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THEORETICAL ANALYSIS OF MISSION SCENARIOS POSSIBLE IN THE EARTH - MOON - MARS SPACE USING A SPACE ELEVATOR

Abstract

The space elevator is a very long tether constructed from the surface of a planet or moon (referred to as the parent body) to space. The payload is carried up the elevator till a particular height from where it is injected into orbit. The payload derives most of the kinetic energy for injection from the rotational angular velocity of the parent body, thereby tremendously reducing the fuel energy requirements (very low Δv), compared to conventional rocket launches.

This paper studies some mission scenarios using the space elevator and their trajectory analysis. Elevators built on the Earth, the Moon and Mars are considered for analysis. The planetary elevator is balanced about the stationary radius whereas the lunar elevator about the L1/L2 Lagrangian points. Only equatorial space elevators are considered. The concepts of celestial mechanics are employed. Different manoeuvres (including Hohmann transfer) are examined. The scenarios are studied mainly from the point of view of reducing the fuel requirements (Δv). Time is not of a primary concern as the payload is assumed to be unmanned. Firstly, the orbits from the elevator possible without the need of any additional thrust are studied. It is shown that circular, elliptical orbits about the parent body as well as escape trajectories are achievable cheaply, depending on the release radius along the elevator. Next, some scenarios are studied wherein the elevator can be used to establish an orbit of the desired altitude and inclination about the parent or another body. Specific scenarios studied are using the terrestrial elevator and the lunar elevator to establish Earth/Mars orbits. Another scenario considered is hauling the payload up the elevator on one body, injecting it into space and then using the elevator on another body to bring it down to the surface (elevator - elevator rendezvous). This re-entry is possible without the problem of atmospheric heating as the payload can be brought down at a low speed.

The results are encouraging. Using the terrestrial elevator to inject a payload into the geostationary orbit requires no Δv. The Apollo 16 required a Δv of 17.63 km/s for the Earth - Moon mission. However a terrestrial - lunar L1 elevator scenario can achieve this in a Δv of about 2 km/s. This difference brings out the huge energy savings, atleast qualitatively. Similarly, it is shown that an Earth - Mars elevator rendezvous can be done in a minimum Δv of 4.85 km/s.