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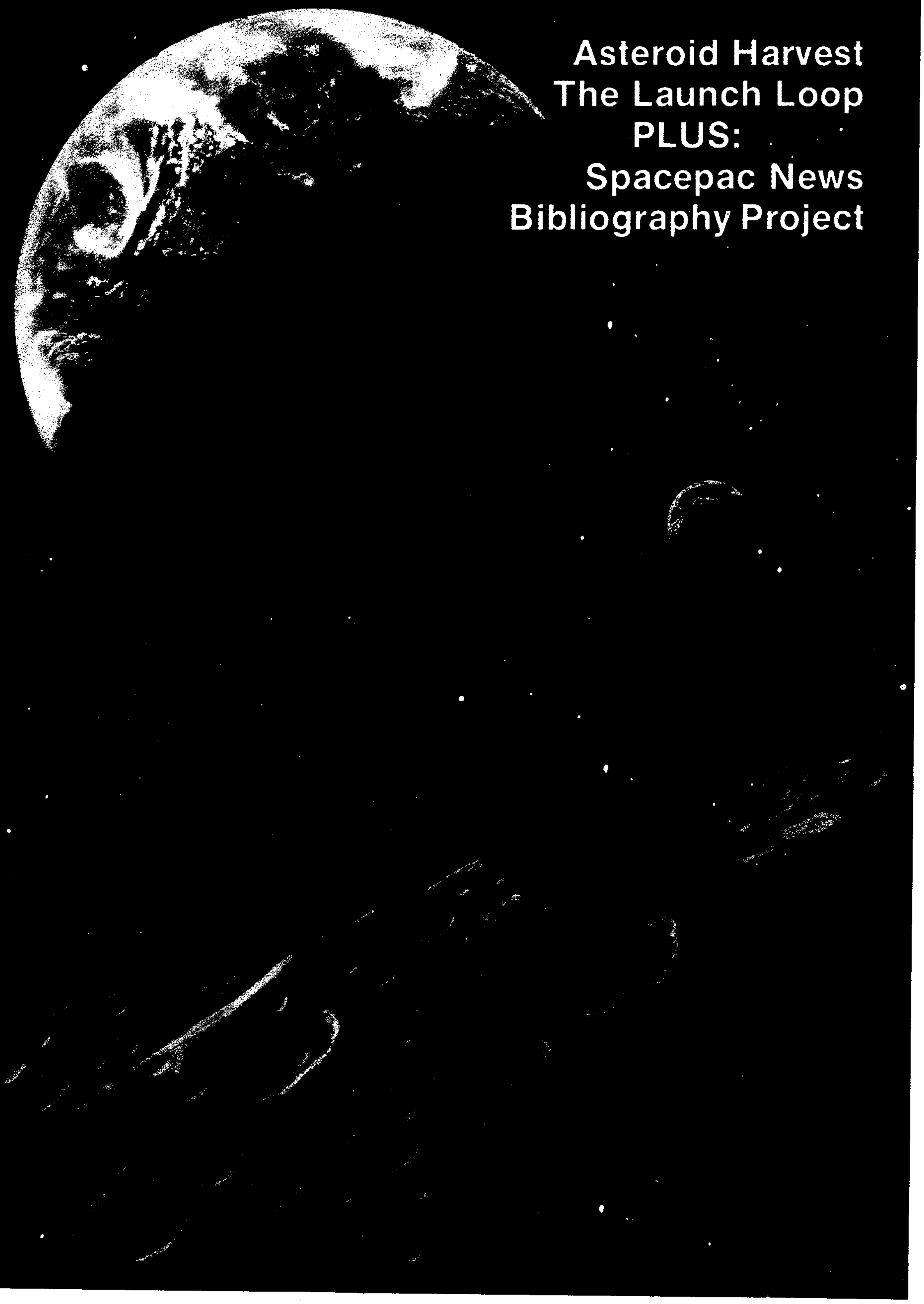

The Launching Pad:

THE LAUNCH LOOP

by Keith H. Lofstrom

In last month's issue of the **L-5 News,** Kenneth Brakke described the Skyrail, a launching system based on momentum and energy storage in an orbiting aluminum cable. I'd like to present an extension of this concept which may prove easier to build and operate. Please read the other article first; it provides valuable background for this article. The Editor was a little shocked to see these similar ideas at nearly the same time; another case of parallel development. It's railroading time, and many railroads are about to be built.

The launch loop is an Earth based launching utility that stores energy and momentum in a very long, small cross section iron ribbon loop moving at 12 kilometers per second and magnetically suspending a controlling track. It can launch 20 five-ton payloads per hour to geosynchronous or near lunar orbits from a track 120 kilometers high and 2000 kilometers long, with 3 g's acceleration.

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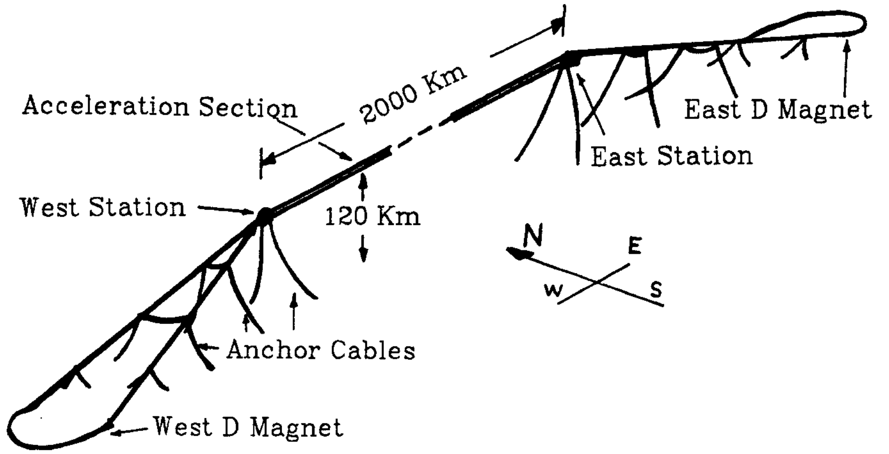

Figure 1. A side view of the launch loop. Most cross sections are centimeters or millimeters, making the structure virtually invisible from a distance.

An orbit is a balance of centrifugal acceleration and gravity. If the centrifugal force on an object is greater than the gravitational force, it moves upwards. If a stream of material is moving faster than natural orbital velocity, extra downwards force is required to hold it to its path. Stationary mass could provide this downward force if it was somehow "hung" on the moving stream. The centrifugal force is proportional to the square of the stream velocity. If the stream moves at 16 kilometers per second (which is twice the orbital velocity in low Earth orbit) the centrifugal force is 4 times the gravitational force. The stream could support itself and three times its own weight.

The launch loop, illustrated in figure 1, is a very large, stationary, gossamer structure built around an iron ribbon loop circulating at 12 kilometers per second. The iron ribbon is 5 centimeters wide and 2.6 millimeters thick and suspends a *non-moving* magnetically levitated track. The ribbon weighs about 1 kilogram per meter, the track from 1.3 to 5 kilograms per meter. To provide a long, low-friction acceleration path for sensitive payloads, the "forward" ribbon used to accelerate the payload is 2000 kilometers long and 120 kilometers high. The "return" ribbon travels from the east end of the loop on another track suspended on cables a few hundred meters below the forward track. Before and after the elevated acceleration track are two sections sloping down to the surface at a 10 to 20 degree angle. The acceleration and sloping sections are joined by two curved, 2500 metric ton deflectors containing magnets, control systems and elevators from the surface. The upper deflectors are called the "east" and "west" stations, and payloads are hauled up to and launched from the west station. Near the Earth's surface, each sloping section joins to an upwards curving ramp with magnets that deflect the ribbon to or from horizontal. The ribbon is deflected 180 degrees at each end with two 20 kilometers diameter "D" shaped magnets. Four 2 kilometer long, high efficiency linear induction motors on the straight surface sections between the D magnets and the upwards deflection systems put energy back into the loop.

The elevated track acceleration section consists of the forward and reverse ribbons and the electronically stabilized magnet structures that hold them at the proper spacing from the tracks and each other. The extra weight of the tracks and coupling cables are just enough (2.7 kilograms per meter) to deflect the ribbons into a circular orbit.

The sloping sections on the way up to and down from the acceleration section are much heavier, and permanent airtight sheath is required to protect the track from air friction while hanging cables provide strain relief and anchor this section against the wind.

The whole structure weighs about 20,000 tons, and can be assembled and started from the ground. It is located along the equator to minimize payload apogee delta v as well as weather and Coriolis effects. Equartorial winds are unpredictable and vary greatly with altitude, but their maximum speeds are relatively low and the lack of Coriolis force inhibits cyclones. The most severe stresses can be expected during squalls; an equatorial site will be chosen for minimum storms.

A typical payload for this loop size is 5 metric tons gross weight. The payload is equipped with rocket engines for orbital circularization at apogee, a lifting shell, and a heat shield and parachutes for reentry of human cargo if the system fails. Insurable, inanimate payloads will not need this protection. Magnets hold the payload off the ribbon using eddy current repulsion on the moving ribbon, generating a lift of 5 tons and a drag of 15 tons, accelerating the payload to 3 g's. The payload center of mass is on axis with the ribbon, with stability provided by magnetic damping and thrusters.

If 200 megawatts is available for acceleration, the loop can launch a 5 ton payload every hour. The maximum payload rate is limited by the power plant and by heat dissipation in the ribbon; a 4 gigawatt power plant allows the maximum loop output of 20 five-ton payloads per hour. Power plants may be brought on and off line as necessary. The energy storage capacity of the loop will allow it to launch at high rates for short periods with less than full power plant capacity.

The launch loop will be started on the ground, at rest. Startup imposes some of the most severe stresses on the system, as the normally in-vacuum acceleration track must be protected with a temporary vacuum sheath. The track must now support the ribbon, not vice versa, so the track-ribbon system may be started upside down. The ribbon weighs 5000 tons; to get it moving at 12 kilometers per second requires 100 million kilowatt-hours of energy. If this energy is put in at a 400 megawatt rate, the system will need 250 hours to get up to speed. 100 gigawatt-hours is the heat equivalent of 8000 tons of oil (modern oil tankers carry up to 700,000 tons). If the system breaks, this energy must be expended in a harmless way.

Once the ribbon is up to speed, the east and west stations, now near the ground, are raised and pulled towards the center while the inclined sections are extended; this involves welding together new sheath around the inclines and removing sheath from the acceleration section. When the process is complete and the acceleration section is at altitude, the temporary sheath around it is stripped off and lowered to the ground. The ribbon is slowed to compensate for the lost weight, and the loop is ready to launch payloads.

Whole system cost is hard to predict, but some costs may be identified. Eleven United Technologies 56 megawatt dual FT4 gas turbine power plants would cost 77 million dollars. Structural materials would include 200 metric tons of Union Carbide Thornel carbon fiber at $5 million, and $25 million for 1000 metric tons of DuPont Kevlar aramid fiber. Magnet systems would use 1500 tons of copper wire at $3 million and $16 million for 400 metric tons of formed Alnico 8 magnets. Unknown costs include sheath and track manufacturing, motors, ramps, pumps, electronics, and overall systems engineering and construction. If the loop is built on land, many square kilometers of land must be purchased; if at sea, floats and anchoring cables are needed.

A launch loop costing $1 billion (a guess), used at 50 percent capacity with a 500 megawatt generator (24,000 metric tons per year), and amortized over 1 year as a high-risk venture would cost $55 per gross kilogram (including 6 cents per kilowatt-hour for turbine fuel). Later, launching 750,000 tons per year with 4 gigawatts power capacity, 5 year amortization, $9 billion capital cost, and 1.3 cents per kilowatt-hour fuel cost, the cost per gross kilogram is $3. At this cost, labor and payload systems will probably dominate net payload cost. Total launch loop system cost may be well below that of Earth-to-high-orbit rocket systems.

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The launch loop described here launches 5 ton payloads from the Earth to geosynchronous, high orbit, and lunar destinations, but other applications are possible—such as higher speed interplanetary loops or short, low speed loops on the Moon. Passive ribbons in orbit may capture payloads launched from Earth or Moon. Loop structures on the ground could replace electrical transmission lines and store power for peak leveling very efficiently.

The launch loop promises to greatly lower the cost of launching payloads from the Earth. The structure, while very long, is small in total weight and volume compared to existing large systems, and may prove affordable to the private sector. Details of launch loop operation have not yet been determined; the idea may prove impractical because of instabilities, expense, or political obstruction. Regardless of its success, the idea may stimulate others to think about other low-cost approaches to Earth launch using existing physics and existing engineering materials.

Members of the Portland, Oregon chapter are now building 2 meter across, racetrack-shaped, 100 meter per second model of the launch loop. This first experimental model uses a 500 gram per meter ribbon, which is thinner than the final loop as this ribbon must be bent around a 75 centimeter radius. Otherwise, ribbon, motor, and deflector magnets will have the same cross sections, power, and acceleration levels as a commercial system. Richard Pilz is building tooling for the linear motor ferrite cores. Neldon Wagner and Sig Peterson are building control electronics, sensors, and programming the control computer. Tom Billings will be working on the power supplies and switching systems, and Dana Johansen is working on model sheaths for later versions of the system.

We plan to scale the system up rapidly as money becomes available, and have a commercial system as soon as 15 years from now. This project is being constructed with volunteer labor and paid for out of our personal savings. We could use more volunteer, technically competent help. A more extensive paper is available on request from:

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