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Cloud of Space Debris from a Close Approach with the Jupiter

Jorge Kennety Silva Formiga[1]
São Paulo State University (Unesp), Institute of Science and Technology, São José dos Campos, Brazil
Denilson Paulo Souza dos Santos[2]
São Paulo State University (Unesp), São João da Boa Vista, Brazil

1 Introduction

Since the launch of the first satellite in 1957, there is a large expansion in findings related to space, due to the great advances in space technology obtained in the last decades. The artificial satellites launched are used for several purposes, including the observations of the Earth, climate monitoring, studies of the atmosphere and the Earth's gravitational field. The present paper has the goal of studying the modifications of the orbital parameters of each individual element of a cloud of particles that makes a close approach with the Jupiter. Clouds of particles are formed when natural or man-made bodies exploded for some reason. After an explosion like that, the center of mass of the cloud follows the same orbit of the body the generated the explosion, but the individual particles have different trajectories. The cloud is specified by a distribution of semi-major axis and eccentricity of their particles. This cloud is assumed to pass close to the Earth, making a close approach that modifies the trajectory of every particle that belongs to the cloud. The present paper makes simulations based in the "Patched-Conics" model to obtain the new trajectories of each particle. Then, it is possible to map the new distribution of the Keplerian elements of the particles, using the previous distribution as initial conditions. Those information are important when planning satellite missions that have a spacecraft passing close to the cloud, because it is possible to obtain values for the density and amplitude of the cloud, so finding the risks of collision and the possible maneuvers that need to be made to avoid the collisions.

2 Mathematical model

The methodology is based in the calculations of the orbital variations of each particle of the cloud. Initially, the particle is in an elliptic orbit around the Sun and its motion is

[1]jorge.formiga@ict.unesp.br
[2]denilson.santos@sjbv.unesp.br

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coplanar with the orbits of the Jupiter. Our study starts with the particle at the initial point, where the particle is at a distance that can be considered far enough from the Jupiter, and it is possible to neglected the effects of the Jupiter to consider the Sun-particles as a two-body system. The Jupiter is assumed to be in circular orbit around the Sun. More details can be seen in [2] and [3]. The orbital elements of of the spacecraft with respect to the Sun before the explosion are: semi-major axis (a), eccentricity (e), energy (E) and angular momentum (C). They are obtained from Eqs. (1) shown below.

$$a = \frac{r_a + r_p}{2}; e = 1 - \frac{r_p}{a}; E = -\frac{\mu_s}{2a}; C = \sqrt{\mu_s a(1 - e^2))} \tag{1}$$

where r_p is the periapsis of the orbit of the particle around the Sun, r_a is the apoapsis and μ_s is the solar gravitational parameter. It is possible to obtain the variations of velocity, energy and angular momentum for each particle (Eq. 4).

$$\Delta v = \vec{v}_{0i} - \vec{v_i} = 2|\vec{v}_{\infty_i}|\sin \delta_i \tag{2}$$

$$\Delta E_i = E_{+i} - E_{-i} = -2\vec{v}_2 \cdot \vec{v}_{\infty_i} \sin \delta_i \sin \psi_i \tag{3}$$

$$a_i = -\frac{\mu_s}{2E_i}; e_i = \sqrt{1 - \frac{C_i^2}{\mu_s a_i}}; \Delta C_i = \frac{\Delta E_i}{\omega} \tag{4}$$

where ω is the angular velocity; δ is half of the angle of deflection; and E_{-i}, E_{+i} are the energy before and after, respectively. The sub-index i is used to indicate each particle of the cloud. Finally, having determined the variations of energy and angular momentum due to the maneuver, it is possible to obtain the semi-major axis and the eccentricity of the orbit for each particle after the close approach, by using equations 4.

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