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A FEMTOSAT SWARM MISSION IN LEO: DIFFERENTIAL DRAG CONTROL UNDER POWER AND COMMUNICATION CONSTRAINTS

Abstract

This study has been conducted as a part of the trade-off analysis for a tentative ionospheric mission, whose objective is to conduct multipoint ionospheric plasma depletions measurements and mapping, distinguishing temporal and spatial variations of the measured parameters. It has been shown that for the experiment in question a swarm of a few dozen FemtoSats is required, which is deployed in a near polar low-Earth orbit and is maintained so as to keep intersatellite distances within a few hundred meters to ensure swarm connectivity.

The proposed swarm comprises identical PCBSats designed on a 9.0 x 9.5 cm standard PCB board with a set of sensors, solar panels, onboard computer, and communication system. Relatively high area-to-mass ratio of each PCBSat makes the differential drag control the obvious choice when it comes to the swarm maintenance, i.e. keeping all FemtoSats in a bounded domain as given by a set of mean orbital elements according to the mission requirements. The differential drag control relies on the 3-axis magnetic attitude control system, which normally switches between the two key regimes: cross-section area control for the swarm maintenance and the sun-tracking mode to recharge the batteries.

Our simulations show that under ideal conditions the proposed differential drag control scheme allows keeping the swarm together as per specified mission requirements. However, the power consumption of the attitude control system becomes a factor that needs to be considered when planning the control actions across the swarm. The power balance is mostly influenced by the required communication (both for control system and payload), attitude actuation, and onboard computer and sensors performance. Given the amount of the measurement data that need to be collected and communicated either to the relay satellite or directly to the ground, the swarm maintenance problem can be formulated as ensuring the mission lifetime to fulfill the scientific goals of the mission for both data handling and intersatellite distances.

We thus propose a modified differential drag control scheme taking into account the power balance of each FemtoSat in the swarm, which on one hand, slightly raises the communication overhead, but on the other hand, ensures the payload priority and keeps track of the batteries state-of-charge. We have applied the proposed scheme to a number of orbits suggested by the project stakeholders and derived the preliminary requirements for mission design as it turns out that not every orbit provides suitable conditions for power-balance based swarm maintenance.