PROBA-2

MISSION AND NEW TECHNOLOGIES OVERVIEW

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ABSTRACT

Following on from the success of PROBA-1, which successfully completed its technological goals in its first year of flight and continues to provide valuable scientific data now into its fifth operational year, PROBA-2, now in phase C/D and due for launch in September 2007, will once again fly a suite of new technology demonstrators with an 'added value' science package of four experiments. Altogether there are seventeen new developments being flown on Proba-2, divided into two groups: platform technologies which are part of the infrastructure and are mission critical and passenger technologies to gain flight heritage and experience before committing them to the infrastructure of other missions. Of the four Science experiments, two are dedicated to solar physics. The two other will study the space weather (plasma physics)
The paper will provide an overview of the PROBA-2 mission and spacecraft along with a description of the scientific payload and technology experiments

2 PROBA 2 MISSION SUMMARY

1.1. Mission objectives

The PROBA 2 mission objectives, as deduced from the ESA requirements, can be summarized as follows:

- PROBA 2 will be a platform to demonstrate and validate new, advanced technologies in order to promote their usage in future missions,
- As such, PROBA 2 shall accommodate a number of selected technology experiments,
- PROBA 2 shall furthermore accommodate a series of scientific payloads, in the fields of space environment (plasma) and solar observations;
- The PROBA 2 system shall be designed to support an in-orbit operational lifetime of 2 years;
- The PROBA 2 orbit shall be preferably a LEO Sun-synchronous orbit with minimized eclipse time;
- PROBA 2 shall have a high degree of spacecraft autonomy and ground support automation.

1.2. Launch and orbit

PROBA 2 is planned to be launched from Plesetsk, Russia, in September 2007, on a Rockot launcher. PROBA 2 will be a secondary-passenger of the launch of the SMOS (ESA) spacecraft. It will be directly injected in a Sun-synchronous LEO orbit, with an altitude between 700-800 km (baseline 728km) and with the LTAN at 6:00 AM +/- 15 minutes. The orbit injection accuracy provided by the launcher is sufficient to guarantee that the LTAN will remain within 6:00 AM +/- 45 minutes without the use of onboard propulsion. The orbital period is approximately 100 minutes.

The targeted orbit is eclipse-free for 9 months per year, thus making the orbit well suited for the solar observing instruments. Maximum eclipse duration during the eclipse season is less than 20 minutes.

Since the orbit remains acceptable for the solar observations during the complete mission lifetime, propulsion is not needed to support the mission. However, as is documented below, a propulsion system is accommodated onboard PROBA 2 as a technology demonstration.

1.3. Ground segment

As for PROBA1, the PROBA2 spacecraft will be operated from the Redu Ground station (Belgium).

2. PROBA 2 SPACE SEGMENT DESCRIPTION

PROBA 2 has a weight of less than 130 kg and belongs to the class of the mini-satellites (*Figure 1*). Its structure is built using aluminum and CFRP honeycomb panels. Triple junction Gallium Arsenide solar cells, body mounted on 1 panel and mounted on 2 deployable panels, provide the power to the spacecraft and a Li-Ion battery is used for energy storage. A battery-regulated, centrally switched 28V bus distributes the power to the units and the instruments. A high performance computer, based on the LEON processor provides the computing power to the platform and for instrument data processing. It accommodates the memory for

Small Satellite Systems and Services - The 4S Symposium; 25-29 September 2006; Chia Laguna Sardinia, Italy (2006).

house-keeping data storage as well as a mass memory for the payload image data. The telecommunications subsystem is designed to establish and maintain space-ground communications link with the ground segment while the spacecraft remains sun-pointing. It is CCSDS compatible for up- and downlink in the S-band. The set of ACNS units support Sun-pointing, inertial 3-axis attitude pointing as well as Earth pointing and a series of attitude maneuvers. Furthermore, it performs all required navigation and maneuvering computations onboard. The spacecraft platform provides full redundancy (*Figure 2*).

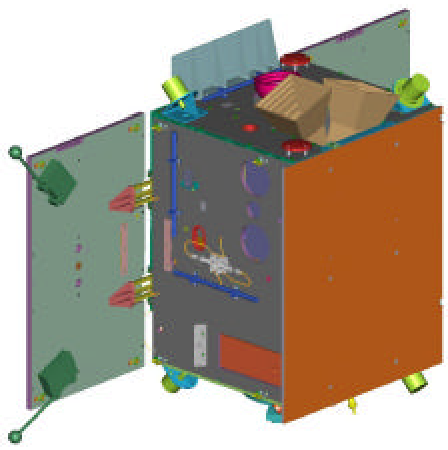


Figure 1. PROBA 2 flight segment design

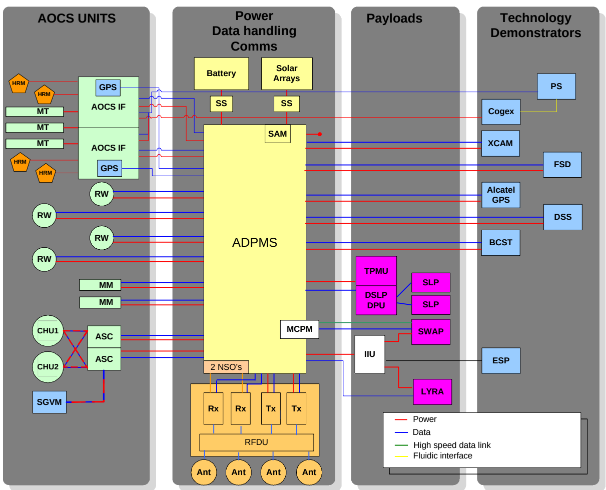


Figure 2 PROBA 2 block diagram

2.1. PROBA 2 platform

2.1.1. Mechanical and thermal

The PROBA 2 structure is derived from the PROBA 1 structure and is compatible with launchers such as ROCKOT, PSLV and DNEPR. The carrying part of the structure is composed of 3 aluminum honeycomb panels mounted in an H-structure and a bottom board. Almost all units are mounted on these inner panels. The bottom board acts as the interface with the launcher. All outer panels without solar cells mounted on them consist of aluminum honeycomb panels as well. They are painted black/white according to the needs of the thermal subsystem. The 2 deployable solar panels, as well as one outer panel with solar cells consist of honeycomb panels with aluminum core and CFRP sheets. The sheets supporting the solar cells are covered with kapton for electrical insulation. The deployable panels are permanently connected to the spacecraft body by hinges based on Carpentier joints. The Carpentier joints provide the opening torque at the moment of panel release as well as the self-locking in the deployed position. During launch, the stowed panels are kept in the stowed condition by the hold-down and release mechanism. This mechanism utilizes thermal knives to release each panel by software command in orbit.

System		Description
Orbit	LEO, 728 km mean altitude Sun-Synchronous, equator crossing at 6:00 am on ascending node. Near-polar (98.42°)	Optimisation for the requirements: Best orbit for Solar observation instruments. Selection of low cost launcher with flight opportunity in a short time.
	Operational Lifetime	2 years
Mechanical	Dimensions	600 x 700 x 850 mm
	Mass	< 130 kg
Thermal	Mainly passive thermal control, heaters for battery	
ACNS	Attitude control	3-axis stabilised providing high accuracy Sun-pointing, nadir and off-nadir pointing capabilities.
	Sensors	Cold redundant dual head, advanced micro star trackers, redundant 3-axis magnetometers, redundant low power GPS receiver.
	Actuators	3 redundant Magnetorquers, 4 Reaction Wheels
	Absolute Pointing Accuracy	Better than 75 arcsec (2 sigma)
	Absolute Pointing Knowledge	Better than 10 arcsec (2 sigma).
Avionics	Processor	Cold redundant radiation tolerant LEON2-FT RISC processor
	Memory	64 Mbyte + 4 Gbit RAM (EDAC protected), 4 Mbyte FLASH,
	Interfaces	RS422, TTC-B-01, analog and digital status lines, direct high speed packetwire interface to Telemetry. Compact PCI boards for integration in main computer
	Uplink Communications	Hot redundant S-band receivers, 64kbps
	Downlink Communications	Cold Redundant S-band transmitters, 1 Mbps
	Communications Packet Standard	CCSDS
Power	Solar Panels	1 body mounted GaAs panel and 2 deployable GaAs panels, 120W peak power (EOL)
	Battery	Li-ion, 11Ah, 28V
	Power Conditioning System	28V battery regulated power bus, redundant battery charge and discharge regulators, power distribution system and shunt regulators.
Software	Operating System	RTEMS
	Data Handling/Application Software	Based on PROBA 1 and SMART 1 onboard software as well as newly developed for PROBA 2.

Table 2-1 PROBA 2 platform specifications overview

The thermal control of the spacecraft is intended to be passive as far as possible. The sun-pointing attitude results however in a considerable thermal gradient through the spacecraft, making as such a completely passive thermal control difficult to achieve and heaters are foreseen to control the battery temperature. Heaters are also required to de-contaminate specific parts of the solar observation instruments. The SWAP instrument (see below) has a radiator mounted on the side of the spacecraft in order to keep the detector as cold as possible.

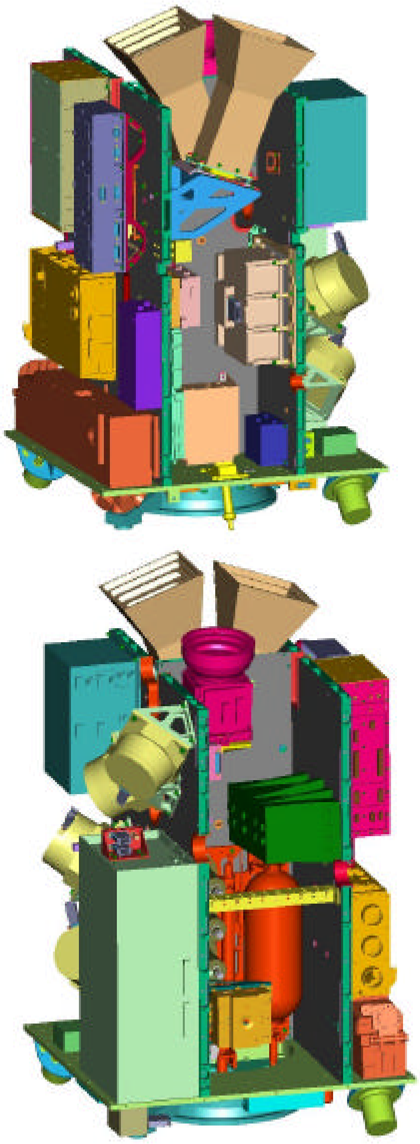


Figure 3 PROBA 2 internal structure and accommodation

2.1.2. Attitude control and Navigation system

The PROBA 2 ACNS is strongly based on the PROBA 1 ACNS. The latter was a complex system providing (i) 3-axis attitude control including high accuracy pointing and maneuvering capabilities in different pointing modes, (ii) full spacecraft attitude control based only on target oriented commands and (iii) the demonstration of new technologies. Furthermore, it was developed relying heavily on the use of Computer-Aided Software Engineering tools. The PROBA 2 ACNS includes the full PROBA 1 ACNS, with the additional functionality to support the solar observation mission. This includes an improved Sun-model and the possible inclusion of a sun-sensor in the control loop. Furthermore, the ACNS incorporates a technology demonstration of a series of new algorithms:

- low-cost determination of the attitude and orbit using temperature, light and/or magnetic-field sensors,
- the use of a Square-Root Unscented Kalman Filter (SR-UKF) for attitude and orbit determination,
- autonomous, high-precision, recurrent large-angle manoeuvre capability during the Sun-Observation Mode to avoid star-sensor blinding by the Earth

Finally, the ACNS functions support automatic “image paving” for the Sun-Imaging instrument (SWAP) in order to increase its actual field of view.

PROBA 2, as PROBA 1, has been fitted with a high-accuracy double head star tracker, with GPS receivers and with a set of reaction wheels for the nominal ACNS operation. This set of sensors and actuators is complemented with the magnetotorquers and 3-axis magnetometers. As explained above, PROBA 2 carries as well an additional star tracker, an additional GPS, an additional magnetometer and a Sun Sensor as technology demonstrations.

As on PROBA 1, the star tracker is the main attitude determination sensor. It provides full-sky coverage and achieves the high accuracy required for Sun pointing. The sensor can autonomously reconstruct the spacecraft’s inertial attitude starting from a “lost in space” attitude with a performance of a few arc-seconds up to an arc-minute. The attitude can be reconstructed at relatively high inertial rates, which allows the ACNS software to perform gyro-less rate measurements sufficiently accurately to control large-angle precise and stable manoeuvres. The model selected to fly on PROBA 2 is the micro-autonomous stellar compass (μ-ASC), a next generation of the star tracker to that flown onboard PROBA 1. It requires less electrical power, has a lower mass and smaller volume, can connect to 4 camera heads instead of to 2 (although only 2 are used in PROBA 2) and provides attitude output at 4 Hz instead of 2 Hz. The star tracker is provided by the Technical University of Denmark.

Orbit and time knowledge is acquired autonomously from measurements performed by a GPS receiver. As a technology demonstration, PROBA 2 flies a redundant set of Phoenix GPS receivers provided by DLR.

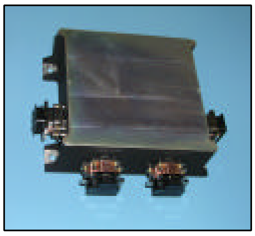


Figure 4 DTU µASC

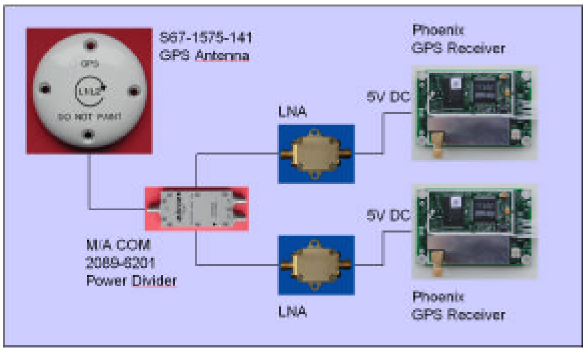


Figure 5 Phoenix GPS architecture for PROBA-2

It is a miniature receiver specifically designed for high dynamics space applications. It is based on SigTech's commercial-off-the-shelf MG5001 receiver board but operates a proprietary firmware developed by DLR. Though originally designed for automotive applications, the receiver board has been qualified for space use in a series of thermal-vacuum, vibration and total ionization dose tests. The receiver employs a GP4020 baseband processor which combines a 12 channel GP2021 correlator and an ARM7TDMI microprocessor kernel. At a power consumption of less than one Watt and a board size of 50 x 70 mm the receiver is among the smallest of its kind and particularly well suited for satellites with limited onboard resources. The Phoenix receiver is extensively used in European sounding rocket missions and has been selected for various other micro-satellite missions in low Earth orbit (LEO) such as X-Sat, ARGO, Flying Laptop and PRISMA. Specific features of the Phoenix receiver software for LEO applications include optimized tracking loops for high accuracy code and carrier tracking, precision timing and integer ambiguities for carrier phase based relative navigation, a twoline elements orbit propagator for signal acquisition aiding, and an attitude interface to account for non-zenith pointing antennas in the channel allocation process. A pulse-per-second signal enables synchronization to GPS (or UTC) time with an accuracy of better than 1µs. Noise levels of 0.4 m (pseudorange) and 0.5 mm (carrier phase) at representative signal conditions (C/N_0=45dB-Hz) have been demonstrated in signal simulator and open air tests which render the receiver suitable for precise orbit determination. While the instantaneous (kinematic) navigation solution is restricted to an accuracy of roughly 10m (3D rms) due to broadcast ephemeris errors and unaccounted ionospheric path delays, an accuracy of about 0.5-1m can be achieved in a ground based precise orbit determination.

The orbital information allows pointing of the spacecraft towards any point on Earth (by using as well an onboard Earth-rotation ephemeris calculator), to autonomously determine the optimal moments for a high-angle maneuver to avoid sensor blinding by the Earth and to perform accurate Sun-pointing.

The generation of control torques is by means of four reaction wheels (Dynacon, Canada) mounted in a tetrahedron configuration. Their inertia capacity is 0.65 Nms and their maximum torque capacity is 30 mNm. The reaction wheels are an evolution of those used on the Canadian MOST mission.

All ACNS sensors and actuators are controlled by the ACNS software running on the central LEON based computer and provides functions including:

- Navigation (NAV) which consists in the on-board Kalman filter based autonomous estimation of the orbit using GPS measurements and the on-board autonomous determination of the attitude using data from the star tracker, digital Sun sensor and magnetometers. The navigation function also includes the prediction for all the mission related orbital events (eclipses, next Earth target passages, next ground station flybys, Earth exclusion angle etc…).
- Guidance (GDC) which consists in the on-board autonomous generation of the commanded reference attitude profiles and manoeuvres, depending on the spacecraft operational mode. The guidance function also includes the computation of the control error, the difference between the desired and the current, estimated, dynamical state.
- Control (CTL) which consists in the determination and execution of the necessary control commands that will bring the current dynamical state of the spacecraft coincident with the desired state. The control function also includes the maintenance of internal dynamic variables within specified boundaries (e.g. reaction wheel speed).
- Failure Detection & Identification (FDI) which consists in monitoring the inputs, the internal and output variables and parameters of the AOCS software to test them for numerical and/or physical validity.

Furthermore, to increase the pointing accuracy of the SWAP instrument, the AOCS SW also provides in-flight compensation of thermo-elastic misalignments of the star tracker relative to the instrument.

The PROBA 2 operational modes for the ACNS are as follows:

- The **Bdot mode** (safe mode): uses the Earth's magnetic field to reduce angular rates after separation and also as a safe mode during the mission. It ensures that the solar arrays on the deployed panels remain roughly pointed towards the Sun.
- The **magnetic mode** (experimental): uses only the magnetic field to point the desired payload toward a desired target.
- The **inertial mode** controls the spacecraft attitude with respect to the inertial frame.
- The **Sun mode** controls the spacecraft attitude with respect to the Sun frame with a stability of 1 arcsec/60s. As part of this mode, four large manoeuvres are performed to maximise the Earth Exclusion Angle (EEA) of the star sensor while still pointing to the Sun. This mode is the main observation mode of the mission.
- The **Orbital mode** controls the spacecraft attitude with respect to the orbital frame (for nadir pointing).
- The **Flight mode** controls the spacecraft attitude with respect to the orbital velocity, to execute propulsion manoeuvres.
- The **Earth target mode** controls the spacecraft attitude so that it points to a target on Earth.

2.1.3. Avionics

The avionics is composed by: (i) a high-performance redundant central computer (ADPMS, which provides part of the power subsystem as well, see below) responsible for spacecraft telemetry and part of the science data, all spacecraft computing tasks, some science data processing tasks and interfaces to every unit of the spacecraft; (ii) a mass memory unit, incorporated within ADPMS, responsible to store all the SWAP instrument science data; (iii) a redundant set of S-Band receivers and transmitters.

2.1.3.1. ADPMS data handling system

The PROBA 2 data handling, storage and processing system (ADPMS, Advanced Data and Power Management System) is highly centralised in a single, redundant, high-performance computing unit, based on the radiation hard LEON2-FT processor. It was developed by Verhaert Space under a separate ESA contract. See [1] for detailed information on the ADPMS development. This unit provides sufficient computing power to perform not only the traditional attitude control and data handling tasks, but also spacecraft autonomy as well as instrument data processing (image analysis and compression).

In order to achieve considerable reduction in power consumption, mass and volume, while maintaining or improving computing performance, modularity and testability, the data handling system design has introduced some drastic changes in the design:

- Replacement of various high consuming peripheral SRAM FIFO devices by the extensive usage of Direct Memory Access.
- Removing some hardware components and moving their functionality into software (e.g. part of the telecommand decoder).
- Selection of a backbone bus that combines high throughput with minimum consumption.
- Usage of low power, low voltage components.
- Extensive utilisation of surface mount technology.
- Replacement of various small FPGA's by one large FPGA on each board.

Furthermore, the unit implements a series of well-proven and fully documented existing industrial specifications for its mechanical (Compact PCI boards with small 3U format), electrical (AMBA AHB bus) and software design, ensuring good compatibility between modules during integration and testing.

ADPMS is specifically configured for the PROBA 2 spacecraft and a separation detection system has been added, which keeps the spacecraft powered off while it is mated with the launch vehicle and powers it up at detection of separation. ADPMS communicates with the other PROBA 2 units by means of serial UART interfaces, digital in- and outputs, analogue inputs, digital pulse, clock and datation lines.

ADPMS furthermore provides a series of telecommand decoders supporting the COP-1 packet telecommanding and direct (MAP-0) ground commands as well as telemetry generators supporting up to 5 Virtual Channels.

2.1.3.2. Mass memory unit

A redundant module, called the MCPM (Memory, compression and packetisation module), to collect and store image data from the SWAP instrument is integrated in the primary and redundant ADPMS as Compact PCI boards. 4 Gbit of memory is available for useful data (protected against SEU) per board and is accessible to the ADPMS LEON processor, which uses spare processing capacity to analyse and compress the acquired images. The processed images are stored in the MCPM memory until downlinked through the telemetry system via a dedicated virtual channel. The memory is provided by a SDRAM memory array.

2.1.3.3. TT&C

The S-band link capacities are 64 Kbit/s for packet telecommanding and a maximum of 1 Mb/s for the packet telemetry. SPL-PCM directly phase-modulated on the carrier is used for the uplink and BPSK for the downlink. Slightly modified off-the-shelf units have been used for TT&C support. The antenna configuration has been designed to maintain contact during the ground station passes without switching whilst keeping the spacecraft Sun-pointed, both for commanding and telemetry.

2.1.4. Power subsystem

The basic power consumption of the platform is 34 - 48 W (depending on the mode). The excess of power will be allocated to the payloads. In Sun-pointing mode, outside eclipse, the solar arrays can generate a power of more than 110 W (end of life).

The solar arrays are built with 40x80 mm² triple junctions Ga-As cells with integral diode. The cells are mounted on two deployable solar panels, which are used during most nominal mission phases and on one body mounted panel for contingency situations. The 16.5 Ah Li-ion battery will be used mainly in eclipse and during specific technology experiments with peak power higher than the power available from the solar arrays. It is built from SAFT cells and PROBA 2 will act as the first in-orbit qualification for these cells.

The PROBA 2 power conditioning and distribution system is based on the effective utilisation of this Lithium-ion battery. While the battery technology was successfully proven in orbit for LEO by PROBA 1, the PROBA 2 power subsystem optimizes the power conditioning and distribution for this specific type of battery. A much simpler charge- and discharge regulation compared to that needed for Nickel-Cadmium batteries has considerably reduced the required size for the power conditioning system. Furthermore, taking into account that all connected units and payloads can withstand certain variations in the incoming power, the regulated 28V power bus used on PROBA 1 was replaced by a battery regulated bus. Both simplifications have reduced the size and dissipation of the system sufficiently to allow integration of these power functions with the digital functions of the data handling system into a single box. Hence ADPMS (advanced data and power management system).

2.1.5. Onboard software

The PROBA 2 onboard software running on ADPMS can be divided in 3 domains: (i) the mission dependant domain, (ii) the mission independent domain and (iii) the platform domain. It's overall architecture is based on the PROBA 1 and SMART onboard software and for the mission independent domain considerable re-use from both missions has been achieved.

The mission dependant domain functionalities concern the main objectives of the mission (earth observation, solar observation, etc.). They relate to the general spacecraft subsystem management and to the payload management. These are the on-board Applications. Despite the different nature of the management of the instruments (PROBA 1 with its target based Earth observation instruments versus PROBA 2 with its Sun-observing instruments operating almost continuously), the PROBA 2 application managers implement a similar level of onboard autonomy. The main target is to limit the need for ground commanding during nominal and routine mission operations and to ensure effective failure detection, isolation and recovery.

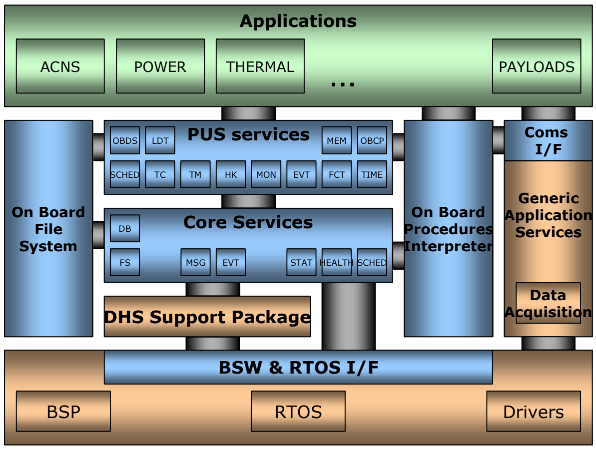


Figure 6 PROBA2 Onboard Software Architecture

The mission independent domain functionalities provide general purpose services such as the on-board data handling. They are generally common for different missions, and we therefore refer to them as the Generic Services. It is in this domain that maximum re-use has been achieved from previous missions, while modifications were aimed at bringing the functionality further in line with ESA's Packet Utilisation Standard. Additional features include support for onboard procedures and safe in-flight software modification support, as such providing more flexibility towards the control of the in-orbit technology demonstrations.

The platform dependent domain functionalities provide low level services such as the operating system and hardware access (kernel software). This domain has been re-developed for the ADPMS hardware, utilizing to a maximum extent the functionality provided by the hardware.

The onboard software incorporates as well the LYRA and SWAP instrument data managers which process and compress the LYRA and SWAP science data, optimizing as such the scientific mission return.

Validation of the complete onboard software is supported by a Software Validation Facility (SVF), running on a PC platform and specifically developed to simulate the PROBA 2 hardware. This approach was successfully applied for the PROBA 1 onboard software validation.

2.2. PROBA 2 payloads

The following sections provide an overview of the scientific and technology experiments that were selected to fly onboard PROBA 2.

The scientific payloads can be grouped in two groups: one set of complementary Sun observation instruments (LYRA and SWAP) and one set of plasma measurement units (TPMU and DSLP).

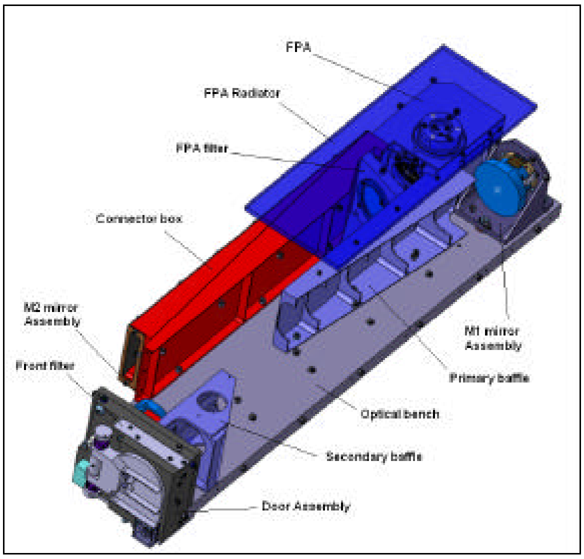
2.2.1 Scientific payloads

2.2.1.1 Sun Watcher using APS detectors and image Processing (SWAP)

SWAP is an extreme ultraviolet (EUV) telescope that will provide images of the solar corona at a temperature of roughly 1 million degrees. The instrument is entirely developed and tested in Belgium under the supervision of the Centre Spatial de Liège for the Royal Observatory of Belgium. SWAP builds upon the heritage of the Extreme ultraviolet Imaging Telescope (EIT) onboard SOHO. It will continue the systematic coronal mass ejection watch program with an improved image sampling rate (1 image every minute instead of every 15 minutes). The spatial resolution of SWAP is complementary to the high temporal resolution of LYRA (see below).

SWAP will demonstrate various improvements over the old EIT design. It is an *off-axis* Ritchey-Chretien telescope which allows for simpler baffling and a smaller aperture. Instead of using classical CCD technology, the SWAP images are focused on a new CMOS-APS detector, covered with an EUV sensitive scintillation layer.

Onboard processing of the SWAP images will be demonstrated, increasing the science data return through the limited bandwidth downlink by near loss-less image compression and prioritising the images based on their contents. It also supports automated detection of space weather events such as flares, EIT waves, prominence and filament eruptions. The SWAP instrument will make use of the PROBA 2 platform agility (the automatic paving manoeuvres) to effectively increase its field of view when needed (up to 3 times the sun radius) allowing autonomous flare tracking up to 3 times the sun radius.



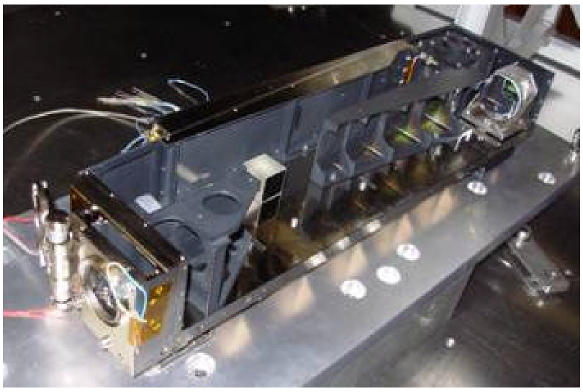


Figure 7 Open view of the main components of SWAP and SWAP Flight Model (image courtesy AMOS S.A.)

2.2.1.2 Lyman Alpha Radiometer (LYRA)

LYRA is a solar UV radiometer manufactured by a Belgian-Swiss-German consortium including the Royal Observatory of Belgium, the Centre Spatiale de Liege, and the World Radiation Centre in Davos. It will monitor the solar radiantion in four UV bands. The channels have been chosen for their relevance to Solar Physics, Aeronomy, and Space Weather: 115-125 nm (Lyman-alpha); the 200-220 nm Herzberg continuum range; 17-31 nm Aluminium filter channel including Helium II at 30.4 nm; and 1-20 nm Zirconium filter channel. The radiometric calibration will be traceable to synchrotron source standards and the stability will be monitored by on-board calibration sources (VIS & NUV LEDs), which allow distinguishing between possible degradations of the detectors and filters. LYRA will benefit from wide bandgap detectors based on diamond. Diamond sensors make the instrument radiation-hard. LYRA demonstrates technologies important for future missions such as the ESA Solar Orbiter. The instrument has an acquisition cadence up to 100Hz.

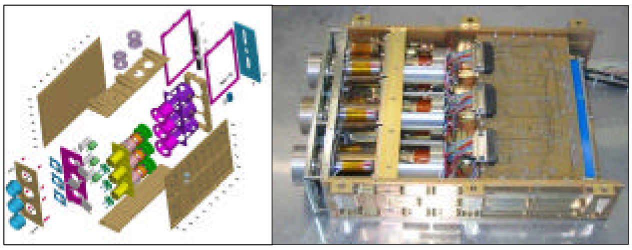


Figure 8 LYRA instrument

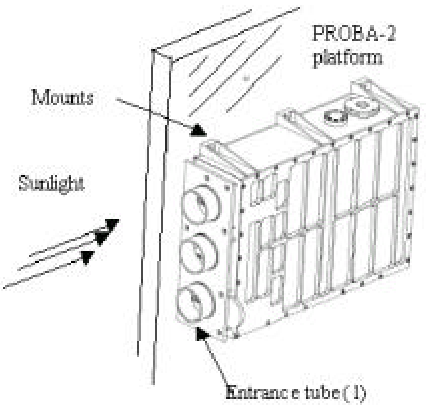


Figure 9 Schematic view of LYRA

2.2.1.3 Thermal Plasma Measurement Unit (TPMU)

The Thermal Plasma Measurement Unit comprises a Sensor Block, which consist of probes and preamplifiers, and a Processing Block. TPMU contains 3 experiments which measure the total ion density and electron temperature, the ion composition and ion temperature, and the floating potential of the satellite body.

The electron temperature part uses three simple circular planar probes with guard rings. A constant voltage shift is maintained by applying the proper amplitude of RF signal. The probe potential is periodically scanned and adjusted for minimum electron temperature.

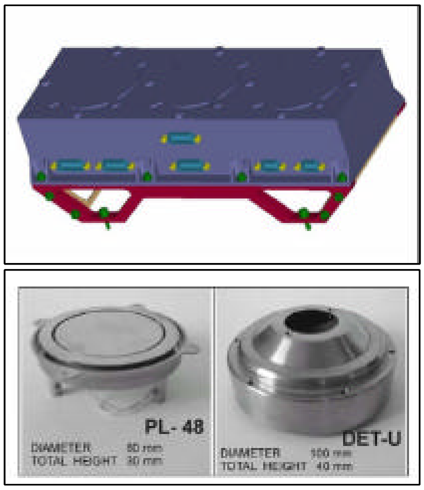


Figure 10 TPMU assembly and sensors

The ion part uses a two-grid planar trap. The ion measurement can work in two modes. The first one is the measurement of the ion flux at plasma potential. The second one is the measurement of volt-ampere retarding characteristics. This uses an analyzing voltage sweep which can be selected in the range 0 to 20 V. Individual measurements are time-stamped and can be related to the spacecraft onboard time and thus orbital position.

The TPMU sensors field of view is aligned with the flight direction of the spacecraft as far as it is allowed by the sun-pointing attitude of the spacecraft. The instrument is provided by a Czech consortium.

TPMU shares some interface, power and processing resources with DSLP.

2.2.1.4 Dual Segmented Langmuir PROBE (DSLP)

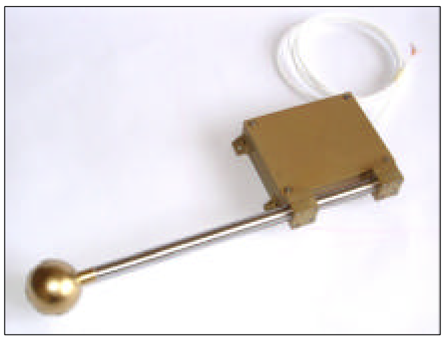


Figure 11 DSLP sensor assembly

The Dual Segmented Langmuir Probe instrument will study the magnetospheric background plasma. The instrument is of ISL (Instrument Sonde de Langmuir) heritage flown on the DEMETER mission of CNES. The objective is to use DSLP for measurements of the density of space plasma and its variations in the range 100 to 5 x 10^6 particles/cm^3, the electron temperature in the 500-3000 K range, and the satellite potential in the range of ± 5 V. The instrument consists of two Langmuir probes. The plasma density and temperature are determined from the Langmuir probe current-voltage curve. The instrument is being developed by the Institute of Atmospheric Physics, Academy of Sciences of the Czech Republic, Prague, Czech Republic.

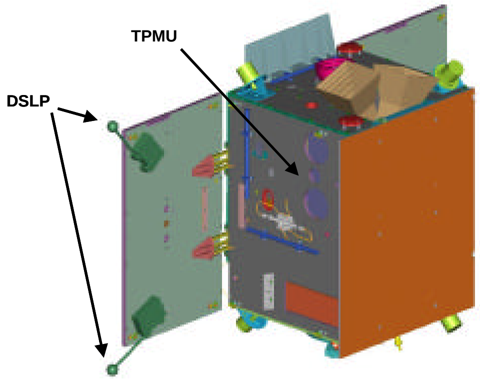


Figure 12 DSLP and TPMU accommodation

2.2.2 Technology demonstration payloads

PROBA 2 will demonstrate in orbit a large number of new technologies. These can be split in two groups: platform technologies which are an integral part of the spacecraft platform (subsection 12 below) and passenger technologies which are for demonstration only and are not mission critical. The passenger technologies fly to gain flight heritage and experience before committing them to the infrastructure of other missions

2.2.2.1 Digital Sun Sensor

The digital Sun sensor to be demonstrated on PROBA 2 belongs to a new generation of miniaturized attitude sensors applying new technology, such as active pixel sensors (APS). It utilizes a sensor which was developed for ESA-ESTEC in the frame of the ARTES-5 (ASTE) program for telecommunication equipment technology development at ESA. If the demonstration is successful, the sensor can be incorporated in the attitude control loop of PROBA 2. It is developed by TNO (NL).

2.2.2.2 Bepi Colombo star tracker

In the frame of the Bepi Colombo mission to Mercury and the Solar Orbitar mission, a demonstration model of the miniaturized Star Tracker has been developed. PROBA 2 will demonstrate and characterize this model in orbit as support to these and other future missions. The star tracker exploits recent technology advances in micro-mechanical devices, active pixel arrays and folded optics. It is developed by Galileo Avionica (IT).

2.2.2.3 X-CAM

Exploration Camera X-CAM is a powerful miniaturized micro-camera equipped with panoramic optics. X-CAM is developed by Space-X (CH).

2.2.2.4 FibRe Sensor Demonstrator (FSD)

The FSD will demonstrate the use of fibre sensors for the measurement of temperature and pressure. It contains 6 sensors to measure the temperature at different locations in the propulsion system and in the spacecraft as well as the xenon tank pressure. The FSD is developed by MPB Communications Inc. (CND).

2.2.2.5 ESP

ESP is a solar panel concentrator experiment. The experiment aims at studying the temperature behaviour as well as the aging effects as a result of radiation and of the concentrated solar flux on the photo-voltaic cells. The experiment uses triple junction GaAs solar cells. The ESP is developed by CSL (B).

2.2.2.6 Science Grade Vector field Magnetometer (SGVM)

The SGVM is an advanced flux-gate magnetometer which delivers in real time the components of the magnetic field with a very high precision calibrated to physical quantities in terms of nano Tesla. The instrument is mainly intended for scientific use, but can be used as well by spacecraft attitude control systems. The SGVM is developed by DTU (DK).

2.2.2.7 GPS

PROBA 2 will demonstrate for the first time a dual frequency GPS space receiver (L1 and L2C reception) in orbit. This GPS receiver will be operated on PROBA 2 completely independently from the low-power GPS receiver which is used for the nominal control of the spacecraft. The GPS receiver is developed by Alcatel (FR).

2.2.2.8 Xenon propulsion system with resistojet

The resistojet experiment onboard PROBA 2 will characterize the performance of an already flight proven resistojet, but now using xenon as the propellant. The utilization of xenon has some advantages such as technological interest (for eventual use in combination with other types of electrical propulsion); no liquefaction under the PROBA 2 conditions as such avoiding any disturbances due to sloshing; and low risk for contamination of the sensitive UV payloads. Although propulsion is not needed to support the scientific part of the PROBA 2 mission, it can be used to compensate the orbital decay throughout the mission life. The system is developed by SSTL (UK).

2.2.2.9 COGEX

The Cool Gas Generator Experiment COGEX will re-pressurize the propulsion tank with nitrogen generated from solid state cartridges. Four cartridges are accommodated to demonstrate in-orbit operation and characterize the effect of the mission duration on its functioning and performance. COGEX is developed by Bradford Engineering and TNO (NL)

2.2.2.10 CCM

The Credit Card Magnetometer (CCM) is a device that measures the magnetic field along three orthogonal axes. This technology demonstrator is developed by Lusospace, Portugal

2.2.2.11 LRR

The Laser Retro Reflector (LRR) is a passive optical device, which reflects laser pulses from ground back to the ground station for determination of the satellite orbit. LRR is developed by Astrium Germany.

2.2.2.12 Platform technology demonstrations

The technology demonstrations that are part of the platform have been included in the description of the PROBA 2 platform above. These demonstrations include:

- Li-Ion battery from SAFT
- µ Star Tracker from DTU
- ADPMS avionics from Verhaert
- First use of the ‘medium-rate’ uplink standard for faster commanding
- A major part of one of the telecommand decoders being implemented in software (all-hardware decoders are implemented in parallel for critical CPDU commands)
- Combined CFRP – Al structure from APCO
- Reaction wheels from Dynacon
- GPS from DLR.

3 References

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4 Acknowledgments

The authors would like to thank Mr Parisis (Spacebel, Belgium), Mr J. Delafontaine (NGC Aerospace, Canada), Mr Berghmans and Mr Hochedez (Royal Observatory of Belgium) for their contributions to this paper.