Dynamics and Mission Design for Space Debris Mitigation in the Geostationary Orbits

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Nowadays space mission design should include the implementation of debris mitigation solutions to preserve the space environment and the sustainability of the project. There is approximately 6,500 ton for the 17,000 objects in orbit [1]. Specifically, a guideline proposed by NASA determines some procedures that a satellite must perform at the end of his mission to limit the risk of explosions and collisions after its life span. These practises involve the depletion of the sources of energy and fuel, the prediction of probabilities of collisions with other debris, and the removal of the spacecraft from Low Earth Orbits (LEO), Medium Earth Orbits (MEO) or Geostationary Orbits (GEO). Removal can occur with a reentry maneuver in the atmosphere or by a transfer to a graveyard orbit, located between100 and 300 km above the geostationary orbit [1]. These rules and policies have had an impact reducing the generation of new debris. But graveyard orbits should be exploited only as short term solutions because the number of objects in these orbits cannot grow indefinitely, in order to avoid the increase of the probability of collisions between objects and the production of clouds of new fragments, some of which that could collide with other satellites, resulting in an exponential increase of the production of fragments [2]. About 400 communication satellites are currently operating in geostationary orbit, while approximately 300 others are out of service and another considerable part in graveyards orbits. However, recent studies show that these graveyards orbits will certainly lead to atmospheric reentry of such debris, to should be implemented in a controlled manner to avoid disasters if they fall in large urban centres [3,4]. So, alternative strategies for space debris mitigation are required.

This work aims to seek alternative methods to divert future communication satellites at the end of their operational life through collisional orbits with the Moon. Our main goal is to perform an investigation of possible alternative mitigation strategies of space debris in geostationary orbits around the Earth exploiting escape properties of trajectories of the Circular Restricted Three Body Problem (CR3BP) and collisional orbits with the Moon. In a preliminary analysis, impulsive transfers between the geostationary orbit and gravitational capture orbit of the moon guided by the invariant dynamical structures associated to the Lagrangian point L_1 are computed. After that, we apply corrections to these solutions to satisfy a more complete mathematical model including Sun, Earth, Moon and spacecraft.

For that, initially, a scattering region around the Earth in the Earth-Moon System is investigated considering different mitigation debris possibilities for different energy levels, revealing different output situations. The different cases are examined based on the analysis of the transport processes between regions and the escaping time of trajectories. These analyses are essential in the context of debris mitigation of space missions.

Given these alternative solutions, the number of satellites in cemetery orbits could reduce, decreasing the risk of collisions between a large population of debris in the area, and reducing also objects with an altitude of 35,786 km. These investigations will determine the additional mass of propellant and on-board propulsion systems required for manoeuvres for effective and safe mitigation of future generations of communication satellites.

References

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