PROBA: AN ESA TECHNOLOGY DEMONSTRATION MISSION WITH EARTH IMAGING PAYLOAD. FIRST YEAR OF IN ORBIT RESULTS.

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ABSTRACT

ESA’s Proba micro-satellite, launched on October 22nd, 2001, is in an elliptical 600 km LEO Sun-synchronous orbit.

Principally meant for the in-orbit evaluation of new spacecraft technologies and satellite operational autonomy, Proba is also being employed as a flight opportunity for a range of Space Environment and Earth Observation instruments, to take advantage of the pointing and agility capabilities of this small gyro-less platform.

Proba’s onboard automatic functions include all payload operations scheduling and execution of high-level requests from users.

Proba’s main Earth imaging payload, CHRIS, used to measure directional spectral reflectance, is capable of imaging the same target at several different sensor view angles in up to 62 spectral bands simultaneously across the 415-1050 nm spectral range, with a spectral resolution of 5-12 nm, a spatial resolution of approximately 17 m at nadir and a swath width of 14 km.

In addition to CHRIS, the HRC is a monochromatic camera with a miniaturised Cassegrain telescope, having 5 m geometrical resolution, a field-of-view of 0.504 deg and a 1024x1024 pixel CCD detector.

Proba users to date include more than 60 Earth observation Principal Investigators within Europe, the USA, Canada, Australia and elsewhere. The mission, initially intended as a technology demonstration to last one year, has been extended for another year for Earth Observation purposes.

1. INTRODUCTION

Proba (Project for On Board Autonomy) is a mission of the European Space Agency’s General Support Technology Programme [1, 2]. Work on the project began in mid-1998 and Proba was successfully launched on October 22nd, 2001 into a LEO Sun-synchronous 681x561 km orbit, with an inclination of 97.9°.
The spacecraft, a 60x60x80 cm box, has a mass of 94 kg, with 25 kg dedicated to eight Space Environment and Earth Observation instruments, in addition to 30 kg devoted to six technology demonstration payloads. Mission operations are located at the ESA Redu (Belgium) ground station.

Proba’s principal objectives are the in-orbit demonstration of advanced hardware and software spacecraft technologies and the evaluation of satellite operational autonomy.

The Proba project development approach is also innovative, based on design-to-cost, a simulated development environment, the adoption of commercial processes and an integrated ESA-industry design and development team.

Proba, however, is also intended as a flight opportunity for various Earth Observation and Space Environment instruments, both for in-orbit demonstration and to exercise the pointing and agility capabilities of the satellite.

2. PROBA MISSION ENABLING TECHNOLOGIES

Proba provides full on-board flight dynamics and orbital navigation computation, as well as automated on-board functions handling nominal spacecraft operations and control and resources management. Payload resources management, payload operations scheduling and execution, target fly-by prediction and computation, and the control of imager pointing and scanning from high-level requests from users (target latitude, longitude and altitude) are hence fully automated.

The point and stare requirements, automatic scanning and motion compensation needs, and the multiple-image scan capability required by Bi-directional Reflectance Distribution Function (BRDF) studies are satisfied, with an accuracy compatible with the instruments performances. Indeed, Proba’s attitude control system allows the platform to perform versatile, automatic, large-angle slews, permitting several different types of imaging modes (e.g. target pointing, BRDF analysis and variable push broom).

A GPS sensor providing 20 m position knowledge, a set of four miniaturised reaction wheels, an autonomous 2-head star tracker for fine attitude determination and two Kalman Filters (10 and 6 states) working at 6 Hz for orbit and attitude propagation, satisfy the navigation accuracy needs and attitude determination and control requirements of the platform for Earth pointing or inertial frames. The absolute pointing accuracy of 150 arcsec and the relative pointing stability of 10 arcsec over 10 s, as well as the spacecraft agility (along- and across-track) and slew rate requirements (up to 1 °/s), enable multiple images acquisition (typically 5) of the same target during a single orbital overpass.

The Proba ground segment provides the complementary functions of spacecraft pass operations, satellite performance evaluation, users requests management and science data distribution.

3. CHRIS RESULTS

Proba’s main Earth-imaging payload, CHRIS (Compact High Resolution Imaging Spectrometer), weighting only 14 kg, produces hyperspectral image data in up to 62 spectral channels across the spectral range 415-1050 nm, with a spectral resolution on 5-12 nm. Although CHRIS is highly configurable in terms of the spectral channels in which it records image data and the spatial resolution at which these are acquired, in practice it is
operated in four main modes when imaging the Earth surface, namely (i) 62 spectral channels at 34 m spatial resolution, (ii) 18 land and atmospheric sensing channels at 17 m spatial resolution, (iii) 18 spectral coastal and inland water channels at 17 m spatial resolution, and (iv) a half-swath mode (i.e. c. 7 km image width) in 34 spectral channels at 17 m spatial resolution.

The combination of the Proba platform and the CHRIS instrument provides unique potential for Earth imaging. It allows hyperspectral image data to be obtained at up to five different sensor view angles during a single orbital overpass through along-track pointing and, cloud-cover permitting, up to 15 looks at the same target within a period of a few days from multiple orbital overpasses. These data can be used to derive information on the biophysical and biochemical properties of the land surface, atmosphere and coastal and inland waters through, for example, the numerical or analytical inversion of BRDF models. The latter describe the physical mechanisms by which solar radiation is scattered anisotropically at the Earth surface. Since many BRDF models are specified in terms of measurable biophysical properties, it is possible to invert CHRIS/Proba data against these models to yield estimates of their driving parameters (e.g. LAI, albedo). The fact that the multiple-view-angle (MVA) data recorded by CHRIS/Proba are provided in multiple spectral channels means that it is also possible to separate more effectively the effects of surface biochemical (e.g. canopy chlorophyll content) and biophysical properties on the detected signal.

An ESA AO was used to select approximately 60 Principal Investigators from Europe, Canada, the USA, Australia and elsewhere to study the data produced by CHRIS/Proba. The data are currently being used for a range of environmental science applications, including the assessment of forest resources, the determination of water quality, crop monitoring and biomass assay, the estimation of atmospheric optical properties, and the evaluation of a range of other land-surface biophysical and biochemical properties. The study sites for which data are being acquired are dispersed around the world. To ensure that as many cloud-free scenes as possible are acquired, a novel image-scheduling procedure is employed, based on predictions of cloud-cover provided by the UK Met. Office.

Early results show that the CHRIS instrument is performing very well. The image data have excellent radiometric properties (dynamic range, signal-to-noise ratio, etc.) and geometric and spectral fidelity. A large number of image data sets have already been acquired. These are currently in the process of being distributed to the PIs.

Figure 1 provides an example of a CHRIS image acquired over an area of agricultural land to the west of Johannesburg, South Africa. The image is a false colour composite of visible and near-infrared channels. Of particular interest are the small water bodies (light blue/cyan) scattered throughout the scene. The excellent radiometric characteristics of the CHRIS data allow numerous features in the water bodies to be discerned. This is promising, since one of the main aims of CHRIS is to evaluate water quality, including algal blooms and suspended sediment concentrations.

Figure 2, by contrast, shows a unique view of the Earth surface provided by CHRIS.
This image extract covers another area of agricultural land, near San Rossore, Italy. Unlike the previous image, however, the colour composite has been produced by co-registering three separate CHRIS images, each recorded in a single spectral waveband (red wavelengths), but at different sensor view angles with respect to the target area. In other words, it is a Multiple-View-Angle (MVA) composite [3]. The colours in this image indicate that the different crop types exhibit contrasting directional reflectance properties. These are primarily controlled by their biophysical properties (e.g. geometric structure). Thus, by exploiting both the spectral and directional reflectance domains, CHRIS provides an enhanced potential for surface materials mapping and their biophysical/biochemical assay.

4. HRC RESULTS

Proba’s HRC (High Resolution Camera), primarily intended for technology, educational and general public information purposes, is a monochromatic camera with a miniaturised Cassegrain telescope, having a total mass of 2.1 kg, an aperture of 115 mm and focal length of 2296 mm. Furthermore, the camera has 5 m geometrical resolution at 600 km, a field of view of 0.504° and a 1024x1024 pixel CCD detector. The fulfilment of HRC very tight requirements, confirmed by this imager’s very good results (an example of which is provided in Figure 3, showing a view of Lower Manhattan, N.Y., USA), has also fully demonstrated the navigation, manoeuvring, pointing and attitude stability performances of the spacecraft platform.

5. CONCLUSIONS

Proba users to date include more than 60 Earth observation Principal Investigators from scientific Institutes within Europe. Proba and CHRIS provide today a unique capability in orbit for remote sensing, providing a wealth of high quality images and of Earth observation data. Due to the obtained results, Proba initial one-year mission as a technology demonstrator has been extended for another year as an Earth observation mission.

6. REFERENCES

1. Proba ESA Web Site: http://www.esa.int/export/esaMI/Proba_web_site/index.html