DESIGN AND DEVELOPMENT OF ASPIICS, AN EXTERNALLY OCCULTED SOLAR CORONAGRAPH FOR PROBA-3 MISSION

J.-Y. Plesseria(1), P. Levacher (2), W. Curdt(3), S. Vives(2), C. Guillon(2) , A. Mazzoli(1), F. Rouesnel(4), A. Paschalis(5), N. Kranitis(5), A. Poulakidas(6), B. Fiethe(7), S. Shestov(8), S. Gunar(9), G. Capobianco(10), P. Lamy(2), P. Rochus(1), K. Tsinganos(11), S. Kuzin(8), P. Heinzel(9), S. Fineschi (10) and the ASPIICS team.

(1) *Université de Liège – CSL (Centre Spatial de Liège), Avenue du Pré-Aily, 4031 Liège, Belgique, +32 4 382 46 00, jyplesseria@ulg.ac.be*
(2) *Aix Marseille Université, CNRS, LAM (Laboratoire d'Astrophysique de Marseille) UMR 7326, 13388, Marseille, France, +33 491 056 931, sebastien.vives@oamp.fr*
(3) *Max Planck Institute for Solar System Research, 37191 Katlenburg-Lindau,Germany, +49 5556 979 420, curdt@mps.mpg.de*
(4) *LuxSpace Sarl, SES Business Center, 9, rue Pierre Werner, L-6832 Betzdorf, Luxembourg, +352 267890-8034, rouesnel@luxspace.lu*
(5) *Department of Informatics and Telecommunications, University of Athens, Panepistimiopolis, 15784, Athens, Greece, +302107275231, paschalis@di.uoa.gr*
(6) *Satellite & Space Applications Department, Hellenic Aerospace Industry s.a., Tanagra, P.O. Box 23, 32009, Schimatari, Greece, +302262046512, POULAKIDAS.Athanasios@haicorp.com*
(7) *IDA Institute of Computer and Network Engineering, TU Braunschweig, Hans-Sommer-Str. 66, 38106 Braunschweig, Germany, +49 531 391-3796, b.fiethe@tu-bs.de*
(8) *Lebedev Physical Institute of the Russian Academy of Sciences (LPI RAS), Leninskiy prospect, 53, Moscow, Russia, +7(499)132-65-97, sshestov@gmail.com*
(9) *Astronomical Institute Academy of Sciences of Czech Republic, Fricova 298, 25165 Ondrejov, Czech Republic, +420 32 3620 340, gunar@asu.cas.cz*
(10) *INAF-Osservatorio Astrofisico di Torino, Via Osservatorio 20, 10025 Pino T.se (TO), Italy, +39.011.8101.961, capobianco@oato.inaf.it*
(11) *Department of Physics, National and Kapodistrian University of Athens, Panepistimiopolis, 15784, Athens, Greece, +30 210 727 6915, tsingan@phys.uoa.gr*

Abstract: *This paper presents the current status of the design of the ASPIICS coronagraph onboard the Proba-3 mission. The development just finished phase B and will enter soon in phase C/D. The Coronagraph System is split on 2 spacecrafts flying in formation. The first satellite (OSC) holds the external occulter while the second (CSC) holds the optical instrument. The instrument itself is based on an axis-symmetrical diffractive optical system imaging the corona on a passively cooled CCD. The instrument also includes a front door mechanism for protection against dust and direct solar flux when not in formation flying, a shutter mechanism to ensure accurate exposure time and a filter wheel. The images will be acquired during the observation periods at the apogee of the orbit and stored on-board where they will be compressed afterwards before being down-linked to the ground.*
The instrument will observe the corona with wide band filter [540 nm – 590 nm], narrow band filter around He I D3 line at 587.6 nm and with different polarisations. The high resolution observation will be performed as close as 1.04 solar radii and up to 3 solar radii.
Keywords: *PROBA-3, ASPIICS, solar coronagraph, external occulter*

1. Introduction

PROBA-3 is a technology mission of the European Space Agency (ESA), devoted to the in-orbit demonstration of formation flying techniques and technologies. Presently at the end of phase B, PROBA-3 will implement a coronagraph (called ASPIICS, “Association de Satellites Pour l'Imagerie et l'Interferometrie de la Couronne Solaire”) that will both demonstrate and exploit the capabilities and performance of formation flying.

ASPIICS is distributed on two spacecrafts separated by 140m with the external occulting disk hosted by one spacecraft and the telescope (optical camera included) on the other one. ASPIICS will perform high spatial resolution imaging of the solar corona from the coronal base (1.04 solar radii) out to 3 solar radii.

ASPIICS is developed by a consortium of European Institutes and Industries from Belgium, Czech Republic, France, Germany, Greece, Italy, Luxembourg and Russia.

The design studies concern the external occulter mounted on one satellite and the telescope on the other one but also the additional metrology tools that will help checking the formation and ensure that the flight configuration is optimal for observations.

2. General architecture

The ASPIICS Coronagraph System is composed of the Coronagraph Instrument, the occulter disk and the metrological sensors.

The coronagraph instrument itself is composed of the Coronagraph Optical Box (COB), of the Camera Electronics Box (CEB) and of the Coronagraph Control Box (CCB). The coronagraph instrument is mounted on the Coronagraph Spacecraft (CSC) while the Occulter Disk is mounted on the Occulter Spacecraft (OSC).

The COB holds the optics, the detector and its radiator, the Front Door Assembly (FDA), the Filter Wheel Assembly (FWA) and the Shutter Mechanism (SHM).

The metrological sensors are the Shadow Position Sensor (SPS) and the Occulter Position Sensor Emitter (OPSE). The SPS is mounted in the COB and its operation is fully integrated in the COB operations. The OPSE (set of LEDs) is mounted in the centre of the Occulter Disk and is observed by the instrument.

3. Optical design

The ASPIICS optical design follows the general principle of a classically occulted Lyot coronagraph [1]. As shown on the following figure, the external occulter (D1) blocks the light from the solar disk while the coronal light passes around the occulting disk then enters through the circular aperture of the coronagraph (A1). The primary objective (O1) forms an image of the external occulter onto the internal occulter (D2). The image of the surrounding bright fringe is blocked by slightly over-sizing the internal occulter. The secondary objective (O2) re-images the entrance pupil (A1) onto the so-called “Lyot Stop” (A3) that blocks the light diffracted by the edges of the pupil. Finally, the corona image is formed by a camera (O3) onto the focal plane (F).

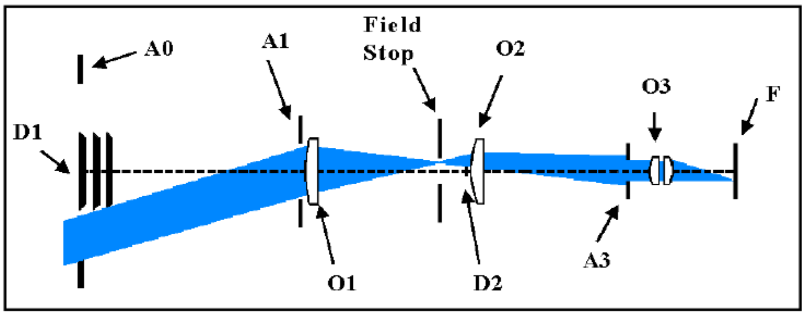

Figure 1. Basic scheme of an externally occulted Lyot coronagraph

The principle described above has been adapted for ASPIICS to take advantage of the formation flying. Indeed, the external occulter is mounted on a spacecraft while the optical instrument is mounted on the second one, both being separated by about 145 m. With this configuration, the instrument is able to observe the corona as close as 1.04 solar radii.

The external occulter mounted on the OSC consists of a circular disk with edges optimized to diminish the amount of diffraction that would reach the telescope aperture. The tolerancing of this disk has to take into account the optical needs but also the capabilities of the formation flying. This disk blocks the light from the solar disk while the coronal light passes through the circular entrance aperture (50 mm diameter).

The optical design of the telescope is a fully dioptric system that consists of a Primary Objective (PO) and Relay Lenses (RL) that image the corona on the detector through filters or polarizers.

The PO forms an image of the corona in its focal plane and an image of the external occulter on the Internal Occulter (IO) which is slightly behind the focal plane. The IO is slightly oversized in order to cover the external occulter image including its edge which is the source of important diffraction and also to cover the possible misalignments of the assembly and of the formation flying.

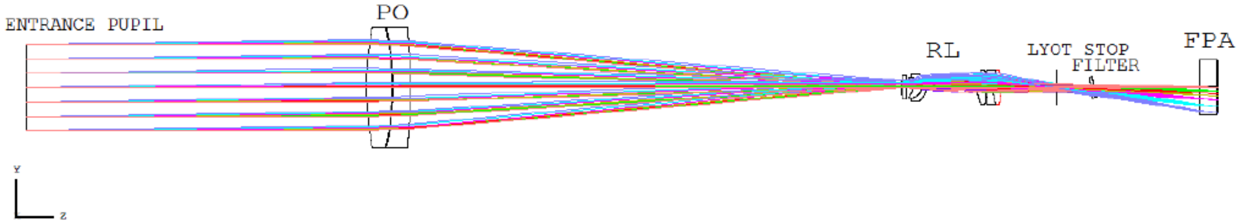

Figure 2. Overall layout of the ASPIICS optical design

The RL re-images the corona from the PO focal plane on the CCD detector and the entrance pupil on the “Lyot-stop”. This Lyot stop blocks the light diffracted or scattered by the edges of the entrance pupil.

The primary objective is composed of two separated lenses made of radiation resistant glasses to avoid darkening. The relay lens is made of two sets of lenses: a doublet, followed by a lens and another doublet. A filter wheel is inserted after the Lyot stop and contains 4 polarisers and 2 filters: a wide band filter ([540 nm – 590 nm]) and a narrow band filter centred on the He I D3 line (587.6 nm).

4. Stray light analyses

A critical point of the coronagraph design in order to ensure performances is the suppression of the stray light. Indeed the intensity of the Sun is several orders of magnitude higher than the corona we want to observe. Even if the external occulter is supposed to hide the Sun, the diffraction by the edge remains the major contributor to stray light. In order to limit this diffraction, the shape of this edge has been optimised by test and by analyses. Figure 3 shows results of the edges performances with respect to a standard knife edge.

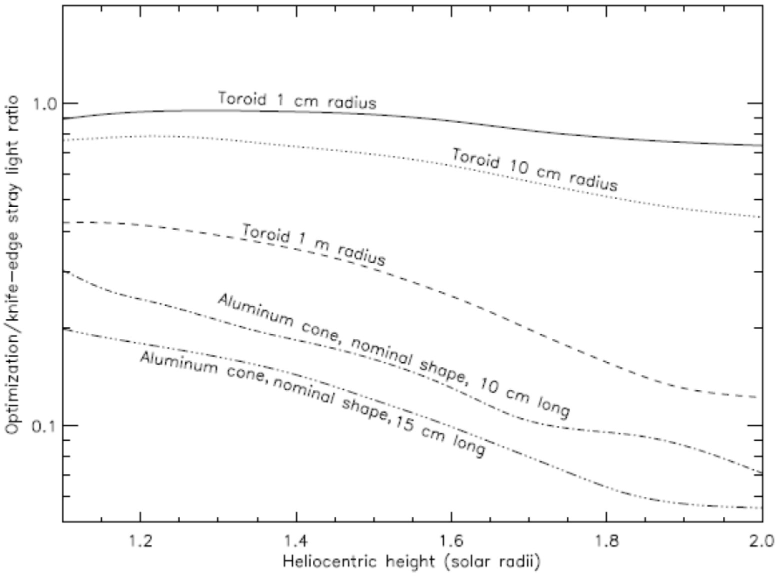

Figure 3. Ratios of light diffracted towards the entrance pupil between different occulter shapes (including cone) and the knife-edge reference.

As expected, this diffracted light will be mainly blocked by the internal occulter, nevertheless, this light will cross the primary objective. Therefore a part of this light will be reflected by the surfaces and will generate ghosts while another part will be scattered by the micro roughness and the contamination of these lenses. To limit these effects, the lenses shall be covered with high performance anti-reflection coating whenever possible and the surface quality will be very good i.e. micro roughness of 0.5 nm or below. Moreover a door must be implemented for all ground activities and launch to protect the primary objective from particulate contamination.
In the next phase (phase C/D), the design and manufacturing performances of the primary objective shall be measured on samples in order to refine the stray light modelling early in the project and ensure that the instrument performances are reached.

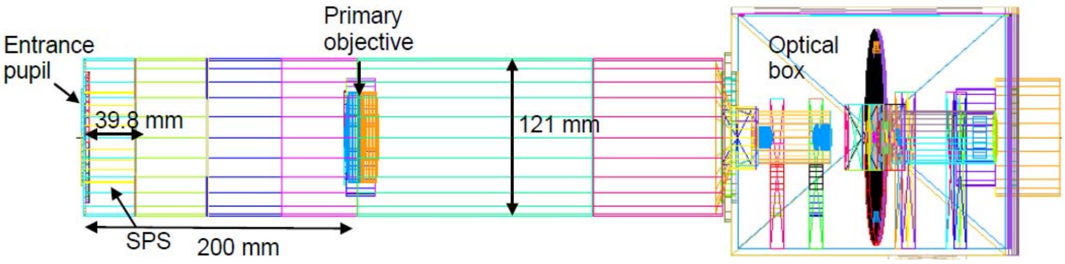

Figure 4. ASPIICS model for stray light analyses.

The internal vanes and the Lyot stop will reduce the stray light that will be scattered and diffracted by the entrance pupil and by all other external sources.

In order also to limit the ghosts in the instrument, the filters and polarisers are tilted by 11 degrees to limit the number of parallel surfaces in the optical design. The remaining critical ghosts sources are the filters (reflection between their faces) and the detector associated with its radiation protection window. The detailed design of these elements shall be performed carefully to limit the ghosts generation.

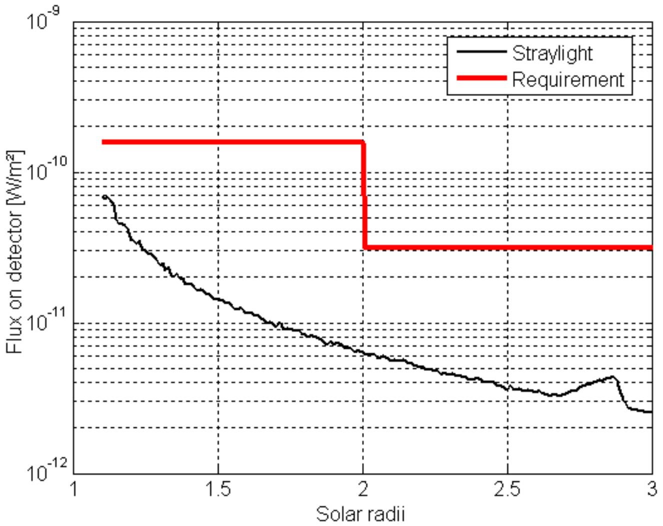

Figure 5. Scattered light on detector due to EO diffraction and PO micro-roughness (0.5 nm).

The stray light analyses have been performed both by applying the Fresnel-Kirchhoff diffraction theory and by ray-tracing.

5. Mechanical and thermal design

The mechanical design of the external occulter is part of the mechanical design of the OSC and is not described here.

The thermo-mechanical concept of the COB has to preserve the position stability of the optical parts after their alignment. The selected optical design concept with axis-symmetrical dioptric optics and a low f-ratio widely helps this task.

The stability required by the optics implies the use of a temperature controlled structure in Aluminium alloy, associated to a time-stability of +/- 2 °C. Moreover, with possible temperature gradients inside the instrument structure, the use of a honeycomb panel is rejected for the risk of temperature difference between the two skins, causing potential optical axis instabilities. To minimize thermo-elastic effects inside this structure, and in particular optical axis rotations, a concept based on a full symmetry with respect to sagittal plane was privileged. A massive structure is therefore our baseline, and shall be dimensioned for temperature gradient effects minimisation.

The mechanical architecture is based on the use of a main structure, supported by three bipods in Titanium, interfacing with the Optical Bench Assembly (OBA) of the CSC. The structure breaks down in two main parts, both in Aluminium alloy:

- A Tube starting at the entrance pupil, and ending just before the focus plane of the first imager. It supports the SPS, the Front Door Assembly, and the entrance objective (the entrance pupil diaphragm is a part of the SPS) at the entrance end, and the Internal Occulter with field stop at the other end. Several optical vanes are distributed inside, to trap the stray light.
- A structured parallelepiped called “EQuipments Box” (EQB) supports, the relay lens(es), the FPA and its radiator, as well as the filter wheel and the Lyot stop assemblies, the shutter mechanisms, and the venting systems. A lid will cover this structure, to prevent dust pollution. The venting systems with a protection against stray light and the electrical connectors interface complete the equipment of the EQB.

The three bipods support the above structure: two front monopods interface with the Tube while both rear bipods interface with the EQB, symmetrically disposed. The shape and size of these bipods have to be carefully calculated to:

- ensure the system rigidity and required first eigenfrequency of the COB,
- minimise the mechanical constraints resulting from temperature gradients between the coronagraph structure and the supporting OBA,
- minimise the transfer of OBA deformations (and resulting stresses) to the coronagraph structure,
- minimise the thermal conductive leaks between COB and OBA.

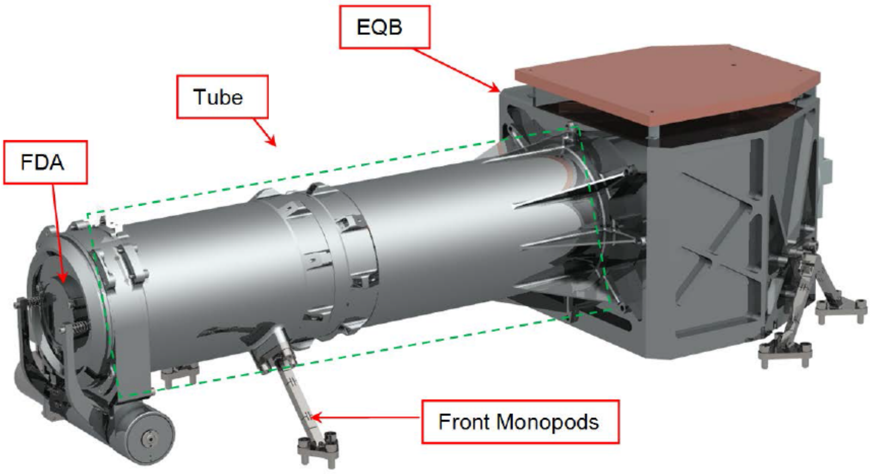

Figure 6. ASPIICS COB

6. Mechanisms

6.1. Front Door Assembly (FDA)

The protection of the instrument against dust particles, during the storage and especially during the launch phase forces to use a protection door. Moreover the presence of this door allows possible photometric calibrations of the instrument by use of a High Density Device (HDD) fixed in the centre of the door, and, when lighted by the Sun, produces a flat field image on the detector.

The FDA allows a several shot closing/opening of the entrance aperture by use of a mobile lid moved by a stepper motor in normal conditions. This lid is only opened at the beginning of the observation period and closed at the end. As redundancy, in case of failure of this actuator, a one-shot wax actuator allows the definitive opening of the lid.

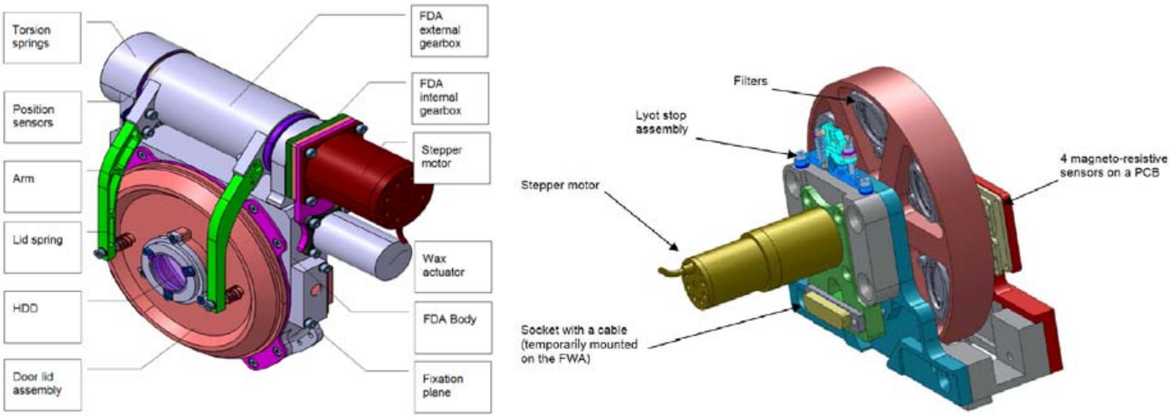

Figure 7. Front Door Assembly (left) and Filter Wheel Assembly (right)

6.2. Filter Wheel Assembly (FWA)

The several possibilities of observation - in a wide bandwidth, in a narrow bandwidth and in polarised light - force to use a motorised filter wheel with 6 positions: narrow-band filter, wide-band filter, and 4 polarisers.
These filters, mounted on the wheel, are inserted in the optical path close to the secondary pupil of the system, and tilted to avoid ghost images on the detector.
The FWA consists of a wheel moved by a stepper motor / gear box with reduced backlash which positions the filters in the optical beam. The position is read thanks to a set of position sensors.

6.3. Shutter Mechanism (SHM)

A mechanical shutter, under form of a blade, is linked to the use of a full frame CCD with short exposure times, and is needed to define the exposure time. It is located close to the intermediate focus and not close to a pupil as usual, because pupil planes are used by optical parts (field stop and Lyot stop).
This particular location allows a protection of the back end of the instrument against full Sun light when the shutter is closed. In this case, the Sun light is blocked by the shutter blade and the corresponding heating power (lower than 0.5 W with full Sun in the wavelength bandwidth of the coronagraph) will be mainly reflected and absorbed by the baffle and tube. All the sensitive parts behind the primary focus are then protected, and the only lighted part is the entrance objective, which can survive to this potential event. To complete the protection, the shutter will close automatically when unpowered, by action of a spring on the shutter blade. With this system, even in case of power failure, the instrument can support a long exposition to full Sun.
The mechanism uses a limited angle DC brushless torque motor, directly mounted on the shutter blade axis. This blade is in the closed position when unpowered, and maintained open by a small electrical current in the motor during the exposure time. The rotational spring is only used for closing the shutter when this current is suppressed. In normal conditions, the control loops ensure this movement. A position encoder completes the hardware to realise a highly reproducible movement.

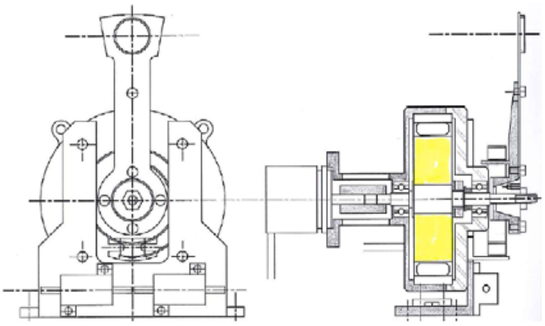

Figure 8. Shutter Mechanism

7. Metrology sub-systems

7.1. Shadow Position Sensor

The Shadow Position Sensor (SPS) verifies the safe centring of the entrance pupil of the coronagraph into the shadow cone of the occulting disc. Initially planned for a high sensitivity relative measurement of the umbra location with reference to the centre of the entrance pupil of the coronagraph instrument, it has evolved towards a sensor giving an absolute location with a high accuracy.

Another function required to the SPS is to signal to the satellite (CSC) that the umbra moves out of the nominal position range of the SPS, this is to prevent the risk of full Sun inside the coronagraph instrument.

The SPS is based on the use of light sensors disposed around the entrance pupil diaphragm of the coronagraph. All sensors are located close to the pupil diaphragm and then, in the nominal flight configuration, in the penumbra zone given by the external occulting disk.

For practical reasons (space around the pupil, redundancy, accuracy), we have disposed 8 light sensors, organised in 2 groups of 4 sensors. The sensors of a group are equally distributed on a circle centred on the entrance pupil centre, and two circles with respective radii of 42 and 52 mm have been selected for the two groups.

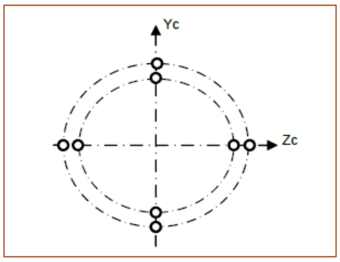

Figure 9. Arrangement of the 8 light sensors around the entrance pupil of the instrument

A sensor in the penumbra sees the light coming from a crescent of Sun. The surface of this crescent is nearly linear with the decentring if it stays sufficiently small. Therefore, the light received by this sensor evolves nearly linearly with the distance with the full umbra, and the principle of measurement is based on this particular property.

As the photo-current of a photodiode is perfectly proportional to its illumination, the voltage signals delivered by the front-end electronics and then digitalised are nearly

proportional to the umbra displacements, except when they are in the full umbra of the occulting disc.
Considering two opposite sensors, they are never in the umbra at the same time, and photometric information is always available.

The SPS head is a compact sub-system which is mounted in front of the instrument Tube, under the lid of the Front Door Assembly (FDA). The following image shows the main parts of this head.

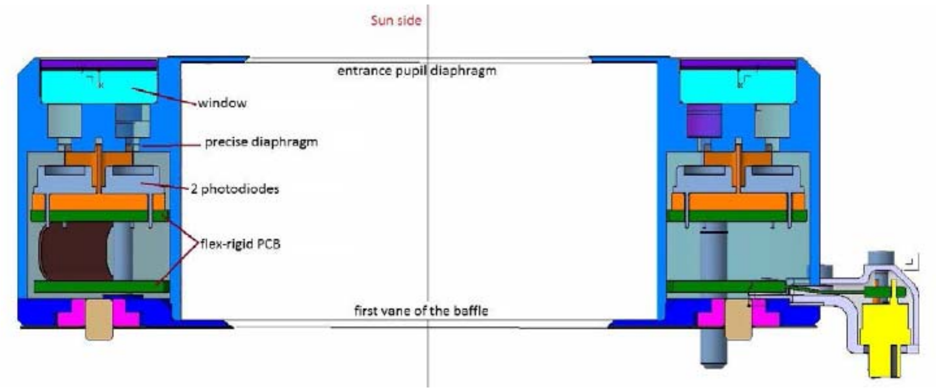

Figure 10. SPS mechanical implementation

The head includes the 8 sensors distributed on two circles with respective radius of 42 mm (sensors #1) and 52 mm (sensors #2). They are mounted on a printed circuit board (PCB) in flex-rigid technology (2 rigid annular parts connected together by a flex circuit and connected to an in/out connector). These two rigid parts of the PCB are mechanically mounted on the base plate (in dark blue) thanks to a set of screws and spacers. The PCB also includes the operational amplifiers, and small components needed to condition the current signals delivered by the photodiodes.
The accumulation of mechanical tolerances in this assembly does not allow a good positioning of the photodiodes. In fact, only the diaphragms in front of the photodiodes are well positioned by use of only one mechanical accurate part which includes the pupil diaphragm at its centre and the 8 diaphragms of the photodiodes (the front cover in light blue). The photodiode sensitive area is selected for having a diameter sufficiently higher than the diaphragms to take into account the assembly tolerances.

7.2. Occulter Position Sensor Emitter (OPSE)

The purpose of the Occulter Position Sensor Emitter (OPSE) is to verify the positioning of the occulting disc in the field-of-view of the coronagraph that is the alignment of both spacecrafts independently of the pointing to the Sun.
The OPSE consists of a set of 3 light emitters mounted on the rear side of the external occulting disc. Their images produced by the coronagraph have a characteristic pattern that uniquely defines the position along the transverse axes, with respect to the instrument coordinate system. Moreover an estimate of the inter-satellite distance (ISD) and of the orientation of the external occulter is also delivered.
The 3 OPSE are located close to the centre of the disk, limiting by this way the size of the density hole in the centre of the Internal Occulter in the coronagraph.

These images are received by the CCD of the coronagraph which, after readout, can be sent on ground for analysis, like other images. The information delivered by the OPSE is therefore not usable onboard in real time.

The use of the OPSE supposes a coronagraph fully operational, door open, and then with the entrance pupil in the umbra or low penumbra; this last point limits its use.

The drive electronics is a part of the satellite and the coronagraph team has only to propose the architecture of this electronics and the corresponding requirements.

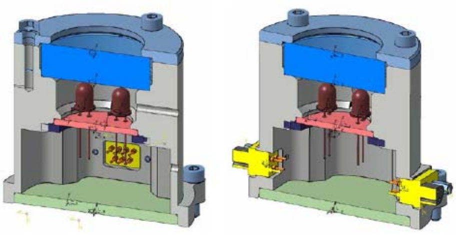

Figure 11. OPSE mechanical implementation

8. Coronagraph Control Box (CCB)

8.1. General description

The instrument electrical design approach integrates the Coronagraph Control Module (CCM) together with Motor Control Module (MCM), Ancillary Electronics Module (AEM) and Power Converter Module (PCM) in a central Coronagraph Control Box (CCB) to achieve a highly compact and efficient design [2]. The CCM together with an integrated mass memory provides sufficient computing resources to cover both, command & control of the complete instrument as well as sophisticated image data processing. This includes the interface handling towards the Spacecraft, housekeeping data acquisition, automatic image data acquisition & processing, and execution of autonomous measurement sequences.

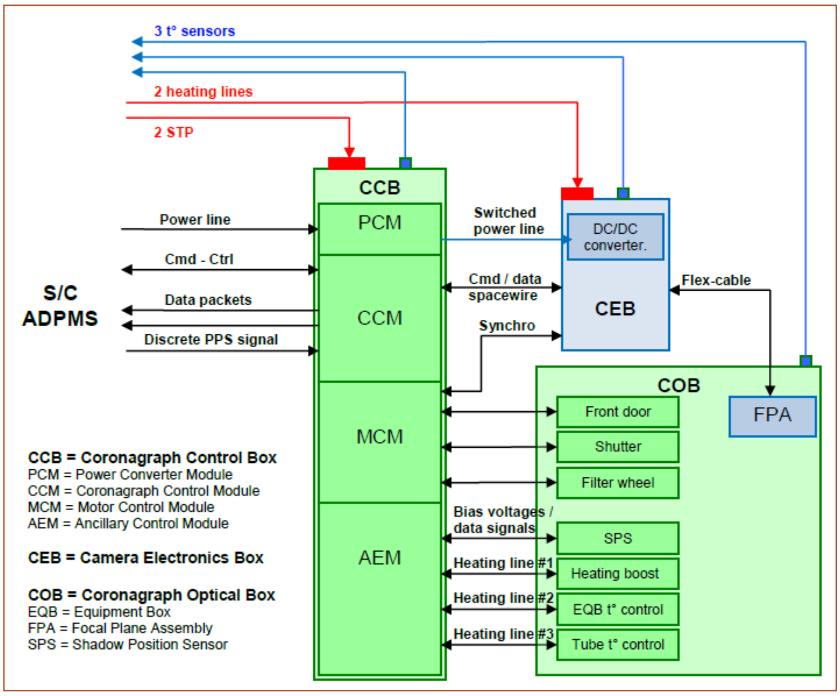

Figure 12. Block diagram of the coronagraph electronics

8.2. Coronagraph Control Module (CCM)

The design utilizes a combination of a LEON-3 based main processor system within a fixed, radiation hardened and TMR by design, one-time programmable FPGA (Microsemi RTAX) together with a dedicated data compression function core implemented within an in-flight reconfigurable FPGA (Xilinx Virtex). Since all data processing steps are performed by dedicated FPGA-H/W, the only moderate processing power (20-30 MIPS) of the LEON-3 processor is sufficient for overall high-level instrument control and for communications with the S/C platform.

The processor will control and synchronise the camera electronics, the Shadow Position Sensor (SPS), the thermal control and the mechanisms control, including shutter, front door and filter wheels. All interfaces and instrument control/monitoring functions needed for basic operations are integrated in the fixed area FPGA to achieve highest reliability. Additionally, this FPGA acts as system supervisor to achieve the configuration control and required SEE radiation tolerance of the reconfigurable FPGA, supported by a high-reliable configuration memory for firmware storage.

The limited telemetry rate combined with the large amount of scientific information retrieved from the camera system demands sophisticated on-board data compression. This is achieved by a dedicated, in-flight reconfigurable processing core attached to the running system by a flexible and glitch-free on-chip communication architecture, named System-on-Chip Wire (SoCWire). SoCWire is based on the well established ESA SpaceWire interface standard. Such a reconfigurable system is currently developed at IDA in the frame of the ESA Dynamically Reconfigurable Processing Module (DRPM) study.

On-board image data compression is based on the CCSDS-122.0-B-1 Image Data Compression (IDC) algorithm. The CCSDS-IDC is implemented as a reconfigurable core in a high density, space qualified reconfigurable FPGA which provides an excellent dynamically reconfigurable on-board payload data processing solution, featuring high reliability (with configuration memory scrubbing), high performance and high circuit density. The CCSDS-IDC core architecture provides a powerful, cost-effective and highly integrated solution since it does not require any external memory.

A complete non-volatile reliable mass memory system, providing significant storage capacity fulfils all needs of intermediate data storage at very low resources need. According to proposed observation strategy an anticipated memory capacity of 256 Gbit is more than sufficient and leaves ample capacity for future changes. For high data rates, it is directly controlled by a DMA-type of flash memory controller within the RTAX FPGA.

The design of the NAND-Flash based system will have complete error correction, taking into account the Flash handling. NAND-Flash based mass storages for space have been intensively studied by IDA in the Safe Guard Data Recorder (SGDR) study by ESA and are currently under development for the Sentinel-2 SSMM.

8.3. Power Control Module (PCM)

The CCB is the first equipment which is switched on after an OFF mode, by activating the only power line delivered by the S/C. This primary line powers the DC-DC converter inside the Power Control Module (PCM), and in particular, the Coronagraph Control Module (CCM), which, after the short time for boot and

initialisation, is able to manage the distribution of primary or secondary power to the others modules.
A power distribution unit is effectively included inside the PCM, which has:

- to deliver the primary power to the Ancillary Electronics Module (AEM) to power the heaters needed for COB warming, thanks to the dedicated amplifiers,
- to power the camera by a switch-on of the primary power line for the CEB, on order from the CCM,
- to deliver the primary power to the Motor Control Module (MCM) to power the pin puller inside the Front Door Assembly (see appropriate section) thanks to a dedicated switching system,
- to deliver the primary power to the MCM after a short time needed to initialise circuits of motor controllers: this avoids the risk of motor jump at switch-on.

8.4. Ancillary Electronics Module (AEM)

The AEM is a module of the CCB. Its two main functions are:

- the acquisition and treatment of the data delivered by the SPS head (front head electronics close to the pupil of the instrument), before a sending to the CCM,
- the temperature control of the 2 controlled zones of the COB: the tube and the EQB. An additional heating line takes advantage of a CEB off to use the corresponding power to boost the heating for a faster heating.

The AEM receives from the SPS head 8 differential signals coming from the 8 light sensors and 2 temperature signals. It has to power the SPS head by a symmetrical power supply.
The differential signals are received by instrumentation amplifiers, followed by two double multiplexers authorising the selection of two signals at a time on the eight received from the SPS head. These two signals are digitalised by two 16 bits ADC at a cadence of 40 samples/s, before a sending to the CCM for a final treatment in software.
The temperature sensors needed by the SPS (2 in the head and 2 close to the ADC) are also conditioned by the AEM.
The second part of the AEM is dedicated to the temperature control of two zones:

- the front tube of the COB,
- the Equipment Box of the COB.

8.5. Motor Control Module (MCM)

The MCM has to command and control the activities of all motors inside the COB:

- the Filter Wheel Assembly stepper motor,
- the Front Door Assembly main motor, which is a stepper motor, and a pin puller system able to open the door in case of failure of the main motor,
- the SHutter Mechanism, using a DC brushless, limited angle torque motor.

This sub-system includes the motor drivers, the position sensors acquisition and conditioning electronics, and all circuits needed to control the position or speed loops. It interfaces with the CCM thanks to a LVDS link. This module receives from the CCM all orders for mechanism activations, controls the motors accordingly, and send back to the CCM the new positions reached by the mechanisms. Only one "intelligent" circuit is used for the 3 motor controls, which are fortunately never running at the same time, greatly helping the design.

9. Camera Electronics Box (CEB)

The primary function of the CEB is to operate the CCD, digitalise the image data and transfer it to the CCM. An overall schematic diagram is shown in the next figure.

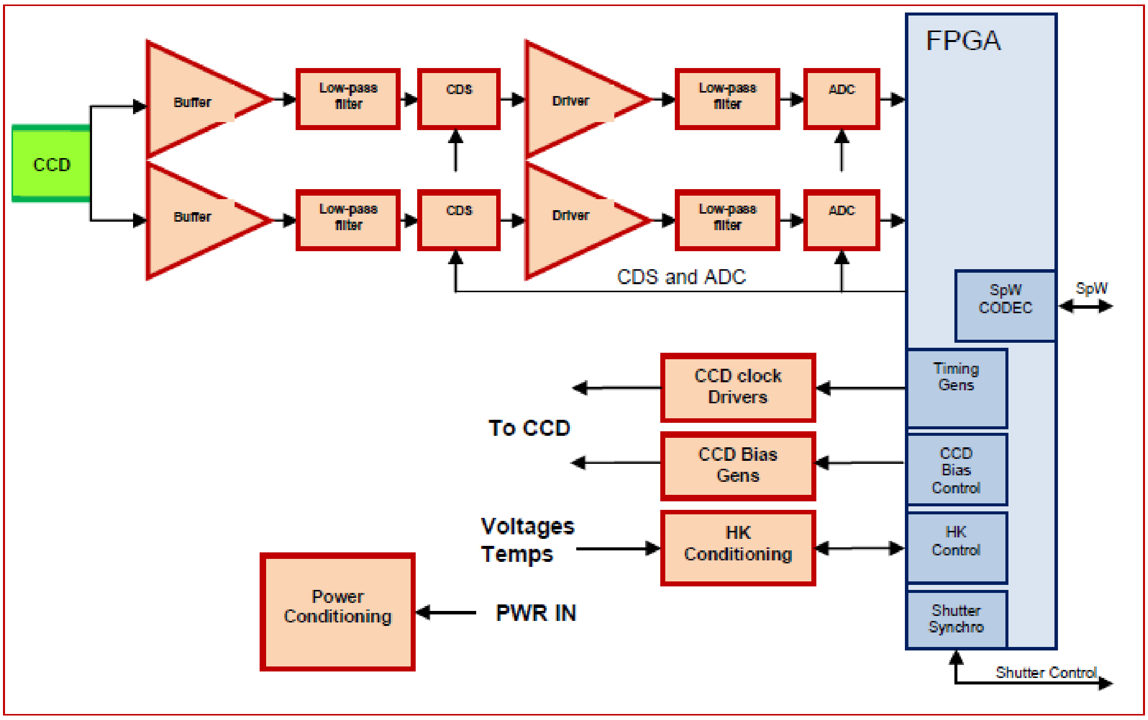

Figure 13. Block diagram of the CEB

The FPGA is the core of the CEB, this receives commands from the CCM. It generates all the clocks necessary for driving the CCD and drive the DACs responsible for providing the bias voltages.
Image data from the CCD is read out serially and alternated through 2 separate 16 bits ADCs. The digitised data from these ADCs is then read back into the FPGA where it is assembled into Spacewire packets and transmitted to the CCM.
Moreover, the CCD activity will be synchronised with the shutter displacements to preserve the stability of the exposure time of successive images. It is also made by the FPGA.

10. Software architecture

The S/W of ASPIICS draws substantial heritage from instrumentation on earlier missions, where a similar approach was implemented (SOHO-SUMER, ROSETTA-OSIRIS, VENUS EXPRESS, ...) and successfully run. The architecture is based on a RTOS and foresees three layers plus a boot loader that resides in fixed memory.
The approach is based on a RTOS and includes a dedicated Onboard Command Language (OCL), a compiler/interpreter system with a full C-like language set and macro-commands for functionalities specific to ASPIICS. OCL provides a flexible,

safe, and easy to use implementation of in-flight reprogrammable procedures. OCL is inherited from various ESA/NASA instruments and satellites application SW.
The three major layer structures of the approach with following sub layer functions are depicted in the figure below.

Layer 1: Low Level S/W
- Interface to the H/W with the next higher S/W level.
- Real-time operating system and driver software.
- I/Fs to both the RTOS and the driver S/W. All S/W I/Fs above this level shall be H/W independent.

Layer 2: RTL and Middleware
- Command execution, also within several operational modes.
- Basic controlling functions, as so called RTL, e.g. for control of data processing, HK acquisition, etc. Also, control of file operations to and from image memory shall be allocated in the RTL.
- Autonomous, time- and event-driven, flexible, and safe instrument control system, On-board Command Language (OCL).

Layer 3: Application Layer (in OCL)
- High level application software, which is developed using the OCL functionalities, e.g. configurable management procedures for mode sequencing, data acquisition and processing sequencing, autonomous reactions on HK or data evaluation events, etc.

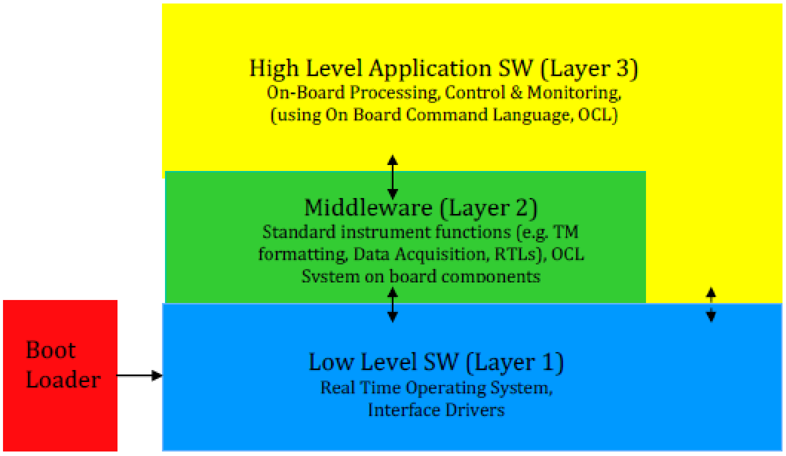

Figure 14. Software architecture

The proposed S/W design reflects the wide range of application driven requirements by means of built-in flexibility for:
- adaptability to different hardware interfaces,
- comprising RTOS to manage different prioritized tasks for both, control functions as well as data processing demands,
- providing means for accessing special function processors for on-line processing demands,
- autonomous control of instrument and data processing,
- provide modularity, e.g. for in-flight changes or updates, and

- failure tolerance to guarantee at least the main control and monitoring functions with uninterrupted performance.

11. Conclusions

This paper presents the current status of ASPIICS, the coronagraph that will be onboard the Proba-3 formation flying demonstration mission. This instrument takes advantage of the possibility to place the external occulter on the second satellite to perform high resolution imaging of the inner corona of the Sun as close as 1.04 solar radii. The instrument optical design remains simple so that the emphasis can be put on critical aspects as the stray light reduction and data handling. The image acquired will be compressed on board in an in-flight reconfigurable FPGA before being downlinked to ground for scientific analyses.

The phase B, performed by an consortium of several European institutes and industries allowed to design a performing instrument and to highlight the critical points that will have to be studied at the beginning of the next phase.

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