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HALOSAT

INSTRUMENT INTERFACE CONTROL DOCUMENT

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1 SCOPE AND APPLICABLE DOCUMENTS

1.1 Scope

This document defines the interfaces between the HaloSat instrument and the 6U CubeSat bus.

1.2 Applicable Documents

The following documents govern creation and handling of documents produced for this project:

- HaloSat-RQMT-0002 HaloSat Mission Requirements
- HaloSat-PLAN-0004 HaloSat Configuration Management Plan
- HaloSat Technology Control Plan for the University of Iowa

2 INSTRUMENT DESCRIPTION

The HaloSat science payload, hereafter called the "instrument", consists of three identical "detectors", each of which contains a silicon drift detector (SDD) sensitive to soft X-rays, an anti-coincidence shield, and associated electronics. The three detectors are physically mounted together in a single mechanical structure. The three detectors will be aligned, calibrated, and tested as a single sub-assembly before delivery of the science payload to the organization in charge of observation integration and testing.

Each detector contains: a silicon drift detector (SDD) with integral thermoelectric cooler (TEC), an anti-coincidence scintillator coupled to avalanche photodiodes (APDs), a collimator, and associated electronics. The SDD detects X-rays from astrophysical sources with a field of view limited by the collimator. The anti-coincidence is used to reject background events in the SDD produced by energetic particles. Each SDD requires a fixed bias of approximately -130V that is determined by the manufacturer on a per-device basis. The output of each SDD is fed into a charge sensitive preamplifier, followed by a shaping amplifier, and then a discriminator and a peak hold circuit that feeds into an analog to digital converter (ADC). The total charge produced by the SDD for each event is digitized. The SDD is cooled via a TEC mounted inside the SDD during science operations. The SDD and TEC operate in vacuum inside a sealed canister. X-rays pass into the canister through a silicon-nitride window. The APDs require a variable bias of 300-400V determined by temperature. The output of each APD is fed into a charge sensitive preamplifier/shaping amplifier hybrid and then into an analog amplifier and a discriminator.

Each detector has an independent signal and power interface to the spacecraft. There are no electrical connections between the detectors. The front end circuitry for the SDD and APDs are contained on small circuit boards mounted close to the sensors. The remaining circuitry, including the SDD discriminator and peak hold circuit, and a processor, ADCs, RS-422 interface, TEC controller, and power supplies are contained on a stack of two larger PCBs. Each of these larger PCBs is laid out in three electrically separate sections, one section for each detector, with no electrical interconnections between the different sections.

- Each detector shall have its own aperture for viewing the sky as shown in Figure 2 – Front View.
- The apertures will be covered with "remove before flight" tagged covers to reduce contamination of the detectors. The nearby spacecraft wall must include clear apertures to allow access to these covers and to allow the detectors to view the sky when the covers are removed. The dimensions required for the apertures are shown in Figure 2 – Front View.
- The instrument will contain an alignment feature. One axis of the alignment feature will parallel to the detector boresights and will define the instrument boresight. Each detector will be aligned relative to the alignment feature before delivery. The exact specifications of the alignment feature will be negotiated at the Spacecraft Kickoff Meeting.

3.2 Alignment

During assembly, the bore sight of each detector will be shimmed to align the detector boresight to the alignment feature to an accuracy of ±0.25°. The alignment feature will then serve as the reference for the instrument boresight.

The instrument will be mounted to the spacecraft structure using the alignment pin and slot and then bolted in place. After attachment, the alignment of the instrument boresight relative to the spacecraft ACS shall be measured using the alignment feature to an accuracy of ±0.05°.

3.3 Mass

The current instrument mass allocation is 4 kg. The spacecraft structure shall be designed to accommodate an instrument mass of up to 5 kg. The current best estimate of the instrument mass is 2.7 kg.

3.4 Center of Gravity

The instrument center of mass will be determined after detailed mechanical design of the instrument is completed and finalized prior to the Spacecraft Kickoff Meeting.

3.5 Thermal Interface

During observations made in Science Mode, the instrument/spacecraft interface shall be maintained at a temperature between +25 C and -20 C. The instrument will dissipate a maximum of 9.0 W (3 detectors at 3.0W per detector), with all three detectors operating in Science Mode. It is preferred to have the instrument/spacecraft interface near the lower end of the temperature range as that would reduce the power required to cool the SDDs.

Thermal modeling of the instrument will be performed before the Spacecraft Kickoff Meeting. The thermal interface requirements will be discussed at the Spacecraft Kick-Off Meeting and finalized prior to release of the final Instrument ICD.

The instrument survival temperature range is +60 C to -20 C. This range will be re-evaluated after component level testing.

4 INSTRUMENT HANDLING AND CONTAMINATION CONTROL

4.1 Cleanliness Level

A cleanliness levels per MIL-STD-1246C of "C" or better for molecular contamination and 750 for particulate contamination shall be maintained during any handling of the Instrument while the "remove before flight" covers are removed.

4.2 Instrument Handling

The payload has "remove before flight" covers over the three X-ray apertures to reduce contamination of the internal surfaces of the instrument. These covers will be in place during transportation and storage of the instrument. They will be removed only during vacuum testing.

The payload and the integrated observatory shall be double bagged during transportation.

The spacecraft must provide a minimum orbit average power for orbits including science observations of 3.0 W enabling operation of two detectors. Per the concept of operations, HaloSat will perform science observations during half of each orbit, from dusk terminator to dawn terminator. Each detector consumes 3.0W during observations and is operated for half of the orbit, so the orbit averaged power is 1.5 W per detector. Nominally, two detectors will be turned on during science observations. If additional power is available, then three detectors may be turned on during science observations this would require an orbit average power of 4.5 W.

Some calibration observations must be performed during the day part of the orbit between dawn terminator and dusk terminator. If necessary for power reasons, the instrument may be switched off during the preceding or following night part of the orbit.

5.4 In-Rush Current

Each detector will be switched on in the following sequence: processor and analog electronics, TEC, then HVPSs (see section 6.2). The in-rush current will not exceed 300% of the nominal current draw (TBC). The spacecraft controls the sequencing and the power on of the different detectors may be staged to minimize the total in-rush current.

5.5 Communications Interface

There shall be a bi-directional Universal Asynchronous Receiver/Transmitter (UART)-style interface between the Spacecraft and each detector for all commands and telemetry. This interface shall consist of a transmit signal from the spacecraft to each detector, for a total of three transmit signals, and a receive data signal from each instrument to the detector, for a total of three receive signals. No handshaking signals are required. The baud rate for this interface shall be 57.6 kbps. There shall be eight bits per character, one start bit, even parity, and one stop bit.

The interface may be implemented via RS-422 or LVCMOS after discussion between the spacecraft vendor and the HaloSat team.

RS-422 interfaces would use the following termination scheme:

- Series source termination with 49.9 Ω series resistance in both output driver signal lines.
- Parallel receiver termination with a 100 Ω resistor and 220 pf capacitor in series across the receiver input lines.

The termination at the receiving end of each interface shall be configurable and determined at the time of build. By changing the resistance and capacitance values, not populating components, or installing zero ohm resistors, the configuration can be tailored to improve performance in the final, as-built system.

- If the spacecraft orbital position is available onboard, then the spacecraft sends 'Record spacecraft position' command.
- Spacecraft sends 'TEC on' command. The 'TEC on' commands for the different detectors may be staged to minimize the total in-rush current.
- After a delay of 120 seconds (TBC), the spacecraft switches on the 'HV enable' discrete line. These commands may be staged to minimize the total in-rush current.
- After a delay of 10 seconds (TBC), the spacecraft sends 'Record events = True' command.
- Each detector processor packs event and housekeeping data into telemetry packets. Whenever the detector has a full packet, it sends the packet to the S/C.
- Every 15 seconds (nominal value), the spacecraft sends 'Record time and pointing' command. If the spacecraft orbital position is available onboard, it also sends a 'Record spacecraft position' command.
- If the spacecraft is commanded to slew, then the spacecraft sends a 'Record time and point' command just before the slew begins and another after the aspect has settled following the slew.

To end an observing session:

- Spacecraft sends 'Record events = False' command.
- Spacecraft sends a 'Flush TM buffers' command to record any remaining data.
- Spacecraft switches off the 'HV enable' line.
- After a delay of 10 seconds (TBC), the spacecraft powers off the instrument.

6.3 Time Synchronization

The spacecraft shall be able to send commands to the detectors indicating the current spacecraft time that must be reconstructable to UTC to within an accuracy of 0.5 seconds.

6.4 Data Handling and Formatting

Each detector will format science data and housekeeping information into packets with a length of between 512 and 2048 bytes with sufficient header information to uniquely identify the detector that produced each packet.

The spacecraft shall be able to store payload State of Health (SOH) data produced at an average rate of 84 kbytes per orbit. This is rate for the instrument with all three detectors operating.

The spacecraft shall be able to store payload science data produced at a typical rate of 104 kbytes per orbit with a peak rate of 5.2 Mbytes per orbit for not more than one orbit per day. This is rate for the instrument with all three detectors operating.