The Feasibility Analysis of a Space Elevator

Tianrui Gao

Shanghai Pudong Dongding Foreign Language School, Shanghai, China
Email: terrygao2007@foxmail.com (T.R.G.)
Manuscript received September 14, 2024; revised October 28, 2024; accepted November 20, 2024; published December 27, 2024.

***Abstract*—Science ancient time, people were hoping to enter the universe and explore the further world. Recent years, with the appearance of rocket, it is able for human to go to the space. However, rocket is not able to recycle, which will cost lots of money on rebuilt it. At this time, people start to consider about the space elevator. There are some models of build a space elevator, one of them called "top-down" structure is the most available model that most scientist are focus on. With the model, scientists also need to find a kind of material that is strong enough to operate in the space. Carbon nanotube, the hardest material over the Earth becomes the first choice the. Even though, there are still several problems that the humanity is facing to build a real space elevator. The space elevator is able to go out of fictional stories in the nearly future after the main problems got solved. This essay is focus on the strength of material and structure of space elevator to figure out the possibility of space elevator. If it is not possible, point out the problems that scientists still facing, otherwise, try to create one.**

***Keywords*—science, space elevator, feasibility, astronomy**

I. Introduction

With the skyrocketing increase of the global population, the resource-carrying capacity of our mother planet, Earth, may reach a limit soon if the population keeps increasing at the current rate. Since the birth of mankind, it has been human instinct to ensure the survival and continuity of our race. Our ancestors used to migrate between continents to find uncultivated virgin lands. With the rapid development of science, we humans have mastered more diversified and cutting-edge technologies and nowadays the migration into outer space is not just a Sci-Fi fantasy. Elon Musk, the richest human on Earth, has made a long-term plan to colonize Mars. However, the normal rocket is very expensive and inconvenient to send people or items into space. For a typical space mission, upwards of 90 percent of the total mass on the Launchpad is the fuel! And most importantly, rockets are single-use projects, people have to rebuild one after use once. In regard to his goal, he founded the SpaceX company in 2002 [1] and aimed to reduce the transportation cost of sending cargo into space through the development of recyclable space rockets.

If mankind can successfully build a space lift, the cost of entering space will be reduced to 10 percent of the current cost, and furthermore, space cities in near-Earth space and interplanetary voyages using this as a springboard will become a reality. However, the reality of the space lift is still facing many challenges, although relevant studies have proved the theoretical feasibility of this project, it is still a big problem to find suitable building materials and construction methods to actually build the space lift, at the same time, the economic cost of building and maintaining the use of the space lift as well as the possible geopolitical issues need to be further investigated. the topic of feasibility analysis of space lifts for research.

It is clear that the feasibility of the space elevator depends mainly on three aspects, the theoretical maturity, the technical capability of engineering, and the economical efficiency. In this mini-review, we will focus on these three aspects to assess the feasibility of building a space elevator. The challenges of building a space lift by the strength of the cable and the building cost and the risk that might happen in building the space lift will be discussed. The economic efficiency of space elevators will be compared to traditional rockets. Furthermore, the potential risks during the operation of a space elevator are discussed.

II. The History of Space Elevator

Compared to interplanetary migration, it is more practical to move humans into the terrestrial space of Earth. The construction of permanent installations in the geosynchronous orbit has been proposed long ago. To achieve such a goal, a more economical way of getting supplies to low Earth orbit is urgently needed. People are considering a new way to go to space, space elevator goes into the range of consider with the advantage of much lower use-cost. The Russian scientist Konstantin Tsiolkovsky in the 19th century made a hypothesis of space lift from the build of the Eiffel Tower in Paris [2]. In his hypothesis, he considered making a similar tower that high enough to reach space. The ideal tower will be built from the ground to an altitude of 35,786 kilometers, which is the height of the geostationary orbit. Such a "Bottom-up" structure concept is quite similar to the building of a Babel tower, as shown in Fig. 1.

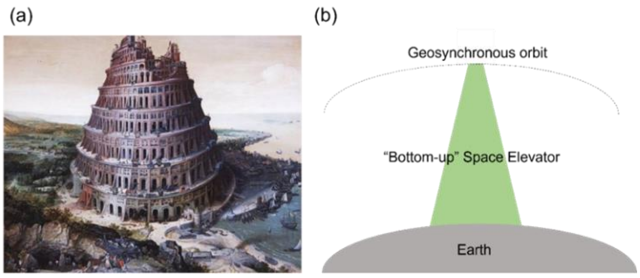

Fig. 1. (a) The tower of Babel. (b) Space elevator with the "Bottom-up" structure [2].

However, it seems unrealistic to build a compression structure from the ground up into the space, due to no materials could afford the strength to support its own weight with these conditions. Therefore, Yuri N. Artsutanov, another Russian engineer suggested a more feasible proposal in 1959. Arsutanov [3] suggested using a geostationary satellite as the base from which to deploy the structure downward. With the help of a counterweight, geostationary orbit is able to lower a cable to the surface of Earth. When the counterbalance extends from the satellite away from the Earth so that the cable is always at the same point on the Earth's surface, it can

DOI: 10.7763/IJET.2024.V16.1290

be defined as a “top-down” structure, as shown in Fig. 2.

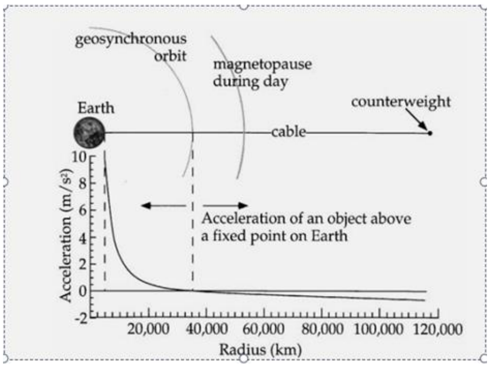

Fig. 2. Space elevator with the “Top-down” structure [3].

From then on, the design of the space elevator is basically based on the “Top-down” structure. As shown in Fig. 3, milestone nodes have been achieved in the development of the top-down structure space elevator.

In 1975, American scientist Jerome Pearson devised a tapered cross-section more suitable for building a lift, with the completed cable being tautest at the geostationary orbit, where the tension is greatest, and narrowest at the tip to reduce the weight per unit area of the cross-section that must be carried at any point on the cable [4]. He recommended the use of a counterweight and the slow extension of that counterweight to 144,000 kilometers (89,000 miles), almost half the lunar distance of the lower part of the lift. The reason was that without a large counterweight, the upper part of the cable would have to be longer than the lower part because gravity and centrifugal force change with distance from the Earth.

In 2000, American scientist Bradley C. Edwards suggested creating a paper-thin ribbon up to 100,000 kilometers (62,000 miles) long from carbon nanotube composites [5]. He chose a ribbon cross-section shape that was both wide and thin, rather than the earlier concept of a circular cross-section, which would be more susceptible to meteoroids. The ribbon cross-section will be less influence by the meteor and lighting. In the production case, the ribbon cross-section need smaller amount of carbon nanotube rather than the traditional circular one.

In 2012, America engineer Michael Laine’s company to built a space elevator from the Moon, because the gravity on the moon is one sixth of the earth. It will be easier to start the building of space elevator on the moon rather than on Earth. In their ways, space elevator is split into two parts, Moon to satellite and Earth to satellite. They developed a “Liftport” system which plans to connect man-made satellite with moon elevator directly, in this case they said it will be more efficient to send people into the moon. However, it fails because lack of money after few years.

In 2017, China Petroleum Limited provide another possible material beside carbon nanotube that is available which is Ultra-High Molecular Weight Polyethylene fiber (UHMWPE), its produce by Sinopec Yizheng Chemical Fiber. China has built Hong Kong-Zhuhai-Macao Bridge by ultra-high molecular weight polyethylene fiber in 2018. UHMWPE has low density, high intensity, high modules, corrosion resistance and impact resistance, those nature of UHMWPE makes it another possible material of cable on space elevator.

On January 23rd, 2019, Shizuoka University in Japan started a test of a space elevator. The test was planned to launch two satellites from the International Space Station, with a 10-meter-long steel cable linking the two satellites, and a small box of about 10 cubic centimeters on the cable to be lifted and lowered in space. However, due to a communication failure between the ground laboratory and the test satellites in space, the test ended in failure.

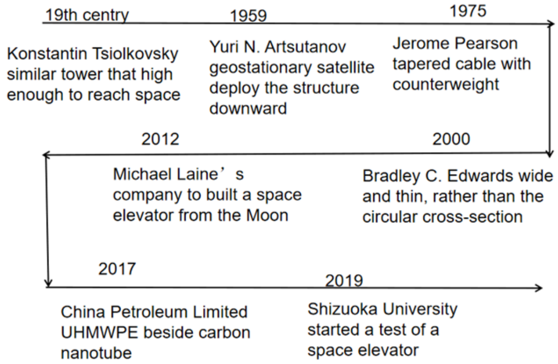

Fig. 3. The roadmap of space elevator [3].

III. Comparison to Rockets

The carrier rocket mainly relies on the engine to consume the booster to advance, and each stage of the rocket will fall off from the main body of the rocket after the fuel consumption is completed, and then free fall in the atmosphere. Although most of the rockets that fall off will burn up in the atmosphere, there will still be a lot of remnants in near-Earth space, due to the lack of air friction, over time, these remnants will become so-called “space junk”, which will cause great trouble to mankind. Space junk is small to the combustion residue of launch vehicles and large to all kinds of spacecraft that are difficult to recover (such as abandoned satellites, abandoned space stations, etc.), they will not only pose a threat to the safety of other spacecraft but also bring no small loss if some space junk falls to the ground [6].

If the launch vehicle is successfully replaced with a space elevator, it will greatly alleviate the space junk problem, because the operation of the space elevator does not require steps such as rocket disengagement, and because it is easier to maintain contact with the ground, it is unlikely to produce space junk.

The space elevator has a greater carrying capacity than traditional rockets. Most volume of rockets are used for fuels to make sure they can reach orbit, but less space for astronauts and cargo to stay, usually the rocket can only have three astronauts. However, with the help of cable, it is no longer a problem for a space elevator to reach the orbit. The cabin can be larger than a traditional rocket, in this case, the space elevator will have more carrying capacity which would make sending 30 astronauts into space at once feasible. In short, the space elevator is much more efficient than a rocket when sending large amounts of people at once.

IV. Operation Means

Although the concept and construction of a lift boom box are similar to those of a regular lift, it is a component that transports both people and products. Even though the lift box is also along the cable to climb up, it must find its own way to the top because it is unlikely to be lifted up by a lengthy cable that is hanging down from the sky. Installing a motor in the lift box and using it to rotate a set of wheels that are attached to the cable to generate pulling power upward is the simplest method. Although all of these options add to the lift box's weight, the power for the motor can come from the cable or from a generator mounted atop it. A more weight-saving technique is to install a photoelectric converter in the elevator hoist box, shoot a laser at it from the ground, and then "shoot" it with electricity. While the light shoots on the translator, light energy transfer to electric energy, which provide the kinetic energy for upward the cabin.

The PSE dynamics of a triple climber was studied and analyzed by considering the effects of different climbers' movement patterns and the mass ratio of the middle climber to the other climbers. Two operational examples were also applied. The first case studies the movement of two climbers from the middle position of the PSE to the main satellite and the end body, respectively. The second case deals with the problem of making all climbers move in the same direction at the same time. The problems were solved using optimal control methods [7].

V. Discussing the Feasibility of a Space Elevator from Different Perspectives

A. Theoretical Feasibility of Space Elevator

1) Apparent gravitational field

The Earth Space Elevator cable rotates with the Earth's rotation. As a result, the cable and objects attached to it are subjected to an upward centrifugal force in the opposite direction of the downward force of gravity. The higher the object's cable is, the less the Earth's gravitational pull is, and the greater the upward centrifugal force generated by the rotation. Therefore, the greater the centrifugal force, the less the force of gravity. In a geostationary equatorial orbit, centrifugal force and gravity are in equilibrium. In a geostationary equatorial orbit, the centrifugal force is greater than the force of gravity, causing objects on the cable to be pulled upwards [8].

The combined force on the object attached to the cable is called the apparent gravitational field. The apparent gravitational field of an attached object is the (downward) force of gravity minus the (upward) centrifugal force. The apparent gravity of the object on the cable is zero in geosynchronous orbit, and the downward gravity is downward in geosynchronous orbit.

Actual downward gravity decreases with altitude, and upward centrifugal force due to planetary rotation increases with altitude. The apparent gravitational field is the sum of the two:

$$r_1 = \left(\frac{GM}{\omega^2}\right)^{\frac{1}{3}}$$

where

g is the acceleration of apparent gravity, pointing down (negative) or up (positive) along the vertical cable (m s−2),

gr is the gravitational acceleration due to Earth's pull, pointing down (negative)(m s−2),

a is the centrifugal acceleration, pointing up (positive) along the vertical cable (m s−2),

G is the gravitational constant (m3 s−2 kg−1)

M is the mass of the Earth (kg)

r is the distance from that point to Earth's center (m),

ω is Earth's rotation speed (radian/s).

At a certain point on the cable, these two terms (downward gravity and upward centrifugal force) are equal and opposite. The object fixed to the cable at this point has no weight on the cable. This height (r1) depends on the mass and rotation rate of the planet. Assuming that the actual gravity is equal to the centrifugal acceleration, there are:

$$r_1 = \left(\frac{GM}{\omega^2}\right)^{\frac{1}{3}}$$

It is 35,786 kilometers (22,236 miles) above the Earth's surface, which is the altitude of the geostationary orbit.

On the cable below the geostationary orbit, the downward force of gravity is greater than the upward centrifugal force, so the apparent force of gravity pulls objects on the cable downward. Any object released from the cable below the horizontal line will initially accelerate down the cable. Then, it will drift eastward away from the wire. On a cable above the level of the geostationary orbit, the upward centrifugal force is greater than the downward gravity, so apparent gravity will pull the object on the cable upward. Any object released from the cable above geosynchronous orbit would initially accelerate up the cable. Then gradually veer off the cable to the west.

2) Cable cross-section

From a historical perspective, the main technical issue has been the ability of the cable to withstand its own weight below any given point under tensile force. The maximum tension of the Space elevator cable is located at the Geostationary orbit point, 35786 kilometers (22236 miles) above the Earth's equator. This means that the cable material and its design must be strong enough to withstand a self-weight of 35786 kilometers (22236 miles) from the surface. If the cross-sectional area of the cable at this height is thicker than that at the surface, it can better withstand its own weight over a longer length. Therefore, how to gradually reduce the cross-sectional area from the maximum value at 35786 km (22236 miles) to the minimum value at the ground is an important design factor of Space elevator cable.

When designing a cable cross-sectional area, in order to maximize the superstrength of a given cable material, it is necessary to ensure that the stress in the direction of the cable length (that is, the pull per unit cross-sectional area) remains constant in most cases. Other factors considered in more detailed designs include thickening at higher altitudes for space debris, taking into account point stresses imposed by climbers, and using different materials. In order to take these and other factors into account, modern detailed designs strive to achieve the maximum safety factor and minimize variation with height and time. In a simple starting design, this corresponds to constant stress.

The band connecting the counterweight to the earth is subject to axial effects. The combination of gravity and centrifugal force causes the tension, because of the rotation of the earth this stress varies along the length of the ribbon. For those longer ribbons, the dimensions are greater. An ideal ribbon design should have constants. The sum of the stresses along the ribbon would imply a variable cross-section area. [9]

For constant stress cables without safety margin, the functional relationship between cross-sectional area and distance from the center of the earth is shown in Fig. 4:

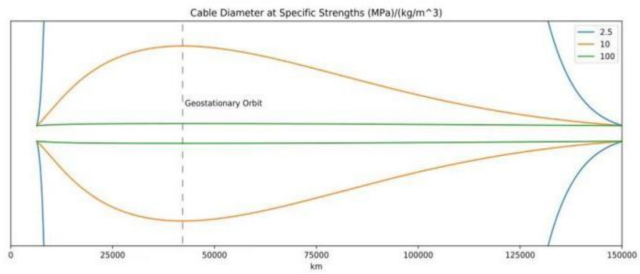

Fig. 4. Several taper profiles with different material parameters [7].

B. Material Feasibility of Space Elevator

1)Cable materials

The ‘conclusions’ are a key component of the paper. It should complement the ‘abstract’ and is normally used by experts to value the paper’s engineering content. A conclusion is not merely a summary of the main topics covered or a re-statement of your research problem, but a synthesis of key points and, if applicable, where you recommend new areas for future research.

Using the above formula we can calculate the ratio between the cross-section at geostationary orbit and the cross-section at Earth’s surface, known as taper ratio, like Fig. 5:

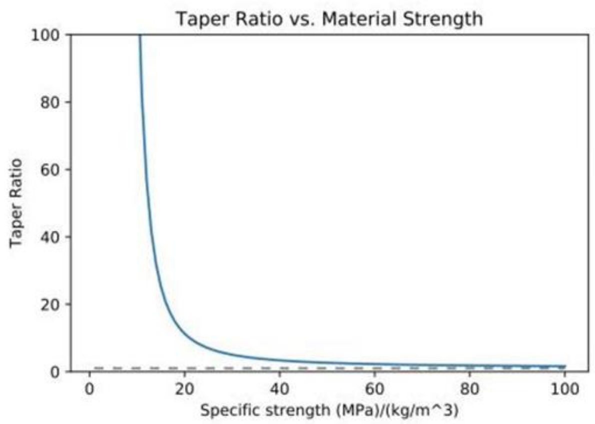

Fig. 5. Taper ratio as a function of specific strength [8].

Table 1. Taper ratio for some materials [8]

Material	Tensile strength (MPa)	Density (kg/m^3)	Specific strength (MPa)/(kg/m3)	Taper ratio
Steel	5,000	7,900	0.63	1.6×10^{33}
Kevlar	3,600	1,440	2.5	2.5×10^{8}
Single wall carbon nanotube	130,000	1,300	100	1.6

The taper ratio becomes very large unless the specific strength of the material used approaches 48 (MPa)/(kg/m^3). Low specific strength materials require very large taper ratios which equates to a large (or astronomical) total mass of the cable with associated large or impossible costs.

Like Table 1, if steel is used to be the cable material, when the bottom is 1 square meter, the top of the cable has to be at least 1.6×1033 square meter due to the taper ratio, as large as rotating a mountain upside down. The size of the top part is incredibly large which makes it not realistic to build. By the way, we’ve tried Kevlar instead, however, Kevlar’s taper ratio is 2.5×108. Although it is quite smaller than steel, the difference is still too large for the cable. Scientists find the hardest material which is carbon nanotube. The taper ratio of carbon nanotubes is only 1.6. Compared to other materials, 1.6 could be negligible, which means the top part of the cable is similar to the bottom area of the cable.

Due to the carbon nanotube’s tiny taper ratio, it has become the most suitable material for the space elevator cable. Therefore, more and more scientists and researchers focus on the fabrication and mass production of carbon nanotubes, like Fig. 5.

2)Carbon nanotube

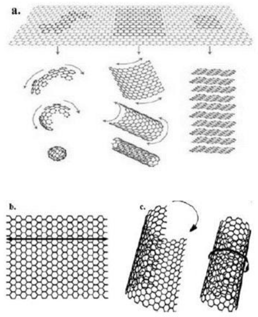

Fig. 6. The schematic illustration of the fabrication of carbon nanotube [1].

Carbon nanotubes have attracted the attention of material scientists and technical experts due to their unique one-dimensional structure and outstanding electrical, mechanical, and chemical properties.

Carbon nanotubes (1300 kg/m^3) have a lower density than Kevlar (1400 kg/m^3) or steel (7900 kg/m^3). Because of their ability to maintain stability in space, carbon nanotubes have a melting point that can exceed 78 degrees Celsius. Carbon nanotubes come in a variety of shapes and sizes, including single, interlaced, open, and closed tubes. According to experimental findings, single-walled, small-diameter carbon nanotubes have a tensile strength of 45,000 megapascals. The amount of technology in use now allows for the adjustment of atomic size to meet specific needs, producing the desired outcome and altering the material’s quality. Bundles of carbon nanotubes will be employed in the future to create carbon nanotube fibers, a remarkable material with exceptional strength and flexibility that can cover very vast surfaces [2].

Nanotubes, which resemble graphite tubes and have hexagonal Pentagon ends, are regarded as microcrystals. Its strength is 200 times greater than that of steel while having a small, hollow, high, and thin outer diameter. As a result, the carbon nanotube is considered to be the material most suitable for space elevator cables because it passes the strength test. It still has some issues with being used for construction, though. Carbon nanotubes can now only be constructed in small diameters, such as millimeters or centimeters. The geostationary orbit is height, 35,786 kilometers, requires a space elevator cable that is longer than that distance. Using carbon nanotubes for the space elevator’s cable would be ideal. we have to increase technology to solve the length problem. How to make a longer carbon nanotube and make sure it contains at least the same strength and hardness will become an important problem to solve. Furthermore, the way to combine several carbon nanotubes together to form a longer one will be also considered.

C. Technical Feasibility of Space Elevator

The construction of a space lift would require the mitigation of a number of technological risks. Some advances in engineering, manufacturing and physical technology will be required. When the first space lift is built, the second and other space lifts will benefit from the previous lifts to assist in their construction at a greatly reduced cost. Such ongoing space lifts will also benefit from the significant reduction in technological risk achieved by the construction of the first space lift [10].

In principle, the production of cables in space would use asteroids or NEOs as source materials. These previous construction concepts were so Space Elevator Economic Feasibility Study that the asteroid could be manoeuvred to the desired orbit on Earth. Since 2001, many studies on space elevators have been devoted to simpler construction methods that require a smaller infrastructure area. In this method, they considered throwing a long cable on a large spool and placing it in space [11].

For early systems, the transition time from the ground to the GEO level was about 5 days. The time spent moving along the Van Allen radiation belts in these early systems would have necessitated shielding to protect the passengers from the radiation, which would have increased the mass of the climber and reduced the load. If the space sensor is located at 45°N latitude, the cable rotates to the south and moves towards the equator by centrifugal force. As a result, it propagates almost horizontally for thousands of kilometres through the Earth's atmosphere, which can attenuate air-related stresses in the cable. Another alternative is to install some sort of radiation shielding on the cable. This allows the lift to pick it up when it is about to reach the conveyor belt. However, such a shield weighs the entire device and disrupts the natural movement of the cable [12].

Space lifts may pose a travel hazard to aircraft and spacecraft. Aircraft can be guided according to air traffic control restrictions. All objects below the maximum height of the cable and out of sync with the cable in a fixed orbit deterrent orbit will affect the cable unless action is taken. One suggestion is to use a moving anchor to route the yarn around any residue large enough to be tracked [10].

The other main question that carbon nanotube is facing recently is the unit cost of carbon nanotube. While the cost is expensive, more experiment groups will not be able to afford the cost of it. With the use of plenty carbon nanotubes to build the cable will be even more unaffordable.

D. Economic Feasibility of Space Elevator

1)Cost analysis of construction

Space elevators have the advantage of being reusable compared to the rockets that people use today. This means that there is no longer a need to spend the cost of building a rocket. A single time of building a rocket could cost 5 million dollars. A part of cost on the building of space elevator is on the main material of cable. Carbon nanotube used to be very expensive before scientist have new explore on it. The product cost of carbon nanotube falls to 2 yuan per unit gram in the experiment of Wuhan. This is much less than the price that was found first in America at the price of 2000 dollars. Although the cost of a single carbon nanotube is decreased by a large percentage, it is still difficult to combine each single one to form a huge cable.

After the building of space elevator, all you need to spend is the cost of fuel. Economically speaking, such a change could save a lot of money. But since the space elevator moves on a trajectory, it can't get anywhere as freely as a rocket. The cost of material transfer into space by rocket is $10000 per kg. For space elevators, the cost can reduce these launch costs by up to $ 10 per kg of material transported to space. Not only does it provide an economic passage to space, but the space elevator is a much safer alternative to rockets.

2)The maintaining cost of a space elevator

Long-term maintenance is essential to keep a space lift running for a long time. The maintenance of the lift can be roughly divided into three parts, which are the repair of the ground foundation, the maintenance of the cable and the lift cabin, and the repair of the space station. The most challenging of these is the maintenance of the cable, due to its length. Due to its length, the cable of a space lift can become thin in diameter or even break due to wear and tear, and in the event of damage, the entire cable will need to be replaced. The cable can also become corroded due to prolonged exposure to air and UV rays, requiring regular addition of lubricants and antioxidant coatings. This may not be noticeable in a short-term space lift, but for a space lift that wants to run for a long time. Once decades have passed, the cables must be replaced to ensure that the space lift is safe to use.

The maintaining of lift cabin have to check about whether the cabin is damaged by space radiation, radiation might cause the cabin corrosion, the emergency evacuation could operate normally. The foundation usually will not face some problem, because it is built on the ground of earth surface. The few problems that foundation might have those nature disaster such as earthquake, tornado or lighting. If any of them attached, the space elevator will face a large problem, even totally damaged. Some scientists suggest that the foundation of space elevator could be built on a moving platform such as offshore oil platform.

E. Challenges of a Space Elevator

1)Potential risks during operation

Even though some protection and maintain on the space elevator has been used, there still appears probability of damage. An Emergency Evacuation Module (EEM) that can be detached from the main body of the lift silo in the event of a real danger. A section similar to a rocket return capsule, Emergency Evacuation Module have to configured several necessary components: a GPS system for find out position, the parachute increase air resistance for deceleration and a catapult for active orbital separation are the components that need to be configured on.

Some scientists have suggested that a space lift's cable could be anchored to a mobile platform in the ocean near the equator. The mobile platform would be like an enlarged version of an offshore oil rig. The mobile platform is equipped with thrusters that can be shifted back and forth to move the space lift to avoid incoming space debris or meteorites.

2)Political risks

The base of the space elevator has to be built on the equator of the Earth to make sure the cable can reach the geosynchronous orbit at 36,000 kilometers above the Earth. This causes it must to be built on one of the equator country's territories. Beside equator countries, let the base of space elevator on the sea surface on the equator might also be a possible solution. However, in this plan people have to create a stable land to support the base of space elevator, where will cost plenty of extra money on it. By the way, not only their population could use the space elevator, instead all humanity should have the license to use it. Some developing country is not able to build it or does not have enough capital to start the building plan.

For the safety of space elevator, it could not be built near by neither the frequent lighting nor hurricane path. As a result, it is necessary to discuss the location of building the space elevator.

For example, in near-Earth orbit (LEO), bright satellites can interfere with ground-based astronomical observations - a trend that may worsen in the coming years as satellite constellations expand. Similar problems arise in lunar exploration, where upcoming missions may cause electromagnetic interference with future radio astronomy observatories on the lunar surface [13].

VI. Conclusion

In this mini-review, this paper has summarized the history of the space elevator. From the "bottom-up" structure first pointed out by Konstantin Tsiolkovsky in the 19th century to the "top-down" model proposed by Russian engineer Yuri N. Artsutanov in 1959, the style of elevator changed from a tower to a thin cable, scientists even sent 10-meter-long steel into to space to simulate the real elevator's cable.

In addition, we also discuss the feasibility of space elevators in three parts: theoretical feasibility, technical feasibility and economic feasibility. In theory, the ability to build a space elevator depends on the strength of the material. If scientists can find a strong enough, inexpensive material and put it into practice, a space elevator could be built. At the moment, the strongest material is carbon nanotubes, which are already strong enough as a tether material for space elevators. However, there are some problems with combining it into one long cable. In terms of economic viability, the price of sending a unit tonnage of material into space has dropped from $250,000 to $10,000, a reduction of about 90 percent.

In the future, human are continuously going to find stronger materials and make sure it is cheap enough to solve the technical problems. From the basic part push the space elevator from scientific fiction into reality.

Conflict of Interest

The author claims that no conflict of interest exists.

References

[1] N. M. Pugno, "On the strength of the carbon nanotube-based space elevator cable: from nanomechanics to megamechanics," *Journal of Physics: Condensed Matter*, vol. 18, no. 33, p. S1971, 2006.

[2] "Konstantin Tsiolkovsky," *In Wikipedia*, 2023

[3] Y. Artsutanov, "V kosmos na elektrovoze," *Komsomolskaya Pravda*, no. 31, pp. 946–947, 1960.

[4] J. Pearson, "The orbital tower: A spacecraft launcher using the Earth's rotational energy," *Acta Astronautica*, vol. 2, no. 9–10, pp. 785–799, 1975.

[5] B. C. Edwards and E. A. Westling, *The Space Elevator*, Bc Edwards, 2003.

[6] H. David, "What is a rocket?" 2011. Available: https://www.nasa.gov/audience/forstudents/k-4/stories/nasa-knows/what-is-a-rocket-k4.html

[7] G. Shi, G. Li, and Z. Zhu *et al*., "Dynamics and operation optimization of partial space elevator with multiple climbers," *Advances in Space Research*, vol. 63, no. 10, pp. 3213–3222, 2019.

[8] "Space elevator," *In Wikipedia*, 2023.

[9] A. K. Misra and S. Cohen, "Space elevator—A revolutionary space transportation system," *Mechanical Sciences: The Way Forward*, pp. 105–120, 2021.

[10] G. Edwards, "Forces of habit: Drugs and the making of the modern world," 2002.

[11] K. Oberauer and L. Hein, "Attention to information in working memory," *Current Directions in Psychological Science*, vol. 21, no. 3, pp. 164–169, 2012.

[12] D. W. Young and E. Ballarin, "Strategic decision-making in healthcare organizations: It is time to get serious," *The International Journal of Health Planning and Management*, vol. 21, no. 3, pp. 173–191, 2006.

[13] G. Giacomo and G. Alyssa, "Can better governance help space lift of," 2023. [Online]. Available: https://www.mckinsey.com/industries/aerospace-and-defense/our-insights/can-better-governance-help-space-lift-off

Copyright © 2024 by the authors. This is an open access article distributed under the Creative Commons Attribution License which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited (CC BY 4.0).