Can We Throw Satellites Into Space?

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Abstract:

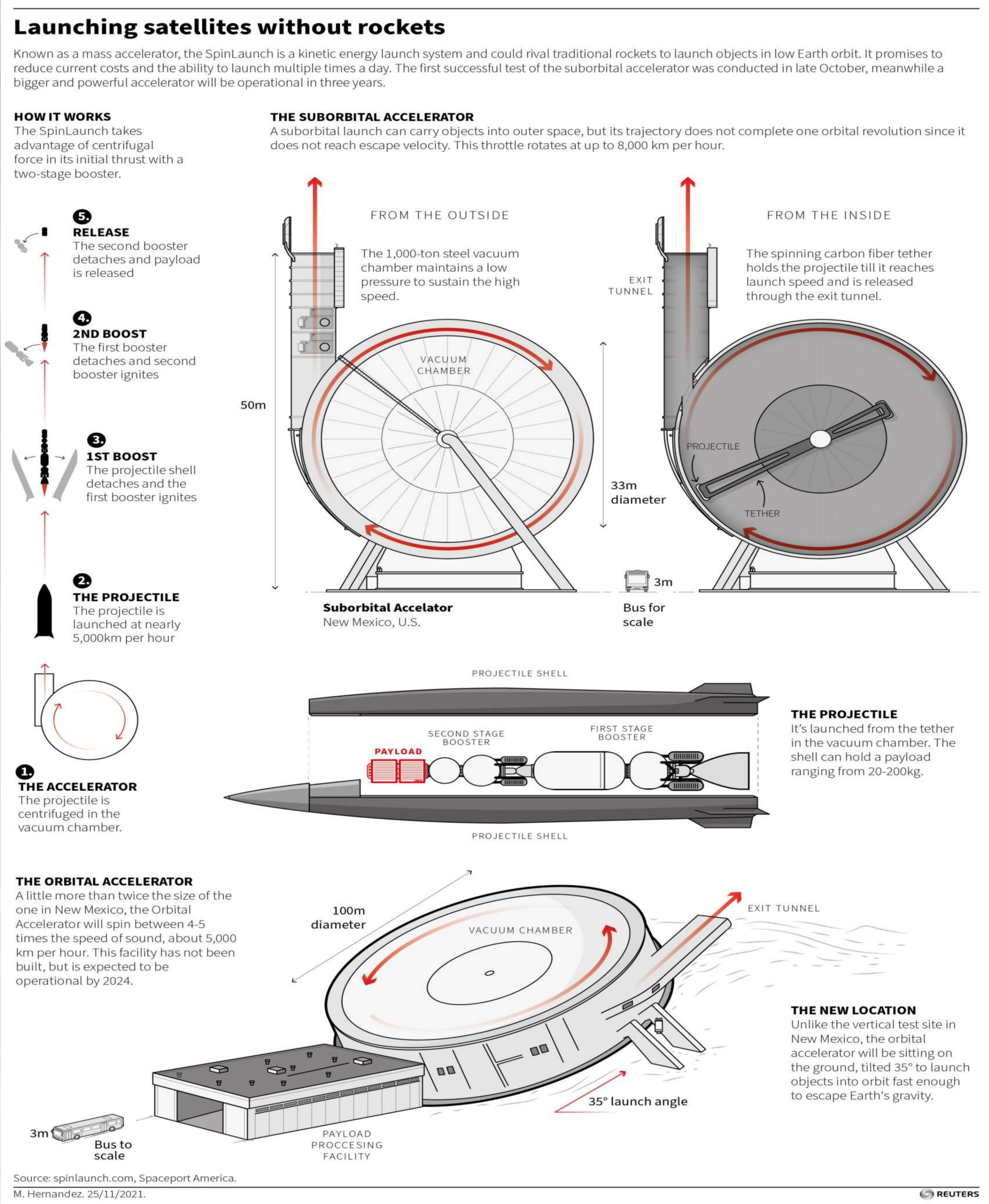
Spinning a 10 ton payload up to hypersonic speeds creates many engineering difficulties. This poster explains three main challenges that the engineers at Spinlaunch has to overcome. The design of the tether, the security of seal of the vacuum and the counterweight all have to be taken into account. The tether has to be extremely strong yet light at the same time, the vacuum is used to preserve the tether from burning up and to reduce air resistance during acceleration and the counterweight has to also be separated from the tether at the same time as the payload for the tether to be in constant balance.

Aim:

The aim of this poster is to find out as much about launch systems that act as a catapult which slingshots satellites and other payloads into space. In this poster I will discuss some of the main challenges that we face from catapulting 10 ton payloads into space. This poster is based on a US company called Spinlaunch and will cover the three main challenges that they have had to try and overcome.

Introduction:

Spinlaunch is a US company founded in 2014 with the aim of irradicating the rocket equation. The rocket equation describes how much fuel a rocket requires to carry its payload to its destination. The catch to the equation is that the fuel required to deliver the payload is also a payload; this makes rockets more fuel than rocket. Rockets are normally 90% fuel which increases the use of non-reusable parts. Spinlaunch has built a centrifugal mass accelerator which can grant a 200kg payload enough kinetic energy in an artificial vacuum chamber to travel up to 72km above ground before igniting the miniaturized 2 stage rocket thus greatly reducing the cost to launch a satellite by a factor of about 20, to under half a million dollars per launch. However, to scale the launch system up enough to launch a 10 ton payload is still an engineering roadblock.



Challenge 1: Tether.

Spinlaunch is aiming to release the payload at Mach 6 (2km/s). The radius of the acceleration circle is about 45 meters, meaning that to achieve that velocity the payload would have to rotate up to 450 times per minute. The g-loading at that speed would be approximately 10,000 g meaning that the payload will exert a force 10,000 times greater than its own weight due to the influence of gravity. Therefore, the tether attached to the 10 ton payload will need to support 100,000 tons. The tether would have to be made with carbon fiber due to its unmatched strength to weight ratio; its cross-sectional area has to be at least 0.23 meters squared at the tip. Each section of the tether has to support the weight of the section above it hence requiring the exceptional strength to weight ratio. With some mathematics we can work out the section of tether closest to the pivot would have to be at least 0.56 meters squared plus a safety factor of 1.5 meters squared.

Spinning a tether up to Mach 6 is impossible in air as the heat produced by air friction would destroy the tether. Therefore, the tether and payload has to be accelerating in a vacuum.

Challenge 2: Vacuum.

If the system is going to support multiple launches, then ensuring the chamber doesn't pressurise too quickly after the payload has exited is crucial. If air rushes into the chamber and makes contact with a tether spinning at hypersonic speeds then the damage would be irreversible. This problem can be mitigated by a double door airlock where the first door closes quickly as the second door opens for the payload to be ejected. However, it isn't all that simple because milliseconds of delay can cause catastrophic damage, therefore the speed an electrical signal propagates, the total time required to overcome the inertia of the door and the time to form a proper seal all has to be adjusted to perfection.

Challenge 3: Counterweight.

A big enough uneven weight attached to the motor can potentially shake the whole structure down therefore a counterweight is required. Spinlaunch needs a way to balance the tether right after it releases the 10 ton payload at the maximum rotational speed. An easy solution would be to release the counterweight on the other side of the tether into a reinforced wall. However, having to clear up the mess the counterweight would produce every launch would cost time and effort which is far from ideal. The ideal solution would be to release a counterweight in the form of another payload after a single half rotation of the tether. The axle that the tether sits on should be able to support the short period of imbalance.

Conclusion:

I believe that the development of kinetic energy space launch systems will soon replace the majority of chemical rockets as it reduces the cost of launches drastically and also reduces the amount of fuel to be ignited below our atmosphere which releases greenhouse gases and accelerates global warming. The system can increase the frequency of launches and decrease the possibility of launch vehicle malfunctions. However, the only limitation it has is the size of the payload and manned missions cannot use this system due to the intense g-loading. The technology required is already in our possession, so the answer is YES! We can definitely "throw" satellites into space. Vertical testing is already being conducted with a miniaturized accelerator (1/3 of the full-scale system) at 20% of its total power capacity hence it is only a matter of time before we see mass production and use of this ingenious feat of space engineering.

Sources:

https://www.spinlaunch.com

https://en.wikipedia.org/wiki/SpinLaunch

https://www.youtube.com/watch?v=yrc632oilWo