CALL FOR IDEAS:
Spacecraft Platform Elements and Technology Experiments for PROBA II

Ref.: IMT-CTE/FM/gs/2002.060

Dear Sirs,

The European Space Agency (ESA) hereby invites you to submit a proposal for the above subject.

The present Call for Ideas refers to the Agency's upcoming PROBA II project (see attached documentation for details): please note that the project's Specification and Mission Design Phase (Phase B) is foreseen to start in mid-2002, with the Production, Qualification and Integration Phase (Phase C/D) starting in 2003.

Please find attached hereto the following document:

"CALL FOR IDEAS: Spacecraft Platform Elements and Technology Experiments for PROBA II", ref. ESTEC/TOS/ES/577.02/jh, consisting of:

- The Call for Ideas proper ref. ESTEC/TOS/ES/577.02/jh, issue 1;
- A description of the Agency's intended approach to micro-satellite activities (Annex 1);
- A technical description of the PROBA 1 satellite (Annex 2);
- The draft Experiment Mission Implementation Agreement for Technology Experiments embarked on PROBA II (Annex 3).

Your proposal, within the scope indicated in section 4 of the Call for Ideas, shall include:

- The technical, planning and financial information listed in section 5;
- A statement of acceptance of the applicable contractual terms and conditions (see note, parts a) and b) at the end of Section 6 of the Call for Ideas);
- A binding statement whereby the Proposer (with his industrial partners, if any) confirms his availability to communicate with the Agency and/or the PROBA II Prime Contractor on technical issues regarding his proposal, including his availability to attend technical meetings, during the final selection phase.

For Platform Elements and Technology Experiments your proposal shall indicate whether the envisaged activity regards:

- **Existing technology, sufficiently mature for a direct Flight Model procurement or**
- **Existing technology requiring additional development work.**

Regarding the envisaged funding for the proposed Spacecraft Platform Elements, your proposal shall indicate which of the following schemes is sought:

- **Full funding within ESA Programmes;**
- **Co-funded activity within ESA Programmes (i.e. maximum 50% funded by ESA and 50% by Proposer);**

Regarding the envisaged funding for the proposed Technology Experiments, your proposal shall indicate which of the following schemes is sought:

- **Full funding within ESA Programmes;**
- **Co-funded activity within ESA Programmes (i.e. maximum 50% funded by ESA and 50% by Proposer);**
- **Non-ESA (e.g. national, industry, other) funding.**

For activities belonging to the latter category, your proposal shall include a confirmation of support by the cognisant funding source or Authority.

For information on the possible contractual arrangements covering the abovementioned types of activity and funding schemes please refer to section 6 of the Call for Ideas.

The funding sources or Authorities (such as National Delegations) for the selected Technology Experiments will also be required to proportionally contribute to launch costs and, depending on the experiments' particular operations requirements, to operations cost.

Please note that the present Call for Ideas does not cover scientific payloads to be flown on PROBA II, the former being the subject of a separate Announcement of Opportunity.

In order to ensure efficient communication amongst all the parties involved, it is recommended that National Delegations be kept informed of any proposals submitted to the Agency under this Call for Ideas.

Your proposal shall be submitted not later than the 15th of April 2002, according to the following requirements:

- One electronic copy (pdf format or similar) shall be submitted via electronic mail to the following address:

  Proba2cfi@esa.int

- One signed hard copy shall be submitted to the responsible Contracts Officer at the following address:

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  for the attention of:
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- One hard copy shall be submitted to the National Delegation's representatives to the Agency's Industrial Policy Committee (see Attachment 1 hereto).

Yours faithfully,

P. J. de Boer
Head of ESTEC Contracts Service for Technology and Support

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EUROPEAN SPACE AGENCY

CALL FOR IDEAS

Spacecraft Platform Elements and Technology Experiments for PROBA II

Issue 1

Contents

1. Purpose of the document

The primary purpose of this Call for Ideas is to invite industry and institutions within ESA Member/Participating States and Canada to submit proposals for the following elements of the PROBA II mission:-

- spacecraft platform elements
- technology experiments (independent of the platform) requiring in-orbit verification and demonstration.

In addition, as a secondary purpose, the opportunity is also being taken to invite preliminary proposals for possible follow-on microsatellite missions. Such proposals may be for spacecraft platform elements (or even for complete platforms) and/or technology experiments.

2. Background

A note on ESA's intended approach to microsatellite activities is attached as Annex-1. Among other aspects, this document highlights the need for an ongoing microsatellite programme to provide the means to flight-test emerging technology for spacecraft platforms. The PROBA I microsatellite mission (launched in October 2001) is the Agency's first step in establishing this programme.

PROBA I is dedicated to the in-orbit demonstration of spacecraft technologies related to spacecraft autonomy, and also provides a flight opportunity for additional technological and small scientific payloads. A description of the PROBA I satellite, with characteristics and performance, is attached as Annex-2.

The next microsatellite in the programme, PROBA II, will follow the same approach as for PROBA I, with the autonomy objective being supplemented by increased minituarisation and integration of the avionics, addition of propulsion and de-orbiting capabilities, increased payload resources, and improvement of onboard software.

3. The PROBA II Mission

The Procurement Proposal for the PROBA II mission was approved at the 185th meeting of the Agency's Industrial Policy Committee (IPC) in September 2000.

ESA delegations, industry and institutions interested in PROBA II will be given the opportunity to submit their technology proposals before the beginning of Phase B; for what concerns industry and institutions, the opportunity takes the form of this Call for Ideas. This process will allow the latest technology to fly on PROBA II, provided that the technology developments required can be successfully co-ordinated with the procurement of the spacecraft.

PROBA I will be used as a reference for PROBA II proposals; i.e. the performance figures for each PROBA I item will be used as the basis for assessing proposals for improvement.

High-level design constraints for PROBA II are as follows:-

- ASAP5 type (depending on actual launcher selected, not necessarily strictly within ASAP5 compatible mass and dimensions)
- LEO or GTO compatible (to be decided in Phase B).

In addition, proposers must take account of the general mass and power constraints applied to all microsatellite elements.

In recent times the Agency has received/discussed quite a number of proposals for payloads in the domains of technology, Earth observation and astronomy. Hence submissions pertinent to missions belonging to these domains will be welcomed. In the meantime, the candidate orbits currently under consideration for PROBA II are:-

- LEO sun-synchronous orbit, 600-800 km altitude
- GTO orbit
- deep space heliocentric orbit.

Missions in all these orbits are foreseen to carry out technology experiments also in the primary phase and (for LEO and GTO) to have a terminal phase during which a semi-rigid tether based de-orbiting device and controlled re-entry technology may be tested. The non-technology experiments (Earth observation, scientific, space environment monitoring, etc) will be selected through a separate Announcement of Opportunity (see also Section 5).

The budgetary estimate for the PROBA II mission is around 10 MEURO, based on the following assumptions:-

- that the selected complement of independent technology experiments and scientific/application payloads will be of a similar complexity to PROBA I
- that a suitable launch opportunity can be procured for no more than 1 MEURO
- that no significant subsystem development costs be covered within the project financial envelope - see note below
- that procurement costs for independent technology experiments are excluded - see note below
- that procurement costs for scientific/application payloads are excluded
- that operations costs within the envelope are restricted to in-orbit commissioning.

[Notes i) It is envisaged that any development costs allowing new technology to achieve flight level (whether in basic spacecraft elements or independent experiments), and also the flight unit procurement costs, be covered either by national programmes, separate activities within ESA programmes, or other (e.g. collaborative) activities.

ii) The funding sources or authorities for technology experiments will be required to contribute proportionally to launch costs and, depending on their particular operations requirements, to operations costs.]

4. Scope of proposals invited

The PROBA II mission is targeted at in-orbit technology verification and demonstration. It will demonstrate at least some or all of the following technologies and technical concepts for spacecraft technology miniaturisation (paragraphs i, ii, iii, v), small spacecraft advanced capabilities (iii, iv), enhanced payload resources allocation (v, vi), and cheaper and more reliable onboard software (vii).

i) Miniaturised attitude measurement sensors to exploit the recent technology advances in micro electro-mechanical (MEM) devices, active pixel arrays, and folded optics for the development of high performance and compact attitude measurement sensors. This technology is considered by the Agency to have high priority for in-orbit demonstration.

ii) Attitude control systems for high spatial resolution sensors, targeting actuator performance, advanced pointing capability and control law design.

iii) Propulsion technology for small spacecraft (e.g. electric, such as FEEP - an attractive technology for small spacecraft but, due to resource constraints, still needs to be optimised at spacecraft system level).

iv) De-orbiting devices, required in order to comply with space debris regulations; a mass-efficient technique is highly desirable. One possibility is to demonstrate the use of a short (30 m) semi-rigid electro-dynamic tether. Another could be aero-braking.

v) Integrated data-handling and power subsystem, to decrease the spacecraft platform mass and power, and to improve payload resources allocation.

vi) Ka-band transmission, to increase the downlink transmission capacity from 1 Mbps to 100 Mbps.

vii) Automatic code generation for onboard software.

Many of the above have been the subject of ESA technology studies. However, proposals should not be restricted to what has been covered by these studies.

5. Proposal submission and selection process

Industrial proposals (for basic spacecraft platform elements and for independent technology experiments) shall include, among others, the following information:-

- a summary of the proposed activity
- a description of the intended scope of the activity (existing technology or further development)

- a cost estimate for flight ready items (either directly procured, or including additional development work)
- the intended funding scheme (including Phase B support - see below)
- estimated development schedule for availability of flight items.

During Phase B (scheduled to start in the second half of 2002, and to last 6 months) the Agency, in conjunction with the PROBA II Prime Contractor, will carry out a selection of the elements and experiments proposed. The following parameters will be assessed during this process:-

- compatibility of the selected technology experiments with the system design and performance - see note below
- advanced nature of the proposed technology
- interest for future missions
- maturity of proposed items
- recurrent price (for spacecraft platform elements)
- adequacy of financial support
- acceptance of the Agency's General Clauses and Conditions for ESA Contracts or (for technology experiments only) of the conditions set forth in the draft Experiment Mission Implementation Agreement. [See also Section 6.]

Proposers will be required to support Phase B, not only for the element and experiment selection process, but also for the remainder of Phase B work. As a guideline, proposals should include support during Phase B for:-

- attendance at two technical meetings with the Prime Contractor, primarily to assess accommodation aspects, to finalise the associated specifications and other documents and, for technology experiments, to agree the experiment interface documents
- prior preparation for the above
- attendance at the Phase B final presentation.

[Note Prior to Phase B the Agency will also be issuing an Announcement of Opportunity for small non-technology payloads to fly on PROBA II; a selection from these will be carried out by the Agency during Phase B. Only on completion of this payload selection can the selection of spacecraft platform elements and technology experiments be finalised.]

6. Contractual aspects

Depending on the type of activity and on the funding scheme sought by Proposers, the contractual arrangements envisaged are given in the table on the following page.

Notes

a) For the cases to be covered by an ESA contract, the latter will be based on the Agency's "General Clauses and Conditions for ESA Contracts", ref. ESA/C/290, rev.5.

b) For the cases to be covered by an EMIA - Experiment Mission Implementation Agreement, a draft version of this Agreement is attached hereto as Annex-3.

	FULL ESA FUNDING	CO-FUNDED ACTIVITY WITHIN ESA PROGRAMMES	NON-ESA FUNDING (e.g. National, Industry, Other)
SPACECRAFT PLATFORM ELEMENT (direct Flight Model procurement)	1) part of PROBA II Phase C/D/E contract, or 2) (exceptionally) separate ESA contract + HW provided to PROBA II by ESA	separate contract + HW provided to PROBA II by ESA	NOT FORESEEN
SPACECRAFT PLATFORM ELEMENT (requiring additional development work)	1) initially separate ESA contract to complete the development, followed by FM procurement as part of the PROBA II Phase C/D/E contract, or 2) (exceptionally) separate ESA contract + HW provided to PROBA II by ESA	separate contract + HW provided to PROBA II by ESA	NOT FORESEEN
TECHNOLOGY EXPERIMENT (direct Flight Model procurement)	1) part of PROBA II Phase C/D/E contract, or 2) (exceptionally) separate ESA contract + HW provided to PROBA II by ESA	separate contract + HW provided to PROBA II by ESA	EMIA – EXPERIMENT MISSION IMPLEMENTATION AGREEMENT (HW to be directly provided to PROBA II by the Experimenter)
TECHNOLOGY EXPERIMENT (requiring additional development work)	1) initially separate ESA contract to complete the development, followed by FM procurement as part of the PROBA II Phase C/D/E contract, or 2) (exceptionally) separate ESA contract + HW provided to PROBA II by ESA	separate contract + HW provided to PROBA II by ESA	EMIA – EXPERIMENT MISSION IMPLEMENTATION AGREEMENT (HW to be directly provided to PROBA II by the Experimenter)

Contractual Arrangements

ANNEX-1

Background Note

ESA's APPROACH

TO

MICROSATELLITE ACTIVITIES

1. Introduction

Over the last two decades the miniaturisation and integration of electronics has revolutionised many terrestrial systems in areas as diverse as computing, communications, and household appliances. The ability to perform more functions with a smaller system that uses less power is ideally suited to space where mass and power are at a premium. Thus considerable use of this capability had been made in the major European satellites. ESA has concentrated on using this technological capacity to improve the capability of large spacecraft, and the lead in using miniaturisation to produce small spacecraft at low cost has been taken by universities and smaller companies outside of the Agency. As a result of these pioneering efforts, Europe has a strong presence in microsatellites; many ESA Member States have active small satellite programmes. Although most microsatellite programmes are run independently of the Agency, in some cases (such as PROBA in GSTP) they form part of the Agency's overall programme of work.

2. Overview of Microsatellites

2.1 Small Satellite Classification and Utilisation

There are a number of ways to define small satellites and in order to be precise the following classification is used:-

Small satellite	500-1000 kg
Mini-satellite	100-500 kg
Microsatellite	10-100-kg
Nano-satellite	1-10 kg

This note is mainly concerned with micro and nanosatellites, although in some cases it extends to minisatellites. In addition to the mass restriction implied by the classifications, microsatellites and nanosatellites are subject to volumetric and power constraints. Typically instrument aperture sizes and focal lengths are less than 30cm and 1m, with power levels of less than 100 watts. However microsatellites have the advantage that they offer a fast and cost-contained route to space. A typical microsatellite programme takes of the order of 2 to 3 years and costs from 3-20 MEURO depending on its capability and the mission. As a consequence of the specific characteristics of micro and nanosatellites they have been used:-

- To complement the large spacecraft still necessary for large-scale science, earth observation and communications missions. Examples of this are the Danish Oersted mission, the Swedish Odin mission, the French CNES Demeter, France-Brazilsat, Picard, and Microscope missions, the Italian Mita series, and the Spanish Minisat, etc.
- To provide a low cost route for the provision of space based services. The Belgian AMS satellite constellation is an example which builds on the IRIS (ESA and Belgium) experience on mailbox type communication services.
- To provide a means of testing in-orbit new and relatively high-risk high-return technologies and techniques. Examples of this are ESA's PROBA I mission which is demonstrating advanced control, navigation and autonomous operations concepts, UOSAT 12 which is demonstrating autonomous orbit maintenance using GPS, Caesar (cooperation between Spain and Argentina), and many others.
- To provide a relatively low cost route via which countries can participate in space activities.

These uses of small spacecraft have evolved over many years; in the last three years more than fifty such satellites have been put into orbit. It is thus not a new field, but one which has a long space tradition. However it is a field which has been given new impetus in the last decade by the advances in miniaturisation that are extending the range of applications that can be handled by such spacecraft, by the availability of launch opportunities for small spacecraft, and by the pressure to reduce the costs of space missions.

2.2 Launch Opportunities for Microsatellites

Microsatellites need inexpensive and regular access to space, since either prohibitively high launch costs or infrequent opportunities would be detrimental to the whole ethos of low cost fast-track microsatellite programmes. One of the main catalysts for the increased use of small spacecraft in the last decade was the development by Arianespace of the Ariane Structure for Auxiliary Payloads (ASAP) in 1988 which provided, for the first time, regular access for 50kg microsatellites into LEO and GTO on a commercial basis. However Ariane cannot provide the number of launch opportunities into LEO (which is the most commonly used microsatellite orbit) and so alternative launch options from sources such as India (PSLV - successfully used for PROBA I) and Russia (Tsyklon, Zenit, and Cosmos) are increasingly being used. A further option is to transfer microsatellites from the orbit provided by Ariane 5 to their final operational orbits. Whatever the means used to launch microsatellites, it is clear that this is a key element of microsatellite systems and has to be considered in the Agency approach on microsatellites at a European level.

2.3 Microsatellite Technology

Currently microsatellites of about 100kg offer about 30kg for payload use and, in LEO, about 20 watts. They can also offer high precision pointing and a reasonable degree of agility; for example PROBA I has a pointing accuracy of ≤150 arcseconds and a slew rate of 0.5° per second. There are two main trends in microsatellites systems, firstly to improve the performance of an individual microsatellite, and secondly to operate more than one microsatellite in combination.

The technology used for microsatellites capitalises on increasing miniaturisation, and in the next 2-3 years it will be possible to offer 60kg and more than 40 watts for payload use. This is due to improvements in electronics, where it will soon be feasible to incorporate many avionics functions on one chip, improvements in energy storage (the use of Li-Ion technology for batteries), and lightweight structures. Whilst most of these technologies are applicable to large spacecraft there is also a need for focused technology developments to ensure the availability of products for microsatellites at the correct performance/price ratio in some areas.

The use of more than one microsatellite in combination is interesting for two main reasons. The first is to provide increased coverage; for example, five microsatellites in one orbital plane can provide 10-20 metre resolution daily coverage of any point on earth. The second reason is that, by tight control of the distance between multiple spacecraft, the effective aperture of the combined system can be significantly increased. Both of these applications mean that constellation operations and formation flying are active areas of current and future microsatellite investigation.

3. ESA Approach in the Field of Microsatellites

3.1 Objectives

The objectives of the ESA approach to microsatellites are:-

- To use microsatellites to achieve the timely results needed for ESA's future missions. A key role for ESA is the use of microsatellites to demonstrate techniques and technologies that require in-orbit verification and for this reason this paper concentrates on this aspect .

- To ensure that European industrial and national programmes maintain a world-class presence in the microsatellite domain by supporting specific activities on microsatellite technology development.

- To encourage the involvement of small and medium enterprises (SMEs) in microsatellite provision and technology development.

3.2 Microsatellite Use by ESA

Microsatellite use by ESA has concentrated mainly on the in-orbit demonstration and verification of techniques and technologies which have a potentially significant benefit for the future missions of ESA. These techniques and technologies encompass both platform and payload technologies, and concern those concepts which have either been identified as innovative, or require a dedicated mission. Typically the concepts have been analysed and their potential performance and use quantified theoretically. However the verification of the theoretical concepts and the risk associated with the concept demand that it is tested in-orbit prior to use on a scientific or application mission. By their nature those concepts best suited for testing on microsatellites often involve spacecraft dynamics, navigation and miniaturisation which cannot easily be tested as passenger payloads on other spacecraft nor on the International Space Station. In line with the objectives in 3.1 the Agency intends to continue to use microsatellites for technology demonstration.

Some of the technologies implemented or under consideration for use on micro and minisatellites are:-

- Autonomous Spacecraft and Payload Operations
  The potential benefit of this is in the operation of spacecraft (for what concerns communications limits, reduced ground support, etc). This was a main objective of the PROBA I mission.
- Formation Flying
  The use of formation flying for the future science and Earth observation missions requires in-orbit verification of the controllability

and the performance of such systems. Smart 2 will demonstrate the high precision formation flying technologies required for space interferometry (as needed for the science cornerstone missions Lisa and Darwin)

- Agile Spacecraft

  Due to their low inertia, microsatellites can be used to demonstrate agile spacecraft operations for science and Earth observation needs. An example of this is the bi-directional reflectivity measurements made by the Compact High Resolution Imaging Spectrometer (CHRIS) on PROBA I.

- Novel De-Orbiting Methods

  Space debris is of growing concern, and research into mass efficient ways to de-orbit spacecraft at the end of life has identified novel techniques for performing this, such as the electro-dynamical tether technique. Such systems may be tested on the PROBA II mission.

- Propulsion Technology

  Propulsion demonstration for microsatellites is a potentially important area. The technology ranges from microthrusters through to combined electrical propulsion and thin-film solar arrays.

The above list is non-exhaustive; on-going studies can be expected to identify further in-orbit demonstration needs.

As well as the use of micro and minisatellites for the purposes of technology demonstration, small satellites will continue to be used to implement specific missions within the science and application domains. This justifies investment in microsatellite technologies such as propulsion, miniaturised attitude sensors, etc.

3.3 Technology Microsatellites - PROBA I and Beyond

In order to perform the in-orbit evaluation of technologies and techniques there is a need for mission specific microsatellites, in addition to the testing of technology on available platforms. The main reason for this is to test a system technique or concept rather than an individual technology. It is therefore foreseen that there will be a number of technology microsatellites in the GSTP programme.

The first microsatellite of this type was PROBA I, with the objective to test and validate on board autonomy and attitude control systems for agile microsatellites.

The second microsatellite planned is PROBA II which has the objective of demonstrating micro-propulsion systems, electro-dynamic de-orbiting techniques, miniaturised communication and avionics, and extremely high pointing accuracy attitude and orbit control systems for microsatellites. This will include the following elements:-

- A miniaturised and integrated control data and power system, with the target to improve the mass and power performance by a factor of 4.
- High data rate (>30 Mbps) compact Ka band transmission system, with the aim of improving the downlink performance of microsatellites.
- An electro-dynamic de-orbiting system with the aim of demonstrating a low mass de-orbiting system for mini and microsatellites.
- A miniaturised propulsion system.
- Fully automatic code generation for the onboard software, building on the current approach for PROBA I where the AOCS and navigation software is implemented using automatic code generation.

In addition to the items identified above, there will be opportunities for industry and institutes to propose additional technology experiments and payloads on PROBA II and follow-on missions.

3.4 ESA Support to Microsatellite Activity in General

In addition to the use that the Agency makes of microsatellites for its own purposes, support will continue to be given to microsatellite activity in general. Such support falls into two main areas described below.

3.4.1 Technology development for microsatellites

Most microsatellites make use of a wide range of both commercial-off-the-shelf (COTS) technology and existing spacecraft technology. Indeed many developments for larger spacecraft, such as Li-Ion batteries, are directly useful for microsatellites. However, there is still a need for specific, dedicated developments for microsatellites. The main focus on these developments has been, and should continue to be, to get a reasonable performance at low price. Potential future technologies are:-

- compact Ka band transmitter
- compact solid state inertial sensing package
- miniaturised attitude sensors
- compact high-speed camera
- etc

The output of the development activities will be units ready for flight.

3.4.2 Partnership with national programmes

Microsatellites also offer an inexpensive means for nations and universities to have a dedicated space mission. ESA has co-operated in this area by providing:-

- technical and technology support to national microsatellite programme initiatives
- providing payloads or bus components for use on national missions.

The reciprocal approach, namely flying nationally funded elements on ESA microsatellites, has also occurred. An example is the CHRIS instrument on PROBA I. A continuation of this successful co-operation with national programmes will continue to play an important role in the future.

3. 5 Launcher Considerations

A key concern is to ensure the availability of reasonable launch opportunities for the very active European microsatellite scene. In order to ensure this a number of actions could be envisaged, including:-

- The co-ordination of shared launch opportunities on ESA and other European microsatellite missions.
- The option of procuring specific dedicated launches. For example the demand for sun synchronous orbits for microsatellites exceeds the availability of passenger slots. Thus, if the demand is sufficient, it would be of interest to share finances for a dedicated launch amongst the participants.

The Agency therefore proposes to investigate, with Member States, the possibilities and the potential interest of such actions.

4. Implementation Aspects

The ESA use of microsatellites, technology for microsatellites, and co-operation with national programmes will continue to be managed within the existing programmes. This means that the ESA use of microsatellites for technology purposes, and technology development for microsatellites, will be continued within the TRP and GSTP programmes and, as such, are open to all Member States (or Participating States for GSTP). The implementation approach will, in general, include:-

- procuring a complete spacecraft within GSTP (e.g. PROBA I)

- harmonising with national activities, for example by using a national spacecraft to perform a technological mission
- participation to an existing microsatellite mission (e.g. the MNT Micro-Nano-Technology experiment flown on the Italian MITA mission).

In order to promote the development of advanced technology to flight level, industry will be given (via dedicated AOs) opportunities to provide high technology equipment and instruments for planned technology microsatellites. Such items could either be part of ESA (e.g. GSTP) or nationally funded developments.

Finally, the emphasis on technology should not be taken to imply that no role for microsatellites in application or science missions is envisaged. Rather, in cases where such a role is identified, they will be undertaken as part of the appropriate specific ESA science and application programmes.

5. Conclusions

Micro and nanosatellites provide a low cost route to meeting some programme and mission objectives. In line with the objectives defined in Section 3.1, the ESA approach on microsatellites aims to:

- Use microsatellites for in-orbit demonstration of high-risk technologies, novel instruments, and new concepts in support of ESA's future needs.
- Support the development of specific microsatellite technologies.
- Provide the means within the Agency to facilitate collaborative multisatellite and payload ventures amongst ESA member and non-Member States.
- Encourage the involvement of SMEs for microsatellite provision and technology development.

Furthermore the Agency proposes to explore the possibility of procuring, on a collaborative basis, specific launch opportunities to assist all European small satellite programmes.

ANNEX-2

PROBA
(PROJECT FOR ON-BOARD AUTONOMY)

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***ABSTRACT** – Proba is an ESAmission dedicated to in-orbit technology demonstration, earth environment monitoring and preparatory earth observation. Proba is a small spacecraft equipped with a selected set of technologies providing advanced on-board functions to support mission operations with minimum ground involvement. This spacecraft autonomy is exercised and demonstrated in realistic scenarios through the utilization of the payload instruments.*

Introduction

Proba is a mission included in the ESA's General Support Technology Programme [Teston 1999]. The project is currently in its final phase: the integration of the flight spacecraft. This mission is part of an overall effort to promote technological missions using small spacecraft. The next step is a follow-on project (Proba 2) which is included in the next phase of the GSTP and is due to start in 2000.

An industrial team led by Verhaert Design and Development (Belgium) is responsible for the project. It is supported by several European subcontractors and suppliers. The payload instruments are provided to the industrial team under ESA's responsibility.

This paper presents a description of the Proba mission, the spacecraft and ground segment design, and the payload instruments.

- PROBA MISSION SUMMARY

Launch and Orbit

Proba is planned to be launched in 2001 on a PSLV from Antrix (India). It will be injected directly into its final polar, sun-synchronous orbit at an altitude of 817 km, 98.7 degrees inclination. The orbital drift (away from sun-synchronism) amounts to about 2 degrees per year and is compatible with the PROBA mission requirements. There is thus no need for on-board propulsion.

Navigation of the spacecraft is performed autonomously on-board by the Attitude Control and Navigation Subsystem (ACNS) with a combination of GPS measurements and orbit propagation. The spacecraft is kept three-axis stabilised by means of attitude measurements provided by an autonomous star tracker and by on-board control through a set of reaction wheels and magneto-torquers.

Payload Instruments
The payload of Proba is composed mainly by a spectrometer (CHRIS), 2 Earth environment monitors (DEBIE and SREM) and 2 imagers (WAC and HRC). These instruments have been selected because they put severe requirements on the spacecraft technology in terms of ACNS, data handling and resources management in addition to scientific interest. For example, the spectrometer uses the spacecraft high accuracy slewing capabilities to perform multiple images of the same scene on Earth from different viewing angles. Also, the planning and the execution of the spectrometer and the imagers observation requests use the on-board flight dynamics function of Proba.
PROBA System Description

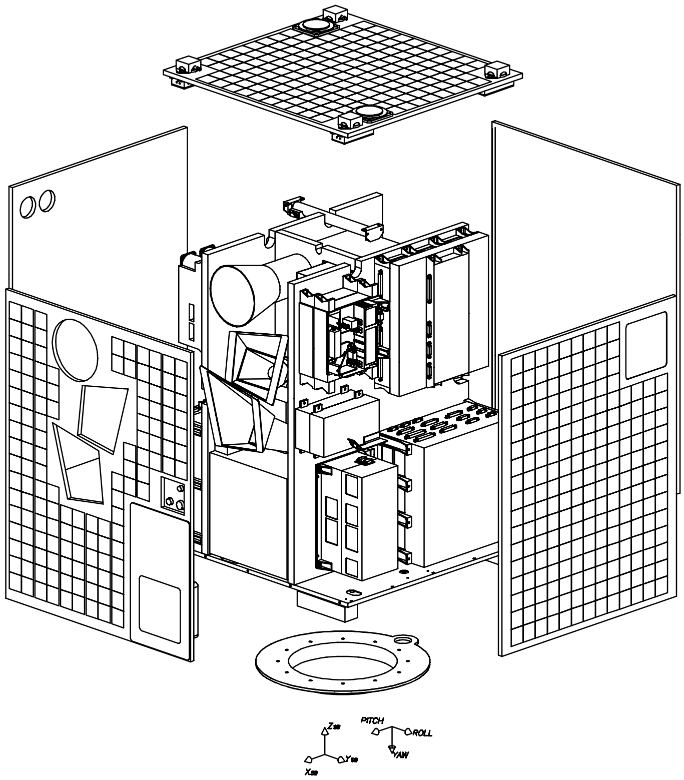

Figure 1: Exploded view of PROBA demonstrating the internal H-assembly with the units and the outer panels with the body mounted solar cells.

Proba has a weight of about 100 kg and belongs to the class of microsatellites. Its structure (Figure 1) is built in a classical manner using aluminium honeycomb panels. Body-mounted Gallium Arsenide solar panels provide power to the spacecraft and a Li-Ion battery is used for energy storage. A centrally switched 28 V regulated bus distributes the power to the units and instruments. A high performance computer provides the computing power to the platform and a Digital Signal Processor (DSP) based computer with a solid state recorder provides the processing power to the imaging payload. The telecommunications subsystem is omni-directional using CCSDS-compatible up-link and down-link for S-band communications with the ground. The set of ACNS units support Earth and inertial 3-axis attitude pointing as well as on-board navigation and manoeuvring computations. The spacecraft platform provides full redundancy.

Whereas commonly available units and well-proven concepts are used for the communication subsystems and part of the power subsystem, the system design of Proba is innovative in many respects, especially in the areas of attitude control and avionics. A core of technologies aiming at the demonstration of spacecraft autonomy is accommodated in the attitude control and the avionics subsystems and forms an integral part of the Proba system design. They are for example, a GPS receiver for navigation and attitude determination, an autonomous star tracker for attitude determination, a high-performance computer, a DSP for on-board scientific data processing and analysis, and a solid state mass memory.

Table 1 provides an overview of the PROBA platform specifications and Figure 2 presents a block diagram of the PROBA spacecraft.

System		**Description**
Orbit	LEO Altitude 817 km Sun-Synchronous (right ascension node at 345 degrees) Near-polar (inclination 98.7°)	Optimisation for the requirements: • Best orbit for main imager • Good orbit for other payloads • Selection of low cost launcher with flight opportunity in a short time.
	Operational Lifetime	2 years for consumables (battery and solar cells)
Mechanical	Dimensions	600 x 600 x 800 mm
	Mass	< 100 kg
Thermal	Passive thermal control	
ACNS	Attitude control	3-axis stabilised providing high accuracy nadir and off-nadir pointing capabilities.
	Sensors	Cold redundant dual head advanced star trackers, redundant 3-axis magnetometers, GPS receiver.
	Actuators	4 Magnetorquers, 4 Reaction Wheels
	Absolute Pointing Accuracy	Better than 360 arcsec
	Absolute Pointing Knowledge	Better than 125 arcsec.
Avionics	Processor	Cold redundant radiation tolerant ERC32 RISC processor
	Memory	8 Mbyte RAM, 2 Mbyte FLASH
	Interfaces	RS422, TTC-B-01, analog and digital status lines, direct high speed interface to Telemetry.
	Uplink Communications	Hot redundant S-band receivers, 4Kbps
	Downlink Communications	Cold Redundant S-band transmitters, 1 Mbps
	Communications Packet Standard	CCSDS
Power	Solar Panels	5 body mounted GaAs panels, 90W peak power
	Battery	36 Li-ion cells, 9Ah, 25V
	Power Conditioning System	28V regulated power bus, redundant battery charge and discharge regulators, power distribution system and shunt regulators.
Software	Operating System	VxWorks
	Data Handling/Application Software	Newly developed for PROBA

Table 1 : PROBA platform specifications overview

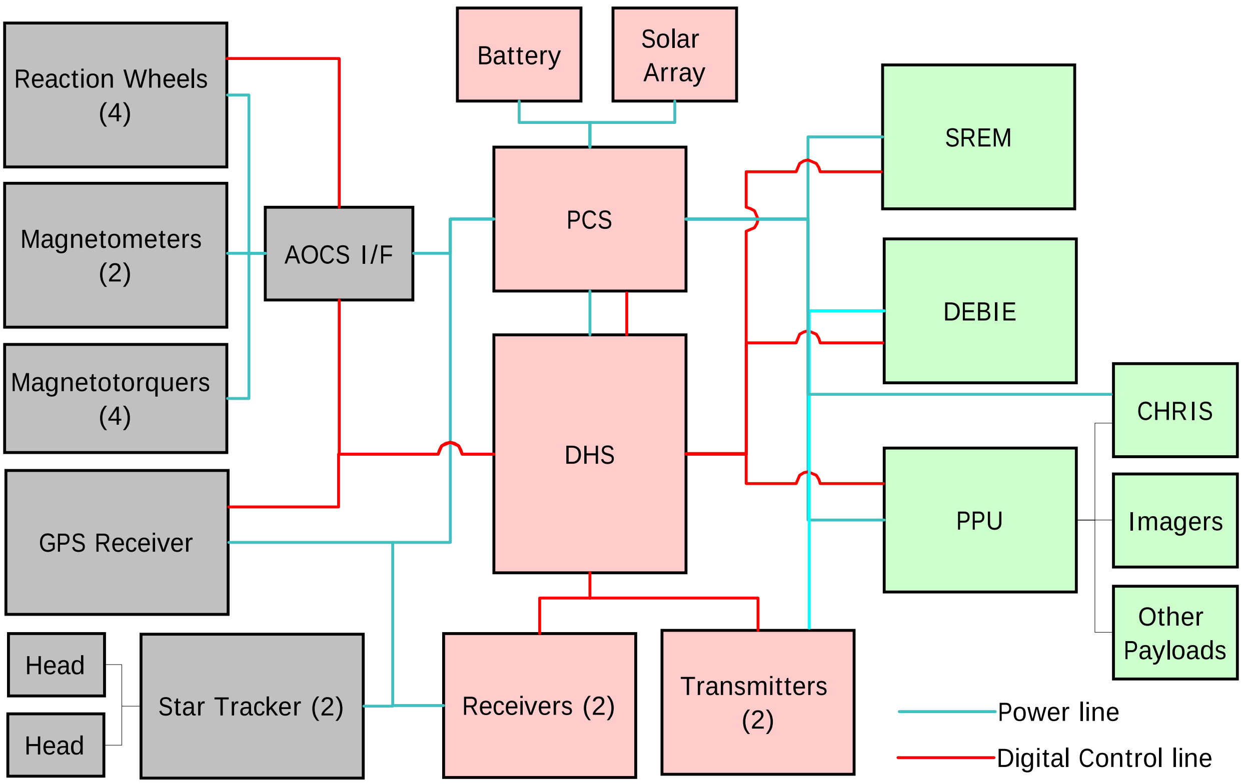

Figure 2: PROBA block diagram showing the AOCS units (left), the power and avionics Units (centre) and the payload units (right). Power and digital commanding and control interconnections between the units are shown. Other interconnections such as analog and digital monitoring lines are not shown.

- Mechanical and Thermal

The PROBA structure was designed to meet the following requirements:

- to provide a carrying structure compatible with the ASAP5 and PSLV launcher requirements
- to accommodate mainly off-the-shelf units and payloads with frozen mechanical design
- to provide easy unit access and modularity compatible with a flexible integration and checkout approach
- to be reusable to maximum extent for other technology demonstration missions.

The carrying part of the structure is composed of 3 aluminium honeycomb panels mounted in an H-structure and a bottom board. Almost all units are mounted on these inner panels. The nadir pointing bottom board of the spacecraft acts as the interface with the launcher. The outside panels have body-mounted Gallium Arsenide solar cells.

The thermal control of the spacecraft is completely passive, by an appropriate choice of the different paints, by the application of Multi-Layer-Insulation and by control of the conductive links between the different units and the carrying structure.

- **Attitude Control and Navigation System**

The autonomy requirements for the PROBA bus and the requirements imposed by the selected payloads have led to the implementation of a complex ACNS. The main requirements on the PROBA ACNS are:

1. Provide 3-axis attitude control including high accuracy nadir and off-nadir pointing and manoeuvring capabilities in accordance with the selected Earth observation instrument requirements
2. The ACNS software shall control the spacecraft based only on target oriented ground commands (i.e. commands specifying the targets longitude, latitude and altitude). The spacecraft sensors shall acquire all required information autonomously.
3. Provide technology demonstrations of GPS attitude and the use of Computer-Aided Software Engineering tools for the development of the ACNS software.

To meet these requirements, PROBA has been fitted with a high-accuracy double head star tracker, with a GPS receiver 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 to be mainly used for momentum dumping and during the initial attitude acquisition operations after separation or non-nominal events (Figure 3). Finally, the core of the ACNS subsystem consists of the ACNS software.

The autonomous star tracker is the main attitude determination sensor during nominal mission phases. It provides full-sky coverage and achieves the high accuracy required in Earth observation. The sensor can autonomously reconstruct the spacecraft's inertial attitude starting from a "lost in space" attitude without any prior estimates of the spacecraft orientation. This is done with a typical 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 which are sufficiently accurate to control large-angle precise and stable manoeuvres. The star tracker selected for PROBA is provided by the Technical University of Denmark.

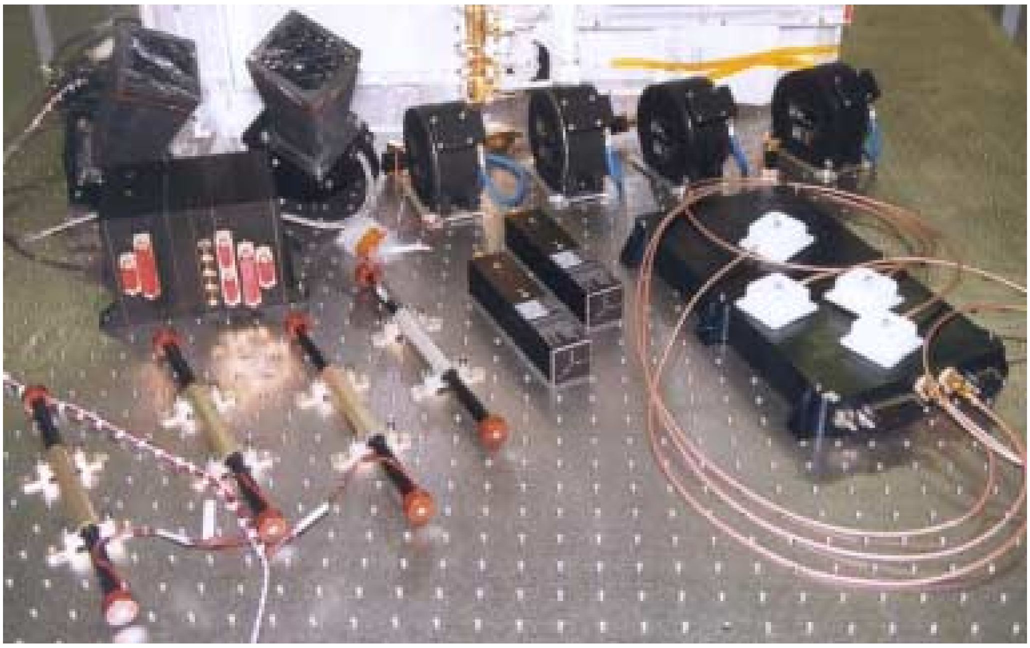

Figure 3: ACNS sensors and Actuators: 4 magneto-torquers, dual head star tracker, 4 reaction wheels, 2 magnetometers, GPS receiver

Knowledge of the PROBA orbit is acquired autonomously with a GPS receiver, supplied by SSTL (UK). The provision of range data from GPS satellites (or pre-processed position, velocity and time measurements from the GPS receiver software) will allow on-board determination of the osculating orbital elements of the spacecraft and a correlation of on-board time with Universal Time Coordinated (UTC) required in the various on-board ephemeris generators. Knowledge of the orbit will allow pointing the spacecraft to any orbit-referenced attitude (including the normal-mode nadir pointing) without the need for an Earth sensor. In addition, using an on-board Earth-rotation ephemeris calculator, pointing to any user-selected Earth coordinates is also possible. The GPS receiver thus forms a crucial component in the on-board autonomy demonstration. In case of GPS failure, the ACNS software obtains the navigation data from NORAD two-line elements automatically uplinked by the ground. Finally, the GPS receiver will be used for the GPS-based attitude determination demonstration.

During nominal operations, the generation of control torques is ensured by four Teldix (Germany) reaction wheels mounted in a tetrahedron configuration. Their storage capacity is 0.04 Nms and their maximum torque capability is 5 mNm at 1500 RPM. As already indicated, momentum dumping is ensured by two redundant, three-axis magnetometers and by four magneto-torquers.

All ACNS sensors and actuators are controlled by the ACNS software (developed by Université de Sherbrouck) running on the central ERC 32 computer and provides complete flight dynamics calculation functions, including:

- Navigation function: the autonomous estimation of the orbit using GPS measurements and the autonomous determination of attitude using the advanced star sensor.
- Guidance functions: the prediction of orbital events (eclipses, next target passages, next station passage etc) and the on-board generation of the reference attitude profile during imaging. These functions provide essential support to the on-board mission planning system.
- Control function: the execution of the attitude control commands for attitude acquisition and hold.

In performing these functions, the ACNS software has to deal with further complications such as latency of the detectors and synchronisation between the different on-board clocks.

Pointing to geographical Earth references will either be to a fixed target (e.g. during ground station overfly for antenna pointing or during utilisation of one of the imagers) or in a scanning motion over a 19 km user-selected target area during the CHRIS imaging mode. Each of the five scans over the target area are executed back and forth at 1/3 the nominal nadir push-broom velocity in order to increase the radiometric resolution. A detailed description of the ACNS can be found in [de Lafontaine 1999].

- **Avionics**

The avionics is composed by:

- a high-performance redundant central computer (DHS) responsible for spacecraft telecommand and telemetry, all spacecraft computing tasks and interfaces to every unit of the spacecraft,
- a Payload Processor (PPU) with a solid-state recorder and a DSP for payload processing and data storage,

- a redundant set of S Band receivers and transmitters.

DHS

The DHS unit was designed to integrate in a single redundant unit all the core functions of the spacecraft avionics (Figure 4) and to provide sufficiently high-performance computing to support not only the traditional attitude control and data handling tasks but also spacecraft autonomy (i.e. the processing normally performed on-ground has been migrated on-board in the case of Proba). It is provided by SIL (UK).

To this end a high-performance RISC processor, the ERC 32, has been used. The ERC 32 is a radiation tolerant (> 80 Krad) SPARC V7 processor providing 10 MIPS and 2 MFLOPS with a floating-point unit. A memory controller includes all the peripheral functions needed by the processor, such as the address decoders, the bus arbiter, the EDAC, 2 UARTS, 3 timers and a watchdog. The chip set is manufactured with the MHS 0.8 micron CMOS/EPI radiation tolerant technology.

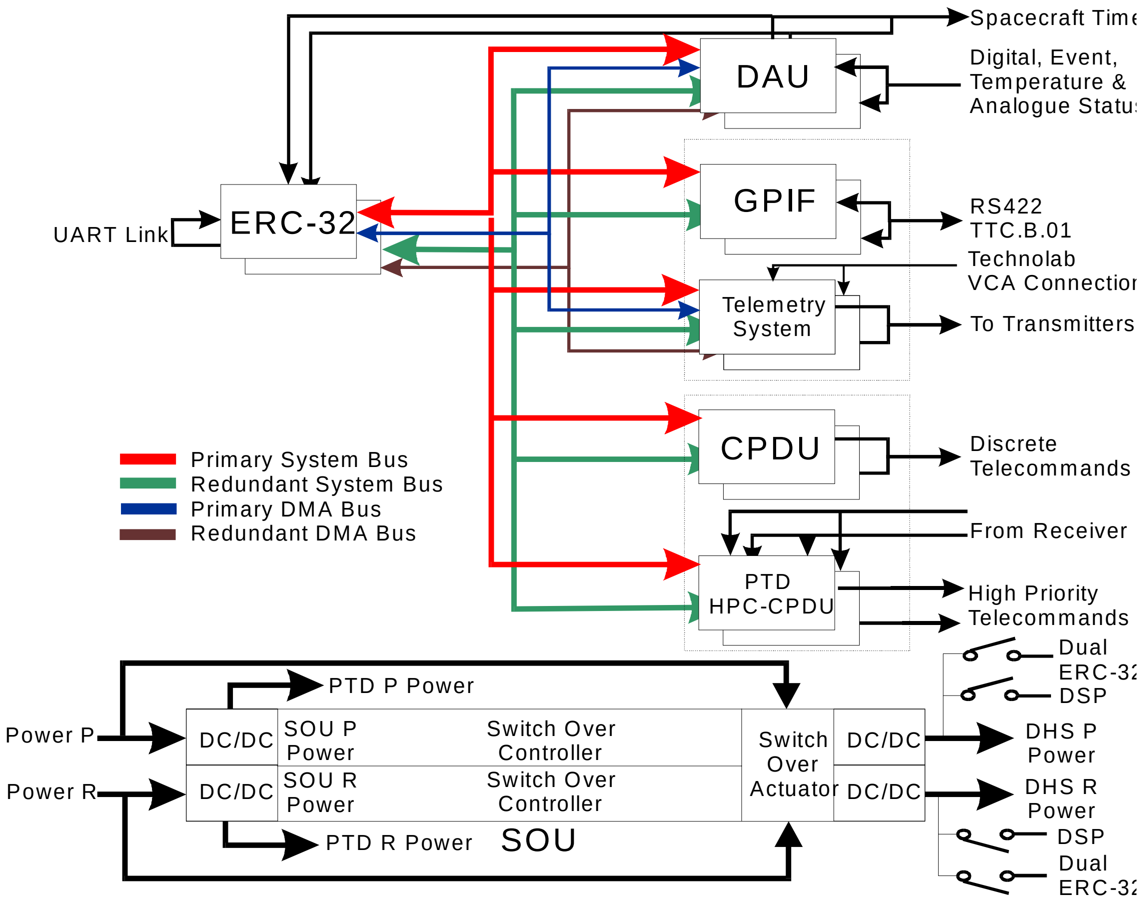

Figure 4: DHS block diagram

The DHS includes 2 of these processors. They are normally used as cold redundant hardware. However, in order to cope with potentially higher processing demands, it is also possible to run the DHS in dual processor mode, where both processors are running concurrently and exchanging data with high speed serial links.

The other functions of the DHS are:

- 2 hot redundant telecommand decoders supporting COP-1 packet telecommanding and direct (MAP-0) ground commands,

- cold redundant spacecraft interfaces, RS-422 or TTC-B-01 for data exchange, pulse, analog, digital, … for commanding, house-keeping and time distribution,
- 2 cold redundant telemetry generators, each supporting 3 Virtual Channels,
- a reconfiguration unit performing the reconfiguration of the DHS in case of software and hardware failure or transient (e.g. Latch-up)

PPU

The PPU is mainly the computer controlling the imaging instruments (provided by MMS UK). It includes a DSP, the TCS21020 for high capability data processing and improved usage of the on-board mass memory through compression.
The TCS21020 is a radiation tolerant (> 100 Krad) 32 bit DSP. It is fully compatible with the ADSP 21020 from Analog Devices. It provides 15 MIPS and 45 MFLOPS. The chip is manufactured by the TEMIC/MHS 0.6 micron SCMOS/2RT+ process.
The mass memory is 1.2 Gbit and uses three-dimensional packaging technology for high-density storage.

The PPU provides also several additional interfaces for other on-board experiments, interfaces to solid state gyroscopes (SSG), an interface to an extra star tracker (PASS), and an interface to a house-keeping bus.
This latter will be used on PROBA to measure temperatures and radiation dose in remote locations of the spacecraft. It uses a collection of devices called SIP (for Smart Instrumentation Point) which are small modules of 15 mm/7,5 mm/5 mm, weighing less than 3 g. They use advanced packaging and include the temperature and total dose sensors, the Analog to Digital converter, and the bus interface. The SIPs were developed by Xensor Integration (NL).

The PPU controls also the imagers (indicated Micro Cameras on Figure 5) covered in the payload section of this paper.

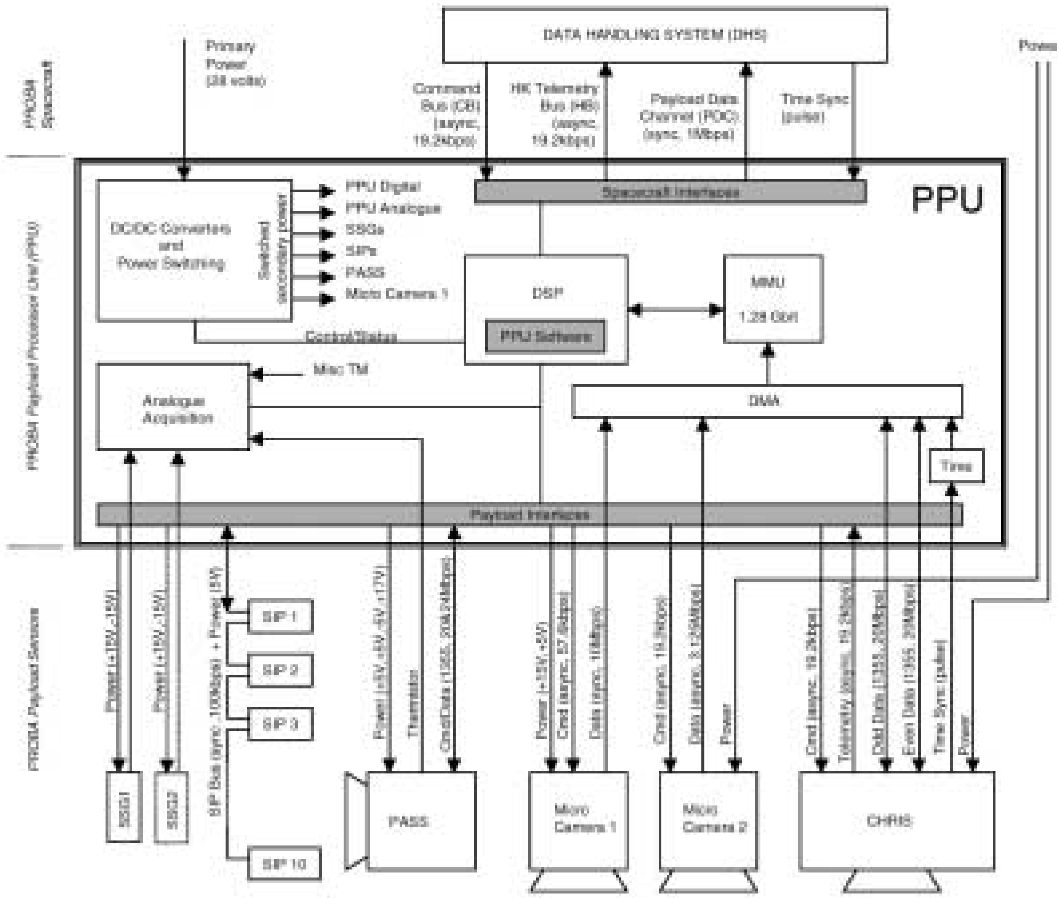

Figure 5: Block diagram of PPU and attached payloads

TT&C

The S band link capacities are 4 Kbit/s for the packet telecommanding and a maximum of 1 Mb/s for the packet telemetry. Standard ESA modulation scheme (PSK/PM) is used for the uplink and BPSK for the downlink.

Off the shelf units from SIL (UK) have been used for TT&C support.

Two hot redundant receivers are connected through a combiner/diplexer to Zenith and Nadir antennas providing omni-coverage commanding of the spacecraft.

Two cold redundant transmitters are connected through a switching unit to Zenith and Nadir antennas providing also omni-coverage telemetry of from the spacecraft.

- **Power**

The basic power consumption of the platform is 35 W. The excess of power will be allocated to the payload. The duty cycle of the instruments will be calculated on board taking into account the available power and energy but also the scientific requests and the available data storage.

The body mounted solar arrays will provide a worst case (end of life, summer solstice) peak power generation ranging from 45 to 67 W per panel. Averaged along the sunlit part of the orbit, the power generation at bus level will be 85 W. The solar arrays are built with 22 strings of 39 to 41 cells grouped in 6 sections. The cells are of a standard size of 3.8x3.5 cm with integrated diode. The panels are provided by Officine Galileo (Italy).

The 9 Ah Li-ion battery will be used mainly in eclipse as the peak power demands in day phase will be almost all covered by power from the arrays. The duty cycle of the instruments will not create a Depth of Discharge higher than 20 %.
The battery is built using standard Li-Ion cells that are screened and matched. Ground testing has demonstrated the compatibility of the battery with the 2 years mission of PROBA.
The battery weights 2.2 kg. It is provided by AEA (UK).

The functions of the PCS are:

- conditioning and distribution of power to users by means of a 28 Volt regulated bus, four non-switchable power lines to the essential sub-systems and twelve switched power lines to payloads and non-essential sub-systems (PDU),
- sourcing of the power from six solar array sections and control by a Sequential Switching Shunt Regulator (S3R),
- sourcing of the power during eclipse or peak power loads, from one battery through two Battery Discharge Regulators (BDR),
- battery monitoring and management (BME),
- battery charging by means of two Battery Charge Regulators (BCR)

Failure tolerance of the PCS is provided by:

- redundant PCS interfaces, BDRs and BCRs,
- majority voting of 3 independent voltages in the Main Error Amplifier controlling the BCR, the BDR and the S3R,

- each of the 6 sections being made of one shunt transistor and two output diodes in series and a seventh “section” connecting a resistor across the power bus,
- redundant End of Charge detection in the BME,
- over-current output protection in the PDU.

The PCS also protects the spacecraft against a power bus under-voltage by turning off all switched power outputs in case of bus or battery under-voltage.

The PCS is controlled by the on-board computer through a redundant 16-bit memory load interface (TTC-B-01) and discrete ground commands. It is provided by SIL (UK).

- **Payloads**

CHRIS
The larger instrument is a Compact High Resolution Imaging Spectrometer (CHRIS) provided by Sira Electro-Optics Ltd (UK) (Figure 6). The scientific objective is to provide multi-spectral data (up to 62 bands) on Earth surface reflectance in the visible/near-infrared (VNIR) spectral band (415 to 1050 nm) with a spectral sampling interval ranging between 2 and 10 nm at high spatial resolution (25 m at nadir). The instrument will use the PROBA platform pointing capabilities to provide Bidirectional Reflectance Distribution Function (BRDF) data (variation in reflectance with view angle) for selected scenes on Earth surface. The instrument will be used mainly to provide images of land areas, and will be of interest particularly in recording features of vegetation and aerosols.

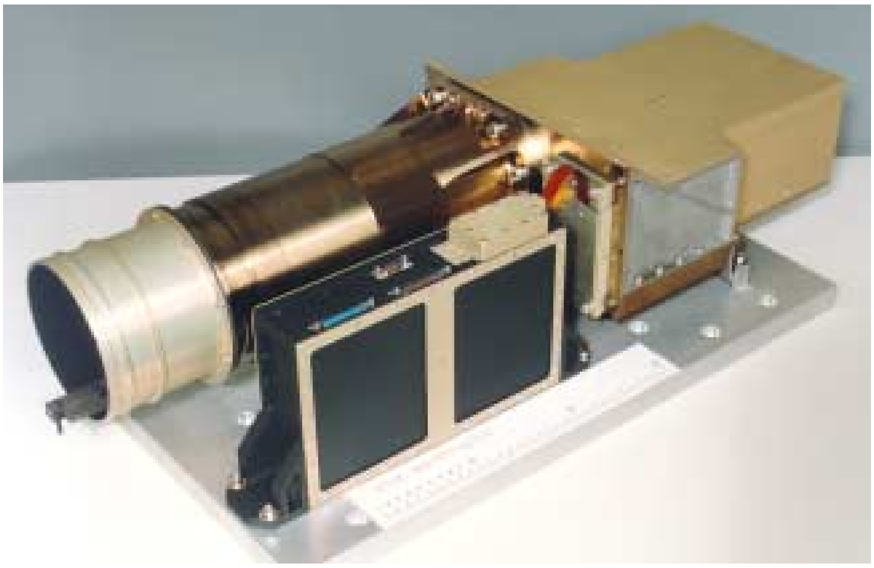

Figure 6: CHRIS instrument

The objective is also to validate techniques for future imaging spectrometer missions possibly on agile small satellite platforms, particularly with respect to precision farming observations, regional yield forecasting and forest inventory.

The instrument is an imaging spectrometer of basically conventional form, with a “telescope” forming an image of Earth onto the entrance slit of a spectrometer, and an area-array detector at the spectrometer focal plane. The instrument will operate in a push-broom mode during Earth imaging. The detector is a thinned, back-illuminated, frame-transfer CCD. CCD rows are assigned to separate wavelengths, and CCD columns to separate resolved points in the Earth image.

The platform will provide slow pitch during imaging in order to increase the integration time of the instrument. This increase in integration time is needed to achieve the target radiometric resolution, at the baseline spatial and spectral sampling interval.

The platform will process imaging demands from ground control specifying:

- target location - requiring roll manoeuvres to point across-track for off Nadir targets,
- viewing directions for each target in one orbit - requiring pitch manoeuvres to point along-track,
- spectral bands and spectral sampling interval in each band,
- spatial sampling interval.

The platform will perform the required pitch and roll manoeuvres and transmit control signals to CHRIS to initiate and terminate imaging, with the required spectral and spatial characteristics.

In-flight calibration for radiometric response, using a dark scene on Earth or the calibration device, will also be supported by CHRIS and the platform.

The digitised data from CHRIS will be stored in a mass memory unit, processed and compressed with a DSP and transmit to ground on command.

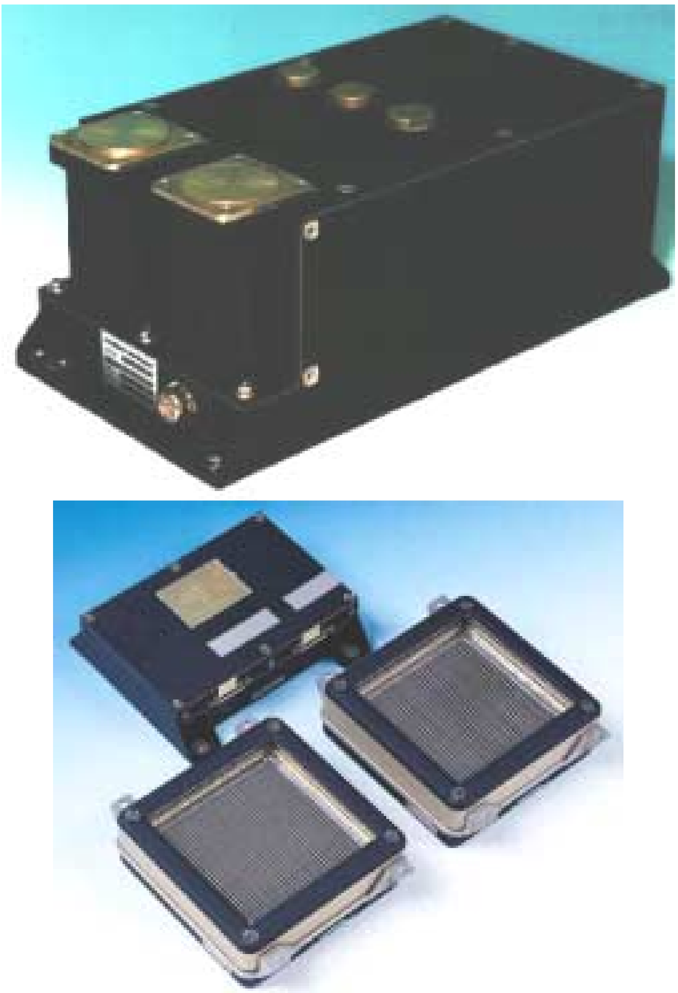

Figure 7: The SREM (left) and DEBIE (right) payloads. Both the processing unit and the 2 sensors of DEBIE are displayed.

SREM

The primary objectives of ESA's Standard Radiation Environment Monitor (SREM) are for space environmental technology research. That is, to derive understanding of the environment which is a hazard to future missions, develop models for engineering, and collaborate in research on the effects of radiation on space systems. However, the SREM data are also available for scientific studies such as particle sources, transport and loss, energisation of radiation belt particles. These activities are strengthened by the availability of SREM data from many different spacecraft.

The path of PROBA will cover the "polar horns", where energetic electrons of the outer radiation belt are transported to low altitudes, as well as the South Atlantic Anomaly (SAA) with its enhanced proton fluxes (the inner part of the inner radiation belt). PROBA will also be exposed to energetic particles from the sun during energetic events, and cosmic rays. These latter environments are modulated by the earth's magnetic field. With SREM, mapping (1), temporal variations (2) and possibly directional measurements (3) of these particles populations will be carried out. The measurements of SREM will also be correlated with on-board degradations caused by radiation on the electronic parts, the CCDs, the solar cells.

(1) Through continuous operation of SREM, the models of the radiation belt positions, the particle fluxes and the geomagnetic shielding will be compared, updated or renewed for various electron and proton energies, and for cosmic rays.

(2) Through long-term operation of SREM, the radiation belt flux variations (storm injections, radiation belt motions), the solar particle event variations, the variation in geomagnetic shielding in response to storms, and the long-term variations in the SAA and Cosmic Rays (CR) fluxes will be studied. The measurements will be correlated with other spacecraft STRV, SOHO, GOES, etc.

(3) Using the manoeuvring capability of PROBA, the anisotropy of the radiation environment at low altitude can be measured. PROBA will be rotated such that the SREM points locally vertically (up and down), and collects particular angles at different locations. In the SAA, PROBA will be slewed up to ±45°. In order to obtain good statistics, this procedure should be performed repeatedly and over a period of time to see long-term flux variations, and during high solar activity to observe possible short-term atmospheric influences. Finally, since the SREM has measurement channels for high-energy protons and heavy ions, asymmetries in cosmic ray fluxes may be observed.

SREM was developed by Contraves (Switzerland).

DEBIE

The DEBris In-orbit Evaluator (DEBIE) detector (Figure 7) on PROBA will measure for the first time the small size particulate fluxes in a polar type orbit. Information on the sub-centimetre size meteoroid and space debris population in space can only be gained by the analysis of returned material (for lower orbits) or by in-situ measurements.

DEBIE, developed by Patria Finnavitec (Finland) uses a combination of impact ionisation, momentum transfer and foil penetration for the detection of impacting particles. Mass and velocity of the impacting particle can be deduced from the recorded signals. The lower detection threshold is about 10^{-14} g.

Two separate sensors facing in different directions (velocity direction and normal to the orbit plan) are mounted on the external walls of PROBA. According to the present models a few impacts per day are expected. The impacts measurements will be sent to ground at each contact together with the time and the sensors attitude and location at the time of the impact.


Figure 8: The two imagers to be accommodated on PROBA: the Wide Angle Camera (left) and the High Resolution Camera (right) providing 10 m resolution.

Imagers

PROBA accommodates two imagers from OIP (Belgium), a Wide Angle Camera and a High Resolution Camera (Figure 8).

In orbit usage of the imagers will be through high level imaging requests which will be scheduled using the fly by prediction and planning functions of the spacecraft. The spacecraft can store and compress hundreds of these images between ground visibility. Images sent to ground will then be distributed using the Web.

WAC is a miniaturised (7x7x6 cm) black and white camera using a 640x480 CMOS Active Pixel Sensor with a field of view of 40 by 31 degrees. Images are digitised on 8 bits before transmission to the spacecraft.

HRC is a miniaturised black and white imager with 10 m ground resolution. The telescope is of the Cassegrain type with an aperture size of 115 mm and a focal length of 2296 mm. The detector is based on a CCD and uses 3D packaging technology. It contains 1024 x 1024 pixels of 14 m size. The field of view (along the diagonal of the detector) is 0.504°. Images are digitised to 10 bits before transmission to the spacecraft.

- **On-board Software**

The on-board software, which is running on the central Data Handling System, is a new development for PROBA. It uses VxWorks as operating system and is implemented in C by Spacebel (Belgium). Apart from the classical functionality of performing the spacecraft control, housekeeping and monitoring tasks, it contains also the autonomy related functionality such as the failure detection, identification and recovery functions, the ACNS software and the on-board mission planner. The latter function plans ground requests for payload operation tasks taking into account the available on-board resources and target visibility as predicted by the ACNS software. The ACNS software, described previously, is produced by the autocoding tool of Xmath and integrated in the rest of the on-board software. The on-board software follows the ESA Packet Utilisation Standard for the communications with the ground. PROBA and its software is designed such that it can be completely reprogrammed in flight.

Development

The classical ESA development approach has been adapted to the objectives and the constraints of Proba. The project life cycle has been split in 3 main phases, the System Design Phase, the Production and Qualification phase and the Integration and Acceptance phase. Between each phase a peer review is performed by Estec.

The model philosophy adapted for PROBA is based on a Structural and Thermal model and the Proto-Flight model of the spacecraft. The PFM approach at spacecraft level was further supported by partial electrical models of most of the bus units.

In the area of software validation, spacecraft testing and operations preparation, the project has tried to optimise the available resources. This has been translated into the usage of a common environment for spacecraft testing and operations and the production of a Software Validation Facility (provided by SSF Finland) the early phase of the project. This latter tool simulates the entire spacecraft and allows that the on-board software executable code is executed in this facility as if it was running in the real hardware while enhanced testing and debugging capabilities are available. This facility is also connected to the common spacecraft test and spacecraft operations environment to provide a spacecraft simulator for the operation teams.

Ground station and operations

One of the benefits of on-board autonomy is the reduced need for ground operators involvement in the mission operations and the associated reduction in ground-station operating costs. To exploit this to a maximum extend, the PROBA ground segment has been automated as much as possible while maintaining the required facilities limited.

With the ground station located in Redu (Belgium) about 4 times 10 minutes of visibility per day will be available in average.

The station, provided by SAS (Belgium), consists of a portable 2.4-m dish with S-band RF front-end and a control centre with limited facilities. The ground station provides the following functions:

1. Automatic link acquisition based on Norad elements and spacecraft navigation data;
2. Communications set-up protocol for the types of data (and their bit-rates) to be received;
3. Automatic uplink of previously screened observation requests and spacecraft planning commands;
4. Automated call of ground staff in case of detection of on-board anomalies;
5. Automated science data filing, notification of scientists and data distribution.

It is the intention that with the combination of on-board autonomy and the automation in the ground station, the involvement of ground operators during nominal and routine mission phases is limited to routine maintenance tasks on (typically) weekly basis. This ground operator receives after every pass a pass report summarising the spacecraft and ground station status. Furthermore, remote access to the ground station via a local network or via the internet provides the operators with the capability to access the downlinked spacecraft data whenever they wish.

To implement the described automations, the ground segment provides besides classical telecommand and telemetry also operation procedures support. These procedures implement the automatic link acquisition, setup procedures, routine spacecraft operation procedures and (limited) telemetry analysis. The same operations environment will also be used during subsystem and system check-out tests performed during the spacecraft integration and validation phase.

CONCLUSIONS

The Proba mission design fulfils the ESA objectives of in-orbit technology demonstration, earth environment monitoring and preparatory earth observation. Technological units represent a significant part of the spacecraft and provide the advanced capabilities required by the instruments.

The instruments will provide valuable scientific or preparatory data.

Proba demonstrates also that microsatellite can efficiently combine in-orbit technology demonstration and operational missions and also be sufficiently flexible to be reconfigured for other missions.

Acknowledgements

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References:

[de Lafontaine 99] J. de Lafontaine, J. Buijs, P. Vuilleumier, P. Van den Braembussche, K. Mellab “Development of the PROBA Attitude Control and Navigation Software”, *ESA-SP-425, Proceedings of the 4th ESA International Conference on Spacecraft Guidance, Navigation and Control Systems,* ESTEC Noordwijk, 18-21/10/1999, p. 427-441.

[Teston 1999] F. Teston, R. Creasey, J. Bermyn, K. Mellab “PROBA: ESA’s Autonomy and Technology Demonstration Mission”, *Proceedings of the 13th Annual AIAA/USU Conference on Small Satellites,* August 23 – 26, 1999

ANNEX-3

DRAFT

EXPERIMENT MISSION IMPLEMENTATION AGREEMENT FOR PROBA II

between

THE EUROPEAN SPACE AGENCY
(herein referred to as 'the Agency')
represented by Mr. A. Rodotà, its Director General,

and

....
(herein referred to as 'the Experimenter')
represented by

....

RELATED TO THE FLIGHT ONBOARD THE PROBA II SATELLITE OF THE .... EXPERIMENT

CONTENTS

PREAMBLE

Whereas the Agency is conducting a mission for the in-orbit demonstration of spacecraft technology (PROBA II or “the Mission”); and

Whereas the PROBA II satellite is a mission for the demonstration of spacecraft technology; and

Whereas the experiment named …….. proposed by …….., the Experimenter, in their capacity as Experiment Provider has been selected by the Agency to form part of the experiment of PROBA II; and

Whereas the Experimenter shall provide the …….. Experiment herein named, also acting as Experiment Provider; and

Whereas the Agency shall supply a flight opportunity for the said Experiment; and

Whereas the provision of the …….. Experiment and of the opportunity for the Experiment to be launched and operated as part of the Mission gives rise to certain rights and obligations for both parties;

The parties hereto therefore agree upon the content of this Agreement:

DEFINITIONS

Experiment item:	The experiment defined herein flown on-board of the PROBA II spacecraft with the aim of obtaining data.
Space Vehicle:	Launcher, satellite, platform or any other means of transport on which the Agency offers the opportunity for an experiment to be flown, operated, and/or tested in space.
Experimenter:	An experiment provider (EP) whose experiment has been accepted for a free of charge flight. The E.P. has the responsibility for the Conduct of his selected investigations vis à vis the Agency (i.e. development, manufacturing, integration, calibration, data analysis).
Data:	Recorded facts, in whatever form, which are transmitted or delivered from space to the ground by telemetry in the form of electromagnetic signals or any other means, whether processed or not.

Abbreviations:

EP	Experiment Provider
EID	Experiment Interface Documents
PROBA II	The PROBA II Satellite

ARTICLE 1 : SUBJECT OF THE AGREEMENT

The Experimenter shall assure the funding and facilities requisite to enable the delivery to the Agency, free of charge to the Agency, of all hardware, software, documentation and services necessary to fulfil the requirements set out in the applicable PROBA II project documentation drawn up to define the supply of an Experiment.

The said hardware, software, documentation and services shall be supplied in accordance with the requirements of the attached EID document list. Notwithstanding that the Agency will make its best efforts to minimise the impact on the Experimenter of any agreed changes to the interfaces as so defined, the Experimenter shall be responsible for the timely implementation of any agreed changes and for the cost thereof.

The Agency shall make provision for the integration of the Experiment into the PROBA II spacecraft, the launch and the post launch and operational phase in accordance with the terms and conditions of this Agreement.

In the event of conflict between the various documents connected with the supply of the scientific experiments, the following documents shall be referred to, the terms and conditions of this Agreement prevailing over all other documents, the Experiment Interface Documents prevailing over all other than the terms and conditions of this agreement.

ARTICLE 2 : RESPONSIBILITIES OF THE EXPERIMENTER

The Experimenter shall be responsible for the discharge of its responsibilities as set forth in the EID, as it may be modified in accordance with Article 1. The responsibilities shall include, but not be limited to, the following:

1) Definition, design, development, manufacture and delivery of the experiment,

2) Execution of the experiment development/procurement programme (qualification, functional interface and performance tests and calibration).

3) Carrying out all tasks and delivery of all items by the agreed dates as specified in the EID or as otherwise agreed with the Agency.

4) Support to the Agency during all project phases (e.g. interface definition, integration, flight preparation, flight, post-flight) as required by the EID and in conformity with Article 4 below.

5) Provision of access to preflight experiment data in accordance with the stipulations of Article 4 below.

6) Evaluation and reporting of experiment performance data during all levels of integration and flight.

7) Support to the Agency during its integrated system tests and ground calibration phases of the experiment and supply of the relevant information in an agreed form.

8) Establishment and execution of the verification programme, ensuring the execution of all tests, etc. necessary for acceptance of the hardware and software.

9) Contribution to launch and operations costs according to the **TBD** scheme.

10) **ARTICLE 3 : RESPONSIBILITIES OF THE AGENCY**

The Agency shall be responsible for the discharge of its responsibilities as set forth in the EID, as it may be modified in accordance with Article 1. The responsibilities shall include, but not be limited to, the following:

1) Management of the development of the space vehicle and coordination of such development with experiment development, ensuring that all mandatory specifications, safety and interface requirements are complied with.

2) Monitoring of the schedule and technical progress of the Experimenter's work as an aid to overall Project Management. To this end, the Experimenter shall grant the Agency's representative(s) access to the experiment at his facilities or at the facilities of his contractor, as appropriate.

3) Granting the formal admittance of the experiment for integration after completion of the necessary acceptance tests.

4) Returning the .... experiment to the Experimenter in case of cancellation or unreasonable delay (i.e. beyond **TBD** months) of the PROBA II mission.

5) Flight data archiving by the PROBA II Operations Control Center.

ARTICLE 4 : INFORMATION AND DATA RELATING TO THE EXPERIMENT

4.1 Information necessary for the Operation of an experiment or for the subsequent Analysis of its Performance

The Experimenter shall provide the Agency with all information which is necessary for the launch and in-flight operation of the experiment. Any proprietary information so provided shall be treated as described in Article 5.

The Agency shall, under similar conditions of confidentiality and as described in Article 5, provide the Experimenter with such information on the integration, test, in-flight performance and operational conditions of the space vehicle as it is necessary for the Experimenter to evaluate the performance of the experiment.

4.2 Distribution of Data from the Experiment

4.2.1 For data acquired through the ESA-operated PROBA II Ground Segment, the Agency shall provide, in an agreed form, to the Experimenter, all relevant data resulting from the in-flight operation of the experiment. The Agency shall be entitled to keep a copy of such data.

4.2.2 For data which may be acquired through an independent Ground Station operated by the Experimenter, the latter shall provide the Agency, in an agreed form, with a log of all relevant data resulting from the in-flight operation of the experiment. The Agency shall have the right to access and use such data upon request.**[TBC]**

4.3 Rights in Data resulting from the Experiment

The Experimenter shall be owner of all unprocessed data directly resulting from the in-flight operation of the .... experiment flown on board the PROBA II spacecraft.

The Agency or its designated representative shall have free-of-charge, unrestricted and irrevocable right of access to the said data, including subsequent rights of data analysis.

The copy of the unprocessed data held by the Agency or its designated representatives shall be kept confidential.

4.4 Publication of Results

The Experimenter shall publish before the end of the nominal mission of PROBA II (1 year), a report presenting the in orbit results of the Experiment. This report shall be agreed by the Agency.

All publications on the experiment or data obtained from the experiment development and/or operation shall make explicit reference to the Agency's PROBA II mission and to the Experimenter's experiment.

Both parties shall provide each other free of charge with three copies of any such publication. Notwithstanding the provisions in Article 4.3 above, each party shall have the right to reproduce and disseminate results which have already been published by the other party.

4.5 Publication of other information

Any publication by the Experimenter concerning the PROBA II mission, with or without reference to the .... experiment, shall be subject to the Agency's written authorisation.

ARTICLE 5 : CONFIDENTIALITY, INTELLECTUAL PROPERTY RIGHT

Any proprietary information provided by the Experimenter to the extent necessary for integration, testing and the in-flight operation of the experiment shall be kept confidential and shall not be communicated to third parties without the prior written agreement of the Experimenter. Such agreement shall, however, not be withheld if, in the opinion of the Agency, the communication is required for the proper operation of the experiment, or for reasons of safety.

The Agency shall, under similar conditions of confidentiality, provide the Experimenter such information on the integration, testing and in-flight performance and operational conditions of the space vehicle as it is necessary for the Experimenter to evaluate the performance of the experiment.

Any invention or proprietary technical data produced by the Experimenter based on and/or after analysis of the data resulting from the integration, testing and in-flight operation of the experiment, shall be the property of the Experimenter subject to the following provisions:

(i) The Experimenter shall inform the Agency of any application for a patent or other form of industrial property right within two months of the filing. The Agency shall treat such information as confidential as long as the application for the patent, or other form of industrial property right, has not been published in accordance with the relevant law or during a period of 18 months following this application.

(ii) The Agency shall be entitled to a free-of-charge, non-exclusive, irrevocable licence to use the invention or proprietary technical data produced by the Experimenter, for its own purposes in the field of space research and technology and their space applications without the right to give sub-licences.

(iii) If the exercise of the above rights should require the use of background information or know-how by the Experimenter, the Experimenter shall give the Agency access to such information on fair and reasonable conditions.

ARTICLE 6 : LOSS OF DATA OR LOSS OF FLIGHT OPPORTUNITY

6.1 The Experimenter shall have no claim against the Agency for any damage or loss arising directly or indirectly from any of the following events and/or from any action which may be taken by the Agency in response to the said events:

6.1.1 Failure to Launch the PROBA II spacecraft, including the experiment

6.1.2 Any malfunction or interruption in the respect of experiment or of spacecraft data

6.1.3 Malfunction of the spacecraft

6.1.4 The Agency's decision not to fly the …….. experiment due to:

- Malfunction of the experiment, which in the opinion of the Agency jeopardises the launch schedule or the safety of the mission.
- Late delivery of the experiment to the Agency or of technical incompatibility between the experiment and the non-experiment elements of the spacecraft, to the extent that in the opinion of the Agency, the Agency's budget or the PROBA II launch schedule or the PROBA II Mission objectives may be jeopardised.

6.2 For events stated under 6.1.4 above, the Agency may decide, after due consultation with the Experimenter, that the experiment cannot be flown and shall so notify the Experimenter in writing of its decision. Notwithstanding the provisions for arbitration contained herein, the Agency's decision deriving from events such as those described under paragraph 6.1.4 shall be without appeal to arbitration.

ARTICLE 7 : LIABILITY FOR DAMAGE AND INJURY

7.1 Each party shall bear the cost of compensation for damage or injury of any kind suffered by its personnel or property in the execution of this Agreement except in cases of willful act or omission by one the Parties.

7.2 The Experimenter shall not make any claim against the Agency and/or its parties for any such damage or for the direct or indirect consequences thereof. Similarly, the Agency shall not make any claims against the Experimenter and/or its parties. Each party shall indemnify the other against all claims which could be exercised by the victim, his heirs, assigns or his social security scheme.

7.3 “The Agency and/or its parties” shall mean the Agency, all Contractors and/or sub-contractors of the aforementioned as well as their employees.

7.4 “The Experimenter and/or its parties” shall mean the Experimenter, scientific partners, all Contractor and/or sub-contractors of the aforementioned as well as their employees.

7.5 The Agency and the Experimenter shall each require their contractual parties and partners to accept the above waiver of liability with the obligation to secure similar agreements with their lower tiers.

ARTICLE 8 : APPLICABLE LAW, SETTLEMENT OF DISPUTES

8.1 This Agreement shall be governed by the laws of ....

8.2 Any dispute which cannot be settled amicably, shall, at the request of any Party, be submitted to an arbitration tribunal. The Party which intends to submit the dispute to arbitration shall notify the other Party.

8.3 The arbitration proceedings shall take place in ....

8.4 Any dispute arising out of this agreement shall be finally settled in accordance with the Rules of Conciliation and Arbitration of the International Chamber of Commerce by one or more arbitrators designated in conformity with those rules.

8.5 The award shall be final and binding on the parties; no appeal shall lie against it. The enforcement of the award shall be governed by the rules of procedures in force in the country having jurisdiction over the Experimenter.

ARTICLE 9 : AGENCY'S REPRESENTATIVES

1. This Agreement and any modifications to it shall not be binding on the Agency unless approved in writing by its Director General or his authorised representatives. For the purpose of this agreement, the authorised representatives of the Director General is

   Mr. ....,

2. For the purpose of this agreement, the Agency's representatives are :

   Mr. .... for technical matters, or a person duly authorised by him;

   Mr. .... for contractual / administrative matters, or a person duly authorised by him.

ARTICLE 10 : ENTRY INTO FORCE AND DURATION

This Document shall enter into force upon signature by ESA and the Experimenter and shall remain in force until completion of the PROBA II mission or any extension thereto. The rights and obligations of Articles 4 and 5 shall survive any expiration of this Agreement.

S I G N A T U R E S

On behalf of the Experimenter by the duly empowered legal representative:	On behalf of the European Space Agency (ESA):
---------------------------------- .... (name and function)	--------------------------------- .... (name and function)

Attachment 1 : EID document list

- Experiment ICD (mechanical, electrical)
- Experiment Parts and Materials list
- Ground handling procedure (TBC)
- Qualification test plan and qualification test report
- Certificate of conformance to in house Product and Assurance standards for flight hardware
- As built CIDL