THE SPACEWIRE INTERFACE FOR HERSCHEL/SCORE SUBORBITAL MISSION

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Short Paper

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ABSTRACT

The HERSCHEL (HElium Resonant Scattering in the Corona and HEliosphere) experiment is a suborbital mission that will observe the Sun and the solar corona in the EUV and in visible light. One of the HERSCHEL instrument is the coronagraph SCORE (Sounding COROna Experiment) aimed at providing images of the extended solar corona in the EUV lines HI 121.6nm and HeII 30.4nm and in the broadband linearly polarized visible light. The two SCORE cameras are developed at the XUVLab of the Department of Astronomy and Space Science of Florence University, in collaboration with the Naval Research Laboratory, Washington, DC. The SpaceWire ESA standard protocol has been selected as the rocket interface. Since HERSCHEL is a suborbital mission and its operation time will be only about 300s, the SCORE SpaceWire interfaces have a customized design to perform specific and automatic procedures. The prototypes and the flight models of the SCORE cameras and the SpaceWire interface have been developed and tested.

1. THE HERSCHEL MISSION

HERSCHEL is conceived as a NASA Sounding Rocket Program providing new EUV/UV (H Lyα and HeII Lyα) and visible-light observations of the solar disk and corona [1].

HERSCHEL will investigate coronal heating and solar wind acceleration from a range of solar source structures by obtaining simultaneous observations of the electrons, protons and helium abundances in the solar corona.

The mission aims at developing instrumentation that for the first time will directly image and characterize on a global coronal scale the two most abundant elements: hydrogen and helium. This will directly address three outstanding questions in the Sun-Earth Connection theme:

1. Origin of the slow solar wind,
2. Acceleration mechanisms of the fast solar wind, and
3. Variation of Helium abundance in coronal structures.

Additionally, HERSCHEL will establish a proof-of-principle for the SCORE Coronagraph, which is in the ESA Solar Orbiter Mission baseline making easier future investigations of CME's kinematics, and solar cycle evolution of the coronal plasma.
The HERSCHEL instrument package consists of the HERSCHEL Extreme Ultraviolet Imaging Telescope (HEIT) for on-disk coronal observations and two coronagraphs, SCORE and HECOR (HERSCHEL EUV Coronagraph) for off-limb observations of the corona. The monochromatic H I (121.6 nm) and He II (30.4 nm) images obtained by the coronagraphs will provide simultaneous abundance, densities and velocities diagnostics from 1 $R_\odot$ to 3 $R_\odot$. HEIT will obtain the intensity of the resonantly scattered He II line below the field of view of the coronagraphs, as well as the He II disk images necessary for the analysis of the coronal emission.

The HERSCHEL instruments will be launched at the end of 2007 with a Terrier-Brant booster drawing a ballistic trajectory with an apogee of 335 km. This altitude is needed to avoid the atmospheric absorption of coronal radiation; because of the ballistic trajectory, HERSCHEL will observe only for ~300 sec, when the rocket will be beyond 250 km of altitude. Due to the short duration of the flight and the relatively small reached altitude, all HERSCHEL instruments must be vibration and vacuum resistant but they do not require a space qualification.

2. THE SCORE INSTRUMENT

The SCORE coronagraph consists of an externally occulted, off-axis Gregorian telescope with multilayer coated optics [1]. The coronagraph has a visible (VLD) and an UV (UVD) detectors and it is capable of simultaneous images acquisition in the visible light (VL) and in two UV narrowbands. A filter mechanism (FM) swaps a Aluminium and an Al/MgF_2 filter to enable the acquisition of the only HeII Lyα line or of HI Lyα line and visible light images. The two independent SCORE detectors will acquire images simultaneously with the Al/MgF_2 filter.

The selected detectors for SCORE coronagraph are a CCD camera for the visible channel and an Intensified CCD (ICCD, a CCD coupled with a MCP detector) for UV. The visible detector is an E2V CCD47-20 1024x1024, frame transfer, operating in 2x2 binning mode in order to enhance the weak coronal signal. It has a 16-bit dynamic range and produces 4Mb images. The UV CCD is the E2V CCD42-40. The UVD camera will acquire both He and H images, by selecting different filter configurations in the telescope. The images acquired by both CCDs are readout at 300 kpx/s [2], [3]. Both cameras are developed by XUVLab with the collaboration of the Naval Research Laboratory (NRL).

The SCORE visible channel includes a polarimetric group to measure the polarized brightness of K-corona [4]. The polarimeter works with an innovative variable retarder plate that uses liquid crystals to select the proper polarization. Modulating the voltage at the input of the retarder plate it is possible to control the alignment of liquid crystal and so to set the proper polarization [5]. SCORE will be the first instrument to use a LCVR (Liquid Crystal Variable Retarder) polarimeter for space applications.

3. THE SPACEWIRE INTERFACE

During the flight, a single board computer will manage the entire scientific payload and the acquisition sequences of each camera; moreover it will work to save and store data and to send them to the ground station through telemetry.

To prevent an overwork of the computer, each camera must reduce the computer control and must keep busy the downlink as short time as possible. Due to the short mission duration the communication protocol must ensure an high data rate avoiding time losses for the images download and maximizing the observation time. For these reasons we chose SpaceWire as the SCORE cameras communication interface [6]. Moreover this standard protocol is reliable, low power, and space compliant. This standard has been chosen not only for the SCORE cameras but it has been adopted as the protocol of all on-board instruments. Both the SCORE cameras are provided with a SpaceWire (SpW) interface developed in our laboratories. Actually the on-board computer implements the revised IEEE-1355 [8] DS/DE sub-standard protocol with LVDS signalling that is however SpaceWire compatible. We chose to implement the same protocol on the SCORE cameras using the SMCSlite device (Atmel T7906E).

In order to minimize the download time of the images toward the computer, the communication interface has two FIFO memories which work together, in order to store a whole image (4 Mb). Every acquired image is readout and stored into the FIFOs, in ~1.7 s (VLD); then the image is downloaded to the computer through the Spacewire link as soon as the computer is ready to received it; then the image is stored in a mass memory and transmitted to the ground station.

A CPLD (Complex Programmable Logic Device) manages the FIFOs writing procedure and it produces all the initialization signals. The reading procedure from the FIFOs is managed by the SMCSlite afterwards a CPLD enabling signal. The SMCSlite transmits images properly coded via the IEEE-1355 link directly to the rocket computer. Each image is packed with some auxiliary informations, placed in the header, as acquisition number, exposure time and housekeeping. The SpW interfaces and the CCD cameras must have an high level of automation: since in the brief observational time is not possible to send commands from ground station, the electronics must recognize errors and must recover them. To realize this smart management we introduced in the interface design a microcontroller as host controller. This device controls the entire acquisition and sets the configuration of the SMCSlite and the CPLD. The host controller manages the communication with the other camera boards through 3 UART links Through this connections it checks that each camera board work properly

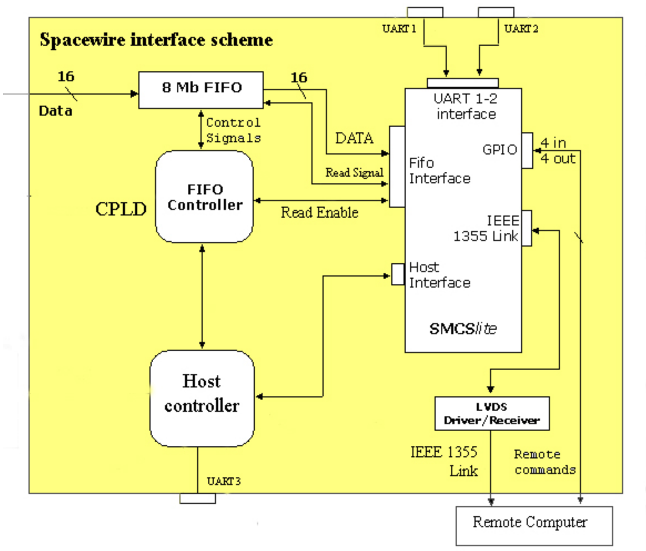

Fig 1: the Spacewire interface scheme showing the interface structure, the main devices and connections.

and it accomplishes housekeeping for the detector and (only for VLD) for the retarder plate writing these data in the header of every image. Therefore the microcontroller is a sort of CCD camera "brain". It accomplishes again the communication with the on-board computer exchanging commands and acknowledgements through the SpaceWire link or over a dedicated (8 bits) parallel link(Rem_Cmd link). Note that the possibility to send and receive data over different links increases the interface reliability. The microcontroller firmware implements also check and recover procedures: if a camera error occurs, the microcontroller points out the error to the on-board computer requiring a camera reset.

Although our SpaceWire interface has been developed for a custom application, its design is quite versatile. In fact the several procedures and functionalities that it offers, are all realized by means of software implementation The choice of reprogrammable devices enables to fit the performances of the interface to a specific applications easily changing the microcontroller firmware. The SCORE SpaceWire interface have also a flexible hardware; for example, it is able to write and store data in the internal FIFOs with an input rate ranging from 0 to 1 MHz without any change. Main SCORE interface features and performances are summarized below:

- 16 bits input data bus with a writing rate from 0 to 1 MHz.
- 8Mb Storing capacity
- 1 SpaceWire link (IEEE-1355 DS/DE) with a maximum data rate of 130Mb/s currently
- 1 general purpose 8 bits parallel link
- 3 UARTs
- Customizable procedures

This versatility will permit us to reuse our SpaceWire interface for different applications and to fit or upgrade it to future instrumentations.

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