An investment in an impractical technology

Summary of the impracticality of Spinlaunch

The **New Mexico Spaceport**, funded by taxpayers, started with Virgin Galactic's space tourism entity as its anchor tenant. It has gained other tenants, thought not yet economically sustainable; space tourism may start in late 2019.

One new tenant is **Spinlaunch**, a company from Sunnyvale, California. **They've raised $40M** from investors, including Google Ventures (now GV) and Airbus Ventures for a speculative technology, which I shall describe shortly below. They propose to use a large spinning platform to launch satellites from the ground (which must be with a rocket to complete the boost).

The idea sounded preposterous to me, so I worked out the limitations, which I claim are solidly against this being practical or even possible. I want to be sure our local governments and local investors don't lose again. I've already filed a Citizen Concern document with the New Mexico Attorney General's office, though this update would be worth adding. Join me now:

The basic technology proposed is:

- A vacuum chamber with a radius of about 50 m (Bill Gutman from Spaceport America let out the knowledge that my first estimate of 500 m was "an order of magnitude too high;" pushing on a completely unrealistic guess helped spring this information loose).
    - Bill says it's patented, but there's only a patent application dated July 2018, US 2018/0194496 Al to Jonathan Yaney.
    - I note that a patent says nothing about the practicality of an "invention." Patent examiners are not allowed to decide on issuing a patent based on practicality. I note that Henry Latimer Simmons obtained patent 536,360 for a ludicrous invention to let one train pass over the top of another on one track.
- Placing the satellite *with its rocket motor* on the periphery and spinning up to a tangential speed of Mach 4-5, as Bill cites. Yes, it could not be to LEO (Low Earth Orbit) speed; of course, the satellite would burn up on launch here in the lower atmosphere.
- Upon launch a rocket engine ignites to reach the speed for attaining LEO.

Calculations:

- I'll take the lower speed, Mach 4, about 1,320 m s^{-1} to give the least stressful conditions.
- At a radius r = 50 m and a speed v = 1320 m s^{-1}, the centrifugal acceleration is very simply calculated as v^2/r = 34,850 m s^{-2}. That's very closely 3,500 g! We're talking about a satellite and its rocket engine withstanding this, including electronics
    - Bill Gutman says that there are already **military projectiles** that get accelerated to 40,000 to 50,000 g – to get a muzzle velocity of 1,000 m s^{-1} in a 10-m barrel. The electronics are potted to withstand the acceleration.
    - Fine, but:
    - (1) A satellite has to have folded solar panels and antennae. These cannot be potted, and I cannot imagine any folding and cushioning that doesn't destroy the joints or the panels. The military projectiles only have to deploy small vanes to steer. (I also don't know how their performance meets specs.)

- (2) To reach v_{LEO} (calculations below), there has to be a rocket engine. It will have to be a solid propellant engine; the complex plumbing and pumps of a liquid-fueled engine could not possibly survive 3500 g.
- This engine should really be two-stage. An effective v_{LEO} of over 8,000 m s^{-1} is needed, with a bit of thrust vectoring to go from horizontal to tangential in the trajectory, as well as to overcome drag in the initial part of the trajectory. I get an estimate closer to 9200 m s^{-1}, not achievable with one stage with solid propellant; see below. The exact calculation of air drag would similar to the math from interceptors such as Nike or the more modern (and low-effectiveness) GMD. So, the additional speed needed is well over 6,700 m s^{-1}.
- The classic rocket equation expresses the gain in speed (yes, let's say speed, since direction is not specified and does change) is $\Delta v = v_{ex} \ln(m_0/m_f)$, where v_{ex} is the exhaust velocity as determined by the propellant type and m_0 and m_f are the initial and final masses of the rocket. I've **written this up, too**. We assume the loss of mass is that of propellant. Taking the final hull and payload (satellite) as having a mass of only 10% of the initial mass (90% burn), we get the logarithmic factor as ln(10)=2.3.
- Solid propellants have only a moderate v_{ex}, hitting about 2,500 m s^{-1}. We get Δv=5,750 m s^{-1}. Yes, I'd say that a second stage is necessary.
- (3) Can a solid-propellant rocket withstand the lateral acceleration? Of course, the rocket has to point up, so the rocket and payload are aligned perpendicularly to the radius. There is an enormous bending force exerted on the rocket body. The force also gets relieved almost instantaneously on launch, generating a change in acceleration called, appropriately, jerk. This sets parts of the launched item into sharp motion – like your innards if you're in a high-speed traffic accident.
- (4) How big a satellite can be launched, given materials limitations? There are some small satellites, e.g., the CubeSats, but they have economical and reliable launches already on standard rockets. For more practical sizes, I'm not about to do the engineering calculations to estimate the stresses on the launch platform and the safety factor. This assumes that the payload and its own rocket survive, which I flatly reject, as above. I note that:
  - The proposed device would only fit small rockets and satellites, of notably smaller dimension than the spinning platform. There is a mature technology and market for launching (and making) CubeSats . Maybe Spinlaunch is aiming (but wildly off) at slightly larger satellites.
- (5) The whole idea was to save energy and cost in launching satellites. There's a lot of energy put into the launch mechanism, far more than the kinetic energy imparted to the (putative) rocket + payload. Maybe some could be recovered in electromagnetic braking...needing a significant amount of electrical storage and circuits to handle massive currents.

There are other niceties:

- Consider the extremely active timing needed to release the rocket + payload. Suppose we want a launch direction error not to exceed $1^{o,}$ or 1/57 of a radian. To reach a tangential speed of 1320 m s^{-1} at a radius r = 50 m, one needs a rotation rate of 1320/50 = 26.4 radians s^{-1}. That's a bit over 1,500 degrees per second. The window is less than 1 ms wide.
- Safety: What's the shield in case the launch mechanism fails, sending out shard at high speed? How about releasing the rocket + payload nearly horizontally by accident? You need a BFS, a big functional shield.

- How about the reaction of the spinning platform when the rocket + payload is released? That's quite a jolt on the suspension. Maybe some engineers can address that, but not the fundamental no-gos (a neologism?) I've noted all through.

Conclusion:

- This is a pipe dream or a scam, poorly thought out at the very best.
- Yes, Google Ventures, now known as spinoff GV, and Airbus Ventures are among the investors in this. I can only attribute their lack of due diligence to their lack of sufficient technical expertise – I think Google and Airbus, both technically solid, spun off the MBAs and not the engineers into their Ventures.

Simple calculations of the speed of Low Earth Orbit:
I'll use energy conservation as the most undemanding case (lowest v_{orb}).

Low Earth orbit is stable when the satellite has a velocity, v_{orb}, high enough to create a centrifugal force, mv_{orb}^2/r, that balances the gravitational force, GMm/r^2. So, we have

$$\frac{m{v_{orb}}^2}{r} = mg(r)$$

We can cancel out the mass, m, since it's the same of both sides.
Here, m is the mass of the satellite, r is the orbital diameter measured from the center of the Earth, G is the universal gravitational constant, and M is the mass of the Earth. We can get rid of G and M by using $GM/r_0^2 = g_0$, the gravitational acceleration at the surface of the earth, where r_0 is the distance of the Earth's surface from its center – the radius of the Earth, which is 6368 km, on average (less at the poles, more at the equator).

We're ready to figure out what the gravitational acceleration is at the distance of the satellite. It's less than at the Earth's surface; it falls off as $1/r^2$, so we have

$$g(r) = g0\frac{{r_0}^2}{r^2}$$

Now we can figure out the orbital velocity in terms of the gravitational acceleration at the Earth's surface (close to 9.8 meters per second squared):

$$\frac{{v_{orb}}^2}{r} = g0\frac{{r_0}^2}{r^2}$$

$$or$$

$${v_{orb}}^2 = g_0\frac{{r_0}^2}{r}$$

Plug in the values $g_0 = 9.8\ m\ s^{-2}$, $r_0 = 6.37\text{x}10^6$m, and $r = 6.67\text{x}10^6$ m, and we get the orbital velocity

$$\begin{aligned} v_{orb} &= 7660\, m/s \\ &= 4.78\, mi/s \\ &= 17{,}200\, mph \end{aligned}$$

- The needed speed is higher than that, for two reasons:
    - 1) Speed is lost in rising to altitude, from energy conservation; you need about 5% higher speed. Again by energy conservation, the work done against gravity is readily

calculated as the gravitational potential energy at orbit minus the gravitational potential at the surface:

$$\Delta U = \frac{GMm}{r_{orb}} - \frac{GMm}{r_0}$$
$$= \frac{GMm}{r_0}\left(\frac{r_0}{r_{orb}} - 1\right)$$
$$\approx 0.05\frac{GMm}{r_0}$$

The last line uses the fact that radius of LEO is about 5% larger than the radius at the Earth's surface. Here, G is the universal gravitational constant, M is the mass of the earth, and m is the mass of the launched object. I'll put in a subscript to make that m_{obj}, to avoid confusion for *m* as meters. We can get rid of G and M using the relation that expresses the gravitational acceleration at the Earth's surface, g_0:

$$\frac{GM}{r_0^{\ 2}} = g_0$$

We get

$$\Delta U = 0.05\, m_{obj} g_0 r_0$$
$$= 0.05\, m_{obj}\, 9.8\, m\, s^{-2}\, 6.3x10^6\, m$$
$$= 3.1x10^6\, m^2 s^{-2}\, m_{obj}$$

We have to add this gain in potential energy to the gain in kinetic energy, ½ $m_{obj}v_{orb}^2$. If all the energy starts as kinetic at a launch speed v_{launch}, we have (canceling out m_{obj} all through,

$$\frac{1}{2}v_{launch}^{\ 2} = \frac{1}{2}v_{orb}^{\ 2} + \Delta U / m_{obj}$$

Putting in v_{orb} = 7660 m s^{-1}, we find that the ΔU term is about 10% of the kinetic energy of orbiting, so that v_{launch} is another 5% higher than v_{orb}.

  - and, (2) a significant amount of speed is lost in traversing the atmosphere. I haven't bothered with this but I'd be quite surprised if it doesn't require another 5-10% at a minimum.
  - and, (3) thrust vectoring to change from a vertical trajectory to a tangential trajectory means that some work has to be done perpendicular to the trajectory at times; this uses fuel but doesn't contribute to the orbital energy.
- OK, if we say that about 20% higher v_{launch} is needed, as a rough estimate, then we're up to 1.2*7660 m s^{-1} or about 9190 m s^{-1}. To get that in a single stage with a solid propellant having v_{ex} of 2500 m s^{-1}, we need a higher burn ratio: $\ln(m_0/m_f)$ = 9190/2500 = 3.68. That means m_0 is almost 40 times the mass of the shell and the payload. This is unachievable. → One needs two stages, with all the separation mechanisms that won't stand 3500 g!