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CHARACTERISATION OF THE DYNAMICAL STRUCTURE OF THE CIRCUMTERRESTRIAL SPACE FOR PASSIVE DEBRIS MITIGATION

Abstract

The complexity of the orbital dynamics in the Earth environment is still not well understood. Notwithstanding the theoretical studies performed on the analytical treatment of orbit perturbations, the exploitation of natural perturbations has, so far, been limited to specific cases. Nevertheless, the Earth's environment presents a richness of resonances, leading to regular and chaotic orbits that can lead the satellite to long-term orbit change. Recent projects on the design of disposal trajectories for Medium Earth Orbits, Highly Elliptical Orbits and Libration Earth Orbits have demonstrated the possibility of exploiting orbit perturbations for designing of passive mitigation strategies for debris disposal. The recently started ReDSHIFT project in the H2020 framework will tackle the debris problem from a holistic point of view. The exploitation of artificial and natural orbital dynamics will be integrated into the mission design as a whole. Indeed, disposal technologies will be designed and produced through 3D printing to enhance the effects of the dynamics for end-of-life solutions, producing a complete integrated design for the operational phase and end-of-life disposal. The theoretical study of the system dynamics can provide the basis for an understanding of the natural orbit evolution. This will allow the identification of engineering solutions for the design of disposal strategies and the technological challenges to be solved such as the coupling between the attitude and the orbit evolution of solar sails for enhancing the area of the spacecraft, the need for demise of the spacecraft in the last phase of re-entry and the impact of these solutions on the growth of the debris population. This paper characterises the dynamical structure of the whole circumterrestrial space from Low Earth Orbit to Geostationary Transfer Orbits using the tools of dynamical systems. The phase space associated with Earth orbits will be mapped to identify the regular and chaotic zones. Long-term propagation through semi-analytical techniques and numerical high fidelity models will be employed. In this way it will be possible to identify the main resonances in Earth orbits that could be of interest for the disposal of spacecraft in any orbital region. Chaos indicators such as the fast Lyapunov indicators will be used to characterise the regular and chaotic zones, pointing out their possible role in the de-orbiting and mitigation strategies. Identify stable and unstable regions in the phase space will allow finding "de-orbiting highways" to reduce the residual lifetime of the objects in any orbital region.