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A LONG-TERM DYNAMICAL EVOLUTION OF LARGE SATELLITE CONSTELLATION AND SPACE DEBRIS PROBLEM

Abstract

There are plans to launch large constellations of satellites in the nearest future. We have considered dynamical evolution of the constellation of 1296 satellites (36 orbital planes with 36 satellites in each plane) at an altitude 1200 km above the Earth over 25 years. The motion of the satellites is not controlled that is without maneuvers.

The 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 27^{th} 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 19^{th} order.

The initial conditions correspond to nearly circular sun-synchronous orbits with the semi-major axis $a = 7578$ km, the eccentricity $e = 0.00001$, and inclination $97.44°$. The initial values of the longitude of the ascending node Ω are varied with $10°$ step. The argument of pericenter $g = 0°$. The initial values of the mean anomaly M are varied with $10°$ step from $M_0 = 10/36N$. Here $N = 0, 1. \ldots, 35$ is the orbital plane number. The area-to-mass ratio $\gamma = 0.04$ m^2/kg. The dynamical evolution covers 25 years. The initial epoch T_0 is $00^{\mathrm{h}}00^{\mathrm{m}}00^{\mathrm{s}}$ UTC 01.01.2019.

We studied the evolution of a minimal distance between satellites in the time. It considered the impact of satellites collisions and explosions on the stability of the constellation. The results depend on initial conditions and the model of collision or explosion. The stable state of large constellation can be realized under continuous path control to avoid the satellites and space debris collisions.

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