PROBA-3 MISSION

L. Tarabini Castellani[(1)], S. Llorente[(1)], J.M. Fernandez[(1)], M. Ruiz[(1)], A. Mestreau-Garreau[(2)], A. Cropp[(2)], A. Santovincenzo[(2)]

[(1)] SENER Ingeniería y Sistemas, S.A. C/ Severo Ochoa 4, 28760, Tres Cantos (Madrid), Spain, +34 91 807 85 00, lorenzo.tarabini@sener.es.

[(2)] ESA/ESTEC, Keplerlaan 1, 2200 AG Noordwijk, The Netherlands, +31 71 565 6565, Agnes.Mestreau-Garreau@esa.int

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ABSTRACT

PROBA is a space program managed by ESA for the in-orbit demonstration of platform and payload technologies. PROBA-3 aims to demonstrate Formation Flying (FF) technology. The mission consists of two small spacecraft of 350 kg and 200 kg flying in a formation with relative position control accuracy of less than 1 mm. The two spacecraft will be controlled in space as if they were two parts of a telescope (i.e. lens and detector). This virtual rigid structure will be commanded to rotate and point to any desired direction. It will also be possible to set the relative distance of the two spacecraft from 25 to 250 meters (i.e. change the focus). In order to complete the end-to-end validation of the formation flying technologies, a scientific instrument, a coronagraph, has been selected with the goal of taking pictures of the inner solar corona. The coronagraph system is distributed over the two satellites; one carrying the detector and the second one carrying the Sun occulter disk. The formation flying demonstration requires a low gravity gradient region that will be achieved during the apogee of a highly elliptical orbit. The selected orbit has perigee height of 600 km and 100 times higher apogee (60.000 km). The formation is broken and reacquired every 20 hours, since it cannot be maintained at perigee. The PROBA-3 spacecraft are designed to execute autonomously this orbital routine with no support from ground.

PROBA-3 is currently being developed by a large consortium with a Core Team of companies lead by SENER and completed with GMV Aerospace and Defence, QinetiQ Space nv, EADS CASA Espacio and Spacebel. The industrial team includes also OHB Sweden, NGC Aerospace, QinetiQ Ltd, Elecnor Deimos and Deimos Engenharia.

PROBA-3 mission relies on fully autonomous operations. Ground uplink a high level telecommand list every four days and the master spacecraft autonomously commands the formation satellites to enter proper GNC modes and switch on and off the required equipments. The designed orbital routine for the PROBA-3 nominal operation is rather complex and consists of four different phases detailed in the following list:

- Perigee Pass Phase. This phase is centered around perigee where relative navigation solution is obtained from GPS measurements.
- Formation Acquisition Phase. Formation flying metrologies are acquired while the spacecraft are drifting. Once metrologies are locked, satellites establish controlled formation at a distance of about 150m.

- Apogee Operation Phase. During apogee operation phase, the formation flying demonstration and experiments activities takes place. Formation flying demonstration counts on different manoeuvres to be exercised. Experiments include different GNC software modes and risky operations like realistic collision avoidances scenarios.
- Perigee Pass Preparation Phase. After Apogee phase, perigee pass manoeuvre is executed to ensure no collision risk at perigee and formation reacquisition at next apogee entry.

In order to ensure spacecraft and formation safety in case of contingency, a distributed Failure Detection, Isolation and Recovery (FDIR) system is designed.
PROBA-3 FDIR deals with the complexity of fault management of two spacecrafts flying in close formation. FDIR system has to monitor and recover failures at spacecraft level (as a stand-alone entity) and failures that can cause a collision between spacecrafts. Any failure at spacecraft level could impact in the formation flying and vice-versa. PROBA-3 FDIR design is composed by two separated entities working together in the system: Spacecraft FDIR (SC-FDIR) and Formation Flying FDIR (FF-FDIR).

FF algorithms are designed to use the metrology sensors to execute autonomously a defined set of maneuvers. These maneuvers have been selected in order to demonstrate the capability to build a large virtual structure in space. In particular the FF algorithms will allow the following operations:

- Formation Station keeping at different relative distances from 25m to 250m.
- Formation Resize between 25m and 250m.
- Formation Retargeting up to 30º.
- Combination of Station Keeping, Resize and Retargeting.

Different performances are required for station keeping and maneuvers.

FF technology demonstration is a milestone for future small and large scale virtual structure mission. Virtual structure will allow small spacecrafts, flying with a fixed relative geometry, to synthesize giant structure-less instruments. Example of virtual structure missions are:

- Solar corona missions, where one satellite is used to eclipse the Sun.
- Two elements space telescopes, composed by a lens-spacecraft and a receptor-spacecraft separated tens of meters.
- Multi-element space interferometer missions, composed by several telescope flyers and a central combiner.
- Multi-spacecraft SAR topographic levelling missions, composed by a fleet of several small satellites.

The paper will provide a description of the PROBA-3 mission currently successfully completing the phase B. Special emphasis will be put on the main mission novelties.