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**Not Science Fiction: An Elevator to Space**  
By **KENNETH CHANG**

ANTA FE, N.M. — With advances toward ultrastrong fibers, the concept of building an elevator 60,000 miles high to carry cargo into space is moving from the realm of science fiction to the fringes of reality.

This month, the Los Alamos National Laboratory was a sponsor of a conference to ponder the concept. Yet, the keynote address was by a titan of science fiction, Arthur C. Clarke, speaking via satellite from his home in Sri Lanka. "I'm happy that people are taking it more and more seriously," said Mr. Clarke, whose novel "The Fountains of Paradise" (1978) revolved around such a space elevator.



The discovery in 1991 of nanotubes, cylindrical molecules of carbon with many times the strength of steel, turned the idea from a fantastical impossibility to an intriguing possibility that could be realized in as little as a decade or two.

Proponents say the economic and technological advantages of a space elevator over rockets make it inevitable. They predict it will lower the cost of putting a satellite into space from \$10,000 a pound to \$100.

"As soon as we can build it, we should build it," said Dr. Bryan E. Laubscher, a scientist at Los Alamos who organized the conference. Just as the transcontinental railroad opened the West in the late 1800's, "I feel the space elevator is going to be such a paradigm shift in space access," Dr. Laubscher said.

Easier economical access to space might also make practical other grandiose projects like solar power satellites that could collect sunlight and beam energy down to Earth.

The conference, a three-day session here, drew 60 people, a mix of scientists and engineers who are working on the concept, space enthusiasts who wanted to hear more and dilettantes from nearby Los Alamos laboratory attracted by curiosity.

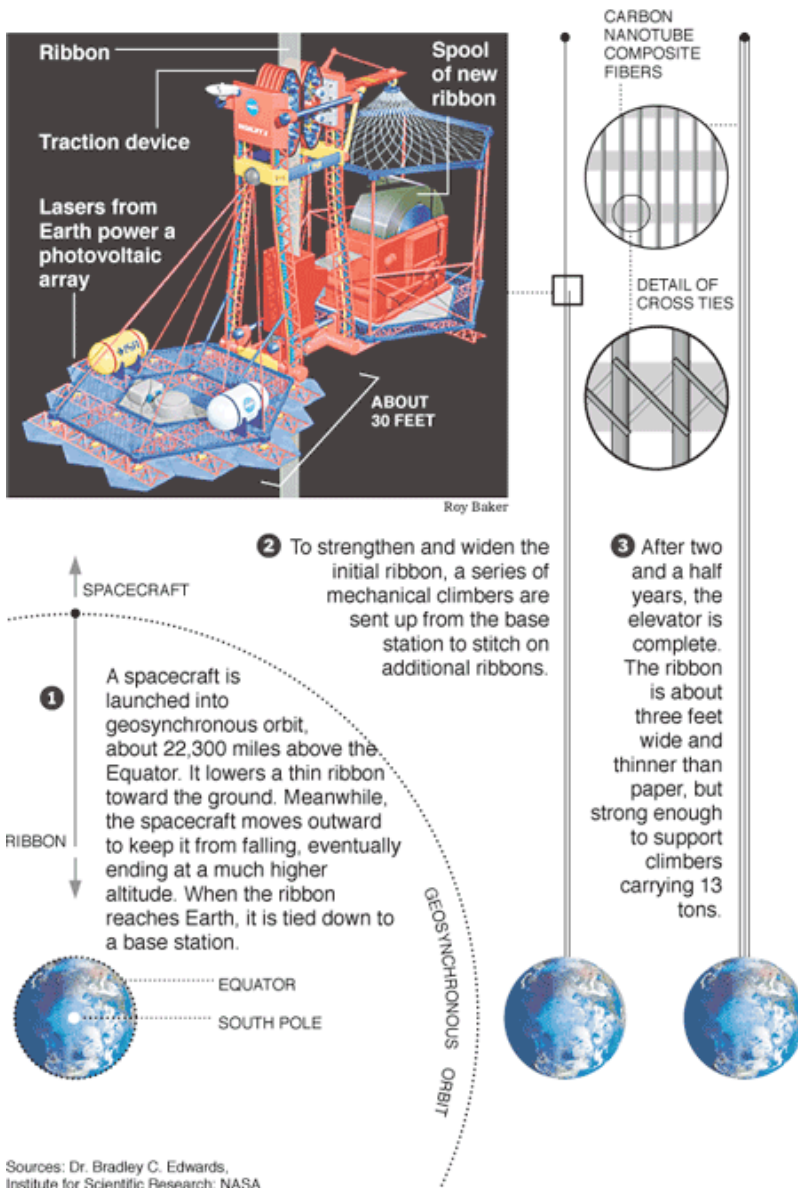
"The first thought is, Is this really going to work?" said Dr. Steven E. Patamia, a researcher at Los Alamos, who was enlisted into performing space elevator calculations a week before the conference. "When you get into it, it begins to make sense. There are a good number of technical issues. They are probably all 'overcomeable.'"

The original idea of a space elevator is more than a century old. In 1895, Konstantin E. Tsiolkovsky, a Russian visionary who devised workable ideas for rocket propulsion and space travel decades before others, proposed a tower thousands of miles high attached to a "celestial castle" in orbit around Earth, with the centrifugal force of the orbiting castle holding up the tower. (Imagine swinging a rope with a rock tied to the end of it.)

But the idea was fundamentally impossible to build. Steel, then the strongest material known, was too heavy and not strong enough to support that weight.

## Going Up

How a 60,000-mile elevator for space cargo could be constructed.



Other scientists periodically revisited and reinvented Tsiolkovsky's idea, inspiring science fiction writers like Mr. Clarke.

Nanotubes spurred NASA to take a more serious look in 1999. A team of scientists envisioned huge cables of nanotubes and magnetically levitated cars traveling up and down. The structure would be so large that it would require grabbing an asteroid and dragging it into Earth orbit to act as the counterweight for holding up the elevator.

To avoid weather, especially lightning, the NASA scientists envisioned the base station as a tower at least 10 miles high.

"We came out of that workshop saying the space elevator is 50 years away," said David V. Smitherman of the Marshall Space Flight Center, who led the study.

Around that time, Dr. Bradley C. Edwards, who was then a scientist at Los Alamos, read an even more pessimistic assessment, that a space elevator would not be built for at least 300 years.

"But there was no information why it couldn't be built," Dr. Edwards said, and he took that as a challenge.

Dr. Edwards simplified the NASA idea to what he calls "the Wright brothers' version," a single ribbon about three feet wide and thinner than a piece of paper, stretching 60,000 miles from Earth's surface.

He sent a proposal to the NASA Institute for Advanced Concepts, which provided him \$570,000 to flesh out the ideas. His results are described in a book simply titled "The Space Elevator" (SpaGeo, 2002).

Instead of using magnetic levitation, the apparatus would lift up to 13 tons of cargo by pulling itself upward with a couple of tanklike treads that squeezed tightly onto the ribbon. Up to eight would ascend the ribbon at any one time, powered by lasers on the ground shining on the solar panels on the rising platforms.

It would take about a week for one to reach geosynchronous orbit, 22,300 miles up, where a satellite circles the Earth in exactly one day, continuously hovering over the same spot on the Earth's surface.

The first elevator would go up only. At the top, the platform would simply be added to the counterweight or be discarded into space.

All the necessary underlying technology exists, Dr. Edwards said, except the material for the ribbon. (The longest nanotube to date is just a few feet long.) But he said he expected that scientists would develop a strong enough nanotube-polymer composite in a few years.

"There's a clear path to building this," said Dr. Edwards, now director of research at the Institute for Scientific Research, an independent organization in Fairmont, W.Va. The institute sponsored the conference with Los Alamos.

Dr. Edwards estimates the cost to build the first elevator at \$6.2 billion, although with the uncertainties in forecasting a decade or two of research and development, "doubling this is probably a good first cut."

"It's gotten to the point," he added, "where we can say it's closer to \$6 billion than \$600 billion."

Building subsequent elevators would be cheaper, \$2 billion each, because the first elevator could lift materials.

By comparison, the estimated cost of building and operating the International Space Station is widely expected to exceed \$100 billion.

Dr. Edwards says he has reasonable solutions for other concerns. The elevator base could be a movable ocean platform in the eastern equatorial Pacific, hundreds of miles from commercial airline routes and easy to defend from terrorist attacks. Hurricanes never cross the Equator, and lightning is sparse in that region. By moving the base station, the elevator operators could drag the apparatus around low-orbit space debris. An aluminum coating could be added to parts of the ribbon to combat decay from the reaction of oxygen with carbon atoms in the nanotubes.

More futuristically, Dr. Edwards imagines that additional elevators can be built on the Moon or Mars, vastly simplifying and speeding spaceflight through the solar system.

"What a wonderful idea if you could ever make it work," said Gentry Lee, the chief engineer of planetary flight systems at NASA's Jet Propulsion Laboratory in Pasadena, Calif., who pushed for financing Dr. Edwards's initial studies. "It is plausible. It is not implausible. I think that the idea has so much promise a couple of million dollars a year aimed at the enabling technologies is not too much to ask."

At the conference, scientists presented calculations that examined details. Vibrations in the elevator ribbon, which would act like an extremely long plucked guitar string, appeared manageable.

Dr. Anders Jorgensen of Los Alamos raised concerns that as the ribbon swung around through the Earth's magnetic field, it would create strong electric currents. Because of the elevator's relatively slow pace, a larger problem could be that any human passengers would receive dangerous doses of radiation as they passed through pockets of high-energy particles trapped in Earth's magnetic field.

The first space elevator would be built to carry only cargo, not people, Dr. Edwards said. The dangers could be reduced on subsequent elevators by speeding them up or providing shielding through magnetic fields.

The logistics of construction "appear to be an interesting problem, as well," said Carey R. Butler, a program manager at the Institute for Scientific Research. The idea is to launch a spacecraft with the initial spools of ribbon into geosynchronous orbit. As the ribbon unspools and falls to the ground, the spacecraft moves higher to keep the center of mass, or balance point, at the same geosynchronous height. By the time the ribbon reaches the ground, the spacecraft has reached an altitude of 50,000 miles.

After the ribbon is attached to the base station, the spacecraft unfurls another 10,000 miles of ribbon.

Then a series of about 230 mechanical construction platforms will ascend to stitch on additional ribbon.

While technologically feasible, years of engineering will still be needed. "There's a lot to be done, obviously," Dr. Edwards said.

Nonetheless, Mr. Clarke, who came up with the idea of using satellites in geosynchronous orbit for communications long before any were launched, thought that he might live to see to live this science fiction idea come true, too.

"I'm 86 now," Mr. Clarke said. "So in 20 years' time, I'll only be 106. So maybe I will see it."

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