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Term Paper

Space Elevators

Once the stuff of science fiction, the concept of space elevators may soon make its way into reality. NASA has funded studies to explore the idea, and has concluded that it is now possible by utilizing carbon nanotube technology. The elevator will consist of a ribbon with one end attached to the Earth's surface and the other end in space beyond geosynchronous orbit (22,000 miles/35,800 km altitude). The competing forces of gravity at the lower end, and outward centripetal acceleration at the farther end, keep the ribbon under tension and relatively stationary over a single position on Earth. Robotic climbers will ascend the ribbon, carrying payloads into either Earth orbit or outer space ("Highlift Systems").

Building and deploying the ribbon will prove to be the most challenging task. The current plan is to deploy it from geosynchronous orbit using four rockets and a magnetoplasmadynamic upper stage. Once this first ribbon is in place, climbers would ascend it, adding additional ribbons along side the first to increase its strength. After 2.3 years, a ribbon capable of supporting 44,000 lb (20,000 kg) cargo climbers would be complete. The climbers will get their energy from lasers aimed at them by a base station as they make their way up the ribbon. Photocells attached to the climbers will convert the laser energy into electrical energy, powering electric motors capable of pulling the climbers up the ribbon at speeds up to 124 mph (200 km/hr.) These initial "builder" climbers will ultimately become part of the counterweight at the space end of the 62,000 mile (100,000 km) long ribbon.

The ribbon will be built using carbon nanotubes which were first discovered in 1991 by the Japanese electron microscopist Sumio Iijima who was studying the material deposited on the cathode during the arc-evaporation synthesis of fullerenes. He found that the central core of the cathodic deposit contained a variety of closed graphitic structures including nanoparticles and nanotubes, of a type which had never previously been observed. A short time later, Thomas Ebbesen and Pulickel Ajayan, from Iijima's lab, showed how nanotubes could be produced in bulk quantities by varying the arc-evaporation conditions. This paved the way to an explosion of research into the physical and chemical properties of carbon nanotubes in laboratories all over the world ("Carbon Nanotubes"). Carbon nanotubes have the potential to be 100 times stronger than steel, and ribbons made of this material could theoretically be 3-5 times stronger than they need to be for the elevator, ensuring that they do not break under load ("LiftPort").

One of the biggest advantages to having a space elevator is the reduced cost in launching vehicles into space. One study estimated that the cost of sending payloads into space could be reduced from $20,000 per pound to $400 per pound. The largest single cost in launching the space shuttle is the rocket fuel, but there are also other costs, such as building and maintaining the vehicle and building expendable rocket boosters. To get into low Earth orbit, the space shuttle burns approximately 4 million pounds (1.8 million kg) of fuel in eight minutes. That's a huge amount of fuel for a 200-mile (322-km) trip. With a space elevator, the need for rocket fuel is eliminated completely ("How Space Elevators Will Work"). Additionally, as the climber moves further up the ribbon, its speed increases due to the centrifugal force produced by the spinning counterweight, pulling it into orbit. By the time it reaches the end of the ribbon, a vehicle could detach and fly off into space at speeds fast enough to reach Mars in days or weeks instead of months. The space elevator should prove to be safer as well, eliminating disasters that have occurred with space shuttles, and more than one can be built and used at the same time.

There are many technical and theoretical questions being asked about the space elevator. Conservation of angular momentum has been one of them. As the climber ascends the ribbon, the spinning of the Earth will cause it to accelerate eastward, and this force will increase as it climbs higher. But if one goes through the math quantitatively, the angular momentum for the climbers requires a pound or so of force over the one-week travel time, and that is done easily with the many tons of material in the anchor and the counterweight (“LiftPort”).

Another major concern is what happens if the ribbon breaks. The base station for the elevator will be located near the equator, in the ocean on a floating platform. A location will be chosen that is free from hurricanes, lightning, and other extreme weather. Since the ribbon is engineered to be at least twice as strong as it needs to be, and capable of withstanding up to a category 5 hurricane, the chances of it breaking are low. If it were to fall, the long end of the ribbon would gain enough acceleration to burn up in the atmosphere while the lower portion would fall into the sea. This lower portion would produce less pollution than current rocket-based launch systems, and is light enough to flutter to the ground like an open newspaper Eventually any portion of ribbon that were to fall to Earth would degrade, but not for a very long time. The debris would resemble long hair and would probably be broken up in interactions with animals, plants, wind, fish, and waves. In fiber form it would be much too large to inhale and would probably work its way through a digestive system unaffected. The only concern would be if it were reduced to nanotube size. This is not yet understood and will be studied to see if there is a problem that would require design changes. Any cargo ascending the ribbon when it broke would either fall, end up in low-Earth orbit, or get tossed into high-Earth orbit, depending on where the break took place and the position of the cargo on the ribbon. Escape pods or re-entry vehicles may be required depending on designs.

Another risk is orbiting objects, such as satellites or other debris, hitting the ribbon. On average, an object would have to be avoided every 14 hours. Having a mobile base station located in the ocean will provide this necessary mobility. Tracking systems will provide collision warnings days or weeks ahead of time, and the anchor will need to be moved about a kilometer each day to avoid the debris ("LiftPort"). Planes are not a threat thanks to the remote location of the base station, approximately 400 miles (650 km) from shipping and plane routes.

The goal at this point is to have a working space elevator in 15 years time. Companies are currently conducting further research and looking for investors to help fund the project.

Works Cited

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