Tethered Satellites: High Tech Skyhooks

TETHER TECHNOLOGY

By Emily Isberg
Smithsonian News Service

In the 22nd century, a visionary engineer named Vannevar Morgan decides to replace "noisy and expensive rockets" with a high-speed elevator into space--a cable that could whisk passengers and payloads from a mountaintop in Sri Lanka to a satellite hovering 32,000 miles overhead.

The space tether depicted in Arthur C. Clarke's 1979 novel Fountains of Paradise is, of course, science fiction. But science fiction could become reality in a few years with the launch of a more modest tether system: a 12-mile-long, super-strong string linking the space shuttle to a satellite orbiting above.

As conceived by Dr. Mario Grossi and the late Dr. Giuseppe Colombo of the Smithsonian Astrophysical Observatory in Cambridge, Mass., "tethered satellite systems" could ultimately exceed even Vannevar Morgan's dreams. One day, tethers could be used to generate electricity for space stations, function as space-borne antennas for communications, boost satellites into higher orbits, transfer fuel or cargo to other spacecraft, link clusters of satellites or provide a controlled 'gravity' environment for biological and physical experiments.

The first flight of a tethered satellite, a joint effort of the National Aeronautics and Space Administration and the Italian Space Agency, will test the system's electrodynamic properties. The flight, scheduled for 1991, will be the first of three missions to determine how a satellite on a string actually behaves in space.

A second experiment being planned for the mid-1990s will offer a special scientific bonus: It will open for observation a region of the atmosphere some 60 to 100 miles above the Earth that has been explored only briefly with sounding rockets. "This region is sometimes called the 'ignorosphere' because we know so little about it," says Dr. Gordon Gullahorn, an SAO astrophysicist investigating tether dynamics and the tether's interactions with the atmosphere. "It's too high for airplanes or balloons, but low enough that the air drag would quickly pull a satellite down from orbit."

To explore this region, the tether will be reeled down from the shuttle to its full length of 60 miles (about the distance from Detroit to Toledo), enabling the attached satellite to monitor atmospheric temperature and composition. In the future, satellites trolling the atmosphere could survey the Earth's magnetic and gravity fields, thus possibly identifying ore deposits and other massive geophysical features hidden beneath the surface.

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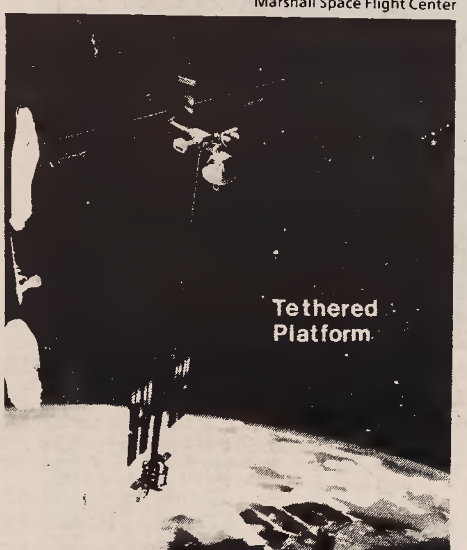
Marshall Space Flight Center



A tether is used in this illustration to isolate a work platform from NASA's planned space station. Delicate instruments, scientific experiments and industrial operations are thus located at a relatively undisturbed site.

Construction of the tether-which looks deceptively like a piece of clothesline-and of the special equipment for deploying and retrieving it is now nearly completed at Martin-Marietta Aerospace in Denver, Colo. For the first mission, the tether will be made in part of insulated copper and Kevlar, a strong polymer used in bullet-proof vests. Only one-tenth of an inch thick, the line will support a 1,100-pound, five foot-diameter satellite designed and built by the Italian company Aeritalia. This spherical aluminum satellite is expected to fly 10 missions with different experiments.

In theory, the tethered satellite is a surprisingly simple system. In 1974, the Smithsonian's Colombo and Grossi showed that the shuttle and its tethered companion would form a single unit that would always remain aligned vertically with the center of the Earth. Because gravity and centrifugal force vary with altitude, the upper and lower vehicles tug against each other, keeping the tether taut.

The tether system has been compared variously to a giant swing, a fishing hook and line, a yo-yo, a dumbbell and a pendulum. But in some ways, Gullahorn says, the tether is most aptly compared to a child's Slinky, a tightly wound, flexible spring coil. Any disturbance in the system, even an astronaut pushing off the wall of the shuttle, could make the satellite jiggle and bounce on the end of its string, affecting delicate instruments. Gullahorn and his colleagues, then, want to determine precisely what shape these vibrations will take.

Radiophysicist and tether originator Mario Grossi says that the first mission also will determine whether kinetic energy from the motion of the tether system can be converted into electricity. As the copper wire in the tether cuts through the Earth's magnetic field, it is expected to form a giant, moving electrical circuit, with the field lines in the ionosphere--the outer portion of the Earth's atmosphere--forming part of the loop. As electrons are collected from the ionosphere at the top of the tether and ejected back into space by an electron gun at the lower end, a current should flow through the tether. For a 12-mile cable, the voltage potential is expected to be 4,000 volts; the longer the tether, the higher the voltage.

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Marshall Space Flight Center

A tether could be used to send the space shuttle back to Earth from NASA's planned space station, as this illustration shows. Tethers from the space station might be used to send aloft payloads, such as satellites and other instruments, with far less fuel than would otherwise be required.

Ultimately, a current generated by the tether could power electrical equipment and recharge batteries onboard the shuttle or an orbiting space station, Dr. Robert Estes, another SAO physicist, says. The first round of U.S. and Italian experiments, however, will focus on gaining a better understanding of the ways in which the tether interacts with the ionosphere.

"Right now, we're interested in basic science, but everything we learn will help in planning future applications," Estes says. "Our first step is to determine that the tether is dynamically stable--that it can be controlled safely and easily."

One concern is how to keep the shuttle out of harm's way in the unlikely event that the tether should break or be severed by a small meteoroid. "Using computer simulations, we are studying possible tether failures and developing maneuvers to keep the tether from recoiling and wrapping around the shuttle," says David Arnold, an SAO scientist investigating issues of operational safety.

Space officials and tether proponents agree that the project has the potential to revolutionize space travel. "With tether operations, you can move masses in space without expending rocket propellant," a NASA spokesman says. "That's the prime idea."

Counting on successful test flights, aerospace engineers are already drawing up plans that could reduce the use of rockets to deploy weather, communications and research satellites from the shuttle. They hope to exploit a principle of physics called "the transfer of angular momentum."

Because the center of mass in a tethered system lies somewhere between the two ends of the tether, a satellite attached above the shuttle would travel faster than normal for its orbit; conversely, the lower shuttle would travel slower than normal. If the tether were disconnected, the satellite would gain momentum and fly into a higher orbit. At the same time, the shuttle would lose momentum and drop closer to Earth.

(Continued On Page 4)