Humans on Space Elevator Transport System

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Abstract

Space is a fast growing industry with new and revolutionary technology being developed everyday. The focus on in-orbit services, satellites and expansion outside the Earth is increasing. This paper introduces space elevators, one such revolutionary idea focusing on the transportation system between the Earth and space. It then focuses on the necessity, both commercial and academic, to expand space elevators to include a human habitable environment. Additionally, a brief study is done to identify possible challenges to creating such a sustainable habitable environment and into identifying the areas of future development.

1. Introduction

Travel and transportation has been one of the main pillars of growth of human civilizations. It is the reason for trade and for globalization which are a backbone of our society. It has also enabled us to reach our potential by sharing knowledge and resources. Just like Earth, growth in space also needs strong transportation for exchange of resources. With the rapid growth of the space industry worldwide, today is the time to focus on transportation in space. Our current methods, including rockets, are definitely not fit to solve the needs and demands for the future, because of their limited delivery statistics.In this report, Space elevator is proposed as a solution.

2. Space Elevators Construction

A space elevator is a system for lifting payloads from the Earth's surface into space. This system is made of a 100,000 km long tether balanced about a node in geosynchronous orbit reaching down to an anchor point on Earth's surface. Tether climbers, electrically powered spacecraft, travel up or down the tether to reach GEO and the Apex Anchor [1].

These use far lower resources than rockets and reduce an estimated cost in the order of $500/kg. In addition, the cargo capacity/throughput service is two orders of magnitude larger than current rockets .

Tether climbers can continue to the apex anchor - the point at 100,000km altitude – where their speed is sufficient for direct interplanetary travel.

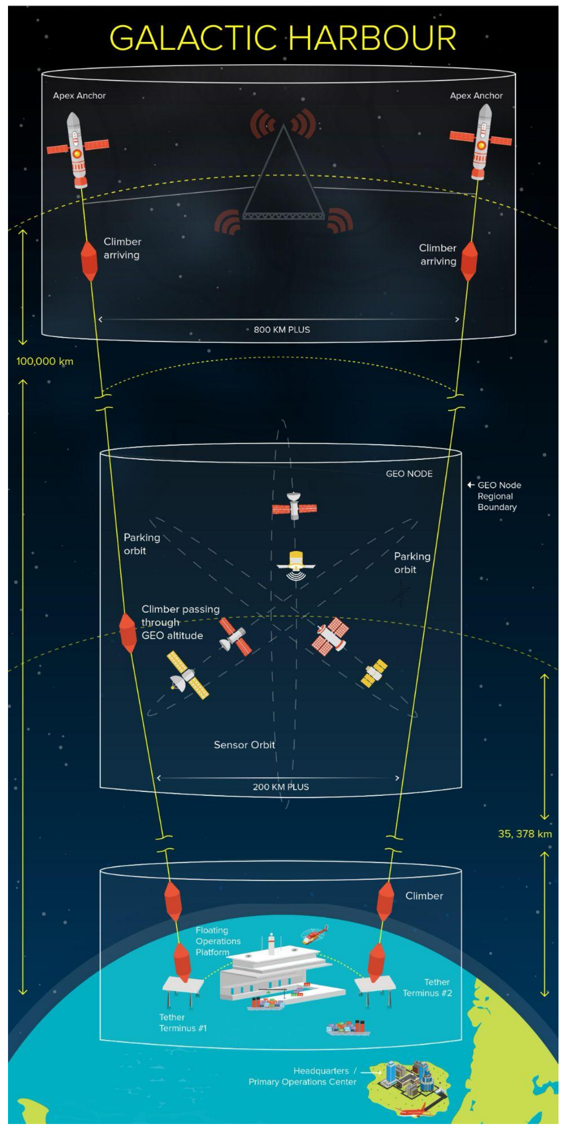

Fig 1. Structure of Galactic Harbour

3. Humans In Space Through Space Elevators

Majority of current space projects are designed for machinery and robots. Even though Human Space Flight frequencies have increased, along with the development of technology supporting it, it is still not possible to plan a lot of space missions to include humans. This is because of the time and resources that are needed to undertake such missions, and also because of the limitations of the current technology to create an environment to support human life.

Additionally, there are also perceptions which highlight the reservations to plan human missions like the belief that human contribution and work would be insignificant compared with the counterparts; machine and robots. Despite the problems and constraints of human supported missions, it is still necessary to consider the benefit of human presence in space missions. It is essential to notice how missions, previously focusing on only using machine assistance, had to use human assistance to succeed and how significant goals were achieved through human missions. One such example is the astronauts' repairing and upgrading of instruments of the unmanned Hubble Space Telescope that made possible its great successes.

It is thus essential to think about human missions, and human space elevators, and it is essential to do that now. The James Webb Space Telescope, launched 31 years after Hubble, was proposed before the launch of the Hubble Telescope. As the first-stage development plan of the space elevator is focused on creating a machine operative environment, the next phase of development should focus on planning human habitable environments supported by space elevators. It is essential to do this now considering the resources, including time, that are needed to undertake big space projects due to the complex and precise nature of their engineering. The next few points in this section focuses on the benefits of development of a habitable environment in space elevators and try to explain how this can be beneficial.

3.1 Assembly Point And Transport System

There are numerous restrictions on the number of rocket launches and the amount of mass we can launch into orbits of other planets from Earth's surface. And as we progress and look ahead in the future, the needs of the era would not only be to be able to transport equipment outside Earth, but to do this in huge capacities and much more frequently.

Space elevators do this, and provide both a very powerful transportation system and an assembly point between Earth and space. This can be attributed to the increased capacity of mass launch and number of launch windows, and cost reduction per launch. These can transport from 30,000 tonnes/yr at operational capacity upto 170,000 tonnes/yr at full operation capacity to GEO[2].

This provides massive advantages against rocket launches. Due to increased windows of launch and the ability to customize launched material in space using space elevator infrastructure, a faster response to space missions is possible. Additionally, space elevators can also be used to manufacture and assemble huge equipment in space, and in geosynchronous orbits overcoming the size restriction barrier of rockets, ensuring tailored responses to mission needs. They also ensure rapid transits to the planets, for example for Moon the transit time is around 14 hours [2]. Because of these efficiencies of space elevators, it will be possible to better support missions in space like bases on the Moon and Mars, and provide a continuous and fast supply of materials to these planets without the need of less efficient rockets.

By human inclusion with this possibility of innovation and continuous transportation of heavy machinery and mass, space elevators open a world of manufacturing and mining in space, and space settlement.

Additionally, the in-orbit service sector is growing with 17,000 satellites predicted to be in-orbit by 2030 [3]. These satellites have a lifetime of around only 15 years[4]. Space elevator provides an infrastructure platform for in-orbit servicing of these satellites without having to bring and launch the machinery and components back to Earth. This would open doors to continuous upgradation enabling reuse and longer lifetimes satellites thus ensuring sustainability.

3.2 Research

"Man must rise above Earth to the top of the atmosphere and beyond, for only then will he fully understand the world in which he lives" – Socrates (469-399 BC).

The contribution of research done in ISS holds significant value to a lot of industries today. This research is unique compared to the one done on Earth as it is possible to take advantage of microgravity conditions and get completely unique data. The examples range from astrophysics studies, biomedical industry to improved protective glasses which is included further in this section [5].

There are a lot of constraints limiting the potential of research done on the ISS. These include limited flight opportunities, constraints on the amount of mass that can be launched, costs and extended times periods between the available flights. It is, in addition, difficult to redesign experiments on ISS because of limited access to raw material to make new equipment. There are also questions about the quality of the research that came from the inability to design, repeat or confirm experiments in ideally controlled conditions to draw sound conclusions [5].

One of the major reasons to have habitats tied to Space Elevators is the potential it holds to overcome limitations of the ISS.

One of the biggest advantages of space elevators is that not only can they act as a platform for these experiments but that they are always connected to Earth. This connection to Earth ensures continuous and a quick demand based supply of materials and equipment to conduct research. An example of how constraints on the amount of material can affect experiments is how doctors monitoring the health of astronauts on Skylab requested several blood samples throughout the mission which spanned 28-84 days, each requiring at least 60ml of blood drawn. The samples were too bulky to store and bring back and the information could not be collected on Skylab[5].

We can overcome these challenges through space elevators. We will have a continuous supply chain of material to and from Earth which enables us to change experiments and collect multiple data sets by changing the conditions.

In addition to all the benefits, space elevators also have the potential to provide a platform attached at different altitudes depending on research needs, and these platforms are not time constrained unlike flight missions. This provides us a way to experiment at different altitudes and study the atmosphere at different heights.

Thus space elevators have huge potential for bringing research forward.

3.3 Commercial Purposes

Space elevators can be used to manufacture not only the products to be used in space, but also products to be used on Earth that can't be manufactured on grounds due to gravity.

One such example is the possibility of producing artificial tissues for repairing damaged organs. In Earth's gravity, the cells grow in a 2D plane. In space, without gravity, it grows 3D similar to how human tissues look. This could be extended to developing organs and researchers believe that microgravity could be an ideal environment for growing "independent" organs [6].

Another example is protein crystallography which is a tool to determine 3D structure of proteins which is needed to make drugs to target specific proteins like in an infectious agent. Obtaining pure crystals for this on Earth is a tedious process with a very low success rate. In microgravity, crystals grow more slowly giving larger and more pure crystals [6].

These examples are not only restricted to biomedical uses. In-orbit service from the previous section is an additional example to highlight how space elevators can be used to produce products and provide services necessary for industries on Earth.

Today, the high costs and the long intervals limit commercial products going to market. Space elevators can exploit this gap in the market to support other industries, and with human incorporation, the potential is limitless.

3.4 Trial Base Camp Environment

With our future goals aimed at setting bases on different planets, there is a need to understand and test both today's technology and medical practices to prepare better for the challenges that we might face. This can be done on Space Elevators. It is an ideal platform to test any technology made for space missions. It is also possible to develop the equipment and advance the idea further after understanding the shortcomings through the continuous supply of material from Earth.

We can also test medical practices and biological responses ,like operation in zero gravity, which have been very challenging to understand and simulate on Earth. Another example of such a problem is viruses becoming more virulence in microgravity [6] .

It would also be an excellent place to train astronauts and other members of the workforce against the harsh environments of space and low gravity. Using the space elevator as a platform to simulate conditions of space bases exposes us to challenges and solutions that were not realized yet.

The technology to solve space industry challenges has continuously driven the technology on the Earth for more advanced understanding of the problems. The development of a trail camp would push these limits much further.

3.5 Tourism

Space tourism is a growing branch that attracts not only people from the space community but also a diverse audience from different backgrounds. The market was estimated at USD 652 million in 2021 and is projected to surpass USD 9.35 billion by 2030, poised to grow at a registered CAGR of 37.5% from 2022 to 2030[7]. Exploiting the capacity of space elevators to work as an infrastructure at different altitudes, it is possible to turn it into hotels and restaurants for the tourism industry. Not only will this fulfill a growing market need, it will also normalize the industry amongst a non-space audience. This would bring more money in form of investments thus contributing to industries growth.

3.6 More Opportunities For Next Generations

Space elevators will make space more accessible for people in both industry and academic research. It would enable the coming generations to see space as more approachable and as something they can learn about and explore easily instead of something that is remote and inaccessible.

Because of the power of the platform, it would also be possible to provide young professionals and students access to the space environment for better preparation in fields like research, space exploration and training for their careers. The supply of these highly experienced and skilled young professionals would supply the industry with a skilled force that understands the problems from a very early stage. This would in turn motivate more research and development of new technology to solve these problems in the industry. Thus, space elevators have the potential to make significant contributions not only in the science community but also in space and other industries around the world.

3.7 Necessary Because Of The Growing Trends

The growing trends of the space industry point towards human flight and human involvement in space projects. As the second phase of the space elevators is planned for much advance in the future, it can be drawn that it would not only normalize but also become a necessity to have humans on space projects and thus space elevators to match both market needs and demands.

4. Challenges And Problems

The future trends towards incorporation of humans in space vehicles highlights the needs to look at challenges to do so. It is essential to think about the challenges and problems that we would face. In this section, some of the potential challenges and problems are highlighted which range from biology of the human body to the laws and economy of such an architecture.

4.1 Reconstruction Of Existing Architecture To Make It Habitable

As the first phase of the elevators is designed for robots, the most challenging aspect of making space elevators habitable would be reconstruction to include architecture needed for survival. This could mean preparing a new structure or upgrading the existing one, both of which would require additional resources and technology.

A lot of these challenges related to human body needs are challenges we have been trying to solve in ISS or for future human missions. These include planning of resources, in addition to food, water and air, that would be needed for survival like temperature control, radiation control, pressure control and gravity control in the environment. A significant technology growth and more accessible solutions can thus be forecasted for these by the time Space Elevators go into phase two.

Additionally, because we are planning for a longer term and more volume of human stay, this comes with a lot of new engineering challenges like drainage and waste disposal systems, backup storage of resources and continuous energy supply.

There is also a need to understand secondary side effects and psychological impacts. Popular examples of secondary side effects on the human body include change in sleeping patterns, elongation of cells and degradation of muscle and bone mass.

As space elevator habitat would be both a home and a workplace for people working one also needs to think about the psychological effect of staying in a closed and controlled environment. As this would be both the workplace and home for people working on research and assembly units, it is essential to understand how this affects productivity, mood and human response to problems.

Additionally, as reaching any point on the elevator means traveling through different altitudes to reach the target one, it is also essential to understand if frequent travels or longer travel times would cause any travel sickness similar to sea sickness. This also means finding the right speed so both traveling time and no reaction from the human body is achieved. There might also be a need to specially train people in similar conditions to overcome some of these effects.

4.2 Adjusting Environment For Experiments And Assembly

As a major use of the elevators is for research, and production and assembly, it is also essential to plan an environment suitable for changing research conditions (like temperature, pressure and gravity) when needed. It also means being able to create the right environment for production and assembly to understand tasks like soldering or working with highly reactive chemicals.

4.3 Additional Safety And Emergency Service

As the space elevator has so many purposes, it can be estimated that a large number of humans would be working on this. To provide a comfortable and safe environment to work, it is essential to think about safety measures and backups in case of failure of main services like temperature control, pressure control etc. There is a scope of planning additional support belts to enhance safety. There is also a need to think about escape mechanisms like pods and capsules. Emergency services and emergency responses also need planning.

5. Future Development And Conclusion

Space elevator is a very revolutionary idea which has the capacity to change and shape the future of the space industry. To fully utilize and exploit its potential, it is essential to consider and plan for human presence. And thus, the future development of the space elevator should consider the idea of possible human expansion and how and if they can prepare for it while establishing the initial structure for the primary phase. It is also essential to research further and complete an in-depth study of all the problems human settlements can face to be better prepared for it. As the space industry is very dynamic, it is necessary to keep revisiting the problems and needs to be able to propose solutions for the future.

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