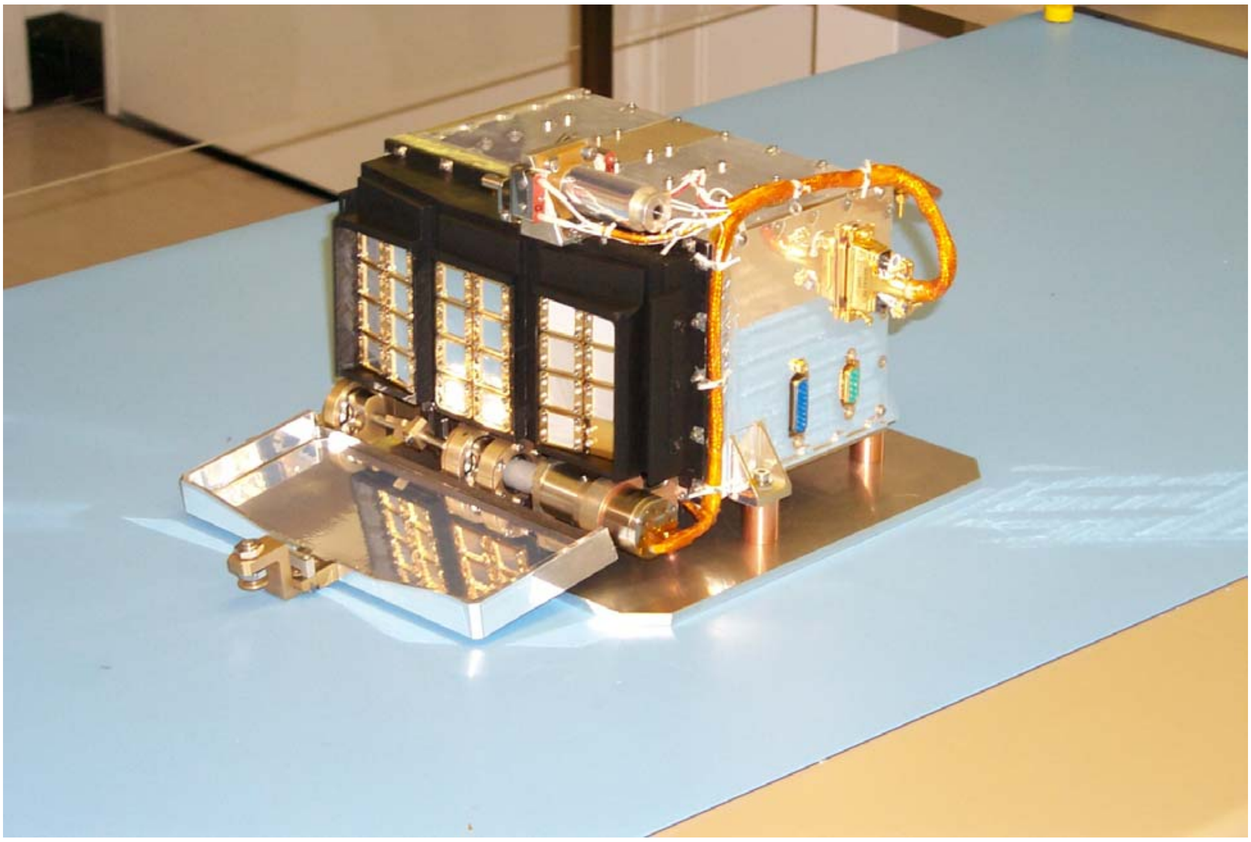


Figure 5-7 Radiation Shield

5.2.1.3.2.8 Solar Monitors

The sensor is an X-ray sensitive diode mounted on a Peltier cooler in a 13x9mm package behind a beryllium window. A front-end preamplifier is in the same detector package.

The Detector Characteristics

Sensor	Silicon diode
Area	0.28mm^2
Thickness	0.5mm
Energy Range	1keV to 20keV
Energy Resolution	250eV at 6keV
Window	Circular Be 25µm window
Field of View	52° half cone angle
Operating Temperature	Peltier Cooled to -20°C

The detector is mounted in a larger package which contains another preamplifier stage.
This package is mounted on the spacecraft.
See *Mechanical ICD S1-CIX-ICD-3004*

5.2.1.3.2.8.1 Solar Monitor Electronics

The system for processing the pulses from the detector and controlling the Peltier cooling of the sensor is contained on a single circuit board within the DCIXS unit.

The system overview is given in Figure 5-8

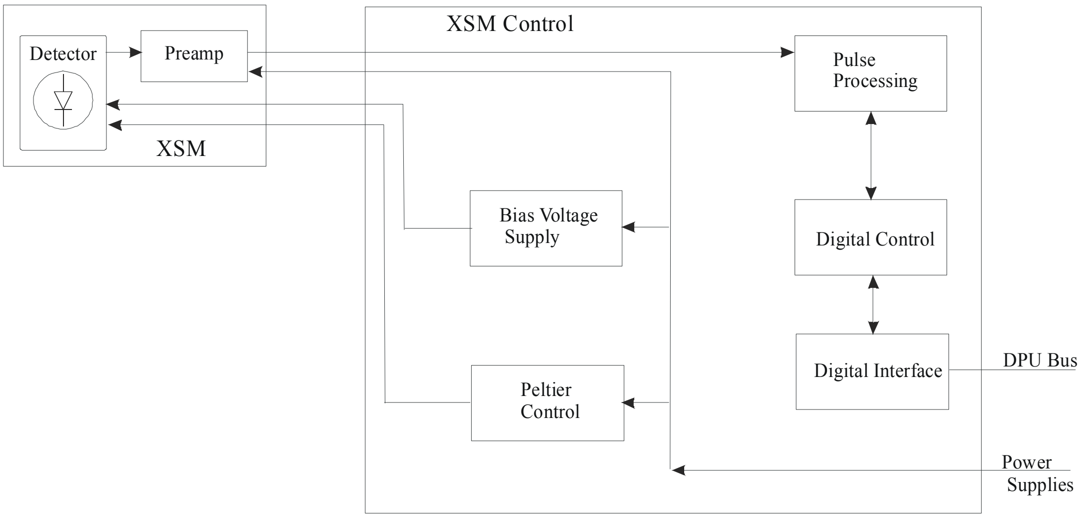


Figure 5-8 XSM System

5.2.1.3.2.9 Power Conditioning

The spacecraft power supply provides a nominal 50V bus which can vary between 49V to 50.5V. Inrush current limiting will be provided to ensure the turn-on profile lies within the required envelope. Emissions from the converter will be supressed by the input filter stage.

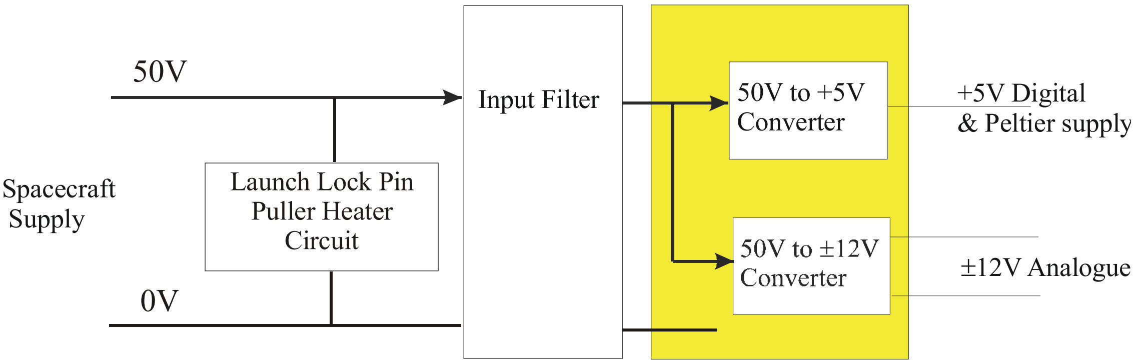


Figure 5-9 Power Conversion System

5.2.1.3.3 Software description

5.2.1.3.3.1 Scope of the software

The Software Product shall be identified as DOBS - DCIXS On Board Software. The software shall be responsible for the control of the DCIXS & XSM experiments for periods of up to 4 days without Earth contact. It shall collect science and housekeeping data from the experiments and forward these to the spacecraft. It shall receive, interpret and execute telecommands for the experiments and perform, autonomously, those actions that cannot be reasonably commanded during Earth contact or predicted sufficiently accurately to be handled by time-tagged telecommands.

The goal of the software is to allow the most effective collection and transmission of science data by DCIXS and XSM consistent with instrument survivability and with the external constraints on resources placed on the instrument. The overall benefits of the mission are, first, proving of the technology of the DCIXS and XSM experiments and, second, collection of data on solar X-ray flux (XSM) and Lunar soft X-ray emmisions (DCIXS). The Lunar soft X-ray events (photons) must be time tagged with sufficient accuracy to allow location of the source on the Moon. The Solar X-ray flux is required contemporaneously with the Lunar soft X-ray data for calibration purposes.

During the (long) cruise to the Moon, certain astronomical sources shall be observed by DCIXS for calibration purposes. One (the Crab Nebula) shall be at least two orders of magnitude brighter than the flux from the Moon. However, Solar X-ray flux and time tagging of the soft X-ray photons is not required for these observations. The software shall need to provide separate modes (or sub-modes) of data acquisition/formatting to suit these different types of observation.

5.2.1.3.3.2 General Capabilities

The following general functions are required of the software:

- Receive, validate, interpret and execute DCIXS telecommands.
- Set up the instrument and electronics into the required operating state (usually in response to a TC).
- Acquire and collate science data from the DCIXS and XSM detectors and format into PUS packets for transmission.
- Gather analogue housekeeping data from the XSM and DCIXS electronics once per second.
- Once per second, monitor analogue housekeeping data. Report results in housekeeping TM.
- Take appropriate action when anomalies are detected.
- Format housekeeping data into PUS packets for transmission every 64 seconds.
- Maintain an on-board time reference synchronised with the Spacecraft on-board time to allow time stamping of TM packets and of DCIXS photon events (for correlation with attitude history).
- Maintain a history of instrument operation (TCs, events, anomalies) for subsequent transmission.
- Perform routine system health checks.
- Perform such autonomous actions as are necessary for the continued collection of useful science data.
- Respond to an external watchdog timer in the event of a software anomaly.
- Provide an emergency operating mode in the event of a system failure to enable diagnostic data to be transmitted and recovery procedures to be effected.

5.2.1.3.3.2.1 Receive, validate, interpret & execute DCIXS TCs

The TCs must be acquired from the CAN-bus interface as CAN packets and assembled into PUS TC packets. Each of the TCs described in *Data Handling ICD S1-CIX-ICD-3002* must be supported.

5.2.1.3.3.2.2 Set up instrument/electronics into required operating state

Mechanisms & power:

On start-up or entry into standby or ROM-emergency mode, the DOBS must ensure that the XSM, DCIXS detector electronics and mechanisms are powered off.

On entry into self-test or operating mode, the DOBS must Optionally (as specific in the mode change TC) power on any selected combination of the XSM and the two DCIXS processing chains.

WGA, FPGA and analogue processing:

The XSM must be set to its normal cooling mode. Also, at these transitions, the DOBS must load the correct waveform into the WGA, via the I2C interface on the RICA, and set up the FPGA and Analogue registers for each of the two DCIXS analogue processing chains.

5.2.1.3.3.2.3 Acquire and collate science data from the XSM and DCIXS electronics

XSM: The DOBS must regularly read the XSM event FIFO, collating the events to produce a 512 element XSM spectrum every second. The 1 second spectra shall be combined to produce 16s spectra for downlink.

DCIXS: The DOBS must regularly read the DCIXS event FIFO, depending on data formatting sub-mode and data rate, the events shall be reported either in a time-tagged event TM packets or in high or low rate spectra.

5.2.1.3.3.2.4 Gather Analogue HK data from DCIXS and XSM every second/ Monitor analogue parameters

Analogue HK values shall be collected from the DCIXS electronics and from the XSM electronics each second. Simple health checks shall be performed. The Each HK packet shall include the latest collected values for selected signals.

5.2.1.3.3.2.5 Take appropriate action when anomalies are detected.

If an analogue HK parameter exceeds a safety limit, the corresponding subsystem (XSM or DCIXS science electronics) should be switched off/disabled.. No DCIXS analogue parameters have yet been identified for which a safety limit with corresponding action may be defined.

5.2.1.3.3.2.6 Perform routine system health checks

The XSM leakage current must be monitored against a threshold, its rate of increase should also be checked against a second threshold. In operating mode, the DCIXS detector total counts should be summed and checked against a threshold to detect excessive ambient ionising radiation. Individual detector total counts should be checked against a limit to detect damage.

5.2.1.3.3.2.7 Perform autonomous actions

If the XSM leakage current exceeds a threshold determined by two software parameters, which are monitored and updated during flight, the XSM must initiate an annealing sequence. After the sequence, XSM performs spectral calibration, updates the leakage current threshold, and returns to scheduled operation.
The total duration of XSM annealing sequence is about 6 hours.

If the total counts for 16 (software parameter) or more of the 24 DCIXS detector count totals exceeds a certain threshold (software parameter) the DCIXS detector door must be closed. The door shall be opened when the total count falls below a lower threshold (also a software parameter) for 8 (software parameter) or more detectors. If the total count for a particular detector should exceed a separate (software parameter) threshold, that detector shall be disabled and prevented from feeding data into the DCIXS RICA FIFO pending action/decision on the ground.

5.2.1.3.3.2.8 Respond to external watchdog timer

A watchdog timer shall restart the DOBS in ROM-Emergency mode in case of a software crash. The software shall reset the timer no less often than once per second when executing correctly.

5.2.1.3.3.2.9 Emergency Mode

The software must have an emergency operating mode that allows patching to RAM and dumping of memory locations. This mode shall be entered in case of a failed test at start-up or in case of a crash of the RAM-based software. The emergency mode should, if possible make no use of RAM or interrupts.

5.2.1.3.3.3 General constraints

- The software must be compatible with the target processor (RTX2010)
- The code and constant data for the software must fit within 128K bytes. If the code and constant data can fit within 64k bytes, this would save two PROM devices
- The variable data structures used by the main program memory must not require more than 64 kbytes of RAM – this limit is imposed by the C compiler. Extended data structures such as history records, queues etc. may occupy other pages of RAM but must then be accessed via assembler routines
- The emergency mode software must run from PROM and be able to function given any one page of working RAM – preferably being completely PROM based with no RAM requirements
- The processing requirements must not exceed available resources (4.192 MIPS)
- Memory and mill time constraints must be satisfied with at least a 30% margin

5.2.1.3.4 On-board calibration

5.2.1.3.4.1 D-CIXS Field of View Calibration

This calibration measurement determines the operational characteristics of the collimators and will be carried out only once at the very start of the cruise phase. It will involve multiple scans in orthogonal directions for each of the three detector facets of the instrument.

5.2.1.3.4.2 D-CIXS Detector Calibration

These measurements will be taken at regular intervals, monitoring the detectors for degradation of performance due to effects such as proton damage. Approximately one detector calibration per month will be taken throughout the cruise phase, and we would hope to continue this through the lunar phase also, providing this does not impact the lunar observations of the other instruments on board.

A calibration of a single sensor for reference purposes will be made in regular intervals (TBD) using radioactive on-board Fe55 source with Ti filter, with emission lines at 4,508 keV (Ti), 5,895 keV and 6,492 keV (Fe).
Purpose of the calibration is to determine the spectral channel width and offset in physical units, and estimate the spectral resolution of the detector to monitor the degradation of the sensors in the radiation environment.
The format of calibration data is identical with that of normal observation. The calibration source is located in place of a collimator element and will not cause radiative effects external to the sensor.

5.2.1.3.4.3 XSM Calibration

Calibration will be made in regular intervals (TBD) using radioactive on-board Fe55 source with Ti filter, with emission lines at 4,508 keV (Ti), 5,895 keV and 6,492 keV (Fe). Purpose of calibration is to determine the spectral channel width and offset in physical units, and estimate the spectral resolution of the detector. Calibration can be made during time when XSM is not observing the Sun (shutter is closed). The format of calibration data is identical with that of normal observation. The calibration source is located inside XSM sensor module, and will not cause radiative effects external to the module.

5.2.1.4 Summary of Instrument Operations

The operations envisaged for each phase of the mission are outlined in Table

Table 5-4: Operations during each phase of the mission

LEOP	Instrument Off
Escape Continuous Thrust	Instrument Off - radiation shields closed in radiation belts
Escape Coast Arcs	Radiation Shields closed in radiation belts DCIXS Calibration Astronomical observations Auroral Observations DCIXS/XSM on-board calibrations
Lunar Observation	Lunar Observation Astronomical observations DCIXS/XSM on-board calibrations

The experiment modes are defined below and the possible mode transitions are shown in Figure 5-10 Mode Transitions - Command Validity

The DCIXS and XSM radiation shields should only be opened in OPERATING mode when prevailing radiation environment is acceptable. i.e no large proton fluxes

The experiment modes and the data handling states will be used during the mission phases as shown in Table 5.2.

Table 5.2 Experiment Mode/Mission Phase Correlation

Experiment Mode	Mission Phase / Experiment Data State	Pre-Launch	LEOP	Escape Continuos Thrust	Escape Coast Arcs	Lunar Observation
LAUNCH LOCK		X	X			
OFF		X		X	X	X
EMERGENCY		X			X	X
STANDBY		X			X	X
SELF-TEST		X			X	X
OPERATIONAL	DCIXS - Time tagged Event Format	X			X	X
	DCIXS - Low Count Spectrum Format	X			X	X
	DCIXS - High Count Spectrum Format	X			X	X
	DCIXS - Autoformat [Default]	X			X	X
	XSM	X			X	X
	Housekeeping	X			X	X

5.2.2 SYSTEM CHARACTERISTICS AND CONST.

5.2.2.1 Instrument System Budgets

5.2.2.1.1 Mass budget

The measured mass breakdown of the D-CIXS and XSM system is given..

The data are based on the following configuration

1. D-CIXS unit to include
    - Detector assemblies
    - D-CIXS processing electronics
    - Spacecraft communications interface
    - Radiation Shield and actuator system
    - Power conditioning and switching
    - XSM Processing electronics
2. XSM Detector Assembly (+X spacecraft panel)
3. Harness 2.8m to +X Panel XSM

Mechanical Interface Drawing Reference KE-0140-001

Item	Mass kg
DCIXS	4.65
XSM	0.21
Harness	0.19
Total	5.05

5.2.2.1.2 Power budget

Table 5-5 shows the instrument power used for each mode. The use of each mode is indicated in the last four columns, with a "Y" indicating that this mode may be used during this phase of the mission. Note that the mode "STANDBY + launch lock pin puller" will be used only once during the mission.

Table 5-5 Power

Mode	Instrument Power	Heater Power	Pre-launch	LEOP	Cruise (inc. commissioning	Lunar phase (inc. commissioning
Off	0	10W	Y	Y	Y	Y
STANDBY						
After Power-ON	7.8	-	Y	Y	Y	Y
On return from OPERATING mode	10		Y		Y	Y
STANDBY + DCIXS door drive	12.2 for 20s	-			Y	Y
STANDBY + Launch Lock PinPuller	23.8 for ~ 2 mins	-			Y	
DCIXS ANNEAL	60 for TBD hours				Y	Y
OPERATING MODE						
XSM only	15.2	-	Y	Y	Y	Y
XSM + shutter	15.2	-	Y	Y	Y	Y
XSM + DCIXS door drive	17.5 for 20s	-			Y	Y
Half DCIXS detectors only	13	-	Y	Y	Y	Y
Half DCIXS detectors + door drive	15.3	-			Y	Y
Full DCIXS detectors only	17	-	Y	Y	Y	Y
Full DCIXS detectors + door drive	19.3	-			Y	Y
Full DCIXS + XSM	24.5	-	Y	Y	Y	Y
Full DCIXS + XSM + DCIXS door drive	26.7 for 20s	-			Y	Y
Full DCIXS + XSM + shutter	24.5	-	Y	Y	Y	Y
TEST MODE	17	-	Y	Y	Y	Y

5.2.2.1.3 Data Handling budgets

5.2.2.1.3.1 Time-tagged Command Budget

All commands are 14bytes long which includes 6 bytes command and 8 bytes PUS packet header and CRC. In the event of anomalous operations requiring a memory patch the command length be longer.

Phase	Time-tagged commands
Cruise	100 /4 days
Lunar Observation	16 /4 days

During lunar observation we would in principle just command the instrument into an observation state and leave it run for 6 months.

This is based on a simple situation where the spacecraft is continuously pointing at the Moon and there are no regular manoeuvres to view stars for example.

There will be a lunar observation commissioning phase during which we will assess the thermal balance and adjust our operational state to ensure the detectors are cold enough.

With no routine commanding identified at the moment, the budget for 16 /4 days during lunar phase gives 4 commands/orbit which should the enable shield closures to be commanded at positions round the orbit.

5.2.2.1.3.2 Inertial Staring/ Cruise Phase

There may be some cruise phase orbits where all of the observing states will be used for some part of the orbit. Consequently the calculation of the data collected in a 4 day period must take this into account. This will be possible when a more detailed analysis of the observational constraints and commanding logistics have been made.

The observation programme will be constructed to be compatible with spacecraft resources – mass memory allocation and CAN BUS usage.

Table 5-6 Cruise Phase Observations

Observation	Data Format	Event Rate /s	Packets /s	Observation Duration (hours)	Total Data Packets /4 days	Mbits
Earth's X-ray aurora: Argon line and N-S Conjugacy.	DCIXS Time tagged events	50	0.78125	1	2812.5	6.30
Earth's Magnetotail.	DCIXS Low Count Spectrum		3	1	10800	24.19
Astronomical objects	DCIXS High Count Spectrum		3	20	216000	483.84
XSM Solar Monitoring	XSM sensor		0.25	48	43200	96.77
X-ray emission from Comets	DCIXS Time tagged events	64	1	0	0	0.00
DCIXS Calibration Spectral	DCIXS High Count Spectrum		3	2	21600	48.38
DCIXS Calibration FoV	DCIXS High Count Spectrum		3	0	0	0.00
Housekeeping	Housekeeping		0.015625	96	5400	12.10

The DCIXS Field of View (FoV) calibration is a measurement which will be made only once when it possible to open the radiation shield and view an appropriate celestial X-ray source. The total amount of data will depend on the spacecraft manoeuvre rates.

5.2.2.1.3.3 Lunar Observations

The event rate is dependent on the state of the sun and the sun/moon/spacecraft geometry. A typical case is given in the table below.

Table 5-7: Lunar phase observations

Observation	Data Format	Event Rate /s	Packets /s	Observation Duration (hours)	Total Data Packets /4 days	Mbits
Lunar geochemistry -DCIXS	DCIXS Time tagged events	2	0.03125	44.25	4978.125	11.15
Lunar geochemistry -DCIXS	DCIXS Low Count Spectrum		3	3.75	40500	90.72
Lunar plasma interaction – DCIXS only	DCIXS Time tagged events	0.08	0.00125	48	216	0.48
XSM Solar Monitoring	XSM sensor		0.25	48	43200	96.77
Housekeeping	Housekeeping		0.015625	96	5400	12.10
				Total Packets/4 days	94294.125	211.22

The worst case event rates generate more packets than can be accommodated by the mass memory allocation. The observation times will therefore be optimised within the allocation

5.2.2.1.4 Pointing and alignment budgets

Table 5-8 FoV and Nominal Alignment

	DCIXS	XSM +X Panel
Nominal Boresight	+Z	45° from –Z axis in Z-X plane
FOV	Z-Y Plane ±20° Z-X plane ±4°	105° full cone
Minimum sun aspect	No constraint except – 90° during astronomical observations in escape phase	N/A

5.2.2.1.4.1 Pointing Requirements – Escape Phase

5.2.2.1.4.1.1 DCIXS - X-ray observation of terrestrial aurora

5.2.2.1.4.1.1.1 Direction:

+Zs to centre of Earth (accuracy dependent on distance from earth – highest accuracy ±2°)
Centre of Earth in Xs-Ys plane
Sun not within ±20° of Zs axis

5.2.2.1.5 Accuracy and Rate

Pointing	X-axis	Y-axis	Z-axis
APE	10°	10°	2°
AMA	Not critical		
RPE(10s)	Not critical		
RMA(10m)	Not critical		

5.2.2.1.5.1 Earth's Magnetotail

No requirement – in-situ measurement only

5.2.2.1.5.2 DCIXS - Observation of celestial X-ray sources Time Variability

5.2.2.1.5.2.1 Direction

+Zs axis to Object
Observations can only be made when the angle between the sun and $+Z_s > 90^o$.
A preliminary selection of 6 sources to be observed are given below.
More will be included if the observation time permits.

Source	Name	Right Ascension	Declination
#1	M82	10:04	+70
#2	3C273	12:26	+02

#3	NGC4151	12:06	+39
#4	M87	12:28	+12
#5	NGC5548	14:14	+25
#6	CEN A	13:22	-42

5.2.2.1.5.2.2 Accuracy and Rate

Pointing	X-axis	Y-axis	Z-axis
APE	2°	2°	2°
AMA	6\`	6\`	6\` (1)
RPE(10s)	1\`	1\`	1\`
RMA(10m)	2\`	2\`	2\`

Celestial X-ray source observation will also be used for DCIXS alignment calibration

(1) This is not an absolute requirement for these time variability measurements but corresponds to a 10% error in time variability measurement compared to the declared spacecraft capability of 30\` which corresponds to ~25% error.

5.2.2.1.5.3 XSM - Observation of solar X-ray variability

5.2.2.1.5.3.1 Direction

Sun within the field of view of one of XSM sensors
Sensor Boresight ±40°

5.2.2.1.5.3.2 Accuracy and Rate

Pointing	X-axis	Y-axis	Z-axis
APE	10°	10°	10°
AMA	1°	1°	1°
RPE(10s)	Not critical		
RMA(10m)	Not critical		

5.2.2.2 Instrument Characteristics

5.2.2.2.1 Functional Requirements

- Survive launch and space environment
- Detect X-rays in the 1-10keV range from the lunar surface and celestial objects
- Operate from a 50V spacecraft power supply
- Communicate with spacecraft via CAN-bus interface
- Respond to ground commands via spacecraft
- Transmit data to ground via spacecraft

5.2.2.2.2 Key-performance Table

The main DCIXS instrument performance requirements which are independent of the solar x-ray source and spacecraft capabilities are :

X-ray spectral energy resolution	200eV
Minimum detectable energy	500eV

5.2.2.2.3 Calibration Data

The instrument energy resolution and field of view calibration will be performed at regular intervals during the cruise phase and in lunar orbit by observation of celestial objects with known X-ray emission characteristics. During the instrument AIT phase the response to Fe55 line emissions has been measured at the nominal operating temperatures.

5.2.2.2.4 Pointing and Stability Analysis and Budgets

See 5.2.2.1.4

5.2.2.2.5 Radiation Susceptibility

Total Dose - Shielding designed and components chosen to survive expected mission dose

Latch- Up - circuit protection included in design

SEU - watchdog timer system included

Damage - protons - Door and shutter provided which will close when proton fluxes are high enough to potentially cause damage.

5.2.2.2.6 Limited Life items

Launch Lock Pin-puller 100 operations

After launch hopefully only one operation will be required.

5.2.2.2.7 Instrument Performance Degradation

An objective of the mission is to measure the performance degradation of the detectors in the radiation environment particularly solar protons.

5.2.3 INTERFACE DEFINITION

5.2.3.1 Mechanical interfaces

5.2.3.1.1 Mechanical ICD - S1-CIX-ICD-3004

5.2.3.1.2 DCIXS Mechanisms design

There are two mechanisms on the DCIXS/XSM instrument.

1. DCIXS Radiation Shield Actuator
2. XSM Shutter Actuator

DCIXS Radiation Shield Actuator - S1-CIX-TN-3013

5.2.3.1.3 XSM Mechanism Design S1-CIX-TN-3903

5.2.3.1.4 Alignment and stability analysis

The alignment on the spacecraft provided by the fastener tolerance is acceptable.
The stability as given in section 5.2.2.2.4

5.2.3.1.4.1 SMM

Not applicable

5.2.3.2 Thermal interfaces

5.2.3.2.1 Thermal ICD S1-CIX-ICD-3005

5.2.3.2.2 TMM (Thermal Mathematical Model)

Interface and dissipation data supplied in ICD S1-CIX-ICD-3005

5.2.3.3 Electrical interfaces

5.2.3.3.1 Electrical ICD S1-CIX-ICD-3003

5.2.3.3.2 EMC Summary results S1-TR-CIX-3009

5.2.3.4 Data Handling interfaces

5.2.3.4.1 Data Handling ICD S1-CIX-ICD-3002

5.2.3.5 GSE interfaces

5.2.3.5.1 MGSE

Transport container only

5.2.3.5.2 EGSE

The EGSE is comprised of:

1. SIS - CAN Interface
2. 50V power Supply
3. Test harness
4. LISN
5. LSPCC

5.2.3.5.3 Fluid interfaces (if any)

Not applicable

5.2.4 INSTRUMENT HANDLING INSTRUCTIONS S1-CIX-PR-3002

5.2.5 INSTRUMENT OPERATIONS

5.2.5.1 Overview of Operating Principles

TBD

5.2.5.2 Nominal Experiment Operational Plans

TBD

5.2.5.2.1 Ground Operational Plan

TBD

5.2.5.2.2 In-orbit Commissioning Plans

D-CIXS has a self-test mode that will be run during commissioning and at various other points during the mission.
During commissioning the release of the pin-puller will also be carried out.
DCIXS and XSM will calibrate with an on-board Fe55 source, and will do so at various other points in the mission also.

5.2.5.2.3 Flight Operations Plans by Mission Phase

TBD

5.2.5.3 Failure Detection and Recovery Strategy

TBD

5.2.6 MODES DESCRIPTION

5.2.6.1 Summary of all nominal and back-up modes

The experiment modes are defined below and the possible mode transitions are shown in Figure 5-10.
The DCIXS and XSM radiation shields may be opened or closed in OPERATING and STANDBY modes

5.2.6.2 Mode transition diagram

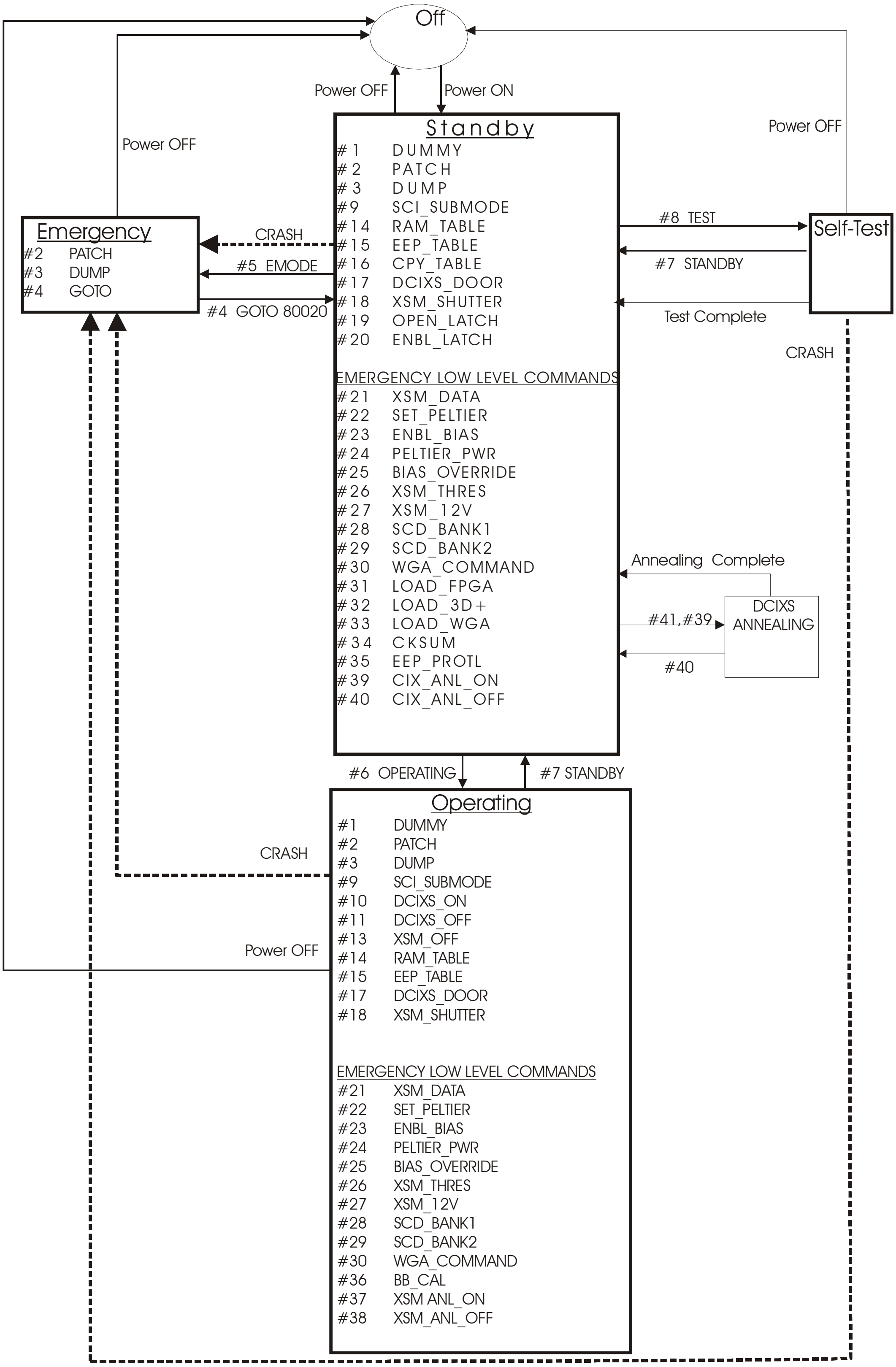


Figure 5-10 Mode Transitions - Command Validity

The experiment modes and the data handling states will be used during the mission phases as shown in Table 5.2.

Table 5-9 Experiment Mode/Mission Phase Correlation

Experiment Mode	Experiment Data State \ Mission Phase	Pre-Launch	LEOP	Escape Continuous Thrust	Escape Coast Arcs	Lunar Observation
LAUNCH LOCK		X	X			
OFF		X		X	X	X
EMERGENCY		X			X	X
STANDBY		X			X	X
DCIXS ANNEAL					X	X
SELF-TEST		X			X	X
OPERATIONAL	DCIXS - Time tagged Event Format	X			X	X
	DCIXS - Low Count Spectrum Format	X			X	X
	DCIXS - High Count Spectrum Format	X			X	X
	DCIXS - Autoformat	X			X	X
	XSM	X			X	X
	Housekeeping	X			X	X

5.2.6.3 Detailed mode description

Table 5-10 Experiment Mode Definition

Mode	State	Functionality
LAUNCH LOCK		Instrument switched off. DCIXS Launch Lock **engaged**
OFF		Instrument switched off. DCIXS Launch Lock **disengaged**
EMERGENCY		Software Crash operating from PROM Processor Only System data only in Housekeeping Packet
STANDBY	LAUNCH LOCK	DCIXS Launch Lock engaged Housekeeping data collection No detector operation No science data collection.
STANDBY	POST LAUNCH	Housekeeping data collection No detector operation No science data collection.
DCIXS ANNEAL		Annealing DCIXS Detectors
SELF-TEST		Housekeeping data collection Detectors in operation, and self-checking of background noise spectrum.
OPERATIONAL (1)	DCIXS - Fixed Time-tagged Event Sub-mode	Housekeeping data collection Detectors in operation Science data - Time tagged Event Format XSM data

Mode	State	Functionality
	DCIXS - Fixed Low Count Spectrum Submode	Housekeeping data collection Detectors in operation Science data - Low Count rate Spectrum Format XSM data
	DCIXS - Fixed High Count Spectrum Submode	Housekeeping data collection Detectors in operation Science data - High Count rate Spectrum Format XSM data
	DCIXS - AutoFormat Submode	Housekeeping data collection Detectors in operation Science data - AutoFormat XSM data
	DCIXS - Fixed Time-tagged Event Sub-mode	Housekeeping data collection Detectors in operation Science data - Time tagged Event Format XSM data
	DCIXS - Fixed Low Count Spectrum Submode XSM not operating	Housekeeping data collection Detectors in operation Science data - Low Count rate Spectrum Format
	DCIXS - Fixed High Count Spectrum Submode XSM not operating	Housekeeping data collection Detectors in operation Science data - High Count rate Spectrum Format
	DCIXS - AutoFormat Submode XSM not operating	Housekeeping data collection Detectors in operation Science data - AutoFormat
	XSM only DCIXS not operating	Housekeeping data collection XSM data

(1) The 2 DCIXS operational states can be used in any combination with the 2 XSM data gathering states

Table 5-11 Power

Mode	Instrument Power W	Heater Power W
Off	0	10
STANDBY	7.8	-
STANDBY + DCIXS door drive	10.0 for 20s	-
STANDBY + Launch Lock PinPuller	23.8 for ~ 2 mins	-
DCIXS ANNEAL	60 for TBD hours	
OPERATING MODE States:		
XSM only	15.2	-
XSM + shutter	15.2	-
XSM + DCIXS door drive	17.5 for 20s	-
Half DCIXS detectors only	13	-
Half DCIXS detectors + door drive	15.3	-
Full DCIXS detectors only	17	-
Full DCIXS detectors + door drive	19.3	-
Full DCIXS + XSM	24.5	-
Full DCIXS + XSM + DCIXS door drive	26.7 for 20s	-
Full DCIXS + XSM + shutter	24.5	-

5.2.6.4 Instrument Mode Related Software Actions

5.2.6.4.1 Power ON

- STANDBY Mode [V2.0] Software Version 2.0 runs
- Only Processor and CAN interface circuits operating
- DCIXS Signal Channel processing disabled
- DCIXS Door remains in the state prior to Power ON
- XSM unpowered
- XSM shutter remains in the state prior to Power ON
- Housekeeping data packets transmitting at 64s intervals

5.2.6.4.2 Activating Software Version 2.6

- Software Version 2.6 loaded via Emergency Mode and GOTO see Figure 5-12
- STANDBY Mode [V2.6] Software Version 2.6 runs
- Only Processor and CAN interface circuits operating
- DCIXS Signal Channel processing disabled
- DCIXS Door remains in the state prior to software load
- XSM unpowered
- XSM shutter remains in the state prior to software load
- Housekeeping data packets transmitting at 64s intervals

5.2.6.4.3 Transition to Operating Mode

Housekeeping data packets transmitting at 64s intervals

DCIXS Load Signal Data Processor FPGA configuration
Load Signal A/D converter configuration
Load detector drive Waveform Generator [WGA] configuration
Start WGA
16 seconds after mode transition Offset Calibration performed
Offset Calibration Data Packets transmitted
22 seconds after mode transition Offset Calibration performed
Offset Calibration Data Packets transmitted
24 seconds after mode transition DCIXS initialisation complete
Fixed Time Tag science data format selected
Fixed Time Tag science data packets transmitted for enabled detectors

XSM If XSM has not been disabled in STANDBY
Set XSM to State 0
Close Shutter
Start Run-up sequence see Figure 5-11

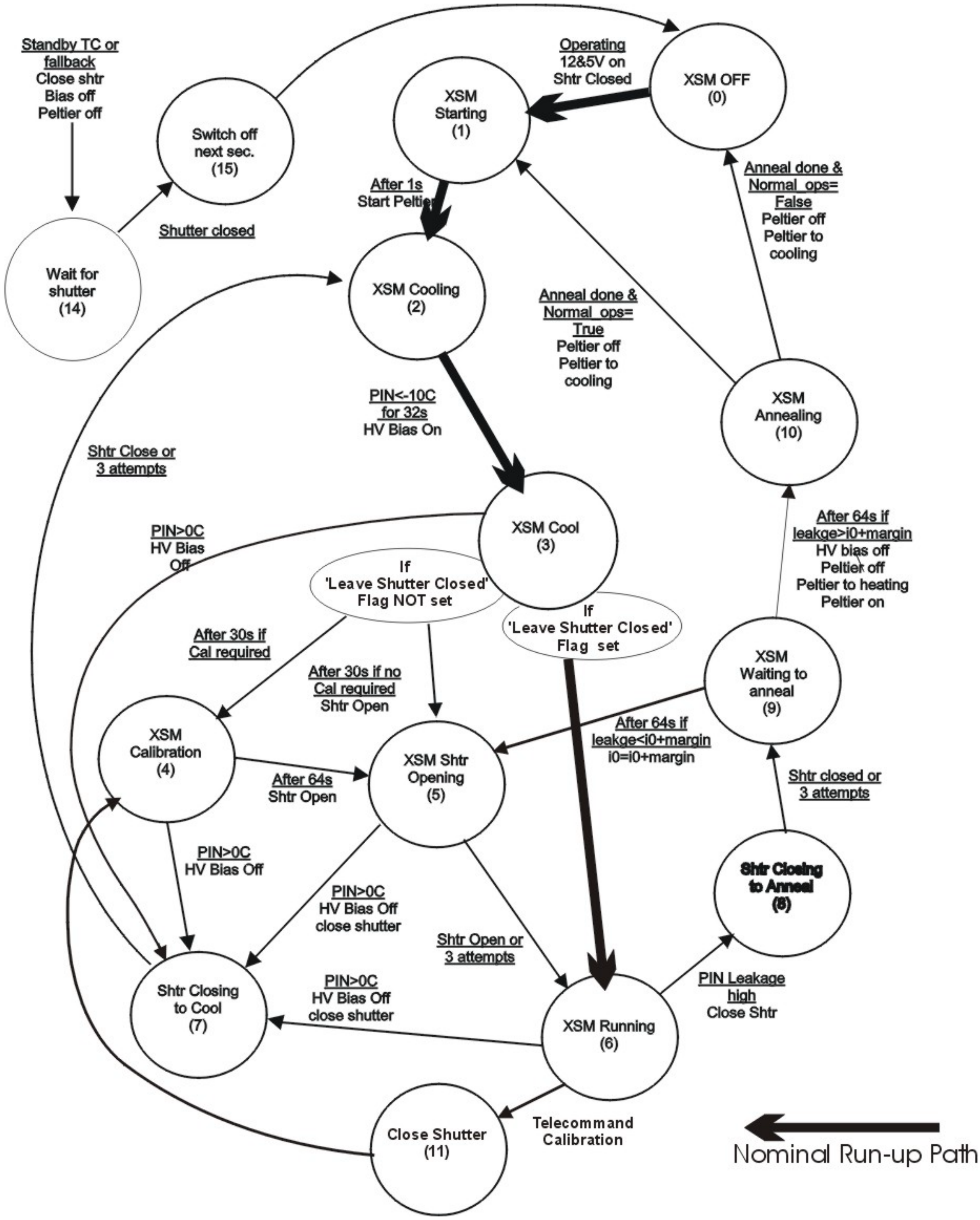


Figure 5-11 XSM Software State Diagram

State	Name	Description
0	XSM off	The software starts in this state, On entering Operating mode, provided that XSM operations are not disabled, The XSM is powered on and the state is set to 1
1	XSM Starting	XSM shutter close is initiated, the peltier target temperature is set and peltier cooling is started. The state is set to 2.
2	XSM Cooling	If the XSM has been in this state with the PIN below -10˚C for 32 seconds, the HV Bias is enabled and the state is set to 3
3	XSM Cool	If the PIN temperature rises above 0˚C, the HV bias is switched off, a shutter close is initiated and the state is set to 7. Otherwise, once the leakage current settling time has elapsed, XSM data processing is enabled and either a shutter open is initiated and the state set to 5 or (if a Calibration is requested) the state is set to 4
4	XSM Calibration	In this state, the XSM control software waits until 64 seconds have elapsed and then initates a shutter open and sets the state to 5. If the PIN temperature should exceed 0˚C wilst in this state, a shutter close is initiated, bias is disabled and the state is set to 7
5	XSM Shutter Opening	In this state, the XSM control software waits untils the shutter is open (or for 3 attempts) then sets the XSM state to 6. If the PIN temperature should exceed 0˚C wilst in this state, a shutter close is initiated, Bias is disabled and the state is set to 7.
6	XSM Running	This is the nominal state for the XSM in operating mode. If the PIN temperature should exceed 0˚C wilst in this state, a shutter close is initiated and the state is set to 7. If the PIN leakage current exceeds the limit specified in software parameter 43, a shutter close is initiated and the state is set to 8
7	Shutter Closing to Cool	In this state, the XSM control software is waiting for the shutter to close before restarting XSM cooling. When the shutter has closed, or 3 attempts have been made, the state is set to 2
8	Shutter Closing to Anneal	In this state, the XSM control software is waiting for the shutter to close before starting annealing of the detector. When the shutter is closed, or three attempts have been made, the state is set to 9
9	Waiting to Anneal	The XSM control software waits for 64 (nom.) seconds in this state and re-checks the PIN leakage current. If the leakage current is still greater than i0+software parameter 44, the peltier is set to heating mode and the state is set to 10, Otherwise, a new value for i0 is set (old i0 + software parameter 43), a shutter open is initiated and the state is set back to 5
10	XSM Annealing	The XSM control software stays in this state for the time period given in software parameter 45 (in seconds). At the end of this period, if the NOMINAL_OPS disabled bit is set in software parameter 2, the peltier is set to cool (with power off) and the XSM is powered down. Otherwise the peltier is set to cool (with power off) and the state is set to 1 (XSM starting)
11	Commanded Calibration Shutter closing	Shutter is closed (3 pulses) Control is then passed to State 4 XSM Calibration

Table 5-12 XSM Control State Descriptions

5.2.6.4.4 Transition OPERATING to STANDBY mode

The transition to STANDBY can be initiated by:

Command X007C

Autonomous action when 3D+ A/D converter packages exceed safe operating temperature

DCIXS Stop sensor Waveform Generator
Power off sensors

NOTE: *DCIXS door is not affected*

XSM Disable XSM bias
Disable Peltier cooler
Close shutter

5.2.6.4.5 DCIXS Annealing

The instrument must be in STANDBY mode.

Having followed the command procedure Section 5.2.7.6.3 the instrument is effectively in STANDBY mode whilst annealing is in progress and therefore CARE should be taken to ensure no commands other than those to STOP the annealing or change the parameter table entry for the annealing time are sent.

5.2.6.4.6 DCIXS Door Operation

The software actions are as follows:

1. XSM peltier cooler is disabled
2. Door is driven open or closed until microswitch indicates operation complete or maximum stepper motor drive pulses sent.
3. XSM peltier cooler re-enabled

The door closure can be initiated by:

1. Command X017C in STANDBY or OPERATING mode
2. Autonomous action in OPERATING mode when the number of sensors disabled due to excessive count rate exceeds a given number (parameter) Default is 16 sensors
3. Autonomous action in OPERATING mode when the XSM sensor leakage current level or rate of change of level exceed given thresholds (parameters). The default thresholds are set for this option at levels such that this function is disabled.

5.2.6.4.7 Transition to Test Mode

This only possible in STANDBY mode and must be initiated by command (X008C)

NOTE: *The Test mode action can only stopped prematurely by commanding a transition to EMERGENCY MODE.*

The software actions are as follows:

1. Load Test mode data processing FPGA configuration
2. Load Test mode sensor waveform generator configuration
3. Readout data for each sensor
4. Transmit Test mode data packets
5. Restore OPERATING mode data processing FPGA configuration
6. Restore OPERATING mode sensor waveform generator configuration
7. Return to STANDBY mode

5.2.6.4.8 DCIXS Science Data Packet - Autonomous switching

The default DCIXS Data collection format is fixed Time Tagged.

When the count rate exceeds 192/s from all sensors combined the excess are discarded.

Autonomous switching between Time Tagged events and Low Count Spectrum format can be selected by command SCI_SUBMODE X009C[03h].

It starts in Time Tagged format

If count rate exceeds 180/s the data format changes to Low Count Spectrum.

In Low count Spectrum

If count rate exceeds 150/s the data format changes to Time Tagged.

5.2.7 NOMINAL AND CONTINGENCY OPERATIONS PROCEDURES

5.2.7.1 First Switch-on

Operation	Mode	Commands	TM Packets [Type]/Interval	Spacecraft Actions	Door State	Shutter State
DCIXS Launch Lock Release						
Power-On	STANDBY v2.0		HK - [0]/ 64s		Closed	Closed
Select v2.6 software	Emergency Mode	EMODE X005C	None		Closed	Closed
		GOTO page 6 X004C [6]	HK - [0]/ 64s		Closed	Closed
Release Launch-Lock	STANDBY v2.6	See section 5.2.7.6.2			Closed	Closed
DCIXS sensor characterisation						
Go to DCIXS Test Mode	TEST (autonomous return to STANDBY)	TEST X008C	HK - [0]/ 64s Test - [7]		Closed	Closed
Go to OPERATING mode	OPERATING	OPERATING X006C	HK - [0]/ 64s Time-Tagged - [1] XSM - [4]/16s		Closed	Closed
DCIXS on-board Fe55 sensor #23 spectral calibration	OPERATING		HK - [0]/ 64s Time-Tagged - [1] XSM - [4]/16s		Closed	Closed
XSM Fe55 Calibration	OPERATING		HK - [0]/ 64s Time-Tagged - [1] XSM - [4]/16s		Closed	Closed
Verify shutter closed	OPERATING		HK - [0]/ 64s Time-Tagged - [1] XSM - [4]/16s		Closed	Closed

5.2.7.2 First Commissioning Procedures

Operation	Mode	Commands	TM Packets [Type]/Interval	Spacecraft Actions	Door State	Shutter State
DCIXS sensor characterisation						
Power-On	STANDBY v2.0		HK - [0]/ 64s		Closed	Closed
Select v2.6 software	EMODE	EMODE X005C	None		Closed	Closed
		GOTO page 6 X004C [6]	HK - [0]/ 64s			
Go to DCIXS Test Mode	TEST (autonomous return to STANDBY)	TEST X008C	HK - [0]/ 64s Test - [7]		Closed	Closed
OPERATING mode	OPERATING	OPERATING	HK - [0]/ 64s Time-Tagged - [1] XSM - [4]/16s		Closed	Closed
DCIXS on-board Fe55 sensor #23 spectral calibration	OPERATING		HK - [0]/ 64s Time-Tagged - [1] XSM - [4]/16s		Closed	Closed
DCIXS Spectral Calibration						
Select High Count Spectrum Format	OPERATING	SCI_SUBMODE X009C [2]	HK - [0]/ 64s High Count - [3] XSM - [4]/16s		Closed	Closed
DCIXS Open door	OPERATING	DCIXS_DOOR X017C [E0h]	HK - [0]/ 64s High Count - [3] XSM - [4]/16s		Open	Closed
DCIXS Spectral Calibration	OPERATING		HK - [0]/ 64s High Count - [3] XSM - [4]/16s	Point at source for TBD minutes	Open	Closed

Operation	Mode	Commands	TM Packets [Type]/Interval	Spacecraft Actions	Door State	Shutter State
DCIXS Close door	OPERATING		HK - [0]/ 64s High Count - [3] XSM - [4]/16s		Closed	Closed
DCIXS Field of View Calibration						
DCIXS Door Open	OPERATING	DCIXS_DOOR X017C [E0h]	HK - [0]/ 64s High Count - [3] XSM - [4]/16s		Open	Closed
DCIXS FoV Calibration	OPERATING		HK - [0]/ 64s High Count - [3] XSM - [4]/16s	Scan across source	Open	Closed
DCIXS Close door	OPERATING	DCIXS_DOOR X017C [C0h]	HK - [0]/ 64s High Count - [3] XSM - [4]/16s		Closed	Closed
Return to Time Tagged Format	OPERATING	SCI_SUBMODE X009C [0]	HK - [0]/ 64s Time-Tagged - [1] XSM - [4]/16s		Closed	Closed
XSM Spectral Calibration						
XSM spectra collection	OPERATING		HK - [0]/ 64s Time-Tagged - [1] XSM - [4]/16s		Closed	Closed
XSM Field of View Calibration						
XSM shutter Open	OPERATING		HK - [0]/ 64s Time-Tagged - [1] XSM - [4]/16s		Closed	Open

Operation	Mode	Commands	TM Packets [Type]/Interval	Spacecraft Actions	Door State	Shutter State
XSM spectra collection			HK - [0]/ 64s Time-Tagged - [1] XSM - [4]/16s	Scan across Sun	Closed	Open
XSM shutter closed			HK - [0]/ 64s Time-Tagged - [1] XSM - [4]/16s		Closed	Closed

5.2.7.3 Cruise Operations

5.2.7.3.1 DCIXS Detector Calibration

Operation	Mode	Commands	TM Packets [Type]/Interval	Spacecraft Actions	Door State	Shutter State
DCIXS sensor characterisation						
Power-On	STANDBY v2.0		HK - [0]/ 64s		Closed	Closed
Select v2.6 software	EMODE	EMODE X005C	None		Closed	Closed
	STANDBY v2.6	GOTO page 6 X004C [6]	HK - [0]/ 64s		Closed	Closed
DCIXS Test Mode	TEST (autonomous return to STANDBY	TEST X008C	HK - [0]/ 64s Test - [7]		Closed	Closed
DCIXS Spectral Calibration						
Go to OPERATING Mode	OPERATING	OPERATING X006C	HK - [0]/ 64s Time-Tagged - [1] XSM - [4]/16s		Open	Closed

Operation	Mode	Commands	TM Packets [Type]/Interval	Spacecraft Actions	Door State	Shutter State
DCIXS Open door	OPERATING	DCIXS_DOOR X017C [E0h]	HK - [0]/ 64s Time-Tagged - [1] XSM - [4]/16s		Open	Closed
Select High Count Spectrum Format	OPERATING	SCI_SUBMODE X009C [2]	HK - [0]/ 64s High Count - [3] XSM - [4]/16s		Closed	Closed
DCIXS Spectral Calibration	OPERATING		HK - [0]/ 64s High Count - [3] XSM - [4]/16s	Point at source for TBD minutes	Open	Closed
DCIXS Close door	OPERATING	DCIXS_DOOR X017C [C0h]	HK - [0]/ 64s High Count - [3] XSM - [4]/16s		Closed	Closed
Go to STANDBY mode	STANDBY	STANDBY X007C	HK - [0]/ 64s			

5.2.7.3.2 DCIXS Astronomy

Operation	Mode	Commands	TM Packets [Type]/Interval	Spacecraft Actions	Door State	Shutter State
Go to OPERATING Mode	OPERATING	OPERATING X006C	HK - [0]/ 64s Time-Tagged - [1] XSM - [4]/16s		Open	Closed
DCIXS Open door	OPERATING	DCIXS_DOOR X017C [E0h]	HK - [0]/ 64s Time-Tagged - [1] XSM - [4]/16s		Open	Closed
Select High Count Spectrum Format	OPERATING	SCI_SUBMODE X009C [2]	HK - [0]/ 64s High Count - [3] XSM - [4]/16s		Closed	Closed
Astronomical Observation	OPERATING		HK - [0]/ 64s	Point at source for TBD	Open	Closed

			High Count - [3] XSM - [4]/16s	minutes		
DCIXS Close door	OPERATING	DCIXS_DOOR X017C [C0h]	HK - [0]/ 64s High Count - [3] XSM - [4]/16s		Closed	Closed
Go to STANDBY mode	STANDBY	STANDBY X007C	HK - [0]/ 64s			

5.2.7.3.3 XSM Calibration

The on-board XSM calibration source is within the field of view when the shutter is closed.
Calibration data is taken in parallel with the DCIXS data

5.2.7.4 Second Commissioning In Lunar Orbit

5.2.7.4.1 DCIXS sensor characterisation/Calibration

Operation	Mode	Commands	TM Packets [Type]/Interval	Spacecraft Actions	Door State	Shutter State
DCIXS sensor characterisation						
Power-On	STANDBY v2.0		HK - [0]/ 64s		Closed	Closed
Select v2.6 software	EMODE	EMODE X005C GOTO page 6 X004C [6]	None HK - [0]/ 64s		Closed	Closed
Go to DCIXS Test Mode	TEST (autonomous return to STANDBY)	TEST X008C	HK - [0]/ 64s Test - [7]	Closed	Closed	
OPERATING mode	OPERATING	OPERATING X006C	HK - [0]/ 64s Time-Tagged - [1] XSM - [4]/16s		Closed	Closed
DCIXS on-board Fe55 sensor #23 spectral calibration	OPERATING		HK - [0]/ 64s Time-Tagged - [1] XSM - [4]/16s		Closed	Closed
DCIXS Spectral Calibration						
Select High Count Spectrum Format	OPERATING	SCI_SUBMODE X009C [2]			Closed	Closed
DCIXS Open door	OPERATING	DCIXS_DOOR X017C [E0h]	HK - [0]/ 64s High Count - [3] XSM - [4]/16s		Open	Closed
DCIXS Spectral Calibration	OPERATING		HK - [0]/ 64s High Count - [3] XSM - [4]/16s	Point at source for TBD minutes	Open	Closed
DCIXS Close door	OPERATING	DCIXS_DOOR	HK - [0]/ 64s		Closed	Closed

Operation	Mode	Commands	TM Packets [Type]/Interval	Spacecraft Actions	Door State	Shutter State
		X017C [C0h]	High Count - [3] XSM - [4]/16s			
Return to Time Tagged Format	OPERATING	SCI_SUBMODE X009C [0]	HK - [0]/ 64s Time-Tagged - [1] XSM - [4]/16s		Closed	Closed

5.2.7.4.2 Lunar Orbit Operations

Operation	Mode	Commands	TM Packets [Type]/Interval	Spacecraft Actions	Door State	Shutter State
Power-On	STANDBY v2.0		HK - [0]/ 64s		Closed	Closed
Select v2.6 software	EMODE	EMODE X005C	None		Closed	Closed
	STANDBY v2.6	GOTO page 6 X004C [6]	HK - [0]/ 64s		Closed	Closed
Dark side	STANDBY v2.6		HK - [0]/ 64s		Closed	Closed
Go to OPERATING mode	OPERATING	OPERATING X006C	HK - [0]/ 64s Time-Tagged - [1] XSM - [4]/16s		Closed	Closed
Select Autoformat for DCIXS science data packets	OPERATING	SCI_SUBMODE X009C [3]	HK - [0]/ 64s Time-tagged - [1] or Low Count - [2] XSM - [4]/16s		Closed	Closed
TBD deg before terminator DCIXS Open door	OPERATING	DCIXS_DOOR X017C [E0h]	HK - [0]/ 64s Time-tagged - [1] or Low Count - [2] XSM - [4]/16s		Open	Closed

Operation	Mode	Commands	TM Packets [Type]/Interval	Spacecraft Actions	Door State	Shutter State
5 minutes after OPERATING mode transition - Open XSM Shutter	OPERATING	XSM_SHUTR X018C	HK - [0]/ 64s Time-tagged - [1] or Low Count - [2] XSM - [4]/16s			
Sunlit Side	OPERATING		HK - [0]/ 64s Time-tagged - [1] or Low Count - [2] XSM - [4]/16s		Open	Open
TBD deg after terminator go to STANDBY mode	STANDBY v2.6	STANDBY X007C	HK - [0]/ 64s		Open	Closed
DCIXS Close door	STANDBY v2.6	DCIXS_DOOR X017C [C0h]			Closed	Closed
Dark side	STANDBY v2.6				Closed	Closed

5.2.7.4.3 XSM Spectral Calibration

The on-board XSM calibration source is within the field of view when the shutter is closed. Calibration data is taken in parallel with the DCIXS data

5.2.7.5 Contingency Recovery

DCIXS Detector Annealing

A high 'off- scale' count rate detected by the DCIXS system will cause the radiation shield to close autonomously. It will remain closed until ground command opens it again.

When an autonomous door closing is detected the following steps should be followed:

Examine DCIXS data up to point of door closure:

- Detector disable flags
- offset calibration data for changes in signal channel noise statistics
- performance of calibration channel #23
- science data where possible for degradation in energy resolution

If signal channels show significant offset changes and resolution reduction beyond 250eV FWHM the implement the annealing procedure - section 5.2.6.4.5

5.2.7.6 Nominal Procedures

5.2.7.6.1 Power-on Procedure

The operational version of the on-board software is held in a page of EEPROM.
The instrument powers up and loads an out of date software system from the PROM and enters STANDBY mode.
There is no problem using this PROM version of the software in STANDBY.

To restart the software using the EEPROM version the following commands must be issued.
The system will then be in STANDBY mode running the correct software.

The sequence and details are given below.

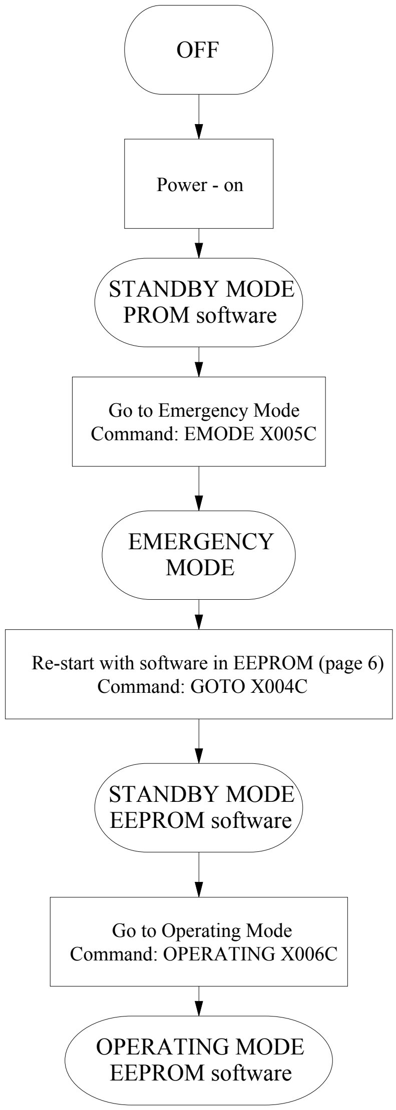


Figure 5-12 EEPROM Power -on Sequence

X005C COMMAND - EMODE		X004C COMMAND - DCIXS GOTO	
Parameters		Parameters	
Byte 7 - XCmdType	= 05h	Byte 7 - XCmdType	= 04h
Byte 8 - Xnull8	= 00h	Byte 8 - Xpage	= 06h
Byte 9,10 - Xnull16	= 0000h	Byte 9,10 - XAddress	= 0000h
Byte 11,12 - Xnull16	= 0000h	Byte 11,12 - Xnull16	= 0000h
Byte 13,14 - Xnull16	= 0000h	Byte 13,14 - Xnull16	= 0000h
Byte 15,16 - Xcheck	= AAAAh	Byte 15,16 - Xcheck	= AAAAh

Table 5-13 EEPROM Start-up Command Detail

5.2.7.6.2 Launch Lock Release Procedure

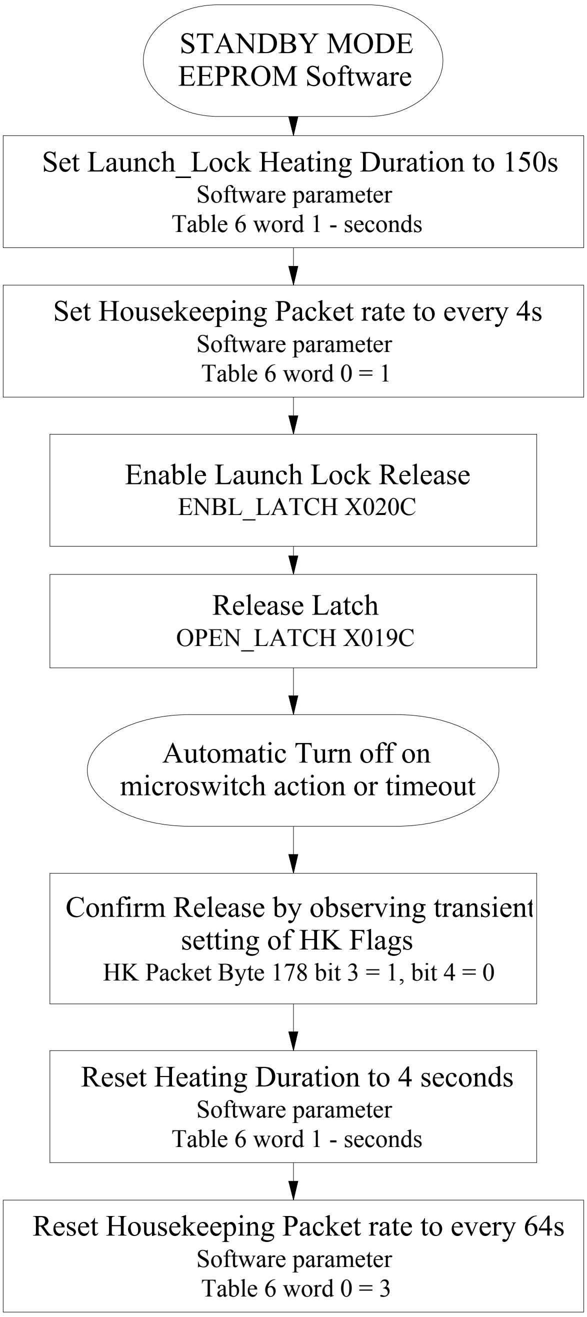
The Launch Lock release is initiated in STANDBY mode only.

The duration is set to a default of 4 seconds for safety reasons. This must therefore be set to the required value before commencing activation . An enable command is also required.

NOTE: The duration must be reset to 4s afterwards as the same timer is used for the Annealing Procedure

Also the tell-back flags which indicate the successful release are only transient - this is because the when the power is removed the pin-puller is pushed back by the microswitches a small amount but enough to allow the switches to open again.

To get to STANDBY MODE see 5.2.7.6.1



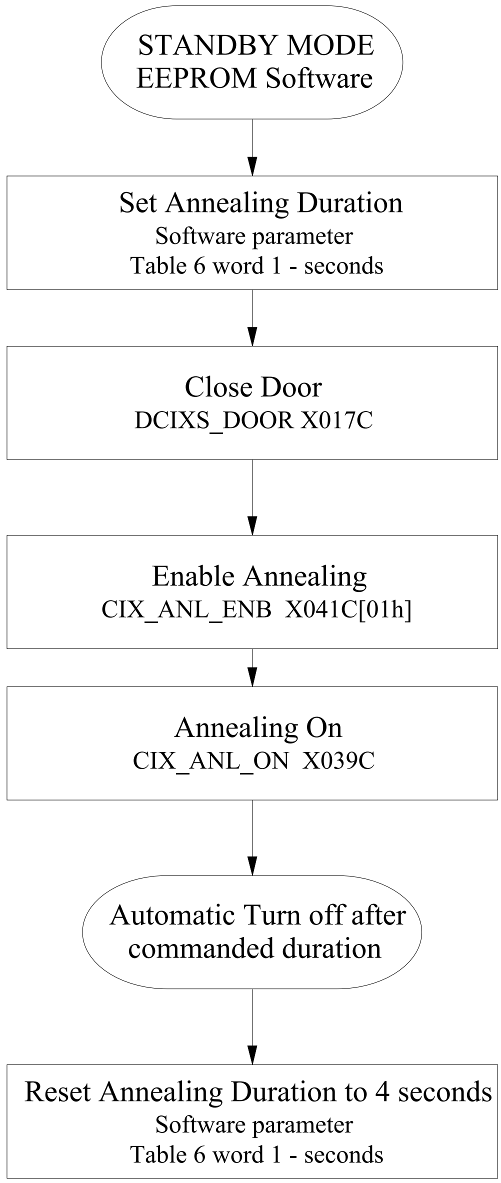
5.2.7.6.3 DCIXS Annealing Procedure

The annealing is initiated in STANDBY mode only.

The duration is set to a default of 4 seconds for safety reasons. This must therefore be set to the required value before commencing annealing. An enable command is also required.

The power drawn from the 50V spacecraft bus is ~60Watts.

To get to STANDBY MODE see 5.2.7.6.1



5.2.8 SUMMARY OF TELEMETRY AND TELECOMMAND DATA

5.2.8.1 List of dangerous commands

None.

5.2.8.2 Summary of Telemetry and Telecommand Packets

See section 5.2.3.4.1 Data Handling ICD S1-CIX-ICD-3002

5.2.8.3 Summary of Telemetry and Telecommand Parameters

See section 5.2.3.4.1 Data Handling ICD S1-CIX-ICD-3002

5.2.8.4 Software Control Parameters and Command Implementation

The parameters, which can be changed by ground command or parameter table changes, are presented below in a structure which represents the instrument operations and functionality.
Having identified from the block diagram/flow charts the instrument sub-system which needs to be adjusted the appropriate parameter table and/or commands are identified.
Specific details of the parameters are given in Section 5.2.10.4

5.2.9 DIAGNOSTIC COMMANDS

NOTE: COMMANDS X021C to X042C are for EMERGENCY DIAGNOSTIC use ONLY
They should not be used without full assessment of impact on the system.

MODE COMMANDS

Dummy Command DUMMY X001C
Emergency Mode EMODE X005C
Operating Mode OPERATING X006C
Standby Mode STANDBY X007C
DCIXS Test Mode TEST X008C

MEMORY COMMANDS

PATCH 8 bytes X100C
PATCH 16 bytes X101C
PATCH 32 bytes X102C
PATCH 64 bytes X103C
PATCH 128 bytes X104C
PATCH 196 bytes X105C

DUMP X003C

GOTO X004C

PARAMETER TABLE COMMANDS

Copy specified Parameter Table from EEPROM to RAM
CPY_TABLE X016C [Table Number]
Copy all Parameter Tables from EEPROM to RAM
CPY_TABLE X016C [FFh]

RAM TABLE COMMANDS
Patch type commands used for updating RAM Table Parameters
8 bytes X110C
16 bytes X111C
32 bytes X112C
64 bytes X113C
128 bytes X114C
196 bytes X115C

EEPROM TABLE COMMANDS
Patch type commands used for updating EEPROM Table Parameters
8 bytes X110C
16 bytes X111C
32 bytes X112C
64 bytes X113C
128 bytes X114C

DCIXS SYSTEM

COMMANDS:
Turn OFF DCIXS FPGA and Science TM
DCIXS_OFF X011C
Turn ON DCIXS FPGA and Science TM
DCIXS_ON X010C

XSM SYSTEM

COMMANDS:

XSM_OFF X013C [00h] Turns off XSM power and Science TM

XSM Power Control
+12V ON XSM_12V X027C [01h]
+12V OFF XSM_12V X027C [00h]

Figure 5-13 Command Structure

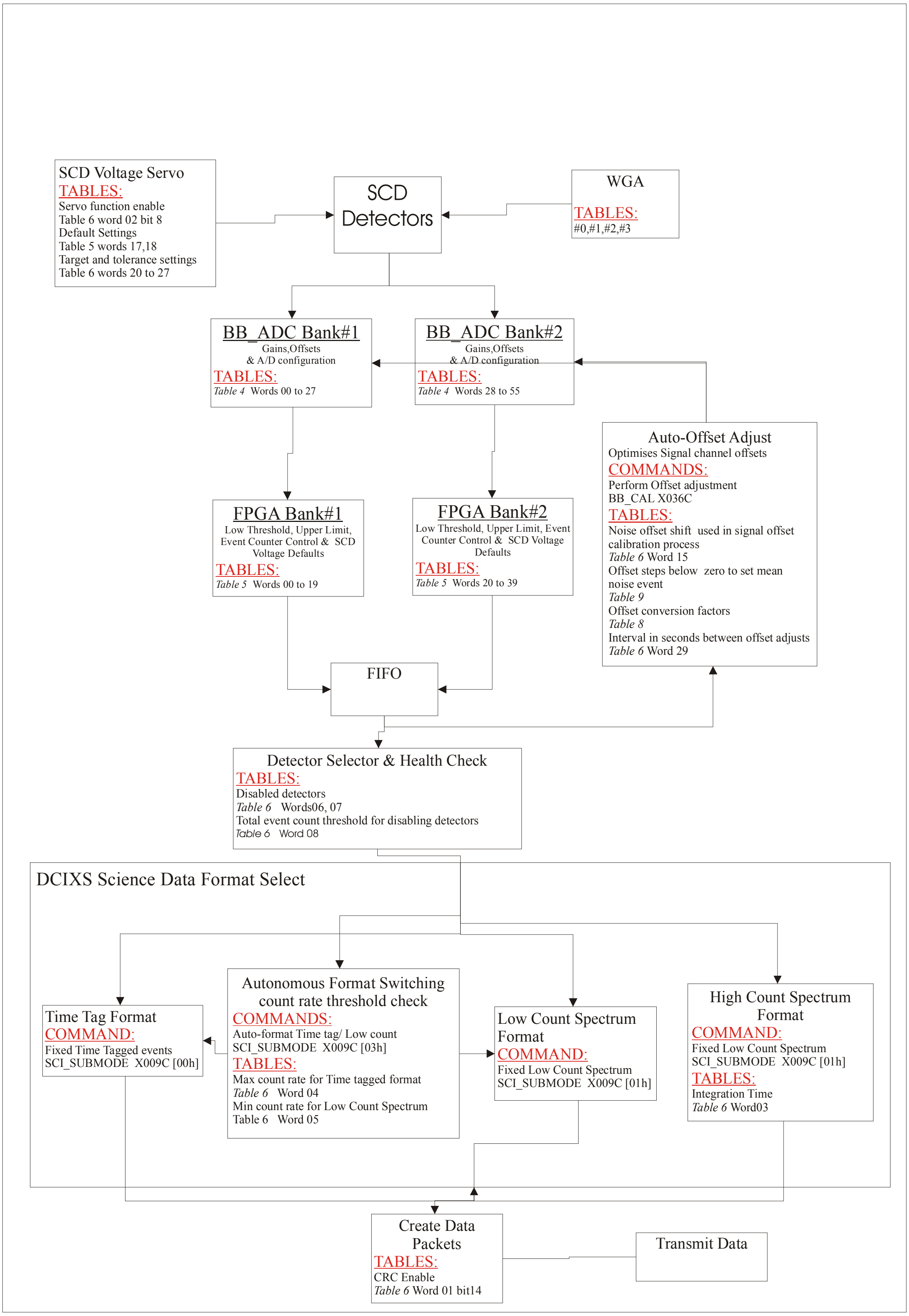


Figure 5-14 Signal Channel Processing Parameters

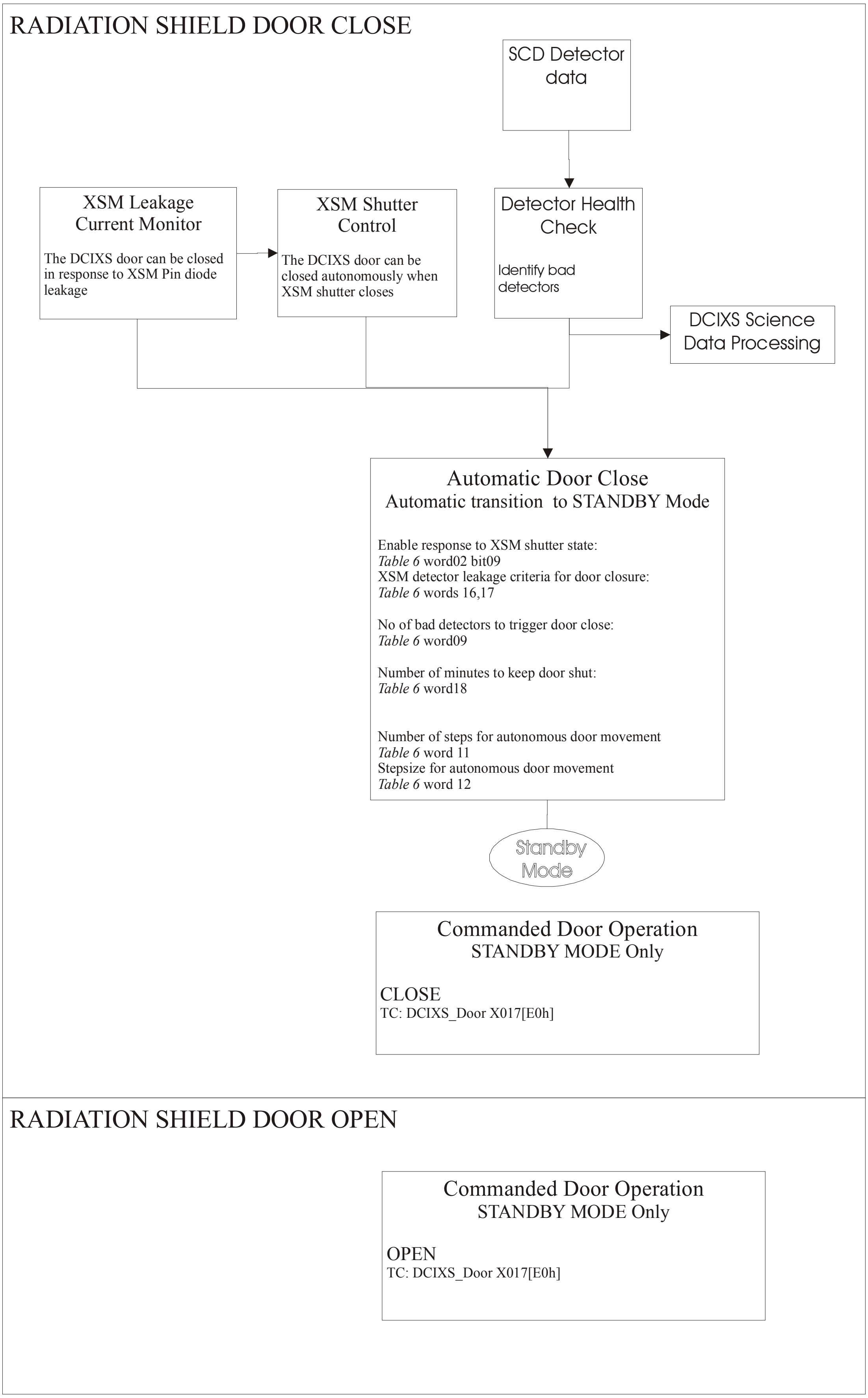


Figure 5-15 Radiation Shield Control Parameters

Launch Lock
STANDBY Mode only

COMMANDS
ENABLE LATCH X020C [D6h]
DISABLE LATCH X020C [00h]
OPEN LATCH X019C [00h]

Parameters
Maximum activation period for Latch heater
Table 6 word 01
[note same timer as the annealing heater]

Annealing
STANDBY Mode only

COMMANDS:
Annealing ON CIX_ANL_ON X039C
Annealing OFF CIX_ANL_OFF X040C
Annealing ENABLE CIX_ANL_ENB X041C[01h]
Annealing DISABLE CIX_ANL_ENB X041C[00h]

TABLES:
Maximum activation period for Annealing
Table 6 word 01
[note same timer as the latch heater]
Annealing Temperature Limit

Figure 5-16 DCIXS Launch Lock and Annealing Parameters

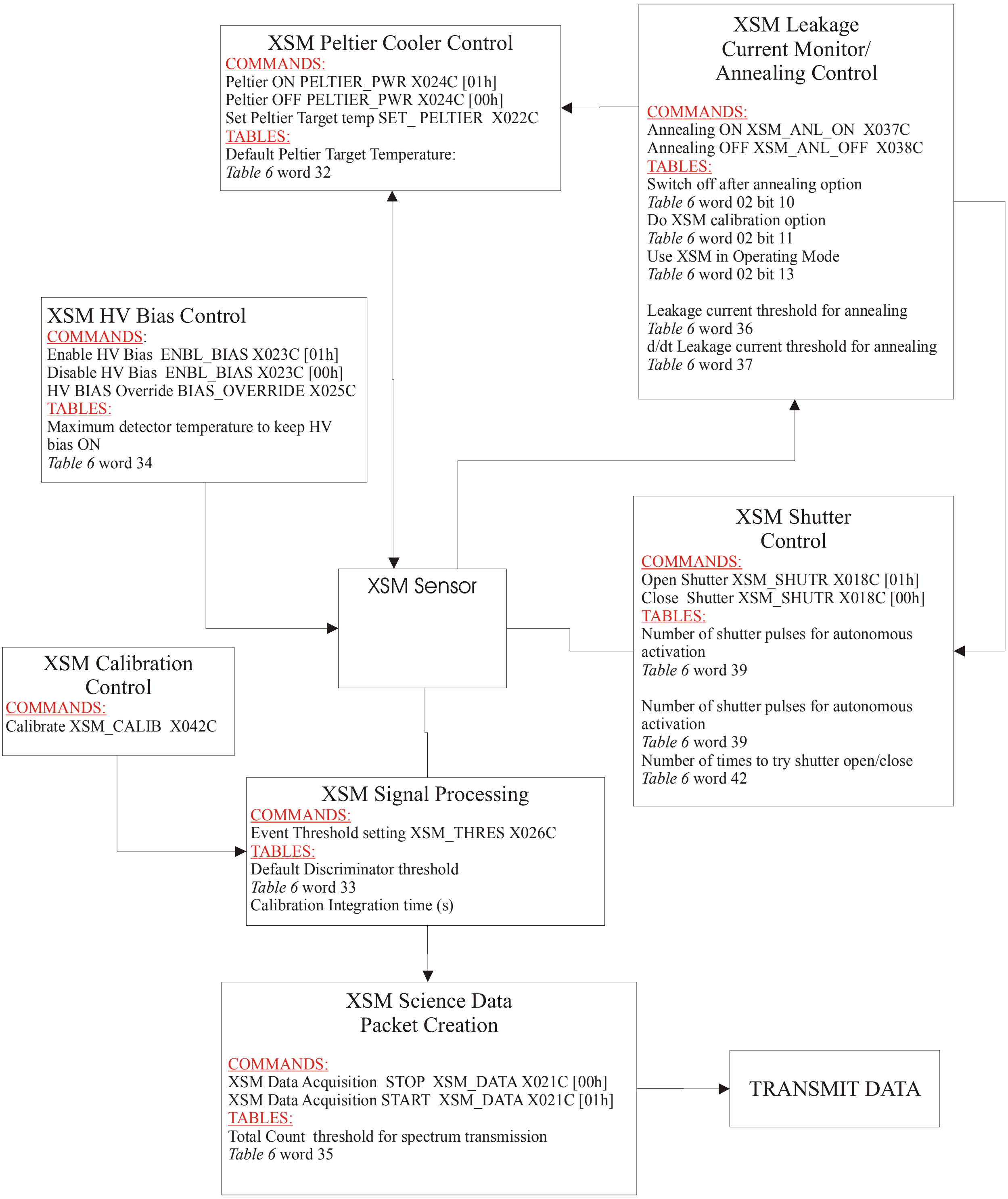


Figure 5-17 XSM Control Parameters

5.2.10 DATA OPERATIONS HANDBOOK

5.2.10.1 Telecommand Function Definitions

See section 5.2.3.4.1

5.2.10.2 Telecommand Parameter definitions

See section 5.2.3.4.1

5.2.10.3 Telemetry Packet definitions

See section 5.2.3.4.1

5.2.10.4 Parameters Tables

See section 5.2.3.4.1

List of Figures

List of Tables

ANNEXES:

Annex A: Mathematical models N
Annex B: Pointing and special requirements
Annex C: Auxiliary Data Requirements
Annex D: List of Abbreviations
Annex E : Instrument Contact Point