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DE-ORBITING LARGE SPACE DEBRIS OBJECTS FROM THE SUN-SYNCHRONOUS ORBIT BY AERODYNAMIC BRAKING

Abstract

We have conducted a study to understand the feasibility of de-orbiting large space debris objects (m ¿ 1000 kg) by means of aerodynamic braking, which can be effected by tethering to such objects inflatable balloons, thus increasing the atmospheric drag force acting upon the tethered system. Our numerical experiments were carried out with a model of a tethered system dynamics accounting for all the major environmental forces and torques known to be of importance in the LEO environment. The focus of the study was on determining the conditions that guarantee the absence of the end-bodies' collisions during the operation.

It turns out that the duration of the system's motion without collisions essentially depends on the initial mutual positions of the end-bodies. Consider, for instance, the initial positions of the end-bodies in the orbital plane and the tether taut and tangent to the orbit, whence the system proceeds with the large amplitude in-plane librations that are accompanied by the out-of-plane oscillations of increasing amplitude. The dynamics becomes irregular, the tether is no longer stretched, and the collision of the end-bodies takes place a few days after the commencement of the operation.

On the other hand, for the tether initially aligned along the local vertical and the end-bodies' positions corresponding to the relative equilibrium, the system's dynamics is mainly small amplitude in-plane librations for the first few months. Afterwards the amplitude increases, the system start rotating about its center of mass, the tether becomes loose, which results in irregular dynamics and collision of the end-bodies. Any parameters variations such as the tether length or the balloon dimensions do not lead to qualitative changes in the system's behavior, except for the altitude at which the described instability becomes manifest.

Our analysis of this instability shows that it can be characterized as a resonance phenomenon, because it is exhibited when the frequency of the tethered system's librations coincides with the frequency of atmospheric density along-the-orbit variation. Such resonant behavior has been previously encountered by specialists in tethered systems dynamics.

Basically, our numeric experiments confirm the possibility of de-orbiting a large debris object from SSO in reasonable time (less than 10 years) by attaching to it a braking balloon, whose surface area is about 100 m^2. Additional technical solutions to ensure that the system's dynamics is collision-free are discussed.