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GPS-BASED RELATIVE NAVIGATION FOR THE PROBA-3 FORMATION FLYING MISSION

Abstract

The PROBA-3 mission represents a major milestone for the emergence of distributed cooperative spacecraft systems. The primary mission objective is to build a solar coronagraph composed of two satellites flying in close formation on a high elliptical orbit and tightly controlled at apogee. Both spacecraft will embark a low-cost GPS receiver, originally designed for low-Earth orbits, to support the mission operations and planning during the perigee passage, when the GPS constellation is visible. The paper demonstrates the possibility of extending the utilization range of the GPS-based navigation system to serve as sensor for formation acquisition and coarse formation-keeping. In this analysis, the formation is controlled autonomously using a two-impulse scheme, the first maneuver being executed right after the perigee and the second one at apogee, which requires the availability of an onboard relative navigation throughout the complete orbit. In high elliptic orbits, the limited availability of the GPS signals (only 5% of the orbit period) makes necessary the introduction of a real-time navigation system able to provide accurate relative position and velocity information when the GPS satellites are visible and to propagate the navigation solution during the rest of the time. The results presented in the paper aim at achieving an unprecedented degree of realism. To that end, a high-fidelity simulation environment has been employed, enforcing a precise modeling of the forces acting on the spacecraft and including real hardware receivers in the loop, fed by a GPS signal simulator. A modified version of the flight-proven PRISMA navigation system, composed of two single-frequency Phoenix GPS receivers and an advance real-time onboard navigation filter, has been retained for this analysis. For several-day long simulations, the GPS receivers are replaced by software emulation to accelerate the simulation process. Special attention has been paid to the receiver link budget and to the selection of a proper attitude profile. Overall the paper demonstrates that, despite a limited GPS tracking time, the onboard navigation filter gets enough measurements to perform a relative orbit determination accurate at the centimeter level at perigee. Afterwards, the orbit prediction performance depends mainly on the quality of the onboard modeling of the differential solar radiation pressure acting on the satellites. When not taken into account, this perturbation is responsible for relative navigation errors at apogee up to 50m. The errors can be reduced to only 10m if the navigation filter is able to model this disturbance with 70% fidelity.