# Riding the Cosmic Highway: The Future of Space Elevators

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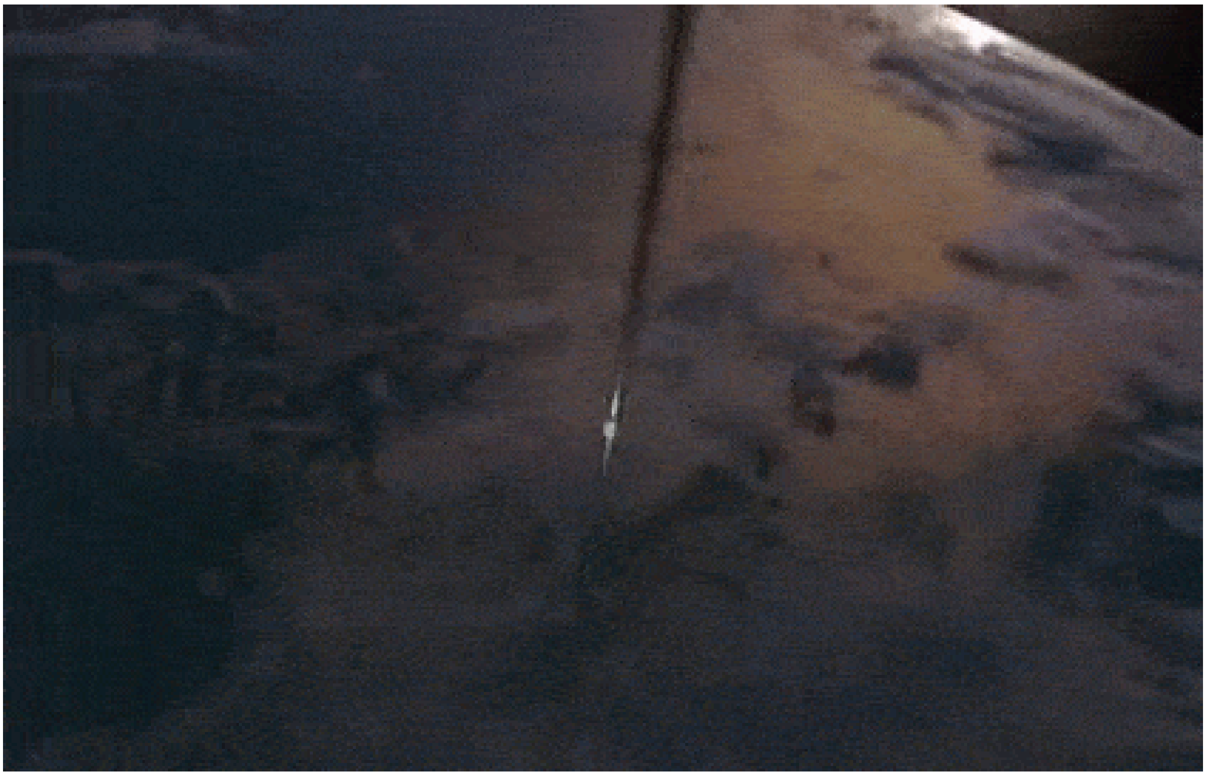

(https://gifs.com/gif/space-elevator-concept-nasa-animation-mPg08d)

Step into the world of the extraordinary, where the boundaries of space and Earth converge. Imagine a tower reaching to the heavens, a bridge between our planet and the deep unknown. This is the concept of a space elevator, a remarkable feat of engineering and imagination. From the remarkable mind of Konstantin E. Tsiolkovski, who defied all odds to become one of the visionary founders of this concept, to the brilliant inventors Yuri Artsutanov and Jerome Pearson, who brought it to life, the space elevator holds the key to unlocking new frontiers and revolutionizing space exploration.

Join us on a captivating journey as we delve into the intricacies of this extraordinary creation and explore the possibilities it holds for the future of humankind. The sky is no longer the limit; it's just the beginning.

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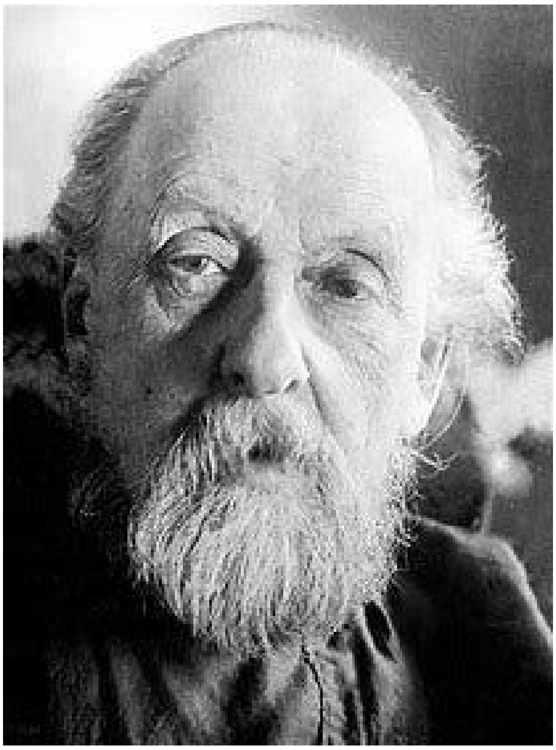
### History of the Space Elevator

In a small village in Russia in the year 1857, a remarkable child was born. His name was Konstantin E. Tsiolkovsky. This man suffered during his childhood after he became deaf due to an outbreak of scarlet fever at the age of 9. Despite the challenge, he became one of the most visionary founders of the space elevator. When Konstantin turned 14, he decided to teach himself using his father's library. Two years later his father noticed the progress he had made and sent him to study technology in Moscow where he had then begun to learn all about space.



In 1880, Konstantin was appointed as a teacher for geometry and arithmetic. This is where he began to write about his technical and scientific findings and began to write Western science fiction. In these novels, he would include bits of his scientific ideas with science fiction creations. However, he sometimes got so into the technical speculations of his writings that he forgot about the characters of his story altogether!

He even built experiments to test his many theories, one of which was the testing of how many G's a living organism could survive. He would place an insect or chicken in a hemispherical bowl and spin it fast to represent how much gravity they could survive, therefore understanding how fast the human body could go without being harmed.

Tsiolkovsky also began to envision extremely large towers and tethers to illustrate some effects he had predicted about the environment of space. He wrote about them in essays explaining how if these towers were electromagnetic, they could launch different-sized payloads into space without any sort of propellant.

He also proposed the idea of something similar to "Train tracks." This idea involves several "train track" -like structures in the Earth's atmosphere at different levels. He proposed the idea that if you were on one of these tracks that was moving at a relative speed around the Earth and you jumped up you could land on the second track, if you continued to do this several times you could bypass the gravity of Earth pulling you downwards and enter space. (This is if you could breathe in space and survive the large amounts of pressure when exiting the Earth's atmosphere).

Konstantin's "Train Track" idea

However, this man was merely just a philosopher of technology. The real inventors behind the space elevator were Yuri Artsutanov and Jerome Pearson, both in the late 1900's. Artsutanov's idea developed after his coworker had given him a sample of a high-strength material. He had then begun to think about how this material could be used and if it could support a large-scale project such as a space elevator. On the other hand, Pearson's idea came from hearing Arthur Clarke describe geostationary communication satellites, and Pearson began to wonder how space elevators could be geostationary.

They both developed ideas for the public but it wasn't widely publicized to the technical industry until Pearson wrote about them through his technical literature. After Pearson published his writings both he and Artsutanov started applying this technology to potential uses on the moon. They began to adapt Tsikolvoski's ideas such as the "rolling satellite" (Talked about later on), which involves a satellite orbiting the Earth with metal spokes that reach the ground to pick up passengers or payloads.

John Isaacs was also one of this idea's creators. He was an oceanographer who began to think about the process of "throwing" payloads into space. However, his ideas never generally penetrated the area of space flight engineering. Several science fiction novels began to come out about space elevators after these ideas were more thought of and publicized.

This idea wasn't just thought of in the last 200 years, it was thought of far before then. For instance, the writing of Moses references a civilization in 2100 BC trying to build a tower to heaven. Another case would be a man in 1900 BC, named Jacob, who dreamt of a ladder to heaven, commonly known as "Jacob's ladder."

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### What is a Space Elevator??

Putting it extremely simply. It's like an elevator except instead of pressing a button inside of an office lobby to reach the top floor, it goes to space. The deep, dark, tundra of space. Scientifically however it is a connection between Earth and a satellite in geosynchronous orbit (GSO).

Before I go on however you probably should know what GSO is because it's mentioned quite a bit. Geosynchronous orbit—an orbit around a planet (Mostly in this case it's Earth or Mars), in space. For example, a Geosynchronous satellite would orbit the Earth every day. Now, this is not to be confused with GeoSTATIONARY orbit which is a particular GSO that stays in the same place over the equator. Which would be if you looked directly into space, the elevator would look… well… stationary.

Now, let's continue. There are many different types of space elevators which I will explain later in this article but for now, think of it as a space tether (a long cable used to connect things like satellites) that hangs down from a satellite in the sky and attaches to a station on the ground. Something that would look like this:

A space elevator reaches an approximate height of 35,786km. An equivalent to 44,732 giraffes stacked on top of each other. (I don’t know about you, but in my opinion, that’s a lot of giraffes.) The structure is mainly used for the transportation of payloads to space. Once that is achieved, the use of a space elevator sending people to space wouldn’t be too far in the future.

## In-depth GEO Space Elevator Design

The major obstacle to building space structures is the high cost it takes to launch these payloads. The areas for space development require this cost to be lowered. Currently, it costs somewhere between $10,000 and $25,000 USD to send something to space and $250,000 to send SOMEONE to space using conventional rockets. The use of a space elevator (since there are low energy requirements) lowers the cost to about $10 per kilogram.

During a 2000 workshop at NASA, a space elevator concept was designed to represent the scale, purpose, and complexity of a space elevator. This concept was imagined as a platform at sea and would work similarly to a seaport where cargo and passengers could transfer payloads between space and Earth. This space elevator would be located in international waters because the project would need international cooperation to be executed.h

The best design for traveling to such an extensive height would be a vehicle propelled up the tether by electromagnets. These magnets could travel several kilometers per hour and there wouldn't be any need for moving parts such as wheels which could potentially wear down the tether over time.

In space for this design is a GEO transfer station. It allows for travelers or payloads to then be transferred to additional space vehicles after riding the elevator. Like Tsiolkovski's or Isaacs's design, the GEO Space Elevator at 47,000km altitude could then launch or "throw" passengers into space.

### Technology for this design:

- **Materials**—Must exhibit strength 100 times stronger than steel.
- **Tension Structures**—Developments of space tether technologies to gain experience.
- **Electromagnetic propulsion**—This needs to be developed for high-speed propulsion systems.
- **Space Infrastructure**—Reusable payload launch systems for continued use of space elevator.

This structure's design is not impossible because it is theoretically possible to build any tower of any height with any material, just by increasing its thickness. This space elevator's strength requirements are assumed to be about 62.5GPa.

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## Different Types of Space Elevators

Elevators for launching payloads of great sizes into space cheaply can be supported by static force balance or by the dynamics of unmoving masses. These designs about to be mentioned are based on the use of a stream of magnetic grain particles that can be harvested from the moon, acting as a current carrier to move a desired object (In this case a payload or person) into space. Spacecraft equipped with these grains generate high magnetic fields and it also helps to decelerate the speed of a spacecraft.

However, with all of these designs, the environmental effect on both Earth and in space in the event of a catastrophic failure of a space elevator could potentially be extremely hazardous and even deadly. The biggest concern however is potential collisions with the space elevator from asteroids or space debris.

### The Static Space Elevator

This structure would range somewhere between 2,000 to 4,000km in height. (Around 757 giraffes). Has a statically balanced structure that is centered in a geostationary orbit. It extends both ways: Downward towards Earth and upward towards space to balance it out. The lower end touches the equator and the upper end acts as a counterweight balance to allow for structural tension, giving it the ability to lift payloads without crashing down to Earth. Transferring a payload up from the Earth's surface would require less of a change in velocity and would be easier to send up. This idea was invented by Isaacs, Pearson, and Artsutanov. This concept however requires high-strength materials and is vulnerable to collisions.

PBO fibers could be used to develop towers of this height. The tower could be built in sections to keep pressurized gasses from reaching the bottom of the tower.

### Dynamic Space Elevator

Overcomes the material requirements of the static space elevator. Paul Birch proposed this concept that involves an orbital ring of conductive materials moving faster than orbital velocity inside of a thin torus circle that is around Earth. A moving cable allows for the structure to be usable and supports the idea of "Jacob's Ladder."

### Rolling Satellite

Imagine the static elevator from above. If you forgot what that is already, just move two paragraphs up and give yourself a brief refresher. Now imagine that this satellite is set into rotation around Earth. So, in other words, it is no longer geostationary. A rotating tether in orbit like this provides enough orbital energy to launch a payload into space without a rocket engine. When payloads get sent back, they enter on the far side of the elevator, and they get shot back to Earth down the elevator. No net energy is required for this design. However, the concept faces the challenge of tether dynamics and high-speed rendezvous.

**STOP!** Ok, you're probably like, you lost me. What in the world is high-speed rendezvous???? Well, that's what I'm here to explain. Consider this a brief intermission to our types of space elevators.

### High-Speed Rendezvous (simply explained):

High-speed rendezvous is a technique used in spaceflight where two spacecraft meet at high relative velocity and dock together. It is used to save fuel and time by reducing the number of orbits required to reach the destination. The technique involves one spacecraft chasing another spacecraft that is ahead of it and then matching its speed and trajectory. The two spacecraft then dock together.

Now back to elevators...

### Grain Stream Space Elevator

Overcomes most all problems from previous design attempts, similar to the orbital ring however these use less massive streams of magnetic particles. This design dispenses with a massive enclosing torus. Grain is then dispensed naturally by the gravitational fields of satellites just like the rings on Saturn are. One of these structures in elliptical orbit around Earth could support a lot including a space elevator and a space station. This structure is also entirely in the atmosphere where no debris can penetrate it and it can be built in stages.

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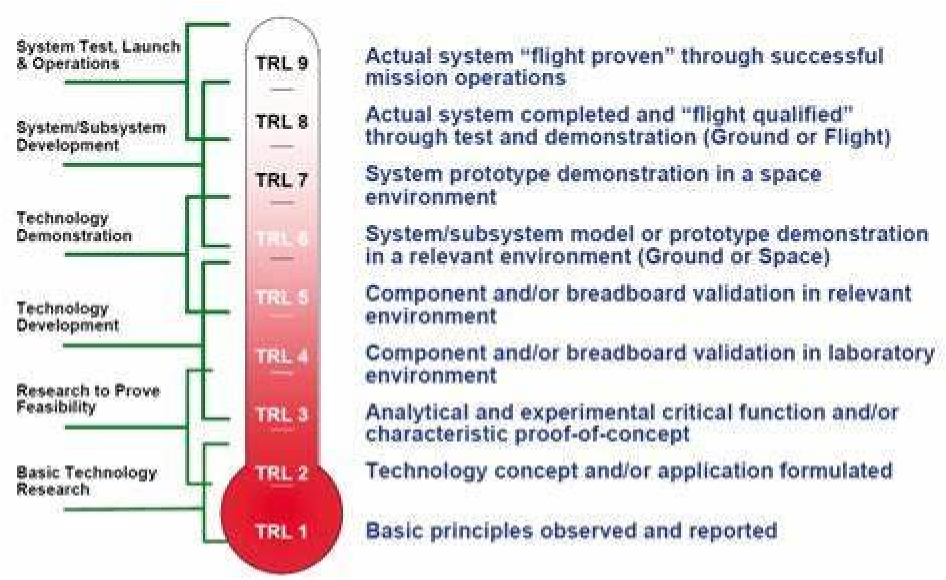
### Critical Technologies Needed



[Technology Readiness Level (TRL) chart with criterion descriptions... | Download Scientific Diagram (researchgate.net)]

Materials for this design would still need to be worked on to construct a tower this size. Climatic conditions could be an issue and the cost and technology needed to repair in the event of a troubling climate and space debris could be greater than the use of current conventional rockets. So, let's assess the overall feasibility of this design over the next few years of development.

For this, we are going to use a NASA-derived system known as TRL. The TRL scale is used to rank a technology's readiness allowing the overall feasibility of a project to be assessed. There are 9 different TRL levels including 1–2 Basic Tech Research, 3–5-tech development in laboratory experiments, and 6–9 integrated systems ready for flight.

The reason NASA has not gone too in-depth with developing plans for space elevators is because of the technology's ranking on the TLR scale. For instance, these technologies are a few needed for the space elevator that was given a low ranking:

- Carbon Nanotube (CNT)—Development of single-wall carbon nanotubes with characteristics in the 150gpa range.

**Ranking: TRL 4**

- CNT Composite Fiber Development—Incorporating large amounts of CNT into a composite fiber matrix. The process must also be scalable for mass production.

**Ranking: TRL 2**

- Ribbon Design—The ribbon for the tether structure must be designed for environments it will encounter. Stressed in this ribbon matrix in the 60GPa to 80GPa range when the target GPa has to at least be 100.

**Ranking: TRL 2**

- Robotic Climber Operations—Used to construct the ribbon and make repairs to maintain the space elevator.

**Ranking: TRL 3**

- Ribbon Control Systems—To keep the ribbons for tether in geosynchronous orbit. Also controls tension, climber dynamics, induced waves, and atmospheric effects.

**Ranking: Between TRL 2 and TRL 3**

Overall full-scale ranking of a space elevator is a TRL 2 which is the main reason the technology is not yet ready to be executed or invested in.

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**Steps needed to be taken before building the space elevator:**

1. Ground Tests
2. Material Development and Testing in a Relevant Environment
3. Vertical treadmill tests

- Micrometeoroid impacts
- LEO objects and debris
- Radiation and atomic oxygen
- Atmospheric conditions

**4**. Tethered balloon tests

**5**. Spaceflight tests and demonstrations

**6**. GEO deployment demonstration

**7.** GEO deployment and Traversing demonstrations

- Such as a geosynchronous communications satellite and LEO to GEO elevator.

**8.** Full-scale lunar demonstration

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**A New Tool for Space Studies**

A space elevator would allow for more studies of biological systems in the environment. Currently, biological systems are placed on rockets where they stay in space for a certain period before being sent back to Earth. These are conducted to study stuff during specific situations in real-time. The largest biological systems were actually done on humans themselves. The only thing these tests cannot test yet is the evolutionary effects of a species.

With a working space elevator plants and small animals can be lifted intact without any large vibrational spikes that could alter the test. They can be studied through remote cameras before being brought back down to Earth.

A space elevator will also allow payloads to be delivered to Earth orbit, Mars, asteroids, the moon, or other planets as well. A space elevator could lift 13-ton payloads to space every three days!

Example: A biosphere experiment. A sphere that is 5 m is sent to space in a geodesic structure (Think of the Epcot ball at Disney World, just smaller). These would be the weight requirements to send it to space using a space elevator:

- 100kg of KW power
- 200kg of cameras
- 500kg of diagnostic modules
- 1000kg of altitude control systems
- 100kg of Hardware
- 1020kg, the weight of the sphere itself
- 55kg of the air inside the sphere

This leaves a total of 10,000 kg of weight the elevator can still lift, which could be used for biomass materials to fill the sphere with.

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### This is the Future of Space Technology

The concept of a space elevator represents a remarkable feat of engineering and scientific imagination. While its origins can be traced back to visionary thinkers like Konstantin E. Tsiolkovski, the true inventors behind its development were Yuri Artsutanov, Jerome Pearson, and other dedicated scientists and engineers. The space elevator holds the potential to revolutionize space exploration by drastically reducing the cost of launching payloads and even enabling human transportation to space. However, the current technological readiness of the required materials and systems is still at a relatively low level, as indicated by the NASA-derived TRL scale. Extensive research, development, and testing are needed to overcome the challenges posed by materials, construction, tether control, and environmental factors before the space elevator can become a reality.

Despite the significant obstacles ahead, the space elevator remains an enticing prospect for the future of space exploration. It offers the promise of unlocking new scientific discoveries, facilitating more extensive studies of biological systems, and enabling efficient transportation of payloads to various celestial destinations. As advancements continue in material science, robotics, and other relevant fields, the feasibility of constructing a space elevator may increase. With international collaboration and concerted efforts, humanity may one day witness the realization of this monumental structure that connects Earth to the vastness of space, ushering in a new era of exploration and discovery.