On-board Orbit Determination for a Deep Space CubeSat

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CubeSats offer new perspectives for constellations, formation flying swarms or deep space missions provided a micro-propulsion for orbit maintenance. In deep space, a relative autonomy is highly desirable for the orbit determination, and ultimately for the orbit correction maneuvers themselves: more system resources could be allocated to the payload, and less resources to ground operations and teletransmissions. Within a technological roadmap for deep space CubeSats with a micro-propulsion-based AOCS (Attitude and Orbit Control System), we present its on-board orbit determination function in "cruise" context.

Starting from optical measurements of foreground bodies like planets or asteroids in the background of stars, we develop an on-board algorithm to produce 3D reconstructed locations that eventually feed a Kalman filter. A sensitivity study provides requirements on the optical accuracy in line with the hardware currently available at CubeSat scale. However, for a given expected accuracy, multiple measurements at different time steps are required and introduce some limits in terms of delay for the orbit determination (duration and ageing of the estimate). These limits can be over-come by applying an additional step with a propagation model, at the cost of a decreasing accuracy.

The development for an autonomous navigation concept and, in particular, for an on-board orbit determination has started in 2013 [1] with the financial support of the Laboratoire of Excellence ESEP. The sensitivity study was first presented in 2016 [2] and an update will be provided. Depending on the achieved results at the time of the talk, we will open the discussion to the context of "proximity operations" where the CubeSat remains in the vicinity of a mothercraft sent to deep space for instance to explore an asteroid in situ.

References

[1] Segret *et al.*, "BIRDY: an interplanetary CubeSat to collect radiation data on the way to Mars and back to prepare the future manned missions", *SPIE Proceedings*, **Vol. 9150** (2014), doi: 10.1117/12.2056114
[2] Segret *et al.*, "Orbit Determination for a deep-space CubeSat", *6th Interplanetary CubeSat Workshop, Oxford* (2016)