Microscope mission: on-orbit assessment of the drag-free and attitude control system

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Microscope is a CNES-ESA-ONERA-OCA mission whose main objective is to progress in fundamental physics by testing the Equivalence Principle (EP) with an expected accuracy of 10^{-15}. The scientific instrument is a differential electrostatic accelerometer developed by ONERA. The more than 300kg drag-free microsatellite was launched on April 25th 2016 into a 710km dawn-dusk sun-synchronous orbit for a 2-year mission.
The Drag Free and Attitude Control System (DFACS) use the scientific instrument itself in the control loop for sensing linear and angular accelerations. A set of 8 cold gas proportional thrusters perform the 6-axis actuation. In mission mode, the propulsion subsystem continuously overcomes the non-gravitational forces and torques (air drag, solar pressure, etc.) in such a way that the satellite follows the test masses in their pure gravitational motion. Several attitude guidances (inertial, rotating) are available to choose the frequency of scientific interest Fep of the session (Fep, from 0.17 to 3.11mHz). The drag-free performance demonstrated on Microscope is now by far the finest ever achieved on low Earth orbit : $<10^{-12}$ m/s^2 @Fep, three axis for up to 8 days.
The attitude control is also very accurate: the long-term attitude measurement is provided by a beefed-up two-camera head star tracker; an original accelero-stellar hybridization finely performs the estimated attitude in order to fulfil the angular rate stability requirement ($<10^{-9}$ rad/s @Fep)

The paper will be divided into three main sections:

- From a brief description of the Microscope mission, we will recall some of the most challenging performances and constraints that the DFACS has to comply with, and how they led to the hardware and software design: the star-tracker layout, the propulsion configuration, the specific hybridization of the angular measurements, the complex problem of the huge gain controllers;
- Then, we will outline the major phases of the commissioning months: from the first switch-on of the scientific instruments, the star-trackers and the propulsion system, gradually picking up steam until getting all of them in the same control loop; and finally carrying out definitive tunings and reaching full performance;
- We will mainly focus on the most striking on-orbit observations: the linear and angular orbital perturbations (air drag, solar pressure, gravity gradient effects, and magnetic torques), the micro-perturbations (on-board *clanks*, debris impacts), the accelerometer and star-tracker low frequency performance, the propulsion main feature (response time, noise, gas consumption); we will finally point out the DFACS overall performance with the comparison to the simulations.

The 26th ISSFD symposium will take place one year after the Microscope launch, the paper and the presentation will provide the first description of the DFACS behaviour and performance observed in-flight.

References

[1] Valerio Cipolla *et al.*, 'Microscope, a microsatellite for Equivalence Principle Measurement in Space', 25th Annual AIAA/USU Conference on Small Satellites