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A NEW EUROPEAN SMALL PLATFORM: PROTEUS, AND PROSPECTED OPTICAL APPLICATION MISSIONS

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RESUME - Les avancées technologiques des dernières années et les nouvelles méthodes industrielles rendent possible l'étude de missions optiques évoluées sur la base de petits satellites, comme la plate-forme multi-mission PROTEUS. Plusieurs missions utilisant des instruments optiques, placés sur cette plate-forme, ont été étudiées soit par AEROSPATIALE / ESPACE & DEFENSE, soit par le CNES (Centre National d'Etudes Spatiales).

Cet article présente

- a) l'approche retenue pour la plate-forme PROTEUS, développée en partenariat par AEROSPATIALE et le CNES pour améliorer l'accessibilité à l'espace dans la gamme des petits satellites (500 kg),
- b) la description de la plate-forme générique et de ses principales performances (pointage, masse embarquable, puissance disponible, stockage de données, etc...), et les interfaces avec la charge utile (mécanique, thermique, électrique, contrôle/commande),
- c) des exemples de missions optiques pour l'astronomie, l'exploration interplanétaire et l'observation de la terre.

ABSTRACT - *Progress in technology in recent years and new industrial approaches now make it possible to design valuable optical missions using a small-class satellite, like the PROTEUS multi mission platform. Some future space optical missions using existing or planned instruments, combined with the PROTEUS platform, have been assessed by AEROSPATIALE / ESPACE & DEFENSE and/or the CNES (French National Space Agency).*

This paper presents:

- a) the approach for the smallsat platform PROTEUS, developed in partnership by AEROSPATIALE & CNES in order to increase space accessibility, with a new class of small satellites (500 kg),*
- b) the generic platform description and main performances (pointing, allocated mass, power, data storage, etc..), and payload interfaces (mechanical, thermal, electrical, command & control),*
- c) examples of optical missions for the astronomy, for the interplanetary exploration, and for the Earth observation.*

1. INTRODUCTION

This article presents a new European small platform: PROTEUS, currently developed by the CNES and AEROSPATIALE, and some prospected applications using optical instrumentation. CNES initiated the PROTEUS design study in order to define a new Low Earth Orbit Satellite class (500 kg) with the aim of improving space **accessibility**. Three major targets were then assigned to the PROTEUS platform. A **very wide field of missions** (orbits, attitude, instruments and launch vehicle compatibility) will be implemented on the PROTEUS platform at a **very attractive cost**, and within a delivery time of **24 months**.

Technically, the platform architecture is generic: adaptations to each mission consist in relatively minor changes in a few electrical interfaces and software modules. Generic mechanical and thermal validation is achieved through mock up manufacturing, testing and mathematical model correlations. Platform electrical and software validation is achieved through the implementation of a ESSVB (Electrical and Software System Validation Bench) on which each mission application software and electrical adaptation can be validated.

In addition, PROTEUS is developed as a product line, with all the engineering tools necessary to allow a quick adaptation to any new mission compatible with the generic user's domain of application.

Concerning organizational aspects of the program, we have devised methods of improvement by merging different program phases and reducing different Work Breakdown Structure layers.

- Engineering, Ground Validation & Testing, In orbit Satellite Operations
- Customer, Prime, Equipment manufacturers (no subsystem layer).

Regarding Quality, applicable requirements are tuned according to industrial experience in specific space applications and as a function of the technical risks involved.

AEROSPATIALE's industrial approach for the PROTEUS program has already been described in paper [Bert 96], while prospected scientific applications have been presented in paper [Dubo 96].

This one deals more specifically with optical payloads aboard PROTEUS.

2. PROTEUS PLATFORM DESCRIPTION

2.1. General platform description

The platform configuration complies with a wide range of small candidate launchers. Its shape is cubic (nearly 1m side) without central structure, and all the equipment units are accommodated on the four lateral panels and on the lower plate. The interface with the launcher is realized through a specific adapter bolted at the bottom of the structure. The mechanical interface with the payload is provided through the four upper corners of the platform. Figure 1 gives an overview of the general design of the platform.

The platform thermal control is sized to withstand the highest thermal environment loads extracted from the PROTEUS missions domain. The concepts uses passive SSM radiators and an active regulation, heaters being monitored by the central computer.

Electrical power is generated by a symmetrical two wings solar array covered with classical Silicon cells, providing about 800 W when facing the sun. It is distributed through a single non regulated primary electrical bus (21/35 volts) using a recurrent Spot4 NiCd battery.

The on board control & command chain relies on a fully centralized architecture shown on the figure 2. The main function devoted to this chain are the following

- satellite modes management : automatic modes transitions and routines,
- failure detection and recovery : monitoring and switching to the SHM if needed,
- on-board observability : housekeeping telemetry permanently registered,
- satellite commandability : managing of the telecommands sent by the ground either to hardware or software.

The DHU (Data Handling Unit) performs most of the main tasks through the central 3-1750 processor running the satellite software. It supports also the management of the communication links with all the satellite units either via point to point lines or via a MIL-STD-1553 bus. It generates a clock reference, manages data storage and insures telemetry frame decoding. Finally, it distributes power towards platform and payload equipment.

There are five distinct AOCS modes : Star Acquisition (STAM), Normal Operations Mode (NOM), Orbit Correction Mode with 2 or 4 thrusters (OCM2, OCM4), and Safe Hold Mode (SHM). In NOM, a zero-momentum three-axis control with four reaction wheels and a gyro-stellar attitude determination provide a typical pointing performance better than 0.1 degree (3 sigma). In SHM where satellite is sun pointing, coarse sensors and magnetometers provide attitude measurement and magneto torquers generate torques. In addition, 2 among the 4 reactions wheels are used to provide gyroscopic stiffness.

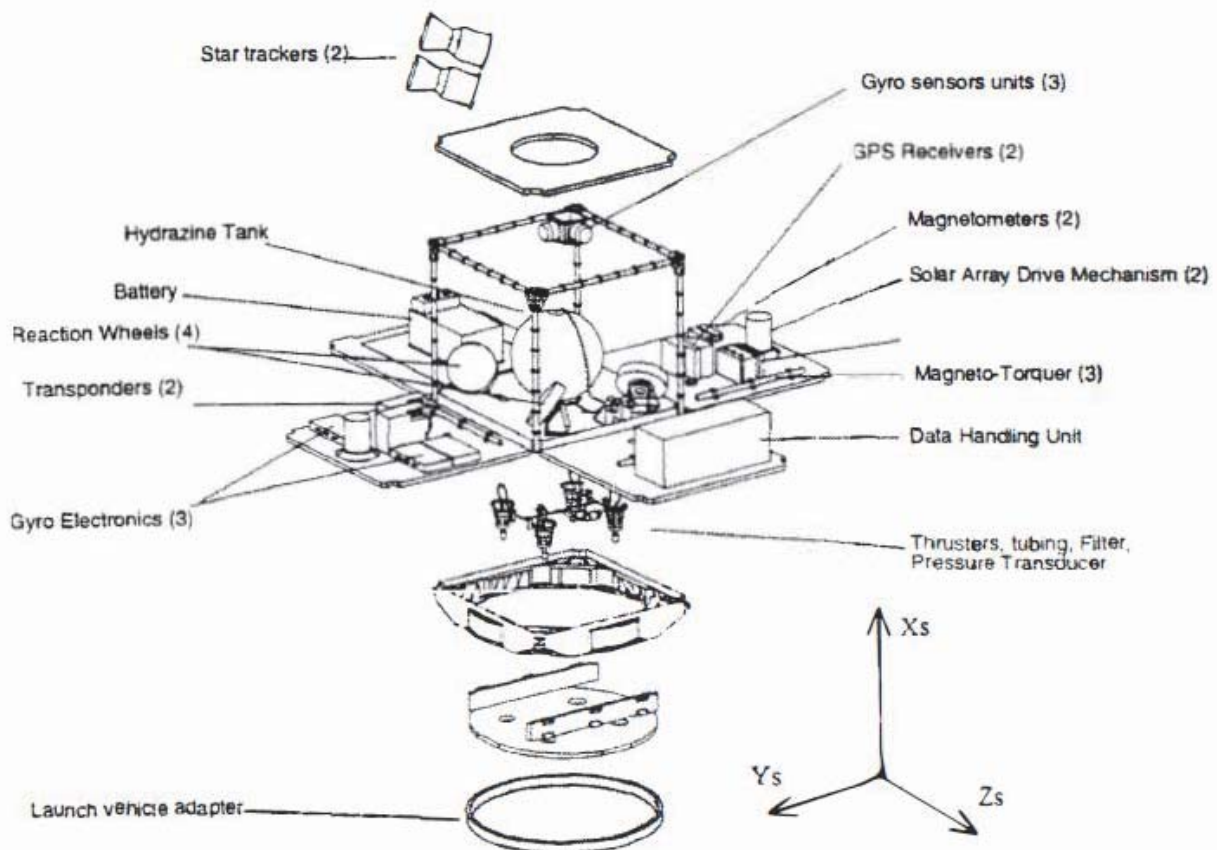


Fig.1: Internal view of the PROTEUS PLATFORM

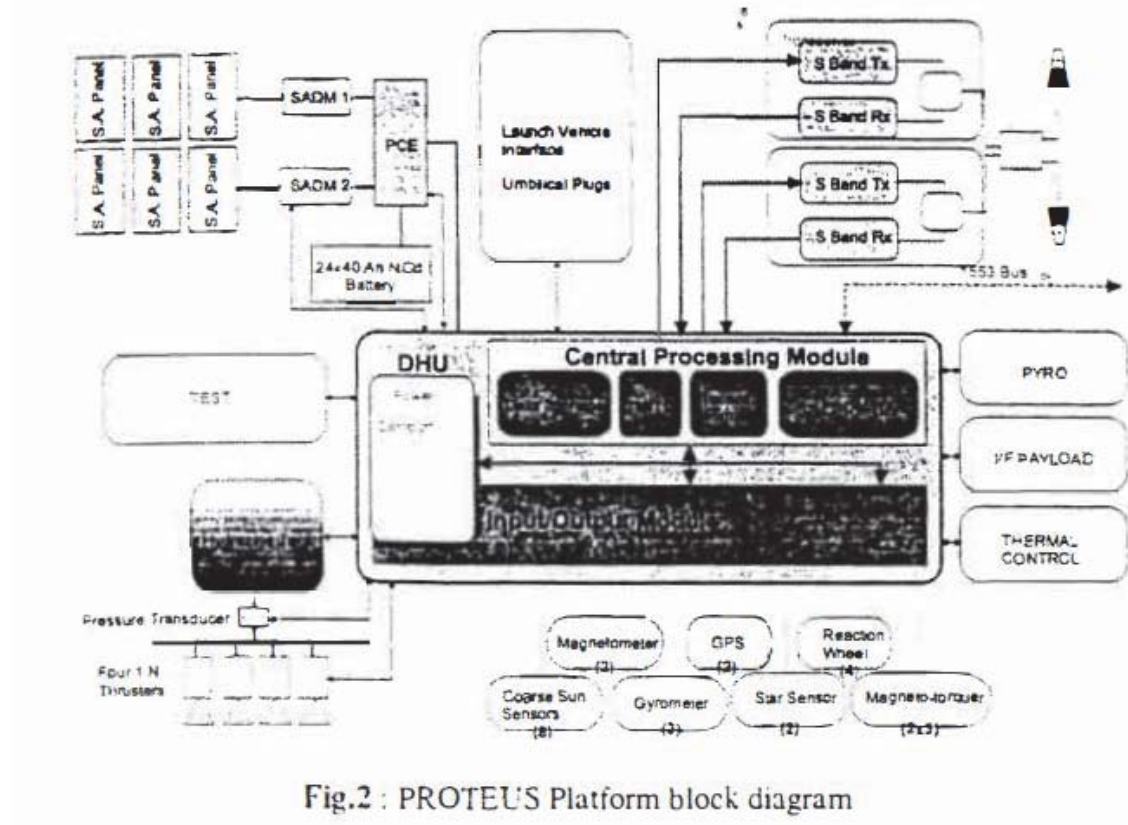


Fig.2 : PROTEUS Platform block diagram

2.2. PROTEUS Platform Main Performances.

- The following table summarizes the PROTEUS platform's main characteristics:

30 kg Hydrazine Capacity
Up to 5 Years Lifetime
Platform Dry Mass : 245 kg
Platform Average Power Consumption : 170 W
Platform Size (W/O solar Array) :
954 x 954 x 1004 mm³
QPSK 650 kbps S Band Down Link

The multi-mission performances of PROTEUS are expressed hereafter:

- The platform provides a wide range of payload pointing capabilities, the accuracy of which is mission dependent
 - Earth and Anti-Earth pointing.
 - Inertial pointing.

Pointing Accuracy

	Roll	Pitch	Yaw
Earth	0.035°	0.04°	0.035°
Inertial	0.02°	0.027°	0.02°

- The PROTEUS Platform is designed to be compatible with various orbits, with altitudes ranging from 500 to 1500 km, for any orbital plane inclination

- The platform is designed to be compatible with several existing or currently developed launchers such as :TAURUS, Delta 2, LMLV 1&2, COSMOS, ROCKOT, PSLV, SOYOUZ and ARIANE 5. The stowed platform is then compatible with Small Launch Vehicle fairing diameters of 2 m.

2.3. Payload accommodation and interfaces

2.3.1. Typical payload accommodation for different types of pointing

The PROTEUS platform can accommodate a large variety of optical payloads. Considering the line of sight of each instrument, there are some preferred configurations.

- Earth pointing : in the case of an Earth pointing instrument, the satellite should generally be oriented with the yaw axis Zs toward the Earth. Two major sub-cases are encountered
 - free pointing around Zs : if the mission imposes no constraint around yaw, the yaw rotation will be optimized with respect to thermal and power criteria. Thus, the satellite will follow a yaw steering movement to point solar array toward the sun. This payload accommodation is convenient for every orbit in the mission envelope.
 - three-axis pointing : if the yaw axis is imposed by the mission, the satellite will fly with its Xs axis near to the orbital speed. This is compatible with sun-synchronous orbits and low inclination orbits.
- Inertial pointing : in the case of an inertial or nearly inertial pointed mission, the instrument will have its field of view boresight toward +Xs satellite axis. In case of a free pointing around boresight, the attitude of the satellite around Xs axis can be chosen taking into account thermal constraints.

These typical payload accommodations must be adapted on a case by case analysis, considering all mission constraints.

2.3.2. Payload interface data

- Payload Mass: The payload mass is typically in the 100-300 kg range. The payload maximum mass is set at 300 kg taking into account the whole Proteus domain, including the envelope environment of above-listed launchers, and must be discussed on a case by case basis. In particular, AEROSPATIALE-led studies have shown that in case of a SOYUZ launch, payload masses up to 500 kg would be compatible with the PROTEUS platform current mechanical design.
- Power available to payload: The typical power available to the payload is up to 250 W on the Proteus flight domain. On specific orbits, like the dawn-dusk Sun-synchronous orbits, the available power is increased. For pulsed payloads, the available power is raised to about 800 W for 20 minutes. Dedicated payload lines are available for pyro (8 nominal + 8 redundant) and thermal needs (7 lines).
- Payload interface plate: The standard payload mechanical interface consist in 4 mechanical links at the 4 upper corners of the platform (860 mm distance between corner fittings).

- Payload data management: A MIL-STD-1553 bus line is available for standard payload command-control and data retrieval. Numerous acquisition (48 analog and 12 serial lines, 8 logical status, 24 relay status, 48 temperature acquisitions) and command (48 relay commands, 8 serial commands, 16 open collector-types) lines are provided for the payload. Data Handling Unit software, memory and computing power resources are allocated for the payload. A standard 2 Gbits End of Life payload data storage capacity is provided. The downlink rate is 650 kbit/s using the S-band telecommunication system. For mission requiring more data storage and downlink rate, typically Earth observation ones, a specific Mass Memory Unit and a high rate X-band system (up to 100 Mbits/s) will be implemented in the payload module.

2.4. PROTEUS project status

In July 96, the CNES decided to initiate the first satellite development with the Jason project. An AEROSPATIALE project team was immediately organized in Toulouse, in the framework of the CNES/AEROSPATIALE partnership. The Preliminary Design Review has been held successfully in April 1997. Phase C & D activities are on-going in order to launch Jason, the first Proteus satellite in the end of 1999.

3. EXAMPLES OF OPTICAL MISSIONS FOR THE ASTRONOMY

3.1. COROT

3.1.1. Mission and Orbit

COROT (CONvection and ROTation) [Cata 96] will be the second scientific mission on PROTEUS after Jason, and is a very high accuracy stellar photometry experiment. Its first objective is to study the interior of stars, by means of astro-seismology. COROT will measure luminance variations over a very long period of time (150 days for each mean star without any Earth occultation). This will enable stellar oscillations to be measured with a frequency resolution better than $0.1 \mu\text{Hz}$.

As a second objective, COROT will be able to detect the presence of exoplanets if they transit in front of any star in the observed field of view.

The mission involves two observation programs : an exploratory program only with seismology measurements, and a central program comprising both types of measurements.

The exploratory program will take the place of the EVRIS mission on MARS 96. It will yield a 20-day observation of a great number of stars (30 to 40), allowing a fine seismological characterization through the Hertzsprung & Russel diagram. At least one giant planet (Jupiter or Saturn) will also be observed.

The central seismology program will be focused on hydrodynamic processes inside some well known stars. The resolution required for the detection of a photometric signal is 2.5 for a star magnitude up to 5.

The search of exoplanets could lead to the discovery of about a hundred telluric planets slightly bigger and warmer than the Earth. To achieve such a result, the instrument will be able to measure a 10^{-4} loss of signal.

COROT's orbit will be polar, inertial, with an altitude around 900 km. The satellite attitude will also be inertial, the line of sight being assigned to keep the same direction for each 6-month observation period. The whole mission (at least 5 observation periods) will thus last 2.5 years.

3.1.2. Payload

The payload includes

- a telescope,
- a CCD block, $1.5^\circ \times 1.5^\circ$ f.o.v.,
- a 2-axis pointing drive,
- electronic modules.

Several possibilities are under study for the telescope, the basic ones being:

- a TMA (three-mirror anastigmat) with a virtual entrance pupil,
- a telescope with a mix of mirrors and lenses and a real entrance pupil.

A block of 4 CCD will be used, two of them being used for asteroseismology (for 1 to 10 stars with a magnitude between 5 and 9), and the other two for the detection of exoplanets (for every stars with a 10 to 15 magnitude in the field of view).

One of the main challenges of this payload is the Earth light attenuation : a goal of $5 \cdot 10^{-14}$ is allocated, in order to achieve a detection of $3 \cdot 10^{-4}$ variation on the signal. Thus, a baffle (1.80 to 2.5 meter long, depending on the telescope design) will be necessary.

3.1.3. COROT Satellite description

On the PROTEUS platform, the COROT instrument is vertically assembled, its line of sight being the X-axis. On orbit, this configuration will allow very long periods (up to 6 months) without occultation by the Earth, as also the largest external surface for detector passive cooling.

Accommodation of the payload onto the PROTEUS platform uses generic interfaces, without any modification.

To improve pointing accuracy, the stellar sensor must be located on the telescope structure, and turned toward the same direction as the instrument. A specific fine pointing mode is being studied, using the instrument as a sensor, and both PROTEUS wheels and the instrument internal pointing drive as actuators.

The total mass of the satellite is 335 kg, with a 250 W mean power consumption.

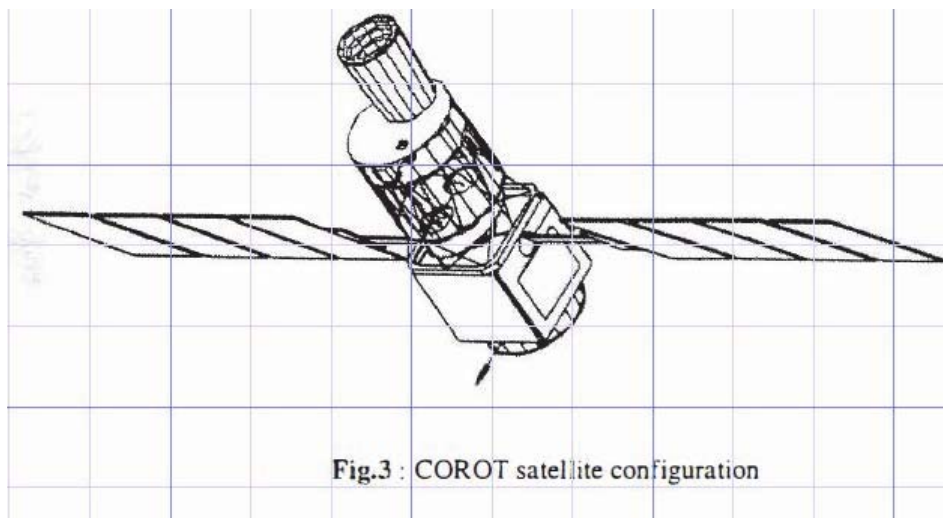


Fig.3 : COROT satellite configuration

3.2. UVEX (Aerospatiale proposal)

3.2.1. UVEX (Ultra Violet Explorer) Mission Description

The objectives of the proposed mission are to perform UV astronomy using two instruments accommodated on a PROTEUS platform. The cost of the mission would be minimized using a PROTEUS platform and already existing instrument concepts:

- the TAUVEUX ([Bros 92],[Blas 93]) instrument developed by the University of Tel-Aviv (Israel)
- the UBRIS [Mill 96]: instrument proposed by the Laboratoire d'Astronomie Spatiale (France).

The science objectives are to perform a partial sky survey using TAUVEUX and UBRIS.

TAUVEUX : The purpose is to perform a partial sky survey in three UV spectral bands (centered at 155, 200, 250 nm, bandwidth 30 nm each) and specific observations in two other spectral bands. TAUVEUX will cover in one exposure a field of view of 54 arcmin, with an angular resolution of 10 arc seconds, each field being observed once. The limiting monochromatic magnitude is 18.5 with a signal to noise (S/N) of 5 in the "intermediate band filters". Taking into account the 0,63 square degrees FOV of the instrument, and assuming an observing policy of one field per orbit, a partial sky survey, focused on the Galactic polar caps to a galactic latitude of 60°, leads to a mission duration requirement of 3,7 years. The science yield at the completion of the survey mission will be a catalogue of about 80,000 QSOs, 60,000 galaxies, and 1000,000 stars for which TAUVEUX will measure the UV properties.

UBRIS: The purpose is a spectroscopic survey of diffuse sources in the spectral range 90-185 nm, with a 0,15 nm resolution. This diffuse background spectroscopy survey will trace the physical condition in the galactic interstellar medium and probe the origin of the extragalactic ultraviolet background with a sensitivity far exceeding any other existing or planned mission. This survey is essential for probing the global dynamics of the transitional ISM and for measuring the extra galactic background.

Proposed mission profile: This is based on the observation of one polar cap (the northern cap) during half a year (Summer, Spring), the other cap (the southern cap) for the other six months (Winter, Autumn), in order to avoid Earth occultation.

Pointing: The mission requires inertial pointing during each observation, with the following accuracies, for TAUVEUX: 5 arc min. (maximum limit cycle: 2 to 3' arc); for UBRIS: 0,3 arc min. (+/- 20 arc sec.). The current platform performances (about 1 to 1,5 arc min) are sufficient for the TAUVEUX mission, but are slightly below those required by UBRIS. The pointing accuracy could be increased by using the TAUVEUX data (difference between the detected centroid of the tracking star and its expected location) as input to the PROTEUS attitude control system.

Orbit: A 650 km altitude, near equatorial orbit is proposed, taking into account the mission objectives, the launcher performances (Shavit 2 launched from Kourou taken as baseline), and the ground segment aspects.

3.2.2. Payload Description

TAUVEUX : The instrument consists in 3 co-aligned telescopes of 20 cm diameter, imaging the same area with photon counting detectors.

The overall payload comprises:

- an optical module: 3 telescopes with their baffling system, a wheel filter on each telescope to separate the spectral bands, and associated electronic circuits for detector operations,
- an electronic module: common elements for data acquisition and storage (2 hard disks of 84 Mbytes in a pressurized container), power supply and thermal stabilization.

UBRIS :The instrument consists of two telescopes, working respectively in 90-120 nm (FUV) and 125-185 nm (VUV) bands.

The telescopes employ:

- a 13-15 cm diameter, 38 cm aperture off-axis primary,
- a spherical, holographically ruled grating in a Rowland mount.

3.2.3. UVEX Satellite configuration

The satellite mechanical and thermal architecture takes into account:

- the PROTEUS platform design,
- the instruments' mechanical interfaces,
- the instruments' mounting constraints (UBRIS must be preferably installed along the launcher longitudinal axis to withstand the launch environment),
- the thermal constraints (implementation of instruments electronics and associated radiators on satellite "cold faces")
- the compatibility with 1.6 m diameter launcher fairings (Shavit 2 class).

The resulting satellite configuration is illustrated below:

- Deployed configuration, showing the platform and the payload module with the instruments' cover deployed (the covers could possibly be dispensed with). The propulsion system, four nozzles located inside the spacecraft cylindrical sleeve at the opposite of the payload, is well away from the payload optics. Two semi-hemispherical coverage antennae on each side of the platform allow telecommunications links to be established independently of the S/C attitude relative to Earth.
- Stowed configuration (solar panels and telecommunications antennas folded, instrument covers closed). This "compact" satellite configuration, designed to be compatible with a 1.6 m diameter fairing has two non-standard platform features: vertical solar panel storage and deployable antennae. On the rear side of the platform, the stellar sensor used for attitude control, and the propulsion system valves can be seen.

The total mass of the satellite is 382 kg, with a 354 W mean power consumption.

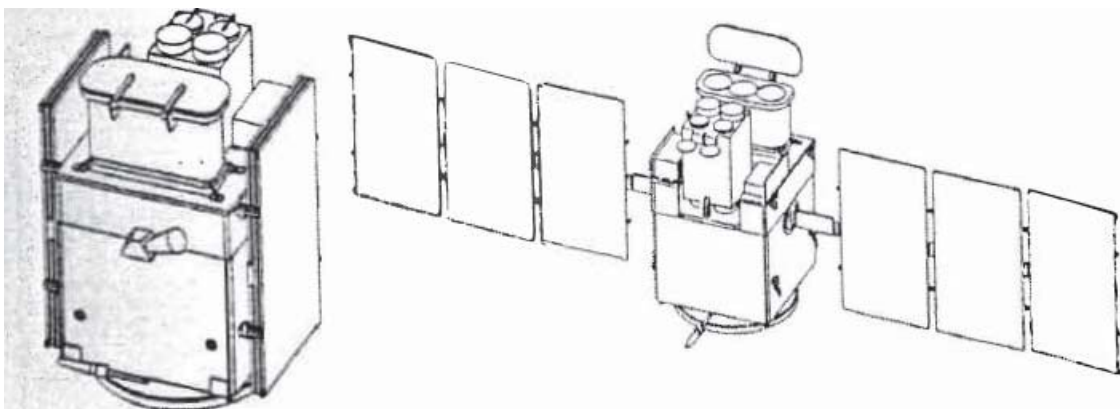


Fig.4 : UVEX Satellite configuration

4. EXAMPLE OF INTERPLANETARY OPTICAL MISSION: Mars 2001

4.1. Mars 2001 Mission Description

In the context of the Mars 2001 mission, analyses have been made of the potential of the PROTEUS platform for a mission to Mars [Darg 97].

This was performed in order to provide the scientific community with a reconfigurable vehicle for interplanetary missions, a quick access to space for science (<3 years), a modular concept, and a low cost satellite with the use of a generic platform derived from the Proteus CNES/AEROSPATIALE program.

The mission case was a Mars 96 recovery mission, using 5 spare instruments of the Mars 96 spacecraft, with a launch target in Mars 2001.

The main other features of this tentative recovery mission were the following ones:

- launcher class compatible with a 1000 kg spacecraft
- direct injection in cruise orbit to Mars,
- a 198 days cruise to Mars,
- insertion into an elliptical Mars Sun-synchronous orbit by the S/C propulsion system,
- 2 years of exploitation in Mars orbit.

The activities around Mars are shared into 2 phases:

- observation phase: the S/C points to the planet for observation by the instruments (1 hour per orbit)
- communication phase: the S/C is oriented such as it can transmit data to the Earth, and the solar arrays are Sun pointed (4 hours per orbit).

4.2. Mars 2001 Payload Description

The following optical instruments have been selected for the payload:

- HRSC: High Resolution Spectroscopic Camera,
- WAOSS: Wide Angle Optoelectronic Stereo Scanner,
- OMEGA: Visible and Infra-red Mapping Spectrometer,
- PFS: Planetary Fourier Spectrometer,
- SPICAM-E: Multichannel Spectrometer.

Instrument	Unit	Unobstructed F.O.V. (deg)	Scientific F.O.V. (arcmin)	F.O.V. w.r.t. Nadir (deg)	Pointing type	Pointing stability (arcmin/s)
HRSC	Camera head	> 38° x 12°	> 38° x 12°	Nadir	Nadir	0,067 arcmin (short term)
OMEGA	OM-Camera	8,8	4	0 to 30	Nadir or 3 axis	< 1
SPICAM	SPICAM-E	10 x 10	1x1 3x4	Horizon to Nadir	3 axis	NA if star in FOV
PFS	MO	2 (SW) 4 (LW)	TBD	all	TBD	< 10
WAOSS	Camera	TBD	TBD	Nadir	Nadir	TBD

The total payload mass is 120 kg, the maximum payload power is 150 W.

4.3. Mars 2001 Satellite configuration

The spacecraft is constituted by the stacking of three modules:

- the bi-propellant **propulsion module** ensures the transfer to Mars up to the Sun synchronous orbit injection around the planet,
- the « **Proteus** » **module** drawn from the existing PROTEUS platform, ensures the servicing functions during the cruise and when the satellite is operational around Mars,
- the **payload module** supports the scientific instruments and is crowned by the high gain antenna.

The main difference with other Proteus mission configuration is the adding of the propulsion module comprising a 400 N engine for Mars insertion, 16 x 10 N thrusters for attitude control, 4 propellant tanks (630 kg total capacity), and 1 pressurant tank.

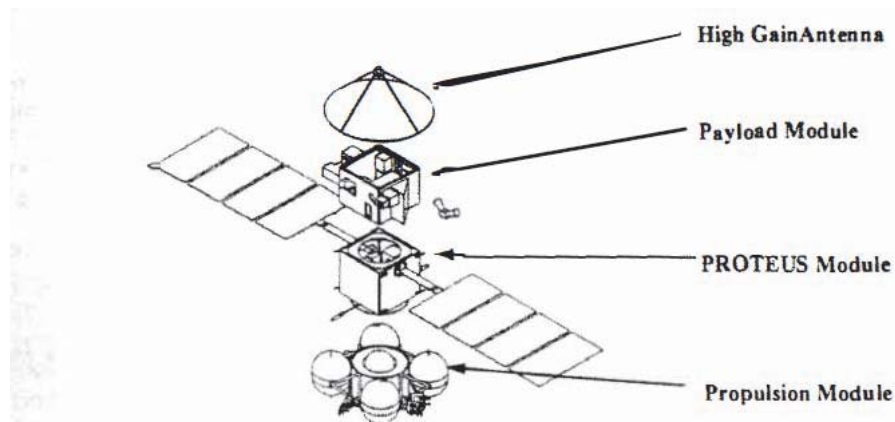


Fig.5 : Mars 2001 Satellite configuration

PROTEUS / MARS 2001	
Platform Mass	238 kg
Payload module Mass	57 kg
Payload Mass	116 kg
Propulsion module Mass	124 kg
& Bipropellant Mass	476 kg
Resulting Launch Mass	1011 kg
Δv Capacity	1920 m/s
Typical Launcher	SOYOUZ-MOLNYA
Apsis altitudes at Mars:	300-10000 km
Electrical Power profile	$275 < P < 375$ W
TM Capacity (worst-case / 2.7 a.u.)	16.9 Kbit/s
Data Storage Capacity (mass memory)	2 Gbit E.O.L.

Mars 2001 mission data

5. EXAMPLES OF OPTICAL MISSION FOR THE EARTH OBSERVATION

5.1. 3S (CNES proposal)

5.1.1. Mission & System

The CNES is currently evaluating the possibility to achieve a follow-on to its SPOT family after SPOT5 (to be launched in 2002), with a significant reduction of costs. One of the studied options for the new system is based on a PROTEUS platform, and is called 3S (for Suite du Système SPOT).

The 3S system is described in another paper of the ICSO'97 [Lac97]. It is composed of 3 high resolution (2,5 to 3 m) satellites, allowing a large coverage and a stereoscopic ability.

In the CNES assessment study, each satellite has a two degree of freedom pointing capacity : $\pm 45^\circ$ along the roll axis, and $\pm 30^\circ$ along the pitch axis. The first one allows a lateral access and is achieved through a pointing turret, which is set between the payload module and the telescope. The second one allows a single satellite stereoscopic capacity along the satellite track, and is achieved through a rotating mirror. As for the SPOT satellites, a third degree of freedom is added along the yaw axis, by the mean of an oscillating rotation of the platform, with a 5° amplitude.

5.1.2. Payload

The 3S payload is composed by an instrument, a data handling and compression unit, a mass memory unit, a high rate telemetry subsystem.

Parts of the instrument are : a TMA telescope, 3 video electronics boxes, the pointing mechanism and its electronic module. The estimated mass of the instrument without mechanism is around 100 kg.

Studies are currently led to adapt an off-the-shelf mechanism for the turret, with a raw specification of a 15 microrad position knowledge. Its speed shall be high enough to ensure a 60° amplitude within a 10 second time, including stabilization.

5.1.3. Satellite

On the PROTEUS platform, the 3S payload units are mounted on a 2-level structure. On the lower plate are stacked : the X-band telemetry subsystem, the mass memory unit and its controller, the stellar sensors of PROTEUS, and the turret mechanism supporting the telescope. The upper plate is hollowed in the middle to allow moving the telescope around the satellite vertical axis. This plate supports the video units and the control electronics of the mechanisms.

Apart from the video data storage and telemetry, which are performed at the payload level, all the PROTEUS facilities are used on the 3S satellite. Depending on thermal requirements for the telescope structure, an additional unit could be added to perform a very fine control of the heat gradients.

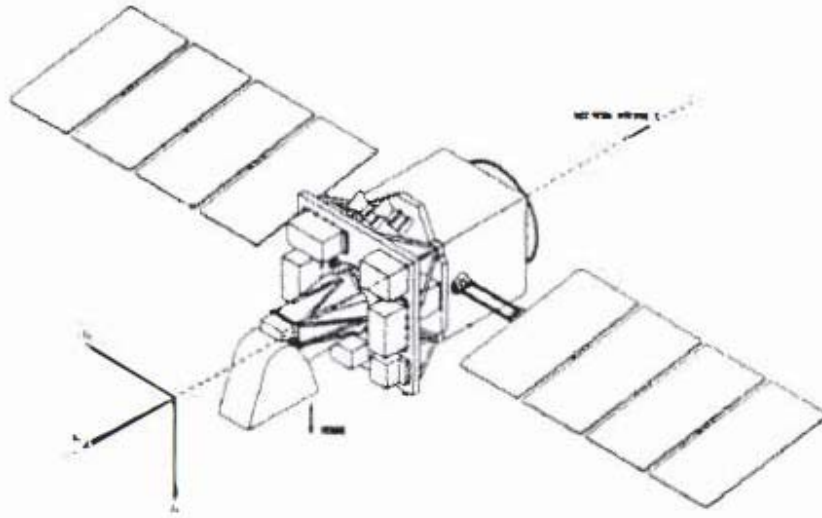


Fig.6 : The 3S Satellite

5.2. TOPS (Aerospatiale proposal)

5.2.1. Mission description

The Thematic Optical Satellite (TOPS) is designed for cartography and remote sensing missions. Depending on the country latitude, TOPS can be launched into either near equatorial (typical 15 to 20 degrees inclination values) or Sun-synchronous orbits, with an altitude of about 800 km. It will perform direct visibility imaging. TOPS offers, within a total field of view from 60 to 120 km, panchromatic (black & white images) observations with a 5 m spatial resolution, and multispectral (images in color) observations with 10 m spatial resolution. The access to a specific scene is made by performing a « roll flip » up to 40 degrees from Nadir, with the satellite.

The mission can be adapted to the customer's needs and improved versions could offer:

- better spatial resolution about 3m,
- increase over 200 km of the total field of view
- quick repointing capabilities,
- imaging capabilities with on-board storage.

The TOPS system components include the launch services, the satellite(s), the satellite control center, the image processing center. AEROSPATIALE offer will be adapted to customer's wish, and could cover the procurement of the full system, or parts of this system ; e.g. the satellite plus the satellite control center, or e.g. the satellite only.

The TOPS system is designed to use off-the-shelf technology, components and equipments.

5.2.2. Payload description

The payload module includes:

- the optical instrument and focal plane CCD detectors,
- the processing electronics,
- the X-band downlink image telemetry system,
- the associated structure, thermal control, harness.

The optical instrument reuses existing technologies and components derived from other space instruments.

5.2.3. Satellite configuration

The satellite is composed of a dedicated payload module on board the generic PROTEUS multi-mission platform.

It offers simple payload / platform interfaces:

- mechanical interfaces: four fixation points
- power supply: semi regulated (21/35 V) bus
- command & control: 1553 MIL Std bus.

The payload and platform integrations can be done in parallel.

The satellite characteristics are typically a mass of 400 kg and a power of 300 W.

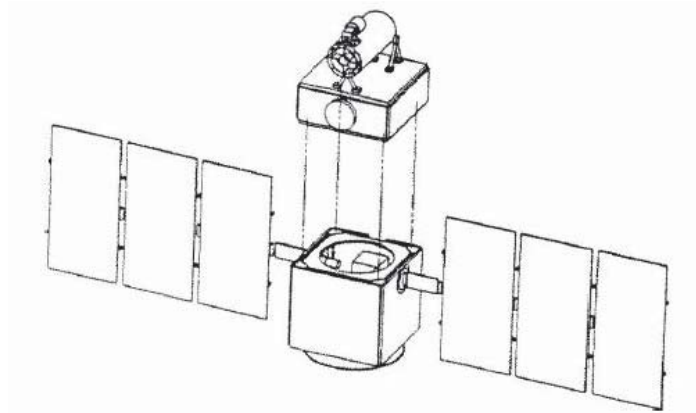


Fig.7 : The TOPS satellite

Fig.7 : The TOPS satellite

5.3. Land Explorer (Aerospatiale proposal)

5.3.1. Mission description

For the post 2000 time frame, the European Space Agency (ESA) is defining candidate missions for Earth Observation. In the class of the Earth Explorer missions, dedicated to research and demonstration missions, the Land-Surface Processes and Interaction Mission (LSPIM) involves a dedicated satellite carrying a single optical payload named PRISM (Processes Research by an Imaging Space Mission). PRISM is a multispectral imager providing high spatial resolution images (50 m over 50 km swath) in the whole optical spectral domain (from 450 nm to 2.3 μm with a resolution close to 10 nm, and two thermal bands from 8.2 to 9.2 μm). The mission provides multi-directional observations for measurements of Land Surface BRDF (Bi-Directional Reflectance Distribution Function) and an access to any site on Earth within 3 days. This means Line of Sight agility in across-track direction for the site accessibility, and along-track agility for the BRDF

measurements. The proposed orbit is a 767 km altitude Sun synchronous circular one, with descending node at 11:00 a.m.

A detailed presentation of this mission and corresponding AEROSPATIALE activities at optical payload and satellite level is made on paper [Laba 97] also presented at ICSO'97.

5.3.2. Payload description

The payload comprises the hyperspectral imager PRISM and the associated on-board image chain. The objective of the PRISM instrument is to produce sets of spectral images of selected Earth sites, simultaneously measured in different wavelength regions. Each spectral image is a 2-D array of samples made of an equal number of rows and columns. The images in all bands are spatially and spectrally co-registered for accurate exploitation of data. The instrument covers two main spectral regions. Region 1 covers the Visible-Near InfraRed (VNIR) and the Short-Wave InfraRed (SWIR) from 0.45 to 2.35 μm . In this region, the instrument works as an imaging spectrometer with a spectral resolution of about 10 nm. Region 2 covers the Thermal InfraRed (TIR), with two bands of spectral width close to 1 μm , from 8.2 to 9.2 μm . The instrument radiometric performance reach a high level of accuracy by involving on-board calibration capabilities. The overall architecture is based on the use of a single optical instrument to perform the complete requirements, in particular the use of a common telescope for region 1 and region 2, and the use of the same detector pitch in all spectral regions. The very large spectral range from VNIR to TIR leads to the use of an all-mirror telescope. The selected concept is a Three Mirror Anastigmat (TMA) with a real entrance pupil. The separation between region 1 and region 2 is performed at the telescope focal plane.

One important feature of PRISM is the very high data rate provided when full spatial and spectral observation is required. The payload data handling architecture includes the video electronics, a data processing unit, an instrument control unit, and a high capacity solid-state mass memory (60 Gbits) and a 100 Mbits/s X band telemetry system.

The PRISM push broom multispectral imager has a typical volume less than 1 m x 1 m x 0,5 m, mass (including electronics) about 300 kg, mean power about 300 W.

5.3.3. Satellite configurations

A candidate satellite configuration based on the use of a recurrent Proteus platform and an instrument equipped with an along track scan mirror is illustrated herebelow. Another candidate configuration consists in a satellite with high manoeuvrability capabilities. The two configurations are presented in [Laba 97].

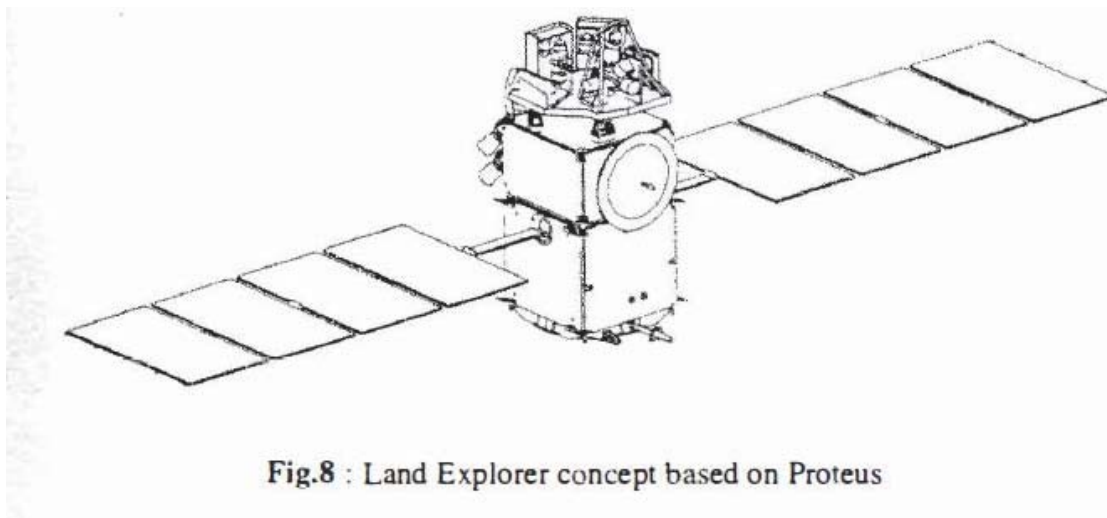


Fig.8 : Land Explorer concept based on Proteus

6. CONCLUSION

- Proteus is a new European multi-mission small platform. Its development is being carried out for the joint CNES / NASA Jason project, due for launch in the beginning of year 2000.
- The development plan allows for 1 mission per year starting from year 2000.
- Missions studied by CNES and AEROSPATIALE show the great potential of PROTEUS for various optical applications, together with an extended capability to domains other than that intended.
- PROTEUS is an attractive product for the space community, offering the following characteristics for future optical missions :
 - multi-mission architecture,
 - low cost and high capabilities,
 - high accuracy payload pointing,
 - easy payload accommodation,
 - multi-launcher compatibility.
- An important aspect of the cost-reduction potential of this platform is the fact that future clients will be able to concentrate their financial and intellectual efforts on the *payload*, leading to optimal mission return for a given global cost.

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