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Graphene and the Idea of a Space Elevator

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Introduction

The primary idea of a space elevator was rather biblical. It was often depicted in various fictional movies and books such as The Fountains of Paradise and was portrayed as a seemingly endless ladder that rose into the sky through heaven and beyond. The idea, with time, as expected, started to fade away. But this dream was revived in the early 19th and 20th centuries by two Russian scientists named Konstantin Tsiolkovsky and Yuri Artsutanov. It is believed that Konstantin was inspired by the Eiffel tower. He believed that a similar structure can be constructed, which takes mankind to heights which no one could ever think of. However, as time passed, research made it pretty evident that the construction of such a structure would require unimaginable amounts of resources, manpower, and money. In the late 1960s, John Isaacs, a renowned British professor published a paper describing a "Sky Hook" in which masses could be launched into the orbit along a tether using the rotation of Earth to generate a large portion of the requisite energy. Soon, after years of trials and errors, in 2003, aeronautical engineer Brad Edwards conducted a study, in which the first-ever practical and applicable way to construct a space elevator was presented. However, the study concluded on a rather disappointing, the construction of the space elevator would require a funding of more than 15 billion USD and more than 20 years of continuous manpower. Edwards had envisioned the elevator to reach up to a height of 64,000 miles up in the sky, the lifter was to be powered by the centripetal force provided by the rotation of the Earth.

Why are we building a space elevator?

Perhaps the biggest factor constituting the construction of this massive structure is that it would significantly lower the cost of putting cargo into space. Although it will be slower than the chemically propelled space shuttle, the lifters reduce launch costs from $10,000 to $20,000 per pound to approximately $400 per pound, delivering heavy or fragile payloads with minimal vibration and costs. Apart from this, space is made much more approachable and explorable through this project. Having an operational space elevator outweighs all the advantages offered to us by satellites and for that matter space shuttles also.

The repairing of malfunctioning satellites and space stations results in costing us more than two hundred million dollars for each and every round trip. The servicing of the Hubble Space Telescope itself costs more than 250 million dollars, even after spending such an amount, it is predicted that the telescope will only produce quality pictures for the next 10-15 years after which it will turn into a major contribution to space junk. This cost can significantly be altered with the introduction of the space elevator.

Building a space elevator will be challenging but not impossible and the initial elevator could be built for approximately 6-10 billion USD (*Bradley Edwards (2003). "11: Budget Estimates").*, less than many of our larger national or international programs. Yet in the long-

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term, the returns which we might receive will be staggering. It might literally change the face of the Earth!

What is graphene?

Graphene is a single atomic thick layer of graphite; an abundant mineral that is an allotrope of carbon that is made up of very tightly bound carbon atoms organized into a hexagonal lattice. What makes graphene so special is its sp2 hybridization and very thin atomic thickness (of 0.345 nm). These properties are what enable graphene to break so many records in terms of strength, electricity, and heat conduction (as well as many others). The mechanical properties of graphene are presented as follows: (JN Fuchs, MO Goerbig - Lecture notes, 2008)

Stiffness

The braking force obtained experimentally and from the simulation was almost identical and the experimental value of the second-order elastic stiffness was equal to 340 ± 50 N m-1. This value corresponds to Young's modulus of 1.0 ± 0.1 TPa, assuming an effective thickness of 0.335 nm.

Strength

Defect-free, monolayer graphene is considered to be the strongest material ever known to mankind with a strength of 42 N m-1, which equates to an intrinsic strength of 130 GPa.

Toughness

Fracture toughness, which is a property very relevant to engineering applications, is one of the most intriguing mechanical properties of graphene and was measured as a critical stress intensity factor, of around 4.0 ±0.6 MPa.

Limitations of graphene

However, this so-called “wonder material” too, has its limitations. For many years, it has been believed that the carbon-carbon bond is the strongest and the purest, which might just turn out to be fallacious. The ceramics industry has stated a couple of years back that even though the carbon-carbon bond is considered to be extremely strong, the larger the carbon plates get, the higher is the probability of the carbon plate having defects. This may sound rather despairing, but the concept of carbon nanotubes is highly active amongst the present group of scientists. Each year we are getting more than 200 hundred papers just on how to improve upon the limitations of graphene production and carbon nanotubes. First of all, let us understand the basic difference between graphene and a carbon nanotube. As we know that graphene is a one-layer thick graphite sheet that has unparalleled physical and chemical properties. A carbon nanotube is just a rolled-up, hollow and cylindrical structure of graphene only. We can consider graphene to be a two-dimensional structure whereas a carbon nanotube occupies space along both axes. Now I have listed a few limitations of carbon nanotube as

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well as graphene: (ref https://www.hpcwire.com/2014/05/05/graphene-faces-real-world-limitations/)

1) Graphene can be highly reactive with oxygen under heat. This limitation is troublesome up till the Earth's atmosphere after which we are left with no oxygen and heat.
2) Graphene is a superconductor, which means it has unimaginable conduction powers, however, it is arduous to turn it off.
3) The most major and disappointing setback of graphene is that it is a single atom thick material which makes it extremely hard to produce it in larger quantities, and as we know, we do require graphene in a major amount for the construction of the elevator.

The practicality of the elevator

So far we must have inferred that graphene as a substance is an unimaginably perfect material, it is highly conductive, tensile, strong, and light. The perfect material for the construction of a space elevator in our opinion too would turn out to have such characteristics only.

The large-scale structure of the cable depends most basically on the physics of a space elevator and the tensions that the cable must support. The overall shape is tapered on both ends and has its largest cross-sectional area at geosynchronous orbit. The other basic design characteristic that has been known for some time is that it is best to have one cross-sectional dimension much larger than the other to reduce the damage meteors can inflict on the cable. The length of the cable would be 144,000 km if no counterweight were used (Bradley C. Edwards Ph.D.). With a counterweight on the upper end of the cable, any length that reaches beyond geosynchronous orbit is theoretically possible. The shorter the cable the larger the counterweight mass required with it eventually reaching infinity when the cable only reaches geosynchronous. The interdependence of the total system mass, counterweight, and cable length are shown in Edwards, 2000. The length of the cable should be determined by the counterweight available, cable size required, and the solar system destinations that are to be accessible from the cable.