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A1_7 Would a Space Elevator be an Eyesore?

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Abstract

This article discusses the area of the Earth that would be able to resolve a space elevator of 100m width. It is found that the area in which the human eye can resolve the tower is comparable with the total area of Peru and half the Earth would be able to resolve the counterweight if it is at geostationary orbit.

Introduction

The idea of the space elevator has been around since the late 19th century, it is the idea that a tower could be built between the Earth's surface and orbit. The most viable version is the tether structure where the tower is hung from orbit down to the Earth's surface making sure that the centre of mass is in geostationary orbit. The centre of mass has to be at geostationary orbit so that the tower as a whole rotates at the same velocity as the ground, otherwise the tower would begin to deform and eventually split as the different orbital velocities send the different parts into different orbits with different periods.

The tower will comprise of two main parts, the main tower, made of super strong materials to deal with the tension from the different orbital velocities acting on each part of the tower. The second part is the counterweight which is required to maintain the tower's centre of mass at exact geostationary orbit. With recent advances in materials, namely carbon nanotubes, we are in a position to start planning for space elevators and we must consider how much of an eyesore they would be.

Dimensions

To work out how far away the space elevator could be seen from we must consider how wide and tall the elevator will be. The height of the elevator is easy to calculate. If we assume that we want the counterweight near geostationary orbit in order offer a useful platform for spaceflight we can equate the height of the tower to the distance to geostationary orbit, $3.5\text{x}10^7$m [1].

The width is subject to much more conjecture, for we need a balance between a strong and light weight tower. If more mass is added the forces acting on each part of the tower increases. A reasonable assumption would be 100m in width, w, of the tower. This means that the cross sectional area of the tower will be $7.83\text{x}10^3\text{m}^2$ and a volume of $2.81\text{x}10^{11}\text{m}^3$.

Resolving the Tower

Now that we have an estimate for the tower width, we can find out from what distance we, as humans, will be able to see the tower. For this we must consider the angular resolution, θ, of the human eye, which can be calculated from the angular resolution equation (1) [2],

$$\sin\theta = 1.22\frac{\lambda}{D}. \qquad (1)$$

In addition to the constant 1.22 we need the diameter, D, of the eye lens and the wavelength of the light observed. The wavelength can be taken as middle of the visible spectrum, 500nm and the diameter of the eye's lens is typically 4mm [3]. Using these values in (1) θ equates to $8.738\text{x}10^{-3\circ}$ or

1.525×10^{-4} radians which means we can use the small angle approximation to equate $\sin\theta$ and $\tan\theta$ as θ. The maximum distance, d, from which the tower can be resolved, is now possible through trigonometry by simply constructing a right angled triangle with an angle, Ø, of 7.625×10^{-5} radians and an opposite side with length 50 meters. So we can use tan in the form of equation (2),

$$d = \frac{w}{2\emptyset} = 6.557 \times 10^5 m, \quad (2)$$

which gives a circular area, using area $= \pi d^2$, of $1.351 \times 10^{12} m^2$, which is slightly larger than area of Peru [4].

Resolving the Counterweight

As was mentioned in the introduction, an important part of the space elevator system is the counterweight. For convenience it would be advisable to use a large asteroid in Earth orbit rather than constructing something in orbit as the asteroid can be moved outwards as the tower extends to keep the centre of mass in geostationary orbit.

We already know the volume of the tower and using carbon nanotubes, with a density of, $1.4 \times 10^3 kgm^{-3}$ [5], as a base we find that the mass of the tower will be 3.93×10^{14}kg so for simplicity if we use an asteroid of the same mass as a counterweight, assuming a similar density to the Moon of $3.35 \times 10^3 kgm^{-3}$ [6], we get a volume for the asteroid of $1.17 \times 10^{11} m^3$. Assuming we have a spherical asteroid then the diameter of the asteroid will be 6.1×10^3m. Using this figure for the diameter of the asteroid in equation (1) we find that d for the asteroid is 2.29×10^9m which is two orders of magnitude greater than the height of the tower meaning that the naked eye easily see the top of the tower.

Discussion

As mentioned in the "Resolving the Tower" section, the area of land able to resolve the tower is approximately the size of Peru. This is without taking the curvature of the Earth into account; however, we can assume that such an area can approximate the area of Peru.

Conclusion

In conclusion the number of people who would be able to see the space elevator and the counterweight is dependent on where the tower is placed.

The Counterweight as has been mentioned can be seen from geostationary orbit. This means that it can be seen from half of the Earth's surface at any time, the other half of course is blocked by the half that can see it.

However, from the point of view of the possible number of people affected by the eyesore of the tower we can use the population densities for both South America and Africa [7]. In the former case approximately 30 million people would be able to see the tower and in the latter 42 million people would be affected. There is also the case of Indonesia as a possible site where 170 million would be affected [8]. This means that if the tower was placed on land approximately between 0.5 and 3% of the world's population could see the tower and half the world could see the counterweight.

References

[1]http://imagine.gsfc.nasa.gov/docs/ask_astro/answers/970408d.html (08/03/2011)
[2] G. Woan (2000) The Cambridge Handbook of Physics Formulas
[3]http://en.wikipedia.org/wiki/Human_eye (21/02/11)
[4]https://www.cia.gov/library/publications/the-world-factbook/geos/pe.html (21/03/2011)
[5] Collins, Philip G. (2000). "Nanotubes for Electronics" Scientific American 67-69
[6]Wieczorek, M.; *et al.* (2006). "The constitution and structure of the lunar interior". *Reviews in Mineralogy and Geochemistry* **60**: 221–364
[7]http://geography.about.com/od/populationgeography/a/popdensity.htm (22/03/2011)
[8]https://www.cia.gov/library/publications/the-world-factbook/geos/id.html (23/03/2011)