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# END-OF-LIFE DISPOSAL OF GEOSYNCRONOUS SATELLITES

**Abstract**

Spacecraft in Geostationary Orbits (GEO) represent a fundamental aspect of space activity and provide valuable services to mankind. According to the publicly available two-line element data-sets, approximately 1200 total objects are catalogued at a semi-major axis around the geostationary value. Apart from the active spacecraft, this population includes also defunct satellites, rocket bodies and smaller pieces of space debris.

Safety procedures for operational spacecraft include the selection of orbits with lower collision risk with debris as well as the implementation of collision avoidance manoeuvres. Moreover, space debris guidelines aim at limiting the creation of new debris by the prevention of in-orbit explosions and the implementation of end-of life disposal manoeuvres to free the GEO protected regions. To this end, ESA applies specific requirements on space debris mitigation for all its projects. Those requirements suggest that, space systems operating in the GEO protected zone shall be disposed into a graveyard orbit with the eccentricity less than 0.005 and a given minimum perigee altitude above the geostationary altitude.

In this paper, we characterise the dynamical structure and study the long-term stability of the circumterrestrial space at the geostationary altitude, including highly-inclined Geosynchronous Orbits (i.e. orbits of the Beidou constellation). Semi-analytical techniques and numerical high-fidelity models are employed for the long-term propagation of the natural dynamics. We produce maps representing the long-term stability of the orbits in the orbital element space. We focus our analysis on the resonant dynamics, due to the characteristic frequencies of lunisolar and solar radiation pressure perturbations and their coupling with the asymmetries in Earth's gravitational potential.

Furthermore, we use the computed maps to design manoeuvres for fuel efficient transfers to stable graveyard orbits. Given the available delta-v for a satellite, the admissible region is defined and the disposal manoeuvre is optimised to target a stable region of the orbit domain, for which the interaction with the GEO active spacecraft population minimises.