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DESIGN OF TRAJECTORIES FOR CONTINUOUS POLAR EARTH OBSERVATION IN THE EARTH-MOON SYSTEM

Abstract

Polar observation is currently carried out with low Earth polar orbits or highly elliptical orbits (HEO). These platforms, however, do not offer continuous and hemispheric view of the Earth, a condition that is essential for accurate polar weather forecasts, uninterrupted telecommunications with polar bases, ship routing and ice pack monitoring. In fact, low polar orbits only cover narrow swaths at each passage; conversely, HEO have a relatively short period (of the order of 12h) to ensure continuous coverage, and they are suitable for observing one hemisphere only.

Previous work done by the authors investigated alternative mission scenarios in the Sun-Earth system, including so-called pole-sitters and periodic high-amplitude vertical Lyapunov orbits. While these platforms offer good visibility conditions for an extended fraction of their period, the major drawback is the distance of the spacecraft from the Earth, of the order of 1-2 million km, which directly affects the quality of the observations and potential telecommunications bandwidth.

With the intent of overcoming the limitations of these different prior mission scenarios, in this paper we explore possible mission scenarios for continuous polar coverage using periodic orbits in the Earth-Moon system.

Several studies in the literature show the possibility of using a gravity assist at the Moon to change the orbital plane of a spacecraft with respect to the lunar orbit, without the need of expensive thrusting manoeuvres. This idea can be exploited for reaching orbits that pass over the Earth's poles at little cost. Examples are so-called lunar backflip orbits.

The advantage of these orbits with respect to HEO at the Earth is that an extended period is spent above either pole. In addition, resonant gravity assists with the Moon can also alternatively change the line of the apsides of the orbit, therefore providing a way to observe alternatively both the poles. This is useful as each pole is lit by the Sun only for half of the year, due to the obliquity of the Earth's ecliptic. Moreover, orbits in the Earth-Moon system are considerably closer to the Earth (of the order of the Earth-Moon distance) than those in the Sun-Earth system.

Finally, continuous low-thrust propulsion or high-thrust Delta-v manoeuvres at perilune are also investigated in combination with the gravitational fly-bys to further change the orbital parameters.