SLINGATRON DYNAMICS AND LAUNCH TO LEO

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Abstract

A circular mass accelerator concept called a slingatron is described in which a large projectile could be accelerated to high velocity using a relatively low power input (compared to a hypervelocity gun). Two examples are given in which a slingatron could be used to launch an object into Earth orbit. The first would use a slingatron of ring radius 640 meters and a low elevation launch at 8 km/sec. The second case is intended as a small scale test machine of ring radius 40 meters that would launch a projectile vertically at 2 km/sec. The projectile could be an encased light gas gun (like a long rod penetrator) that would, upon reaching its peak altitude of ~160 km, fire a small mass at 7.5 km/sec to the East into LEO before dropping back to Earth for re-use via guided parachute.

A mass accelerator, called a slingatron, has been proposed [1] in which a mass could be accelerated in an evacuated guide tube around a circular path of large radius to high velocity. The slingatron is similar to both the ancient sling and also to a modern synchrotron in that the mass is accelerated around the accelerator ring by a wave in which the mass has phase stability. Work is done on the mass by a small-amplitude gyration of the entire accelerator ring (like a giant hula-hoop) that continually pulls the mass radially inward against its centrifugal force. There is no string to break as in a conventional sling and the process is efficient, even though the ring mass is much larger than the accelerated mass. It is similar to swirling coffee in a cup without a spoon by moving the cup in a small circle. A coriolis force is experienced by the mass in a frame rotating with its instantaneous velocity. Because the ratio of the ring radius to the small gyration radius is large, huge wave speeds can be implemented mechanically and controlled electronically.

The accelerated mass (called a 'sled') must slide around the accelerator ring with a low friction coefficient as it is pushed by centrifugal force against the track inside the guide tube. Frictional forces can be made small by either using a lubricating film of gas (a gas bearing) between the sled and track, or by magnetically levitating the sled above the track. The gas-bearing sled is much easier to engineer and has the advantages that a room-temperature steel track can be used, and higher bearing pressures (and centrifugal forces) are more easily accommodated.

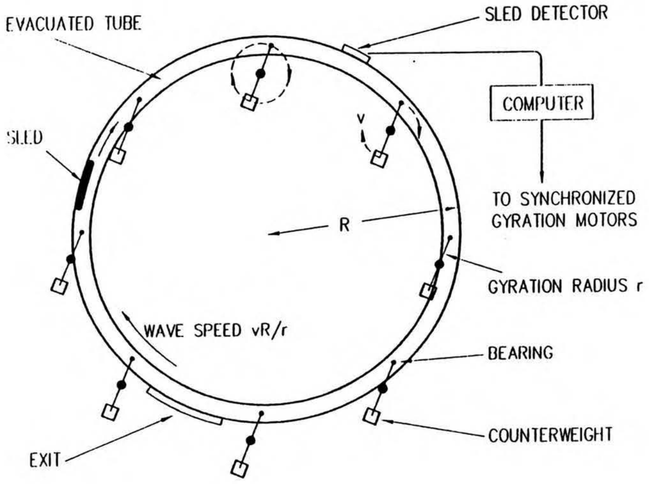

Figure 1
Schematic of a mass accelerated in a slingatron by a phased gyrational motion of the entire accelerator tube.

Figure 1 shows the concept. Acceleration can occur provided the synchronized electric motors that drive the small-amplitude gyration are controlled so that at the sled location the guide tube continually moves with a component that is directed inward along the ring radius. Note that the gyration displacement wave travels around the accelerator ring with a speed vR/r where r and v are the radius and speed of the gyrational motion. This wave speed is large for R>>r, even though the gyration speed v is relatively small (e.g., in the range of 10's to ~100 meters/sec) for practical mechanical implementation.

There are various ways to implement the ring gyration. Figure 2 shows an example in which the drive units distributed around the accelerator ring use conventional rolling technology to roll the ring plus counterweights around a small gyration circle on circular tracks that support the ring mass against Earth's gravity. The drive units consist of both

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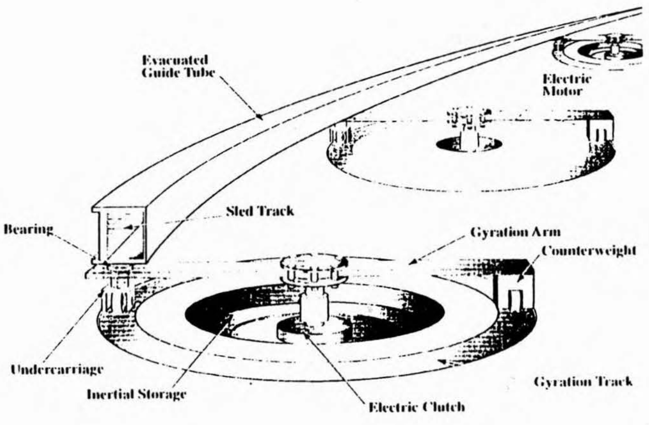

Figure 2
The accelerator ring plus counterweights are rolled around a small circle and propelled by electric motors and inertial storage units distributed around the ring.

electric motors and inertial storage flywheels distributed around the ring. The ring gyration is carried up to an intermediate speed by the motors and then the flywheels are coupled in to provide the surge power as the sled approaches its final velocity.

Figure 2 also shows the ring as having a curved I-beam geometry. This geometry provides lateral restraint for the sled, and allows easy access for operations such as grinding welds and honing the steel track to a polished finish. A large steel ring could thus be constructed out of curved I-beam sections welded together.

The accelerator appears to have a useful range of phase stability, Fig 3, over which the sled can be accelerated by a pre-programmed ramp-up of the gyration frequency. This was observed in a small scale experiment, Fig 4, in which phase stability allowed a pre-programmed acceleration to be used.

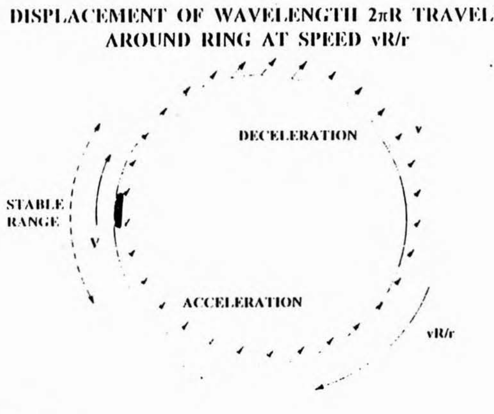

Figure 3
Phase stable acceleration.

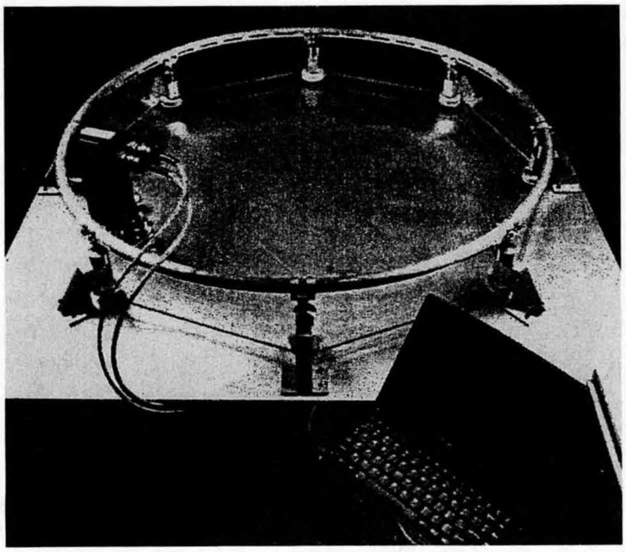

Figure 4
A 'table-top' slingatron of ring diameter 1 meter. The computer-controlled gyration accelerates ball bearing projectiles to above 100 meters/sec.

Note that the ring radius R could range from meters to kilometers depending on the application, Figure 5. The slingatron concept avoids the technical difficulties of electrical pulsed power for such systems since the acceleration process is relatively slow (just as a conventional sling accelerates slowly compared to a conventional or EM gun). This makes it in principle capable of accelerating very large masses to high velocity, possibly including the direct launch of heavy projectiles into space from the Earth's surface [2,3], Figure 6. The need to maintain a low friction coefficient during the acceleration period is the main issue that is expected to limit the accelerator performance for large systems.

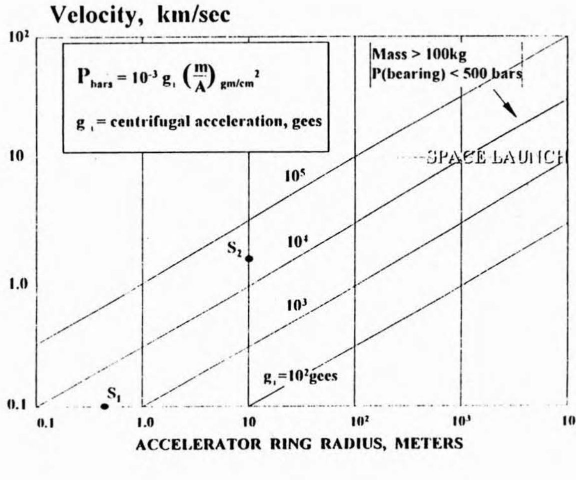

Figure 5
Velocity of accelerated mass as a function of ring radius for various constant values of the centrifugal acceleration.

Consider next the high centrifugal g's experienced by the sled. First note that defense projectiles can be fired out of guns with > 20,000 g's and carry electronics etc. It is also instructive to relate the centrifugal g's to the bearing pressure between the sled and the track, Figure 5, for a sense of what materials or structures can tolerate. For example, 200 bars is easily contained in typical laboratory gas bottles. But 200 bars on one side of a steel slab of thickness 2 inches (i.e.,~40 gm cm^{-2}) will accelerate the slab at 5,000 g's, and 400 bars (also in some gas bottles) will accelerate it at 10,000 g's, which is the centrifugal acceleration experienced by an object traveling at 8 km/sec around a circle of radius 640 meters. An injected or evaporatively supplied gas film can be maintained between the sled and the track at the above pressures for low friction. On the issue of efficiency, note first that the gyration power is supplied globally and continuously to the ring as it rolls with a very low rolling friction coefficient around its gyration circle. Sled acceleration is efficient because the sled extracts energy from the gyrating ring faster than the ring's rolling friction dissipates it. The sled gains a velocity increment of ~2(pi)vsin(theta) per cycle around the ring, where theta is the angle between the sled and ring velocity vectors. Further, the ratio of the kinetic energy of the sled of mass m to that of the ring of mass M is $mV^2/Mv^2 = mR^2/Mr^2$, and is usually greater than 1 so that little energy remains in the ring at the end of the acceleration process.

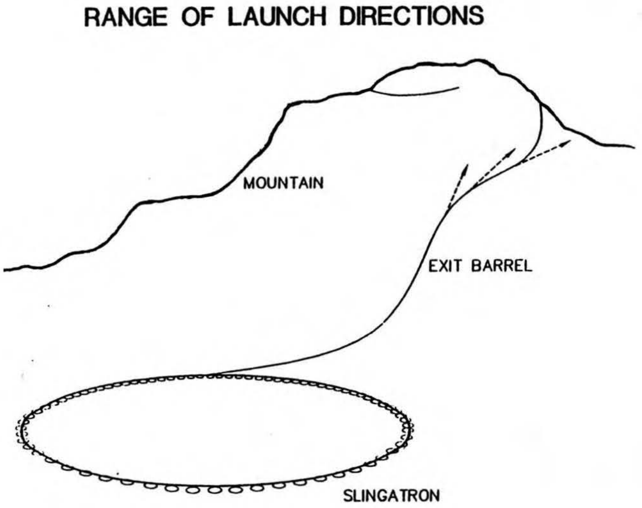

Figure 6
Slingatron Space Launcher in which several exits are located along the barrel as it winds up a mountain so that projectiles could be launched in various directions.

A projectile of mass 500 kg could, for example, be accelerated in a slingatron of ring radius 640 meters (track width ~32 cm) to a velocity of 8 km/sec. Its maximum centrifugal acceleration would be 10,000 g's. If launched at an elevation angle of 30 degrees it could be inserted into LEO with a small rocket kick at apogee.

A much smaller scale test system would be a reasonable first step. For example, a slingatron of ring radius 40 meters could accelerate the same elongated projectile to 2 km/sec. If the projectile consisted of a light gas gun (LGG) which was encased for atmospheric transit (essentially an encased long steel tube), it could be launched vertically from the slingatron to an altitude of ~ 160 km, i.e., well above the atmosphere. At peak altitude the LGG could then fire a small mass horizontally at 7.5 km/sec to the East into LEO, and then drop back via guided parachute to base for re-use. The mass in orbit would probably be too small to be useful in this case. However, this small 'pop-up' system could evolve into the full-scale sling launcher described in the preceding paragraph.

References

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(2) John Kross, 'The Slingatron', *Ad Astra*, National Space Society Magazine, vol.8, pp47-51, Sept/Oct 1996.

(3) D. A. Tidman, R. L. Burton, D. S. Jenkins, and F. D. Witherspoon, 'Sling Launch of Materials into Space', in Proceedings of the Twelth SSI-Princeton Conference, May 4-5 1995, published in *Space Manufacturing 10*, Ed by Barbara Faughnan, Aug 1995, pages 59-70.