

PROBA Spacecraft Family

Small Mission Solutions for Emerging Applications

Jo Bermyn and Chris Dorn

Abstract Small Satellites are now being developed by many organisations. These are now a mature technology and have demonstrated their potential as a product with complementary performances to more conventional mission solutions.

Recent successes with the PROBA 1 (with more than 5 years of operations in orbit) and the UK's Topsat spacecraft show the potential to use these platforms in flexible and low-cost ways for Earth Observation missions. ESA's Earth Observation Directorate uses PROBA 1 on a daily basis in support of research related to vegetation, disaster monitoring, land use, volcano observations, etc. Topsat supports a number of users with up to date imagery and has demonstrated several new approaches to data downlink & distribution.

With continued advances in technology, new areas in Earth observation are being explored and applications like high resolution-, hyper spectral- and small SAR radar missions become feasible with a PROBA scale platform and its derivatives.

As small satellite missions become more ambitious, so the space industry is adapting to the challenge of creating organisations which can deliver the advantages of small satellite technology while retaining compatibility with international data standards and operating practices. The merging of Verhaert Space and QinetiQ's Space Division is a first step in the creation of a solid mid-tier player dedicated to small mission solutions, combining complementary skills in mission design, system integration and key areas of technology development to offer end-to-end solutions to customers worldwide.

This paper will outline high-performance solutions for future Earth observation missions, highlighting the role that cutting-edge technologies have to delivering unique capability to meet customer needs.

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1 Small Missions Heritage

1.1 Proba 1/Proba 2

Mid nineties, ESA initiated the idea for building a small satellite for technology demonstration purposes, called PROBA (Project for On-Board Autonomy). With the financial support from the Belgian Science Policy Office to ESA's General Support Technology Programme (GSTP), Verhaert Space finally could win the phase C/D contract that started in February 1998.

PROBA 1 is the first Belgian small satellite and is developed by Verhaert Space as prime contractor. The satellite, only weighing 94 kg with dimensions $80 \times 60 \times 60$ cm, was realised in about 3 years. The strong features of the PROBA platform lie in the field of autonomous operation (low operational cost), its simplicity in operation, its performant attitude control system and its strong Léon based computing capability. PROBA's 3-axis attitude control system provides fine-pointing capabilities, resulting in precise snapshot images (e.g. HRC instrument – 4 m pan images) and has agility to execute demanding mapping and push-broom scanning scenarios (e.g. CHRIS instrument – 18 m multispectral images).

Although designed for a lifetime of only 2 years, PROBA 1 is now functioning in-orbit for more than 5 years and providing earth observation images through ESA to the science community on a daily basis.

In the meantime, its successor PROBA 2 carrying sun observation instruments is under final integration at Verhaert Space and is planned for launch early 2008.

The PROBA platforms are operated through a small ground station (2,4 m dish) located at the ESA Redu site in the Belgian Ardennes.



Fig. 1 PROBA 1 on PSLV launcher (ISRO./Antrix)

Fig. 2 PROBA/HRC Image of pyramids of Gizeh (ESA)



Fig. 3 PROBA/Chris image of 3 gorges dam China (ESA/SIRA)



Fig. 4 PROBA 2 under integration at Verhaert Space



1.2 TopSat 1

On 27th October 2005, TopSat was successfully launched. It has since been producing high quality imagery to satisfy a range of user requests.

The purpose of the programme is primarily to demonstrate the ability to build and operate a low cost optical satellite capable of generating high quality imagery.

Fig. 5 TopSat spacecraft platform (outer panels removed for clarity)

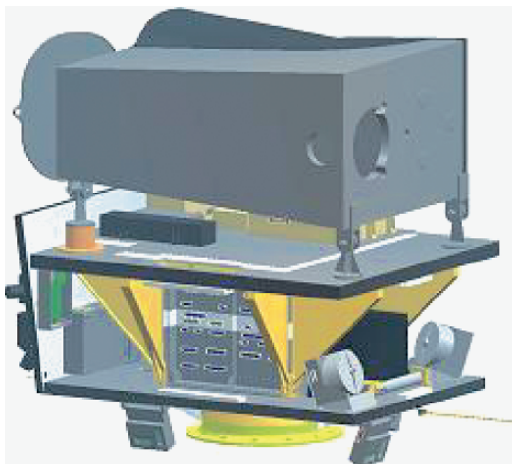


Fig. 6 Image of Marseilles, France



The satellite produces panchromatic imagery (17×17 km) with a spatial resolution of 2.8 m, and multi-spectral imagery (12×18 km) with 5.6 m resolution. Imagery is

routinely downloaded to QinetiQ’s ground station at West Freugh, Scotland, where it is forwarded to the Payload Operations Centre in Farnborough for processing and dissemination to users.

Fig. 7 The West Freugh ground station



Fig. 8 The RAPIDS mobile ground station



In addition, QinetiQ has developed a mobile ground station, consisting of a 2.7 m receiving dish towed by a Land Rover, which has demonstrated the ability to downlink near-real time TopSat imagery directly to end users.

1.3 New Approaches

Missions such as Topsat and Proba are made possible by the pragmatic application of key technologies and new approaches to the programmatic and system design. A flexible response to the customers needs is the hallmark of the QinetiQ-Verhaert approach. Simplified programmatic structures, integrated teams, on-board automation and new technologies all have their part to play in reducing costs. The mission must be

viewed as a complete system and the component segments design to minimise through life costs by matching risk with customer expectation and technical solutions.

2 Small Mission Solutions

Small satellites can play an important role for earth observation applications, which is proven in the meantime by the successful PROBA/Topsat missions.

To date, the application field stays limited to imagery with up to a few meters of ground resolution and a few spectral bands in the visible and near-infrared spectrum. Clearly, this is driven by the resources and performances available on small platforms but thanks to the evolving technologies on payloads and platform side a lot of other applications come within our reach.

A nice example of this capability improvement is demonstrated on PROBA 2; compared to PROBA 1 the payload carrying capability is increased from 30% to 40%. A major contribution in this improvement is coming from our on-board computer based on the Léon chip, 3,3 V and SMD component technology.

Small missions will never be suited, and are not intended, to replace the full capability of large systems, but they will be a very interesting complement to it. Small missions may be able to provide solutions for 80% of the requirements at only 20% of the cost and as such are very interesting as gapfiller, precursor or stand-alone solution.

Over the years, several concepts and ideas were worked out to show the potential of our PROBA platform for emerging applications. Indeed, we can talk about the Proba Spacecraft Family of which some key potential is highlighted hereafter.

2.1 *Small Satellites for Earth Observation*

Future important application fields for small missions lie in the area of high-resolution images (security – dual use), more spectral bands (vegetation – precision farming) and SAR imagery (overnight visibility).

Clearly, this type of instruments requires more power, more volume, more data storage & downlink capability, but smart solutions and optimisations allow overcoming of the challenges.

Several studies were carried out to demonstrate the feasibility of following missions based on a PROBA platform:

2.1.1 High Resolution

The major challenge for this type of missions is the thermal stability on the instrument and platform stability required to provide sharp images.

Availability of high performance gyro's in combination with a performant attitude control system on the satellite, allow to build PROBA satellites which can provide ground resolutions up to 1 meter (e.g. ARGUS phase A study for ESA).

2.1.2 Multispectral/Hyperspectral/Lidar

Access to QinetiQ's specialised hollow wave guide technologies offer the possibility of smaller sensors which will deliver comparable optical performance on small satellites. New mission solutions including Lidar and microwave sounder systems will become possible with QinetiQ's Gallium Nitride technologies. These offer the possibility of even smaller and more electrically efficient sub-systems. Currently a study for a multispectral mission, called PROBA Landobs, is ongoing.

Multi – and hyper spectral instruments work typical at lower resolutions but generate huge amounts of data. Here solutions can be worked out in several areas, starting with data capturing optimisation (to reduce the capture of un-usable data), data compression and storage and high power downlink capacity.

2.1.3 Radar

Radar missions on a small satellite are a challenge since we have to deal with relatively large antenna systems and large peak power requirements.

Studies are ongoing to fly optimised systems with shorter lifetime (less redundancy) on a small platform, and investigation continues in to low altitude missions.

2.1.4 Formation Flying

Formation flying with small platforms is demonstrating the usefulness for pré-cursor missions. Before entering in a very ambitious science mission, critical technologies can be developed and demonstrated in orbit in a fast and cost-effective way.

Currently, two parallel phase A studies are on-going for ESA for a PROBA 3 formation flying mission.

2.1.5 Microgravity Platform

Verhaert Space performed for ESA a study (Wakeshield type of platform for high-quality microgravity research). In this concept, we use a PROBA based free-flyer which operates in the vicinity of the ISS. The challenges added to the platform are related to docking & payload exchange and the triple redundancy required for safety related aspects.

2.1.6 Small Satellites for Interplanetary Mission

NEO missions such as SIMONE, as well as ESMO and Don Quijote are predicated on the use of electronic propulsion (EP) to access regions of the inner solar system (beyond Earth's gravitational influence).

In addition to the existing LEO applications of small spacecraft, new missions are being developed to utilise small satellites in other Earth orbits. Access to MEO, GTO and even GEO is becoming possible with new upper stages and launchers. These can be coupled with a range of propulsion systems for new mission solutions.

2.2 *Small Satellites for Great Science*

Small satellites offer the following advantages for science missions in LEO, GEO, GTO and the inner solar system:-

- More measurements = better science
- Lower cost = affordable where previously assumed not
- Single primary instrument = optimised missions
- Smaller consortia = less compromise (on mission issues)
- Shorter build times = faster response
- Lower cost and faster response = more missions

QinetiQ-Verhaert is involved in the following key areas that make such missions possible:-

- Concept Development (technical and consortia)
- System prime
- Core bus with Electric propulsion options
- Technology insertion (into science group designed instruments)
- Technology adoption at bus level (for greater payload capacity)
- Technology delivery (key subsystems with flight heritage)
- Mission Management and operations

3 **Qinetiq & Verhaert Space, Your Partner for Small Space Missions**

The acquisition by QinetiQ of Verhaert Space in September 2005 paves the way in the creation of THE small space missions company in Europe. The joining of skills from QinetiQ's space division – with a lot of heritage in mission design and innovative technologies, and Verhaert Space – a seasoned small (smart) space systems integrator, creates an entity that can offer attractive small mission solutions to governmental and commercial customers worldwide.

As small missions prime, we enter the so-called Mid-Tier segment, where challenging missions based on small satellite platforms will be developed.

Small missions require smart and innovative solutions but at the same time they have to stay affordable and require realisation within reasonable timescales. In fact, these projects are too big for small companies (risk & capabilities) and too small for large companies (priority & cost effectiveness).

The QinetiQ-Verhaert teaming allows such mission to be undertaken in an appropriate and efficient way, with the right priority (small mission are a key account for us). Furthermore, we combine the flexibility and cost efficient approach of smaller organisations with the quality standards, facilities and credibility of larger organisations. As such we provide optimum value-for-money while delivering flexible solution that meet the customer's *real* needs.

4 Conclusion

The Verhaert Space – QinetiQ team can offer a wide range of small satellite solutions based on the PROBA spacecraft family.

The strong points are:

Reliable/robust platform

- Five years in orbit and still in excellent shape (original mission: 1 year)

Demonstrated its potential as Earth observation platform:

- Originally pure technology demonstration, but now part of earth observation user programme
- Used on daily basis by ~60 user groups

Autonomous Operation

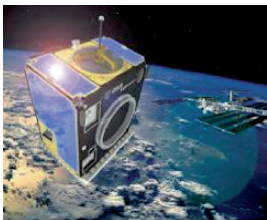
- Onboard Autonomy (orbit & attitude determination, FDIR)
- Ground Segment Automation (low operational cost)
- Simple commanding : 1 image = 1 command (coordinates)
- Performant on-board computer

Fine Pointing & Stability

- Agile platform (3-axis stabilized)
- High pointing accuracy
- High pointing Stability (point & stare – snapshot imaging)
- Complex manoeuvring (motion compensation – push broom imaging – multiple backward / forward scanning)

Modularity and flexibility in design

ESA Quality Label



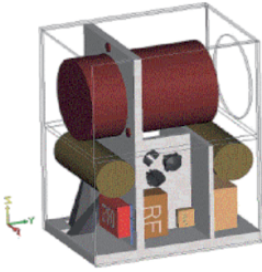
μ G platform



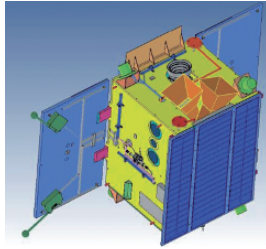
Science mission



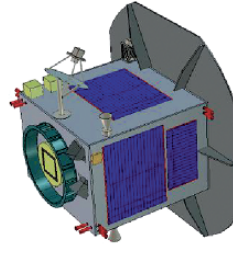
Formation Flying



High-resolution concept



Multispectral mission



Near Earth Object spacecraft