Paper ID: 23305
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SPACE DEBRIS SYMPOSIUM (A6)
Modelling and Orbit Determination (9)

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A DEFORMATION MODEL OF FLEXIBLE, HIGH AREA-TO-MASS RATIO DEBRIS FOR ACCURATE PROPAGATION UNDER PERTURBATIONS

Abstract

A new type of space debris was recently discovered by Schildknecht in near geosynchronous orbit (GEO). These objects were later identified as exhibiting properties associated with high area-to-mass ratio (HAMR) objects. According to their brightness magnitudes (light curve), shapes, high rotation rates and the properties of compositions (albedo, amount of specular and diffuse reflection, color, etc), it is suspected that these objects are made of layers of multi-layer insulation (MLI), following delamination or collision accidents. Observations have shown that this debris type is very sensitive to environmental disturbances, particularly solar radiation pressure, due to the fact that their shapes are easily deformed thus resulting in changes of area and shifts in the position of the center of mass, which will in turn modify the effects and influences of external forces and torques. This makes this type of debris' orbit very difficult to predict with conventional propagation techniques that assume a constant area-to-mass ratio (AMR) and a fixed geometry. This paper proposes a simple yet effective model of the thin, deformable membrane based on a multi-body dynamics. The membrane is modelled as a series of flat plates, connected through flexible joints, representing the flexibility of the membrane itself. The mass of the membrane, albeit low, is taken into account with lump masses in the joints. The dynamic equations for the masses, taking into account the constraints defined by the connecting flat plates, are derived using fundamental Newtonian mechanics. The physical properties of the objects, required by the model (membrane density, reflectivity, composition, etc.), are assumed to be those of multi-layer insulation. This flexible membrane model is then propagated together with classical orbital and attitude equations of motion near a GEO to predict the orbital evolution under the perturbations of solar radiation pressure, Earth gravity field and third bodies (Sun and the Moon). The deformation of the debris leads to change the geometries and AMR, which in turn change the orbit. Simulation results show a more precise estimation of both attitude and orbital parameters of this debris type due to the more accurate shape and provide deformed geometries over a long period and these are compared to a rigid body model.