Paper ID: 68299
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20th IAA SYMPOSIUM ON VISIONS AND STRATEGIES FOR THE FUTURE (D4)
Modern Day Space Elevators Entering Development (3)

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SPACE ELEVATOR CLIMBER DYNAMICS ANALYSIS AND CLIMB FREQUENCY OPTIMISATION

Abstract

The paper describes a spreadsheet-based analysis of the motion of a climber ascending an Earth space elevator tether. The tether is represented by elements of varying lengths, each of mean cross-sectional area based on a taper ratio equation from earlier studies. The tether tension force is calculated in each element based on gravity and centrifugal forces plus the tension force in the element below.

A climber is defined by mass, drive power and maximum speed : no consideration is given to design details, the analysis assumes a tractive force simply defined by the Power. These details are used to derive the mean climber speed on each tether segment and hence the time to ascend each segment. Spreadsheet logic then allocates multiple climber masses on elements at variable travel time spacings, for example 24 hour spacings for climbers despatched from the Earth Port once per day. The effective weight of each climber yields an additional tension force in the tether, giving the maximum tension in the tether at any altitude.

Spreadsheet enhancements include an algorithm for daylight duration at varying altitudes, variable with the time of year : this permits an option for climber spacing to be calculated for solar-powered climbing.

The impact of input parameters (climber mass, power and maximum speed, departure intervals, continuous or daylight-only climbing, etc) yield outputs such as maximum tether tension and climb time.

The value of this technique becomes apparent when inputs are adjusted to yield similar tether tensions, representing a real-world scenario with a maximum permitted tether stress. It is possible to find, for example, how the maximum climber gross mass varies with maximum speed or drive power.

Examples of findings include :

- The benefits of higher power and maximum speed are complex, and highly dependent on the climber power/weight ratio.

- 24-hour climbing might allow 20% more payload (for any given tether strength and net climber performance) compared with daylight-only climbing.

- Two smaller climbers launched each day might enable 15% more payload to be raised compared with a single daily launch.

Such deeper understanding of climber dynamics highlights the complexity of climber design optimisation : key parameters are the net climber power/mass ratio and the ratio of the maximum climber speed to the lowest speed at which full drive power can be delivered.