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POST-DISPOSAL ORBITAL EVOLUTION OF SATELLITES AND UPPER STAGES USED BY THE GPS AND GLONASS NAVIGATION CONSTELLATIONS: THE LONG-TERM IMPACT ON THE MEDIUM EARTH ORBIT ENVIRONMENT

Abstract

During the last decade, since the discovery of the potential instability of the disposal orbits for the satellites of the global navigation systems (GNSS) in medium Earth orbits (MEO), a considerable effort has been devoted in analyzing the initial conditions leading to instability, manifesting itself as a significant growth in orbital eccentricity over a timeframe of decades, due to resonance conditions from the combined gravitational action of geopotential harmonics, Moon and Sun. It was so found, for example, that the disposal strategy initially recommended for the GPS satellites was not able, in general, to prevent the long-term crossing of the altitude shells used by the operational spacecraft of the GNSS constellations in MEO.

As of February 1, 2011, there are in orbit 27 abandoned GPS satellites (10 Block-I, 9 Block-II and 8 Block-IIA) and 6 upper stages associated with the constellation (3 Star-48, 2 PAM-D and 1 Delta 4-2), having apogee altitude greater than 17,000 km. Regarding the GLONASS system, there are 92 abandoned satellites (89 Uragan and 3 Uragan-M), 2 Etalon laser ranging spheres, 40 upper stages associated with the constellation (38 Blok-DM-2, 1 Blok-DM-2M and 1 Briz-M), plus 43 Blok-DM-2 ullage motors and 1 Briz-M tank having apogee altitude greater than 17,000 km.

The aim of this paper is to analyze the long-term orbital evolution of all these objects, over 200 years, taking into account all relevant perturbations. Snapshots of the evolving object distribution during the considered time span are provided, together with an estimation of the changing collision probability with the spacecraft of the operational navigation systems in MEO. An assessment of the evolving collision probability with the overall debris population in MEO is provided as well.

The results obtained are discussed in the context of the instability problem analyzed in previous studies. However, they are also put in the perspective of the MEO regime, where only 5% of the operational spacecraft and 15% of the cataloged objects reside in a volume 34 times greater than the geosynchronous protected region and 237 times greater than the low Earth region. Therefore, the results attained can be useful in providing some further quantitative background to the on-going discussions, at international level, on the opportunity of promoting the adoption of a MEO protected region. Moreover, they can also contribute to the debate on the most effective disposal practices for the satellites and upper stages of the GNSS constellations.