Contents

→ Introduction ........................................................................................................ 4

→ Summary of Achievements & Challenges
  GSTP activities closed in 2009 .................................................................................. 8
  GSTP activities initiated in 2009 ................................................................................ 10
  GSTP market-oriented activities: A.O. closed and initiated in 2009 .................. 12
  GSTP support to projects: SMOS, ESA’s Water Mission..................................... 14
  GSTP In-Orbit Demonstration: PROBA2 ................................................................. 16

→ Annexes
  Annex 1: Complete list of GSTP activities closed in 2009 ................................. 20
  Annex 2: Complete list of GSTP activities initiated in 2009 ............................... 21
ESA’s General Support Technology Programme (GSTP) exists to convert promising engineering concepts into a broad spectrum of mature products—everything from individual components, to subsystems, up to complete satellites—right up to the brink of spaceflight or beyond.

Its objective is to bridge the gap between having a technology proven in fundamental terms and making it ready for ESA and National Programmes, the open market and, eventually, space itself. The GSTP allows such transitions by developing the technology concepts into engineering models or ‘breadboards’, which involves testing their performance in all conceivable scenarios.

The Programme also works on product and process improvements, aiming to provide a flexible response to the needs of other ESA and National programmes, as well as European Industry. By doing so, it also increases the number of European-made space-qualified parts commercially available.

The GSTP is an optional programme, open for ESA Member States (including Canada as an Associate Member State), which chose whether or not to participate and up to which level. It has been in operation for two decades, covering all ESA Service Domains except Telecommunications (TEL), which has its own ARTES Programme.

Achieving the right balance between innovation—product development & support—strengthens European Industry when continuously trying to increase its capabilities and competitiveness. Industry can count on the Programme’s technical support throughout its product development cycle. A recent example is the GSTP’s emphasis on space-worthy components and building blocks, in order to bring them to higher Technology Readiness Levels (TRLs). Another one lies on the support to the new ESA Space Situation Awareness (SSA) initiative, growing under the Security domain. It will provide Europe with its own capabilities to monitor the space assets on which we rely for daily life.

1 Earth Observation (EO), Space Science (SCI), Robotic Exploration (REX), Human Spaceflight (HSF), Space Transportation (LAU), Navigation (NAV), Security (SEC), and Generic Technologies and Techniques (GEN).
The past year 2009 was no exception regarding the GSTP efforts to achieve the previously described objectives. This GSTP Annual Report 2009 presents a brief description of this work, together with the corresponding achievements.

These efforts and achievements are illustrated throughout this report under the form of successful technology developments as well as innovative missions launched in 2009 with the support of the GSTP Programme. This Annual Report hence provides a general picture of these accomplishments.

Due to the large amount of technology research & development activities that the GSTP supports every year (around 40 activities were initiated whereas around 50 were closed in 2009), only a representative sample is presented here.

The permanently open Announcement of Opportunity (AO) for market-oriented activities allows a fast industrial response to various markets identified by industry. Within the frame of the GSTP Programme, the objective of these market-oriented activities is to support the competitiveness of European industries, enhancing their position to face the worldwide space market in the near term.

Seven AO activities were initiated and eight were closed in 2009. An overview of some of them is included here.

The GSTP is also known for its orbital testing and demonstration activities carried out through small technology demonstrator satellites. PROBA 2, the second of the small series satellite, was successfully launched in 2009 carrying a total of 17 technology demonstrators and 4 scientific payloads. This document highlights the technologies and results already obtained by this In-Orbit Demonstration satellite, developed under the GSTP frame.

Last but not least, the GSTP activities can also serve ESA’s specific projects. A vibrant example is provided by SMOS, ESA’s Soil Moisture and Ocean Salinity mission, which has been designed to observe soil moisture over the Earth’s landmasses and salinity over the oceans. SMOS was successfully launched in 2009, carrying the innovative instrument MIRAS, which was partly developed in the GSTP frame. Further details on the specific GSTP activities in support to this project are provided in this Annual Report, together with the current status of the mission.

Overall, the GSTP efforts in supporting technology in 2009 were remarkable, representing 39 new contracts and 46 activities closed. These activities were to develop breakthrough technology, covering mostly all ESA Service Domains, and to support innovative projects and in-orbit demonstrators like SMOS, PROBA 2, and other under-development missions like PROBA 3, PROBA V or EXPERT.

All this has been achieved with the participation of 18 ESA Member States, Canada as Associate Member State and an annual budget of ~80 M€.
GSTP ACTIVITIES CLOSED IN 2009

2009 has been a fruitful year in terms of closure of contracts, completing the technology developments originally targeted. Some examples of the last achievements are presented hereafter.

Non-conventional Matrix/Carbon Nanotubes Reinforced Composite for Applications in Space (NACO)

Carbon Nanotubes (CNTs) possess physical properties (mainly strength and thermal/electrical conductivity) at least an order of magnitude higher than conventional materials. This activity focused on the creation of CNT-Skeletons, thick non-woven papers or felts, that were embedded in metal, ceramic and polymeric matrices.

The infiltration processes were proved successful for ceramic and polymer matrix composites, and brought improvements on electrical and thermal conductivity, as well as on mechanical and damping properties of the materials.

Further steps involve the improvement of the infiltration and manufacturing process for up-scaling dimensions, so that in the future, and based on these results, these reinforced composites could be used as, e.g., adhesive patch for bonding of stiffeners to CFRP plates, as electrical contacts between CFRP structures, or as highly thermally stable structures.

Planetary Robot Design, Generic Visualisation and Verification Tool (3DROV)

The objective of this activity was to extend the robotics simulation package 3DRM with planetary simulation functions, in order to cover planetary exploration missions.

The new 3DROV package provides a solid framework that allows to simulate complete rover planetary surface operations, in connection with the corresponding environment.

It is organised around five main communicating subsystems: the Environment Model (terrain characteristics, handling of the rover location, ephemeris and timekeeping); the Generic Controller, the onboard autonomous software controlling the rover operations; the Rover Model (rover dynamics, models of the power, thermal, communications s/s, and models of scientific instruments); the 3D Visualisation component, providing real-time visualisation of the simulation run and assisting the preparation of rover and robotic arms activities; and the Control Station, that displays telemetry and enables the mission scenario to be uploaded to the 3DROV Generic Controller.

GPS Precise Orbit Determination (POD) Instrument EQM Development

The objective of this activity was to develop a GPS EQM POD compact instrument for all Earth Observation missions in low Earth orbit requiring accurate geo-localisation, focusing on the Swarm and GMES sentinels requirements.

The consortium was able to create a low-mass and low-power consumption instrument, with a fully flexible software that can be adapted to any mission.

It includes an improved real-time navigation algorithm and, as required, the measurement accuracy was proved to be very close to the theory.
**Design, Development and Test of a Mini Ion Engine System**

Electric propulsion is essential for low altitude missions, where the robust ion engine design and inert xenon propellant are little affected by environmental and atmospheric effects such as atomic oxygen. Consequently, this technology is successfully used for the exploitation of large distributed aperture instruments through precision formation flying; and to allow the correct operation of lidar and cloud measuring radar instruments for environmental missions.

However, to respond to the specific propulsion and control needs of these missions, downscaling of the existing thrusting technology is required.

Therefore, this activity presents the design, development and verification of a breadboard Gridded Ion Engine (GIE) capable of delivering precise thrust modulation in the μN to low mN range.

The conceptual design achieved TRL 4, and its success has lead to a currently running follow-on activity to develop the thruster for its application on-board PROBA-3.

**Development of the TMA Telescope of a Compact Wide Field-of-View Reflective Multispectral Imager**

Spot-5 lifetime expires in 2012 and it was necessary to develop an instrument to ensure continuity of the Vegetation products. Different studies have shown that a compact three mirror anastigmatic (TMA) optical design is essential to meet the observation requirements as a follow-up to the vegetation instrument on a PROBA platform. This optical layout uses only reflective elements and allows to significantly reduce mass and complexity of a multispectral imager with a wide field of view.

However, several major challenges existed in these optics. The complexity of the mirrors design caused doubts on the feasibility of the manufacturing within the specifications and tolerances. Moreover, testing the mirrors was also considered critical as the shape of the mirrors was considered far from ideal to be tested with the normal optical test tools available. A final criticality was found in the assembly and the alignment of the telescope.

This activity aimed at facing those challenges, developing the Engineering Model of a TMA by proving that the manufacturing and assembly processes and the alignment procedures of the telescope are fully mastered. These good results have reduced the risk (feasibility and schedule), prior to the manufacturing of the flight telescopes in the frame of the PROBA V program.

**Compact In-Orbit Optical Image Processor**

Synthetic Aperture Radar (SAR) images are typically processed electronically applying dedicated Fourier transformations. This however can also be performed optically in real-time, providing local access to processed information paving the way for real-time decision-making. This could eventually benefit navigation strategy and instrument orientation decisions. Moreover, for interplanetary missions on-board analysis of images could provide important feature identification clues and could help select the appropriate images to be transmitted to Earth, consequently helping bandwidth management. This could ultimately reduce the data throughput requirements and related transmission bandwidth.

An elegant breadboard of an optical processor for real-time SAR data processing was designed, manufactured and tested under this activity. It is suitable for ENVISAT or ASAR data, with enhanced sampling distances compared to the ENVISAT Level 1 IMS product.
Around 40 activities have been initiated in 2009 under the frame of the GSTP. Highlights are presented.

**High Accuracy APS-based Star Tracker Flight Demonstration (HYDRA)**

ESA jointly with CNES has put in place a development programme for a High Accuracy APS-based Star Tracker (HYDRA), composed of up to three independent APS-based optical heads, connected to two redundant electronics units, which will be equivalent to a three classical star sensor assembly but with major advantages in terms of cost, mass, power, robustness and accuracy.

At the beginning of this activity, the design, manufacture and test of an engineering model had been completed, and the tests results exhibited performance compliant with the specifications.

The objective of this activity was to design, manufacture and test, including the in-flight demonstrations, a HYDRA star tracker composed by one electronic unit connected to two optical heads. This star tracker was mounted on a NPO-PM GLONASS satellite for a demonstration flight on a MEO orbit.

A complete campaign of tests, ranging from performance characterization to mechanical and thermal environment tests at qualification level, was successfully performed on the Engineering Model and has allowed to characterize finely the Optical Head elementary performances in order to establish a consolidated performance budget at Critical Design Review.

**Large Format SWIR Focal Plane Array**

Internal ESA studies and interaction with industry have shown that it is necessary to meet the requirements of an instrument to continue the work of the Vegetation sensor (VGT). Such a Vegetation Gap Filler will use an optical design based on a very compact Three Mirror Anastigmatic (TMA). This optical layout requires a large format detector array based on InGaAs technology. InGaAs detectors can be operated without a cooling system, simplifying significantly the design of the instrument and reducing the mass and power budgets.

The future Proba Vegetation mission requires a focal plane detector with 3000 pixels whilst the previous largest detectors were only 512 pixels long.

This activity aims at developing a large format Short Wave Infrared (SWIR) detector for the Proba Vegetation mission. The linear InGaAs detector, together with its Read Out Integrated Circuit (ROIC) are being developed and tested to reach the required format of 3000 pixels.

**ADIBEAM: Adaptive digital beamforming techniques for GNSS receivers**

The precision provided by current generation GNSS receivers together with the use of sophisticated processing methods leaves multipath and interference as the dominant remaining error sources affecting GNSS performance. Moreover, the experience gained in the use of adaptive antenna arrays in terrestrial communications can be incorporated in space-borne GNSS receivers aimed at missions with very demanding accuracy requirements.

The ADIBEAM project has as objective the preliminary definition of a GNSS ground tracking station with digital beam-forming capabilities, as well as to assess via simulation and modelling its possible tracking performance.

The goal is to arrive at intelligent techniques that use most of the information available in the receiver to adapt the antenna array to the particular scenario.
Optimisation of an EMTVC with respect to Side Loads on a Main Cryogenic Stage

The objective of this activity is to enlarge the application area of Electro-Mechanical Thrust Vector Control Systems (EMTVC) to VULCAIN 2-like engine nozzles, featuring the optimisation of the TVC (electro-mechanical actuator, digitally-controlled power electronics, battery system and control loops architecture) to meet the specific side loads constraints.

In a previous GSTP-3 activity, “High Power Electric Actuator (HPEA)”, a HPEA EMTVC breadboard was developed. This new activity is concentrated on the optimisation of the Electro-Mechanical Actuator (EMA) design and of the control laws with regards to side loads. Modifications on the electronics and the battery system could result from a maximum supply voltage constraint identified on a main cryogenic stage due to the presence of gases like hydrogen, oxygen and helium on cryogenic stages.

Phase I of this activity has recently ended with a proposed actuator design, and Phase II will be running to review the requirements, manufacture and test the EMA breadboard and finally update the actuator mathematical model.

Experimental evaluation of MEMS-based micropropulsion for future missions

MEMS technology is feasible for propulsion systems where thrust levels in the μ-Newton range are needed. In this regard, a MEMS-based propulsion system is currently planned to perform its first flight on Prisma in 2010. Although the Prisma flight undoubtedly will be a major milestone in this context, it is clear that this short mission will not be able to cover the requirements imposed by other future missions such as Proba-3, Simbol-X, Xeus or Gaia.

A significant impact on the feasibility of cold gas micropropulsion is the choice of propellant. Trade-off studies on propellant selection have revealed the potential gain, at spacecraft system level, when choosing a different propellant than Nitrogen, which makes MEMS technology an emerging candidate for micropropulsion.

The overall goal of this activity is then to expand the envelope of MEMS-based micropropulsion beyond the current level of verification. The envelope shall be expanded in terms of life & cycle requirements and other propellants than gaseous Nitrogen.

For this purpose, a flight-like micropropulsion subsystem is being built, and it will be tested against a requirement specification (minimum thrust level, thrust noise, specific impulse) covering a relevant portion of future satellite missions. So far, this micro-thruster has an increased thrust control functionality and performance, reached by integration of a MEMS-sensor directly on the MEMS thruster chip, which gives a high performing response time of the actual signal.

Performance enhancements for trace gas monitoring (ANITA2)

The ANITA2 enhancements are hardware and analysis related activities in support of the ANITA Trace Gas Monitoring system development for the ISS. Hardware wise, the most critical elements (i.e. modulator, IR source) have been identified and improvements proposed (stability increase, volume reduction). Today, the main focus is on the modulator and demonstration tests are being performed.

Analysis related activities currently focus on improving and automating the transfer of calibration models from ANITA to the next generation instrument, ANITA2. They are also focused on increasing the robustness of the analytical models on hardware ageing and changing environmental conditions, as well as the autonomy of ANITA from ground based support.

Based on the results of the feasibility tests, a development plan for ANITA2 will be produced, with the aim of reducing the volume of the instrument by ~50%, and its mass by ~40%, while improving robustness and sensitivity of the system.
The Permanently Open Announcement of Opportunity supports the competitiveness of the European Industry, enhancing its position to face the worldwide space market in the near term.

**Novel Sensor for IR Spectroscopy based on Configurable Diffractive Optical Elements**

Under the scope of this activity, a fully functional sensor demonstrator for methane (CH₄) gas concentration measurement was designed, fabricated and tested. The novelty relies in the silicon device: the CDOE (Controllable Diffractive Optical Element) is a micro-opto-electro-mechanical system (MOEMS), which serves as a two-state spectral filter in the infrared.

At the start of the activity, the principle of the CDOE infrared filter had been proven, but no fully functional component had been fabricated. At the end, a stable fabrication process was proved, and the first devices are reliable both electromechanically and optically, according to specifications.

The main advantages of these devices compared to the existing commercial products are the significant reduction in the number of optical components, the simplified sensor assembly and a lower energy consumption.

Finally, the CDOE can be tailored to detect other gases like CO₂ and N₂O through minor changes in the design, and other possible applications have been identified, such as adaptive optics and femtosecond pulse shaping.

**Development of a Miniaturised Laser Ranging System (MYLRAD2)**

Accurately measuring distances without contact is a key functionality, particularly in planetary exploration, robotics, satellite docking and metrology. Distance measurement systems based on Time-of-Flight (TOF) methods with lasers, laser rangefinders using triangulation, 3D time-of-flight cameras, or stereo-cameras using correlation algorithms open a new field of possibilities.

The motivation of the MYLRAD (Micro Laser Ranging Device) project is to explore a direct digitisation method for the phase information of the signals, within a miniaturised light-weight laser TOF ranging device for space applications.

While a previous ESA study developed the precursor MYLRAD1 system, the current activity aimed at developing and testing MYLRAD2, with the objective of optimizing the performance of the instrument. It was successfully accomplished in terms of sensitivity to reflectivity changes, noise and range ambiguity.

**Specific Testing Equipment and Methodology for Sputtering Tests of Electric Propulsion Materials**

The main objective of this activity was to develop, set up and optimise an adequate service to evaluate materials subjected to a relevant sputtering effect (ion bombardment) during their life service. This behaviour has a prime relevance for the design and life prediction of Electric Propulsion (EP) units since the generation and acceleration of ions is at the basis of nearly all EP thrusters.

The proposed approach focused on the evaluation of representative technological samples, in order to get valuable results about sputtering mechanisms involved, sputtering yields and even data for life expectancy assessment of final components.

The testing facility and methodology developed will be an appropriate tool for further development of tailored and optimised ceramic materials for EP systems. A test campaign on these composites was indeed led, whose results constitute a key step for the development of optimised ceramic materials for EP systems.
Qualification of Low Mass Configurable Solar Array Drive Mechanism (SADM)

The development of a new generation of SADMs is an essential part of a program to develop and qualify a new generation of Solar Array Drive products, versatile enough to fill two different type of mission requirements: missions where only limited Solar Array movement is needed, and those requiring continuous 360° rotation of the Solar Arrays during Earth orbit.

The main goal of this activity is to complete the design (selected to fit the requirements of the future Sentinel 1, 2 and 3 satellites), build and qualify a low cost, low mass, low volume, high reliability and configurable Solar Array Drive Mechanism (SADM), focusing on European components.

Within the frame of this activity two SADM Engineering Qualification Models (EQM) will be built. One of them will be equipped with a Twist Capsule to cover the need for non-continuous rotation SADMs. The other SADM EQM will be equipped with a Slip Ring for continuous rotation, using exactly the same drive unit and identical mechanical interfaces than the Twist Capsule, which will give the SADM the desired versatility.

At the moment the Twist Capsule has passed a Preliminary Design Review and the Twist Capsule EQM is currently under manufacture. A preliminary design for the Slip Ring was also proposed, modified to fit the Sentinel-3 requirements.

On-Board Mission Scheduler

One of the most attractive characteristics of the PROBA system is the level of on-board autonomy of the spacecraft, together with the highly integrated level of automation of the ground system. However, the on-board autonomy can be further enhanced by improving the capacity of the platform in terms of resource management and mission scheduling.

In order to enhance the overall operational system performance, this activity proposes to develop a pre-operational model of an automated on-board mission scheduler, to be demonstrated in the future PROBA Vegetation mission (PROBA V). This piece of software application, interfacing with the existing in-house Data Handling System (DHS), will allow the simplification of the ground operator tasks and further increase the on-board autonomy.

The advanced scheduler, dedicated to on-board routine mission programming, will respond to requirements defined at PROBA mission and system levels. This will guarantee that the resulting development fits well the identified mission needs and enhance the overall operability of the system.

Development of out-of-autoclave process for large integrated thermoplastic composite structures

It is estimated that the use of advanced thermoplastic composites such as carbon fibre/PEEK and integrated manufacturing concepts can lead to a 10-15% weight reductions over baseline carbon fibre/epoxy autoclaved structures.

The aim of this activity is to manufacture an integrally-stiffened curved panel or Large Integrated Structure (LIS), using advanced thermoplastic composites, with approximate dimensions of 1m x 2m. This curved panel is based on an Ariane 4 interstage structure, composed of 8 “blade” stiffened panels. This structure will be produced using a vacuum-pressure consolidation Out-Of-Autoclave (OOA) process and specific thermoplastic joining techniques.

This technology will lead to an estimated 60% savings in manufacturing cost. It will also lead to lower the dry mass of future launchers and other spacecraft structures, as well as to reducing manufacturing timescales and to simplifying test procedures.
**SMOS: ESA’s Water Mission**

ESA’s Soil Moisture and Ocean Salinity (SMOS) mission is the first one designed to observe soil moisture over the Earth’s landmasses and salinity over the oceans. SMOS will strengthen Europe’s role as key player in Earth Observation and help advance environmental research, addressing the challenges of understanding how the Earth system works and how human activity is affecting natural Earth processes.

**MIRAS: A completely new type of spaceborne instrument**

Designed and built by a European consortium of industry and science, SMOS shows what European cooperation can achieve. It demonstrates Europe’s excellence in engineering and science by adopting a completely novel approach for observing Earth from space. SMOS’ ability to measure soil moisture and ocean salinity is based on the fact that both parameters affect the electrical properties of land and ocean surfaces.

SMOS carries a novel instrument called the Microwave Imaging Radiometer using Aperture Synthesis (MIRAS), capable of observing both soil moisture and ocean salinity by capturing images of emitted microwave radiation around the frequency of 1.4 GHz (L-band). MIRAS is the first polar-orbiting, spaceborne, 2D interferometric radiometer.

To achieve the spatial resolution required for observing soil moisture and ocean salinity, a huge rotating antenna would have been necessary for a conventional radiometer. Instead, an elegant solution has been found to avoid such a costly and heavy system that would be difficult to employ in space. The required antenna aperture is synthesised from 69 separate antenna elements, which are equally distributed over three deployable arms (which form a Y-shape) and the central structure.

MIRAS’ novelty is also due to the fact that it is entirely reliant on an optical fibre-based communication harness. Dedicated optoelectronic transmitters and receivers as well as passive fibre optic splitters had to be developed, leading to the first mission-critical use of fibre optics.

**GSTP in support of MIRAS**

The design and construction of SMOS involved more than 10 years of research and development, and more than 20 European companies led by EADS CASA Espacio (Spain) for the payload, and Thales Alenia Space Industries (France) for the satellite. During this whole process, the GSTP has supported 11 activities for the development of MIRAS, 7 of which were running during the design and construction phases of the instrument and are now successfully closed, and the 3 remaining ones involving the SMOS operating phase and future improvements of the instrument, and are currently running. A brief description of all of them is provided below.

- **I71.EOS-001** - **I71.EOS-008: SMOS P/L Phase C/D**
  The Proto-flight SMOS payload (PFM PLM) assembly, integration and testing was completed at the EADS CASA Espacio facility in Madrid, and delivered to ESTEC, where the formal payload environmental verification (covering mass properties, acoustic noise and thermal balance/thermal vacuum) and full-performance verification were carried out.

  Shipment to Thales Alenia Space, Cannes, for Star-tracker integration and EMC compatibility took place by the end of June 2007 and, finally, the satellite AIT was successfully completed.

- **I71.EOS-009: SMOS Payload Data Processing Centre (Phase B)**
  Successfully closed in 2005, followed by:

  - **I71.EOS-010: SMOS Payload Data Processing Centre (PDPC) Phase C/D**
    After launch, the PDPC has been switched on and supported the processing of data and distribution to the cal/val team right from the beginning. The processors at Level 1 and 2 are now being evaluated and debugged with real data, and supporting facilities are adapted as needed.

- **I71.EOS-011: Receiver Technology for SMOS Operations**
  The objective of this activity is to study receiver technologies and system aspects of an improved MIRAS-2 instrument and to demonstrate any performance enhancements by prototyping. A two-year study programme was kicked-off in 2007 with EADS CASA Espacio of Madrid, as study leader, and MIER Communications of Barcelona and the Technical University of Catalonia (UPC) as subcontractors.

  Its agreed configuration is now subject to initial breadboarding. Completion, at a level that includes necessary functionalities, like fiber optic communications, correlators and calibration, has been proposed as additional GSTP activities pending approval by IPC and the delegations concerned.
Improving our understanding of the global water cycle

The amount of water in the soil and the salinity of oceans may not seem connected, but, in fact, they are both key variables linked to the global water cycle. Variations in soil moisture and ocean salinity are a consequence of the continuous exchange of water between the oceans, the atmosphere and the land-Earth's water cycle, which not only sustains life on earth but also plays an important role in weather and climate.

There are currently relatively few global datasets on either soil moisture or ocean salinity. However, this information is urgently needed to improve our knowledge of the global water cycle and help understand more about how a changing climate may be affecting patterns of evaporation over the land and ocean. SMOS will fill this gap by providing a global image of surface-soil moisture every three days within an accuracy of 4% at a spatial resolution of 50 km – comparable to detecting one teaspoon of water mixed into a handful of soil.

Data from SMOS will also provide regular maps of salinity in the surface waters of the oceans. These maps are needed to further our knowledge of the processes driving the global ocean circulation patterns that are conducted by changes in the sea-surface temperature and salinity.

Mission Achievements

Launched on 2 November 2009 together with PROBA2, and after a successful Launch and Early Orbit Phase (LEOP), SMOS sent its first images in mid-November 2009, and confirmed that all the systems are operating normally.

During the actual Commissioning phase, expected to finish in May 2010, the instrument MIRAS is being subjected to the various calibrations needed to ensure that the best possible data are delivered. ESA's major concern, the electromagnetic cleanliness of MIRAS itself, vanished after the first tests with the complete instrument, where it achieved unbiased high quality measurements.

In addition, the processing system has to be fine-tuned to account for any disturbance the signal may encounter from the Sun, atmosphere, etc. This is involving scientists and engineers carrying out field campaign activities to take in situ data of soil moisture and ocean salinity that can be compared with the data being received from SMOS. The first of these campaigns has been completed in southeast Australia in March 2010, and the second one will take place in Europe between April and July 2010.
In-Orbit Demonstration is the last step on the technology development ladder. New technology products need to be demonstrated in orbit, particularly when users require evidence of flight heritage or when there is a high risk associated to the new technology. PROBA2 (Project for OnBoard Autonomy) is the second mission of the ESA’s In-Orbit Technology Demonstration Programme, dedicated to the demonstration of innovative technologies. PROBA2 is designed, developed and implemented as a small mission, with a spacecraft only weighing 120 kg., and yet providing performances compatible with demanding science or Earth observation instruments.

 Ensuring a competitive European Industry
Small, low-cost missions allow small companies access to space and provide them with the experience that is essential for European industries to be competitive and innovative. PROBA2 is the result of ESA's commitment to technological innovation. In total, 10 European countries' and Canada were involved in the construction of this small satellite, with a total of 31 participating institutions. Altogether, 17 new technology demonstration payloads and 4 scientific experiments are being flown on PROBA2.

PROBA2 Technology Demonstrations
A large number of new technologies are being demonstrated onboard PROBA2 for fine performance characterisation and to gain flight heritage and in space experience. These can be split into two groups, those that are an integral part of the satellite platform and those just for demonstration purposes and not mission-critical.

<table>
<thead>
<tr>
<th>TECHNOLOGY DEMONSTRATION</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. On-board software</td>
<td>On-board spacecraft software, flight software with new GNC algorithms for full on-board autonomous navigation.</td>
</tr>
<tr>
<td>3. μ-ASC Star Tracker</td>
<td>Miniaturised and high-tracking rate autonomous star sensor.</td>
</tr>
<tr>
<td>4. AOCS design and software</td>
<td>Design and development of the complete AOCS using specification and auto-coding tool.</td>
</tr>
<tr>
<td>5. Reaction wheels</td>
<td>COTS based miniature wheels.</td>
</tr>
<tr>
<td>6. Li-ion battery</td>
<td>New small Li-ion cells.</td>
</tr>
<tr>
<td>7. Propulsion module</td>
<td>Xenon gas propulsion system, using resistojet thrusters and a solid-state nitrogen gas generator to pressurise the propellant tanks.</td>
</tr>
<tr>
<td>8. GPS sensor (Phoenix)</td>
<td>Miniaturised, COTS-based GPS sensor.</td>
</tr>
<tr>
<td>9. GPS receiver</td>
<td>Dual frequency GPS receiver.</td>
</tr>
<tr>
<td>10. Digital Sun-sensor</td>
<td>New development.</td>
</tr>
<tr>
<td>13. Fibre Sensor Demonstrator</td>
<td>New sensing system based on optical fibres to monitor temperature and pressure around the satellite interfacing with the propulsion module.</td>
</tr>
<tr>
<td>15. Set of magnetometers</td>
<td>High-precision, high-rate, three-axis magnetometers.</td>
</tr>
<tr>
<td>17. Laser Retro-Reflector (LRR)</td>
<td>Passive optical device for precise satellite orbit determination.</td>
</tr>
</tbody>
</table>

PROBA2 Scientific Payloads
The PROBA2 science payload consists of four instruments,• Sun Watcher using APS detectors and Image Processing (SWAP)• Lyman alpha RAdiometer (LYRA) and two space weather experiments (plasma measurements instruments):• Thermal Plasma Measurement Unit (TPMU)• Dual Segmented Langmuir Probe (DSLP)

<table>
<thead>
<tr>
<th>SCIENTIFIC PAYLOAD</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWAP</td>
<td>Telescope to image the solar corona in the extreme ultraviolet (EUV), using novel pixel sensor technology.</td>
</tr>
<tr>
<td>LYRA</td>
<td>Solar UV radiometer, monitoring solar radiation in 4 ultraviolet bands, chosen for their relevance to solar physics, aeronomy and space weather.</td>
</tr>
<tr>
<td>TPMU</td>
<td>TPU will measure the total ion density and electron temperature, the ion composition and temperature, and the floating potential of the satellite body. It comprises a sensor unit (probes and preamplifiers) and a processor unit.</td>
</tr>
<tr>
<td>DSLP</td>
<td>Instrument to study the electron density and temperature in the background plasma of the Earth’s magnetosphere. The main objective is to identify ionospheric plasma response to variable solar activity and sudden space weather events. It consists of two Langmuir probes, electronics and small data processing unit. It shares power, interface and processing resources with TPMU.</td>
</tr>
</tbody>
</table>
Mission Achievements

PROBA2 was launched on 2 November 2009, as secondary passenger of the ESA SMOS mission. Following successful insertion into a dawn-dusk 730 km orbit, the spacecraft was activated and the commissioning activities of the platform, instruments, technology demonstrators and ground segment were initiated. The spacecraft is now in operational mode with full performances.

Most technology demonstrators have been successfully activated and first data showed good performances, with fine analysis now on-going with the technology providers. The science payloads, SWAP, LYRA, TPMU and DSLP have also been successfully commissioned, and science data is being acquired since end of December 2009. The images of the Sun so far acquired by SWAP demonstrate the overall excellent health of the platform and the instrument itself.

The commissioning phase finished at the end of January and the nominal mission has started with further exploitation of the technology demonstrators and payloads.
# Annex 1: Complete List of GSTP Activities Closed in 2009

<table>
<thead>
<tr>
<th>Prog. Reference</th>
<th>Activity Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>A03.MMO-010</td>
<td>TMA Telescope with Large Field of View</td>
</tr>
<tr>
<td>A09.MCL-678</td>
<td>Trace Gas Monitor (TGM) Flight Experiment</td>
</tr>
<tr>
<td>A057-01MC</td>
<td>Nitrification Control in Waste Water Treatment Plant</td>
</tr>
<tr>
<td>A054-01MP</td>
<td>Specific Testing Equipment and Methodology for Sputtering Tests of Electric Propulsion Materials</td>
</tr>
<tr>
<td>A061-03ED</td>
<td>Extension of EETF for TOPS mode processing</td>
</tr>
<tr>
<td>A064-01MM</td>
<td>Development of a Miniaturised Laser Ranging System</td>
</tr>
<tr>
<td>A066-07MM</td>
<td>Novel Sensor for IR Spectroscopy Based on Configurable Diffractive Optical Elements</td>
</tr>
<tr>
<td>B35ESC001</td>
<td>LEON and Cocos Chip Integration</td>
</tr>
<tr>
<td>B36.ESD-014</td>
<td>Support for the Distribution of On-Board Control Services</td>
</tr>
<tr>
<td>B45.MCT-989/990</td>
<td>Two-Phase Loop Integration and Lifetesting</td>
</tr>
<tr>
<td>C56.MPA-813</td>
<td>Investigation of the Effect of an Unsteady External Pressure Environment on Separated Nozzle Flows</td>
</tr>
<tr>
<td>D57.MCS-003</td>
<td>Verification of Resin Transfer Moulding (RTM) as Alternative for Space Component Manufacturing</td>
</tr>
<tr>
<td>E62.MM-I-037</td>
<td>PRN-CW Backscatter Lidar Prototype</td>
</tr>
<tr>
<td>A09.MCT-995</td>
<td>Higher Plant Compartment in Bioregenerative Life Support</td>
</tr>
<tr>
<td>B38.ETM-179</td>
<td>Integrated Receiver Front-end</td>
</tr>
<tr>
<td>B45.MCT-697</td>
<td>Thin, Flat Evaporator for Two-Phase Loops</td>
</tr>
<tr>
<td>I74.127-001</td>
<td>Multi-Axial Stress &amp; Strain Sensing of Thermo Hardened Composite Elements Using Fibre Optic Sensors (MASSFOS) (Announcement of Opportunities)</td>
</tr>
<tr>
<td>G101-04MM</td>
<td>Characterisation of New Calibration Diffuser Types</td>
</tr>
<tr>
<td>G102-24EE</td>
<td>Passive Sub-Array Technological Developments</td>
</tr>
<tr>
<td>G102-25MC</td>
<td>Ultra-Stable Structures for Interferometric Antennas</td>
</tr>
<tr>
<td>G103-37MP</td>
<td>Design, Development and Test of a Mini Ion Engine System (parallel contract)</td>
</tr>
<tr>
<td>G203-06MM</td>
<td>Lithographic Manufacturing of Zero Order Gratings (ZOG) for Innovative Achromatic IR Phase Shifters</td>
</tr>
<tr>
<td>G213-13MM</td>
<td>Planetary Robot Design, Generic Visualisation and Verification Tool</td>
</tr>
<tr>
<td>G303-04MC</td>
<td>MELISSA/BIORAT Genetic Stability Study (Phase 2)</td>
</tr>
<tr>
<td>G303-05MC</td>
<td>MELISSA Adaptation for Space - Phase 2</td>
</tr>
<tr>
<td>G308-03MM</td>
<td>High Resolution Diagnostics for Crystal Growth</td>
</tr>
<tr>
<td>G312-06MM</td>
<td>Optical Modelling of Corner Cube Retro-Reflectors (CCRM)</td>
</tr>
<tr>
<td>G408-10MPf</td>
<td>Development and Testing of a Miniaturised Plasma Reflectometer Prototype</td>
</tr>
<tr>
<td>G408-11MP</td>
<td>Tools for the Study of Dynamic Stability of (Re)entry Vehicles in the Transonic/Supersonic Regime</td>
</tr>
</tbody>
</table>
PROG. REFERENCE | ACTIVITY TITLE
--- | ---
G601-13MM | High Precision Linear Actuator
G601-57EC | Next generation APS for AOCS
G601-63MC | Deployment Simulation of Complex Antenna Structures
G601-68MP | High Accuracy Spacecraft Propellant Gauging Using MEMS Technology
G607-18ED | Deployment Demonstration of the CFDP Standard in Space Applications
G608-02QM | Non-Conventional Matrix/Carbon Nanotubes Reinforced Composite for Applications in Space
G608-14QM | Development of New Thermal Control Paints for Space and Launcher Applications
G609-13MM | MAPLE-BIOLIFT 2 - Technique for Printing Microbioarrays
G609-23MM | Compact In-Orbit Optical Image Processor
G609-32ES | Compatibility of the RIT-22 Grid Ion Engine with the New Generation of EPPM
G609-34QC | Technology Flow Evaluation and Qualification of SAW Filters
G609-36MM | Development of an Adjustable Large Range Viscous Rotary Deployment Damper
G609-39MM | Voice Coil Motor Engineering Model
G609-48MM | Development of the TMA Telescope of a Compact Wide Field-of-View Reflective Multispectral Imager
I71.PROT-003 | SGVM: Science Grade Vector Magnetometer

→ ANNEX 2: COMPLETE LIST OF GSTP ACTIVITIES INITIATED IN 2009

PROG. REFERENCE | ACTIVITY TITLE
--- | ---
AO06-01MM | Development of a Multi-Purpose Thruster Orientation Mechanism (TOM)
AO06-02MM | Qualification of Low Mass Configurable Solar Array Drive Mechanism (SADM)
AO86-01MM | Development of X-Ray Window Membrane
AO86-05SY | On-Board Mission Scheduler
AO86-06MC | Development of Out-of-Autoclave Process for Large Integrated Thermoplastic Composite Structures
FF04-03SC | Optical Metrology: Coarse Lateral Sensor (CLS)
FF05-06EP | Development of a Power Conditioning Unit for a Mini-Ion Engine (PROBA3)
G102-46EE | Micromachined Receiver
G103-05ET | Adaptive Digital Beamforming Techniques for GNSS Receivers (ADIBEAM)
G103-13MM | Adaptation of Industrial Motor Technologies for Space Applications
G103-38ED | CCSDS Image Compression ASIC
GSTP Annual Report 2009

PROG. REFERENCE | ACTIVITY TITLE
---|---
G215-01PP | Components Qualification for GAIA Optical Source Electronics (OSE)
G304-04MC | Performance Enhancements for Trace Gas Monitoring (ANITA II)
G408-20MM | Optimisation of an EMTVC With Respect to Side Loads on a Main Cryogenic Stage
A086-03GS | Earth Observation Down Converter Evolutions
G601-73MP | Experimental Evaluation of MEMS-Based Micropropulsion for Future Missions
G601-74MC | Advanced Thermoplastic Materials (ATM) for Spacecraft Applications
G601-75MP | Development of a Low Thrust Biopropellant Thruster Based on Green Propellant
G601-80MP | Preparation for Chemical Propulsion Development / Exploration
G602-26QC | Integrated Radiation Environment, Effects and Component Degradation Simulation Tool
G602-27EE | Proto-Flight Model of the Energetic Particle Telescope (EPT) Phase C/D
G603-32ET | GNSS Space Software Receiver Prototype and Independent AGGA-4 Validation
G603-50EC | High Accuracy APS-Based Star Tracker Flight Demonstration (HYDRA)
G607-20SW | Open Image Generation System II
G609-34MM | Polishing of Brazed Optical Quality SiC Mirrors
G609-46MC | Exchange of TMG Thermal Models Via STEP-TAS
G609-49MM | Large Format SWIR Focal Plane Array
G609-65MP | Experimental Investigation of Key Technologies for a Turbine-Based Combined Airbreather-Rocket Engine - Phase I
G703-05SY | PATP - Application Domain of the PROBA Platform
G703-06SY | Earth Observation Down Converter Q0001/COA2
G703-07ST | ESTEC Incubator - AGRIBASE Project
| ESTEC Incubator - AQUACINEMA
NP10-04ET | European Schottky Technology - Parallel Contract Tyndall
GSTP-ITI | Georeferenced Airport Obstruction
NP10-04ET | European Schottky Technology - Phase 1
NP10-12MP | Development and Qualification of a Slow Acting Latch Valve
NP30-06SY | Mission and Payload Accomodation Analysis for European Space-Based Maritime Reconnaissance & Surveillance System
P3-01 | PROBA-3: Space and Ground Segment
PV-01 | PROBA-V Space and Ground Segment - Phase B
GSTP Participating States

Austria
Belgium
Czech Republic
Denmark
Finland
France
Germany
Greece
Ireland
Italy
Luxembourg
Netherlands
Norway
Portugal
Spain
Sweden
Switzerland
United Kingdom
Canada

A. Tobías
U. Becker
N. Peinado
I. Alonso Gómez

General Support Technology Programme Section
GSTP and Product Development Division (TEC-SG)
Systems, Software and Technology Department
Directorate of Technical and Quality Management

ESTEC
Keplerlaan 1 - P.O. Box 299
2200 AG Noordwijk
The Netherlands

→ GSTP ANNUAL REPORT 2009