

Orbital flips due to solar radiation pressure for orbital debris in near-circular orbits

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Orbital plane flips (flips from prograde to retrograde motion or vice versa) phenomenon due to solar radiation pressure are investigated. We consider initial near-circular orbits with different inclinations including the vicinity of orbits of the GNSS satellites, GEO, geosynchronous orbits, and super-GEO region. Dynamical evolution of orbital debris is studied from a numerical simulation. Initial conditions for the objects are chosen in the GNSS orbit regions (GLONASS, GPS, BeiDou, Galileo) as well as 450–1100 km above to nominal semi-major axes of the navigation orbits, and in the vicinity of GEO, geosynchronous orbits, and super-GEO region. Initial data correspond to nearly circular orbits with the eccentricity $e = 0.001$. The initial inclination is varied from 0° to 80° . Initial values of longitude of ascending node Ω are varied from 0° to 350° . Area-to-mass ratio γ is varied from small values corresponding to satellites $\gamma = 0.02 \text{ m}^2/\text{kg}$ to high values which correspond to orbital debris. Dynamical evolution covers a time spans of 24 and 240 years.

Orbital evolution of objects was modeled with the help of “Numerical Model of Motion of Artificial Satellites” developed at the Tomsk State University. The model of perturbing forces takes into account the major perturbing factors: the gravitational field of the Earth (EGM96 model, harmonics up to the 27th order and degree, inclusive), the gravitation of the Moon and the Sun, the tides of the Earth, the direct radiation pressure (coefficient of reflection of the satellite surface is 1.44) taking into consideration the shadow of the Earth, the Poynting–Robertson effect, and the atmospheric drag. The equations of motion are integrated by the Everhart's method of the 19th order.

Minimum value of the initial inclination which leads to the orbital flips is decreased when the semi-major axis is raised. Near the GNSS region, flips of the orbits due to effect of solar radiation pressure have been observed (the initial epoch T_0 is 00^h 00^m 00^s 21.03.1958.):

- for the GLONASS satellites with area-to-mass ratios γ from 16 to 20 m^2/kg and initial value of longitude of ascending node $\Omega = 180^\circ$;
- for the object above the GLONASS orbit near the 14:29 resonance region with γ from 16 to 76 m^2/kg and initial $\Omega = 180^\circ$;
- for the object above the Galileo orbit near the 3:5 resonance region with γ from 18 to 80 m^2/kg and initial $\Omega = 180^\circ$.

Flips are fixed for high area-to-mass ratio and initial $\Omega = 180^\circ$ only. This result is very important when describing long-term orbital evolution of orbital debris.

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