Jack and the Beanstalk
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1 Introduction

Ever since people have been able to get into space, they have been looking for and easier and cheaper way to get there. Rocket propulsion is our current answer, but because it is expensive, inefficient, and only a one-time use, scientists are looking for other practical ways to accomplish the goal of escaping the Earth's gravitational field. It now costs about US $20 000 per kilogram to put objects into orbit. A NASA study concluded that a space elevator could reduce the cost of payloads to a low $200 a kilogram, while multiple elevators could push costs to $10 a kilogram [1].

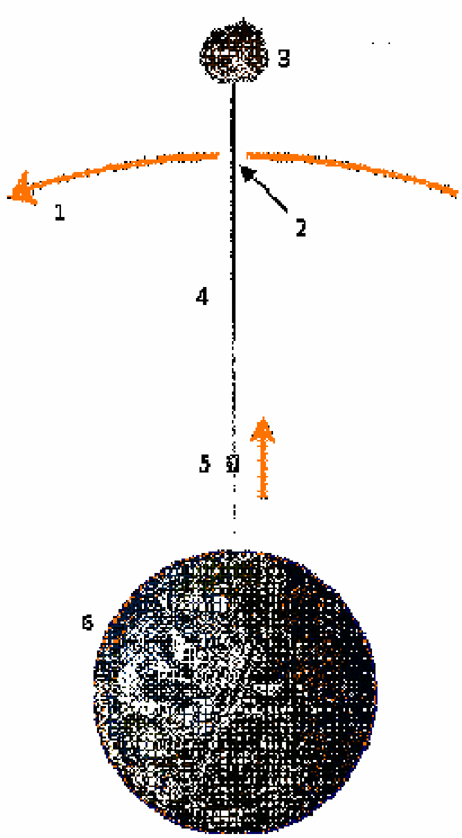

Figure 1: A cable [4] anchored to the Earth's surface [6], reaching into space. A counterweight [3] at the end, inertia ensures that the cable remains stretched taut, countering the gravitational pull on the lower sections, thus allowing the elevator to remain in geostationary orbit [1]. Once beyond the gravitational midpoint [2], carriage [5] would be accelerated further by the planet's rotation.

1.1 Origin

In his 1978 novel Fountains of Paradise, Arthur C. Clarke proposed the idea of an elevator that went from the base to the peak of a mountain, tethered via cable. From this, the modern design for a space elevator can be extracted, something along the lines of a ski lift from the surface of the Earth to a point in space [2].

1.2 The structure

The structure of the elevator has many key points, such as a counterweight, the rope, and the carriage. All of the important structures are explained in figure 1.

1.3 Who has attempted

In light of the then-recent discovery of carbon nanotubes, NASA attempted to create a space elevator in the 90s. Unfortunately, it was unsuccessful due to unforseen problems [3]. Since then, many competitions and awards funds have been set up for relevant technologies. Elevator: 2010, the Robolympics Space Elevator Ribbon Climbing competition, and NASA's Centennial Challenges program have raised the prizes for climbers, ribbons and power-beaming system developments to $4,000,000 [4].

2 Physics

2.1 The Cable

Because the elevator will exert a force opposite to that of the Earth's gravity, it must have a very tensile cable that will not snap under extreme tension. Using nanotechnology, which operates at a molecular level, scientists have been able to construct nanotubes (figure 1), consisting of linked rings of carbon, which are extremely light and very tensile. Either the tubes will be braided into a structure resembling a rope (long carbon nanotubes - several meters long or longer), or shorter nanotubes could be placed in a polymer matrix. Unfortunately, current polymers do not bind well to carbon nanotubes. Unlike typical cables which are the same width from top to bottom, these cables need to be wider at the middle than at the top or bases, because the cable is weakest and most prone to both snapping and the elements in the middle, which results in the matrix being pulled away from the nanotubes when placed under tension [2] [3].

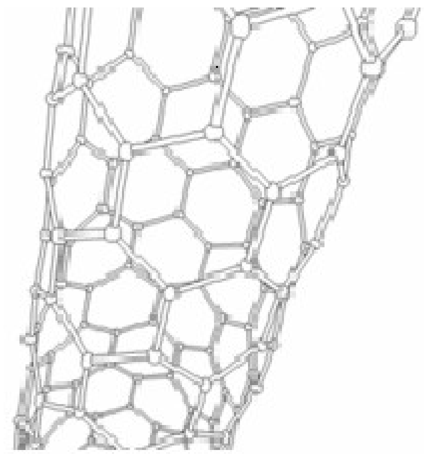

Figure 2: A carbon nanotube structure

2.2 Climbers

There are two main challenges with climbers. The first one is conquering gravity - this is a huge problem because the climbers need to have the same amount of power as an entire space ship blasting off. The second main problem is to keep elevator from sliding back down to Earth, because the gravity of the Earth will overpower the power of the motors and just bring the elevator sliding back down to Earth. Most climber designs call for the a pair of rollers to hold the cable with friction. To minimize cable stress and oscillations and to maximize throughput, the cables must be placed at optimal timing [1] [5].

2.3 The Base

When building the base there are two main types of bases, a mobile and a stationary base. The stationary base would be mounted to a mountain or even a skyscraper. The main advantages of a stationary base are that it can decrease the length of the cable, reducing the width of the cable in the middle, and can be made out of cheaper materials. On the other hand the main disadvantage of a stationary base is that the whole structure cannot avoid high winds, storms, and space debris. Mobile bases are usually large oceangoing vessels. The advantages of mobile bases are that they can avoid the stuff that stationary bases cannot. The dissadvantages of mobile bases are that they have to be made out of more expensive materials and must be longer with wider bases. Although, there have been some mobile airborne station ideas proposed. These would not work be cause there would have to be a constant energy supply to keep it in the air, this is energy that does not have to be used in either the mobile or stationary bases [2][5].

2.4 Counterweights

As explained in 1.2 Structure, a counterweight is necessary for the elevator to work properly. The counterweight is needed to extend past geosynchronous orbit, because once it is past the orbit, the whole structure would rotate at the same speed as the earth. The counterweight would basicly do as it says it would, it would act as a counterweight to balance the elevator. There have been other ideas as to how to avoid a counterweight because eventually, the counterweight would build up its own speed and launch itself into space. The most popular idea that avoids the counterweight is the idea to just make the elevator twice as long and weigh twice as much as it would if it had a weight on it. The ideas are explained below in figure 3.

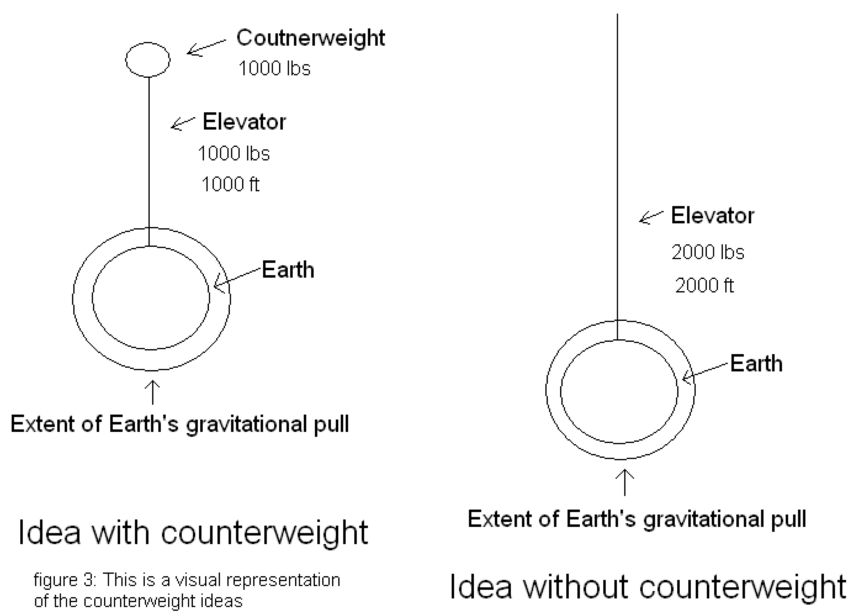

figure 3: This is a visual representation of the counterweight ideas

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