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DESIGN OF OPTIMAL EARTH POLE-SITTER TRANSFERS USING LOW-THRUST PROPULSION

Abstract

Recent studies have shown the feasibility of an Earth pole-sitter mission using low-thrust propulsion. This mission concept involves a spacecraft following the Earth's polar axis to have a continuous, hemispherical view of one of the Earth's poles. Such a view will enhance future Earth observation and telecommunications for high latitude and polar regions. Although extensive research has already been conducted with respect to the dynamics and the generation of optimal pole-sitter orbits, the transfer trajectory from Earth to access the pole-sitter orbit is unexplored. This paper will therefore investigate optimum Earth pole-sitter transfers employing low-thrust propulsion.

The pole-sitter transfer is modelled by distinguishing between a launch phase and a transfer phase. The first assumes a two-body Soyuz Fregat upper-stage transfer from a fixed inclination, low Earth parking orbit up to insertion into the transfer phase. The transfer phase is subsequently modelled in the Earth-Sun three-body problem, with acceleration terms for the low-thrust propulsion system.

To find optimum transfers, the objective is to minimise the mass in the low Earth parking orbit for a given spacecraft mass to be inserted into the pole-sitter orbit. The optimisation is carried out using a direct pseudo-spectral method that solves the optimal control problem in the transfer phase and links the transfer and launch phases in the objective function.

Results are provided for transfers to a variety of pole-sitter orbits including constant altitude and inclined orbits, where the latter allows the spacecraft-Earth distance to be varied during the year. To assess the performance of low-thrust propulsion for the pole-sitter transfer, the results are compared with a ballistic transfer that exploits the manifolds winding of the pole-sitter orbit. It is shown that, with respect to the ballistic case, low-thrust propulsion can achieve significant mass savings in excess of 200 kg for a 1000 kg pole-sitter spacecraft.