By the end of the 21st century, we may toss a satellite up into orbit — then dangle a tether all the way back down

How to construct a ski lift into space

BY MICHAEL LEGAULT

The space elevator would not be rocket science. There would be no fiery plume, no billowing white contrail from a sleek projectile rising into the sky.

But it could be a better way than rockets to put people into Earth orbit.

So simple is the concept that most kindergartners could grasp it: Take a tether — a length of cable about 47,000 kilometres long — and attach it to an Earth-orbiting object. Then dangle it down from space and hoist yourself up, as in *Jack and the Beanstalk*.

For scientists and entrepreneurs, a space elevator would also be like *The Goose with the Golden Eggs*. It would bring down the cost of reaching space by a factor of thousands. Like a highway or a mass transit system, it would be accessible 24 hours a day, seven days a week; it would also be within the budget of many space tourists; and it would probably lend itself to large-scale commercial and industrial development of space.

A Russian engineer, Yuri Artsutanov, was the first to propose the idea, in 1960. Then Jerome Pearson, an American aerospace scientist, refined it in a technical paper. That led Arthur C. Clarke to write *Fountains of Paradise*, a 1978 novel in which engineers build a space elevator from advanced materials on an imaginary island situated on the equator.

There, in the realm of fantasy, most space experts have left the idea.

One ugly fact sullied it. There was no material strong enough to make such a tremendously long tether. Until now.

Carbon nanotubes, discovered in 1991 by a Japanese scientist, Sumio Iijima, are six times lighter and about a hundred times stronger than steel at the same diameter. Tests have shown that they are the strongest material known, stronger than a space elevator would need.

Though the material is currently too expensive for large-scale use, the Herculean strength of carbon nanotubes seems to remove the last fundamental technical barrier to building a space elevator. Researchers speculate that a continuing decline in the cost of making nanotubes, together with certain engineering advances, could make construction of a space elevator feasible by the end of the 21st century.

"Nanotubes change the game," says David Smitherman of the NASA Marshall Space Flight Center's Advanced Projects Office. "This is still futuristic, but we think we now have a technology path for how this can be done."

Smitherman has written a paper summarizing the results of a workshop on space elevator concepts held last year at the Marshall Space Center in Huntsville, Ala. As conceived at the workshop, the centrepiece of the space elevator design is a 47,000-km tether made mainly of carbon nanotubes — one-sixth of the distance to the moon. The tether's upper end is attached to a large counterbalance — perhaps a captured asteroid or some human artifact — while the lower end is fastened to a tall tower on the equator, like Clarke's fictitious island.

Why the equator? So that the tether's centre of gravity can be aligned in a geostationary Earth orbit (GEO) about 36,000 km above Earth's surface. The counterbalance serves the same purpose; without it, the tether would have to be more than 170,000 km long.

"Geostationary" means that the tether stays over the same point above the equator as Earth rotates — a helpful feature for travellers who have been spoiled by the convenience of finding an airport in the same place each time they fly. The tether, though it is attached to Earth's surface, doesn't fall because, like a satellite, it is essentially in orbit.

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In the workshop's design, passengers are transported upward along the tether in electromagnetic-propelled vehicles that can travel at thousands of kilometres per hour. The transport system assumes that electromagnetic propulsion technology, which is already used in high-speed European and Japanese trains, will continue to progress.

Once they reach the GEO transfer station, passengers can connect with other outbound, shuttle-like vehicles, for transport to say, Earth-orbiting research stations, spas or discos. Or they can go on to the end of the structure, which, because it rotates at the same velocity as Earth, can act as a sling that throws vehicles out of Earth gravity for interplanetary travel.

To turn this concept into reality, Smitherman says, a number of technologies would have to be developed and demonstrated in the 21st century. One would be the construction of towers many times taller than Toronto's CN Tower, the world's tallest free-standing structure. A second would be the use of space tethers for payload transport in low Earth orbit. The most critical innovation, however, would be the ability to make long lengths of carbon nanotubes at much lower cost than at present.

Carbon nanotube material now costs about $500 a gram. Ken Smith, a physicist at Rice University in Houston, Tex., and his colleagues are developing a proprietary technology that he says should lower the cost of nanotubes to less than $1 a gram.

"The main thing that makes nanotubes expensive right now is that the process is not very efficient," says Smith.

At present, he explains, out of every 10,000 carbon monoxide molecules fed into a reactor consisting of tanks and pipes, only one carbon atom gets extracted and inserted into a nanotube structure.

The good news, Smith says, is that efficiency can be enhanced by adding catalysts: specially designed chemical agents. He is hopeful that large-scale production plants will lower nanotube costs still further, so that a space elevator becomes economically viable.

If and when a space elevator is built, engineers will have to plan for certain catastrophic failures. Breakage at lower section of the tether, for example, could drop thousands of miles of cable to Earth, and cause large-scale destruction and loss of life. For this reason, a remote ocean location would be safest. As well, use of futuristic "smart" materials might permit detection and repair of tiny cracks in the tether, before they expanded.

Critics argue that by the time huge amounts of money have been spent developing the various technologies necessary for a space elevator, a safer and more efficient means of space transport may be available.

Smitherman, however, contends that no feasible technology on the horizon can match the cost-effectiveness of a space elevator for transporting people and cargo into Earth orbit and beyond. "It roughly costs about $20,000 per kilogram to fly the space shuttle," he notes. "The space elevator will make it possible to orbit for less than $10 a kilogram. That's hard to beat."

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