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DYNAMICAL EVOLUTION OF SPACE DEBRIS ON SUPER-GEOSTATIONARY ORBITS

Abstract

Dynamical evolution of space debris on super-GEO was studied for 240 years. The aim of the research was estimation of time intervals which necessary to space debris objects get into the vicinity of GEO and into the GNSS regions (GLONASS, GPS, BeiDou and Galileo). Initial orbits of the objects were choosing in vicinity of resonances 50 : 49 (semi-major axis $a = 42740$ km), 20 : 19 ($a = 43635$ km), 15 : 14 ($a = 44153$ km), 10 : 9 ($a = 45237$ km), 9 : 8 ($a = 45613$ km). Initial values of the eccentricity e and inclination i correspond to near-circular $e = 0.001$ and near-equatorial $i = 0.001°$ orbit. Initial values of the longitude of ascending node were equal to 0, 90, 180 and 270 degrees. An area to mass ratio was varied from small values corresponding to satellites to large values which correspond to the space debris fragments.

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

The results significantly depend on orbital plane position. Large area to mass values lead to pass the objects through the GEO and GNSS regions due to the solar radiation pressure and the Lidov-Kozai effect produce the long period oscillations of eccentricities and inclinations of orbits.

Let the object is on super-GEO near the 50 : 49 resonance region. The object does not pass GEO if the area to mass ratio is less than 0.4 m^2/kg. It does not pass Galileo, BeiDou, GPS and GLONASS regions if the area to mass ratio is less than 9, 10, 11 and 11 m^2/kg correspondently.

Let the object is on super-GEO near the 9 : 8 resonance region. The object does not pass GEO if the area to mass ratio is less than 3 m^2/kg. It does not pass GNSS regions if the area to mass ratio is less than 10 m^2/kg and does not pass GPS and GLONASS regions if the area to mass ratio is less than 13 m^2/kg.