Paper ID: 14889
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ASTRODYNAMICS SYMPOSIUM (C1)
Mission Design, Operations and Optimisation (1) (4)

Author: Dr. Camilla Colombo
University of Southampton, Italy

Prof. Colin R. McInnes
University of Strathclyde, United Kingdom

CONSTELLATIONS OF INCLINED HELIOTROPIC ORBITS FOR ENHANCED EARTH COVERAGE

Abstract

Elliptical-orbit constellations for telecoms and observation applications may demonstrate an efficient alternative to standard circular orbits. Elliptical rings of spacecraft can form wave-like patterns with peaks in density at apogee; hence they offer enhanced coverage for regions at the apogee point.

This paper proposes mission design of a constellation for improved Earth coverage using a family of 'heliotropic' orbits. The secular effects of solar radiation pressure (SRP) and J2 are exploited to maintain the spacecraft on a family of orbits with a Sun-pointing apogee, so that enhanced coverage is provided during daylight hours for visible light imaging, or providing communications services during peak local demand.

If the tilt of the Earth's equator relative to the ecliptic is neglected, families of equilibrium orbits can be identified in the equatorial plane where the Sun-synchronous condition of the apse-line is achieved passively, and the osculating apogee is maintained Sun-pointing. This family of frozen orbits is then continued out of the equator to high inclinations by setting a 3D heliotropic condition, thus sets of eccentricity, semi-major axis and inclination are defined for a given area-to-mass ratio. When the actual non-zero obliquity angle of the equator is then considered, bounded long-term perturbations due to SRP appear in inclination and anomaly of the ascending node. The stability of these quasi-frozen orbits is analysed and the secular effect of luni-solar perturbations, Earth's shadow and higher terms of the gravity field are estimated.

A future mission concept is designed for a constellation of spacecraft with small solar sails orbiting on families of inclined quasi-heliotropic orbits, which creates a Sun-pointing elliptical torus around the Earth. The initial orbital elements of the constellation are optimised to meet increased coverage requirements. The orbit semi-major axis is selected in the heliotropic family for repeated groundtrack on specific locations on the Earth. Additionally, the use of low-thrust propulsion is considered to artificially extend the family of heliotropic orbits to higher orbit energies, such that the orbit period is synchronised with the Earth's rotation or the spacecraft can continuously monitor a fixed location on the Earth's surface for daylight observation (from local dawn to local sunset).