Paper ID: 32806
oral
student

14TH IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Space Debris Removal Issues (5)

Author: Ms. Eleonora Botta
McGill University, Canada

Prof. Inna Sharf
McGill University, Canada
Prof. Arun Misra
Mc Gill Institute for Aerospace Engineering (MIAE), Canada

ENERGY AND MOMENTUM CONSIDERATIONS IN THE DEPLOYMENT DYNAMICS OF NETS FOR ACTIVE SPACE DEBRIS REMOVAL

Abstract

Tether-nets are considered a promising technology to capture large and massive tumbling space debris from orbit. These flexible devices are designed to be thrown from a dedicated spacecraft towards the target debris by imparting initial velocity to four corner masses and possibly to the net itself. The net is deployed thanks to momentum and energy transfer from the corner masses to the innermost threads of the net. This paper aims at investigating the net deployment dynamics, which needs to be fully understood before using such systems in actual missions. The chosen approach is a combination of analytical observations and numerical simulations.

The analysis of the system dynamics is first performed with the use of work-energy and momentum principles. The case of initial velocity imparted – symmetrically – both to the corner masses and to the net proper is addressed, within the assumption of a lumped-parameter model for the net. Bounds on the attainable values for the velocities of the centers of mass of the corner masses and of the net proper are obtained, as well as relationships between these and different energy contributions. The analytical results allow to identify key parameters characterizing the deployment dynamics, which include the ratio between the mass of the net proper and that of the corner masses, the initial linear momentum, and the direction of the initial velocity vectors.

A simulator based on the lumped-parameter approach is implemented in Matlab and validated by verifying the linear momentum and the work-energy balances in a deployment simulation; through the validation process, interesting considerations on the Kelvin-Voigt tension model with modification to prevent compression loads in the tethers are brought to light. With the use of the numerical tool, the analytical observations can be validated and interpreted further: it is found that the net proper can overcome the corner masses during deployment, if initial velocity is imparted only to the corner masses, or to the corner masses and the net. Visualization of the results of two deployment simulations corroborates this finding. Comparison of the net mouth area and height profiles suggests that more complete and lasting deployment can be achieved if the corner masses alone are ejected. A sensitivity study is performed on the key parameters identified from the energy/momentum analysis, and the outcome establishes that more lasting deployment and safer capture can be achieved by employing comparatively lightweight corner masses, small shooting angles, and low shooting velocities.