MICROSATELLITE AUTONOMOUS GNC IN-FLIGHT VALIDATION

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ABSTRACT

Going toward a higher level of on-board autonomy is of major interest for satellites. For what concerns the Guidance, Navigation & Control (GNC) functions, more spacecraft autonomy allows:

- To reduce the constraints for up-link contact and consequently: less ground operations, less ground station booking (number of passes and volume of telecommands to upload), an increased spacecraft reliability in case of temporary link loss,…
- To enhance the pointing accuracy, using up-to date orbital data for computing the targeted attitude

<u>Context and purpose of the in-flight experiment</u>

MYRIADE is a generic microsatellite bus (150kg class). Since 2004, almost 20 MYRIADE-based microsatellites have flown or are in development. The current MYRIADE GNC includes:

- Ground orbit determination;
- Ground computation of the guidance profile;
- Orbit and guidance uploading to the satellite (typically from 1 time/day up to 1/week);
- Satellite attitude control, based on a 3-axis stabilization with star tracker and reaction wheels.

An autonomous GNC in-flight experiment will be carried out in March 2014 on the MYRIADE-based "PICARD" microsatellite (launched in 2010). The purpose is to upgrade its flight software in order to test and validate an autonomous GNC, allowing the satellite to follow various standard pointing modes with very few (even no more) ground GNC telecommands.

<u>GNC modifications</u>

This modified MYRIADE GNC includes a set of new functions:

- **An orbit extrapolation function**, using ground orbital data, and aimed to use in flight data (GNSS acquisitions) as well. In the peculiar case of PICARD experiment, as no GNSS is embedded, orbital parameters will be uploaded, typically 1 time/day, with a 4h time gap between two of them. This function computes, at each AOCS time slot, the satellite position and velocity, expressed in a terrestrial frame (ITRF). It is based on a dynamical model using a 6-order gravitational terrestrial model and a Runge-Kutta integration (order 6).

- **A reference frame conversion function**, transforming the orbit position and velocity into an inertial frame (GCRF), taking into account the Earth pole rotation, diurnal Earth pole rotation as well as precession and nutation.
- **A Moon and Sun ephemeris computation function**, using MEEUS analytical models.
- **A guidance computation function**, computing 6 standard pointing modes (geocentric, local nadir, track compensation, yaw steering, heliocentric and inertial) and eventually including an attitude bias. This function computes, at each AOCS time slot, the target quaternion.
- **A guidance discontinuity management function**, whose purpose is to avoid guidance steps between two pointing modes. In simple cases, a velocity bias is applied such as to join the two pointing modes, making the attitude guidance continuous. As an option, the attitude discontinuity management is taking into account any sensor (or instrument) dazzling avoidance constraints. In the case of PICARD experiment, the GNC is computing the angle between the two star trackers and the Earth, the Sun and the Moon. When the two star trackers are simultaneously dazzled during a pointing transition, the attitude profile is modified such as at least one of the star trackers remains not dazzled. This function computes, at each AOCS time slot, the guidance quaternion and velocity.

And

- **The attitude control function**, not modified in the frame of this experiment.

<u>Experiment development plan</u>

The most challenging aspect of this experiment is to develop a full autonomous and multi-mission GNC "kit" compliant with an existing in-orbit satellite, with limited on-board resources and in less than one year (from the experiment decision up to in-flight operations).

The GNC has been developed in MATLAB®/Simulink environment and the code automatically generated for its integration into the flight software (the integration is in progress, its feasibility being already demonstrated). The validation will performed in three steps:

- At orbit and guidance level using CNES reference libraries : CELESTLAB and BOLERO for orbit and PATRIUS for guidance (completed);
- At AOCS level using the PICARD AOCS simulator (in progress);
- At satellite level using the satellite simulation bench (planned in February 2014).

The modified GNC will be uploaded to the PICARD satellite beginning of March 2014. The in-flight experiment will last approximately 2 weeks, consisting of commanding different pointing modes, different dazzling conditions, etc.
As there is a strong constraint for starting the PICARD decommissioning by end of March 2014, the autonomous GNC experiment must be completed before this deadline, making the in-flight results and their analyses available for 2014 ISSFD Symposium.

The paper submitted to ISSFD will describe:

- The experiment context and constraints
- The functions implemented and their performances
- The development and validation logics
- The in-flight results
- The lessons learned, including the interest for such an autonomous GNC system