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SIXS: X-Ray and Particle Instrument on BepiColombo

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Abstract

The Solar Intensity X-ray and particle Spectrometer (SIXS) from the University of Helsinki, Finland [1] will fly on board the ESA's BepiColombo mission to determine the solar impact on the Hermean surface in the form of direct X-rays and energetic particles, which induce observable X-ray emission via interaction with the surface of the planet. Particles of concern here are highly energetic solar protons (1-30 MeV) and electrons (0.1 – 3 MeV), and the energy range of measured X-ray spectrum is 1-20 keV. The resulting fluorescence, measured by the Mercury Imaging X-ray Spectrometer (MIXS) from the University of Leicester, UK, [2] will provide detailed information about the elemental composition on the Mercury's surface. This article presents some design highlights of the SIXS sensor unit.

1. Introduction

The science requirements for the instrument were very demanding: During times of maximum solar X-ray flux the detector should measure X-ray photons, electrons and protons with a large field of view while pointing directly towards the Sun from an orbit around Mercury.

The thermal design of the sensor unit had to keep the solar energy and the reflected infrared energy from the Mercury's surface from overheating the sensors and electronics while allowing to radiate energy generated by the sensors' electronics into space. Additionally, the instrument has to be completely shielded against the cm-wavelength radiation from the satellite's communication antenna which might point at the instrument under certain conditions.

1.1 Instrument performance

X-ray detector: energy range 1-20 keV, resolution ~300 eV or better, field of view (FOV) ¼ of full sky

Particle detector: energy range 0.1-3MeV (electrons), 1-30 MeV (protons), resolution dE/E ~ 70%, adjustable. FOV > 180° with some directional information.

2. Thermal Design

As the major challenge was to prevent solar radiation from heating up the instrument, different reflective surface covers were tested for the whole surface pointing towards the Sun during operations. The standard space engineering approach of using Multi-Layer- Insulation (MLI) for this purpose had to be discarded, as the needed high temperature material was too brittle to follow the complex outline of the instrument defined by the FOV requirements. Reflective paints were not efficient enough and could not withstand the high UV flux. The implemented solution is a Titanium heat shield mounted with thermally insulating stand-offs on top of the aluminium structure. The aluminium body and the Titanium heat shield were further insulated from one another by a layer of MLI. The heat shield itself was covered with tiles of Optical Solar Reflectors (OSR), a specially designed mirror material, cut to the needed complex shapes, glued onto the heat shield and additionally secured by highly polished bolts (Figure 1).

The radiator needed to remove the excess heat from the electronics is mounted on the back of the instrument. It has to radiate the energy into space but at the same time reflect the infrared radiation from the planetary surface. This contradiction was solved by machining a zigzag pattern into the surface with one side diamond-machined aluminium, the other painted with white paint.

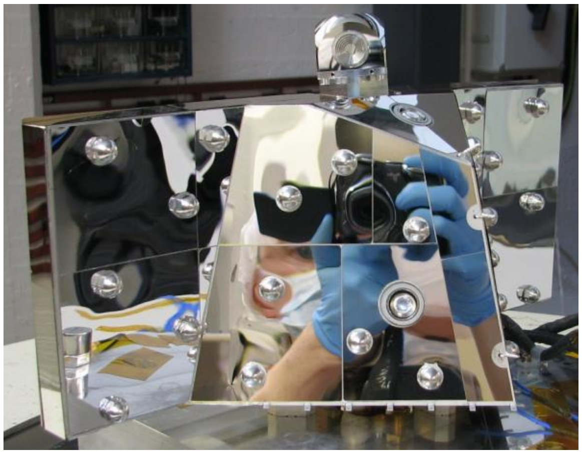

Figure 1: SIXS Sensor unit flight model with three X-ray and a 5-directional particle detector on top

While most of the thermal design is optimized for the operational case with strong solar illumination, the sensor unit has to be heated while off to prevent the internal temperatures to drop below the minimum temperature allowed for some of the electronics components. The heaters are glued onto the sensor unit's outer aluminium structure underneath the MLI and are controlled directly by the spacecraft while the instrument is not powered.

Additionally the temperature for each detector is optimized during operation by the sensor electronics. A Peltier element reduces the X-ray detector temperature to the optimal range between -20°C and 0°C, while a resistive heater for the particle detector increases the temperature. By reversing the voltage applied to the Peltier element it can be used to heat up the X-ray detector for annealing.

3. Detectors

Both the particle and X-ray detectors use specially developed pi-detectors protected by thin metallic layers hermetically sealing them from the outside. The signals from the particles are amplified and analyzed in a dedicated ASIC developed by the Rutherford Laboratory, UK, allowing to separate the signals by particle energy and species and to suppress the background noise by using anti-coincidence techniques. Both detector types were manufactured to specifications and optimized in a long series of laboratory tests including test times at the radiation facility of the University of Jyväskylä, Finland.

4. Sensor Control

Each of the detector types has its own electronics board, controlled by a Field Programmable Gate Array (FPGA), which collects the measurement and housekeeping data, formats them and sends them via a serial link to the data processing unit shared between the MIXS and the SIXS instruments. The same FPGA accepts commands used to configure the detectors and fine-tune the temperatures.

Acknowledgements

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