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Space Elevator Feasibility and Technology (3)

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MOTION OF THE SPACE ELEVATOR AFTER THE RIBBON RUPTURE

Abstract

Building a space elevator requires both a considerable investment and finding solutions to a significant number of complex scientific and technological problems. One of the principal challenges is the development of sufficiently strong ribbon material; another is guaranteeing the longevity and safety of the whole structure. Destruction of the space elevator in case when the ribbon is cut by a meteorite or by space debris has to be studied as quite a probable scenario. Apart from the disastrous consequences for the primary structure, the parts of the destroyed elevator can jeopardize several spaceborne and ground objects. We aim at development of an adequate model for a space elevator and study its dynamics in case when the ribbon is cut. The elevator consists of a tether and a space station located beyond the geostationary orbit. A flexible tether with circular cross-section is simulated by a number of mass points connected by viscoelastic massless rods. We take into account the gravitation, aerodynamics, and inertial forces. We assume that the tether does not slide over the ground. For numerical simulations we create the program TetherCalc. To increase the accuracy of the simulations, we use the algorithm of additional tether discretization for the segments subject to the Earth's atmosphere. We study the case when the ribbon is cut at a point close to the geostationary orbit. After the rupture, the upper segment of the tether moves around the Earth, while the lower part starts falling to the ground. The inertial forces cause the deflection of the tether from the local vertical; afterwards it wraps around the Earth in the direction of its rotation. Analysis of the stress in the tether shows that is does not surpass the limit values for a carbon fibre. For a planet without an atmosphere, the tether falls uniformly to the ground. However, if one considers the effect of the atmosphere, the motion changes. The aerodynamic forces reduce the normal component of the velocity, while the longitudinal component does not change. Therefore the part of the ribbon located beyond the atmosphere falls with increasing velocity and can outran the lower segment of the tether. Some segments become loose and glide freely in the air. One can observe formation of loops that sometimes get out of the atmosphere. The results of the simulation show that rupture of the space elevator ribbon can jeopardize both spacecraft and objects on the ground.