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SIMULATION AND ANALYSIS OF A PHOBOS-ANCHORED TETHER

Abstract

In this paper, we investigate the dynamics and feasibility of a light-weight tether anchored to Phobos near Stickney crater. The tether is initially deployed along the Mars-Phobos line with its tip sitting beyond the Mars-Phobos L1 point. Such a tether could potentially provide a stable, low-gravity anchor point for human or robotic missions, or serve as an elevator for Phobos resources. Unfortunately trajectories near the L1 point are unstable, and there are proportionally large disturbance forces (solar gravity, solar radiation pressure, the libration of Phobos, the ellipticity of Phobos' orbit, the Martian bulge and Deimos's gravity) that can affect the movement of the tether. Here we model the tether and simulate the evolution of its position to determine the feasibility and potential control needs of implementation.

The tether is modeled as a massless string of a specified length, with an anchor fixed to the end of the long axis of Phobos (tidally locked with Mars). The position of the end point is free to move, but is acted upon by external forces and the internal tension of the tether itself. We assume the tether material allows for some natural spring and damping, but that they only act when the tether is extended beyond its nominal length. We also assume various gravitational models and additional forcing functions are generated by the libration of Phobos, which changes the anchor-position with respect to the Mars-Phobos line.

We have found that the dynamics of the tether system are highly dependent upon tether length. Over the course of a two-week propagation, some tether lengths cause the system to collapse (the end point crashes into Phobos), others cause a growth in oscillation amplitude, and some lengths cause a steady state motion. A plot of the amplitude of transverse motion across the Mars-Phobos line shows that the amplitude of motion is strongly dependent upon tether length, but also that some lengths exhibit a resonance-like response.

A Fast-Fourier Transform of a representative tether length is very revealing as to the components of the motion. The frequencies of the forcing functions stand out clearly and can be mapped to the resonant responses.

Finally, we consider material properties (such as modulus of elasticity, breaking force, and cross-sectional area) to determine feasible tether materials. Initial indications show a thin Kevlar tether to be possible, allowing for the possibility that the tether could be easily carried and deployed.