Machine Gun Jetpack

Can a machine gun jetpack jump over a mountain?

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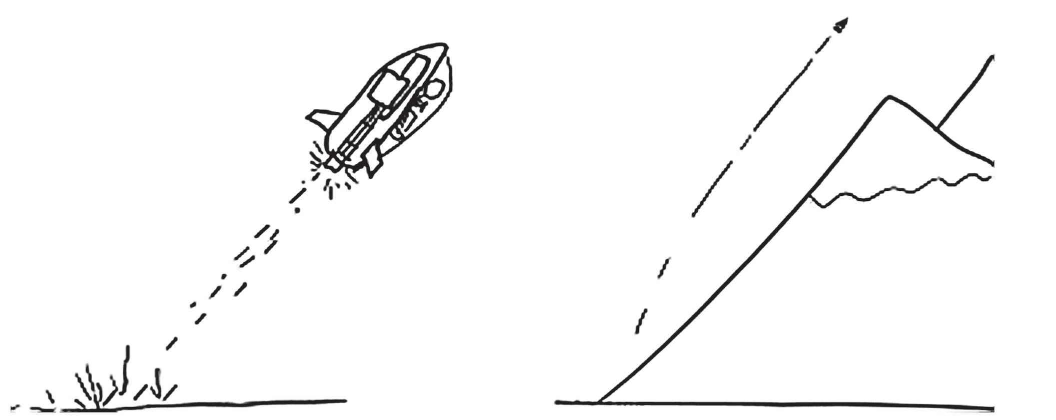
ABSTRACT

When a machine gun is continuously fired downward, the recoil from firing can be seen as an upward thrust force. This flying gun is our machine gun jetpack, inspired by xkcd's "what-if" blog post that claimed a machine gun jetpack could leap mountains. After some abstractions and physical modeling, we have found that, with a GSh 6-30 autocannon and over 5,000 rounds of ammunition, a machine gun jetpack can indeed leap the height of mountains. However, the system has a very steep trajectory, while most mountains have much wider bases relative to their height, making the jetpack unable to actually leap over many mountains despite being able to reach their height.

Machine Gun Jetpack Jumping Mountains

When a gun fires, the gun recoils in the direction opposite the bullet. A machine gun has a firing rate much higher than that of a regular gun, which makes the recoil a nearly constant force moving the gun "backwards." If we apply this principle to a machine gun firing at the ground, "backwards" becomes "up," and the gun will rise into the air as it fires. Thus, the machine gun will function like a jetpack, carrying a load upwards.

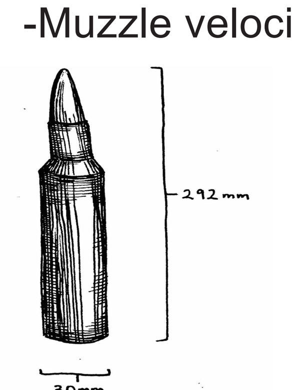


A rendering of a machine gun jetpack jumping mountains, from xkcd.com

XKCD wrote a popular what-if blog article about the feasibility of such a system. At the end of the article, they claim that a Gryazev-Shipunov GSh-6-30, a Russian aircraft autocannon, could jump mountains. We are here to investigate that claim.

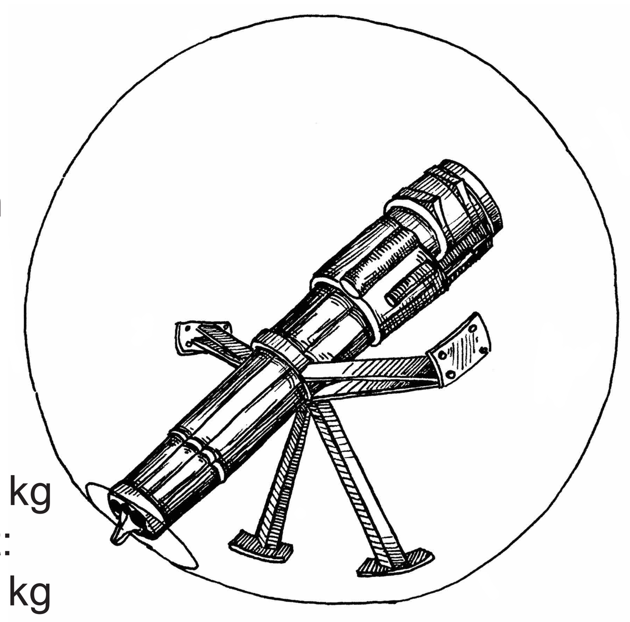
So What Are We Looking At Here?

Gun Type: GSh-6-30
-Length: 2.04 m
-Weight: 149 kg
-Rate of fire: 6000 rounds / min
-Muzzle velocity: 845 m / sec



A 30 x 165 mm Round

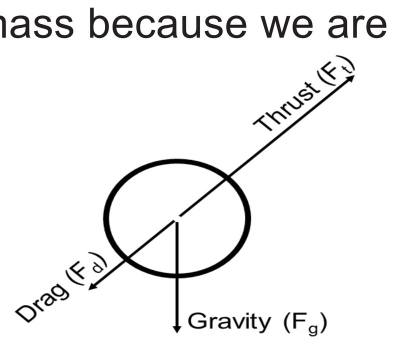
Bullet Type: 30 x 165mm
-Weight: 0.390 kg
-Casing weight: 0.442 kg
-Diameter: 30 mm
-Length: 292 mm



The GSh-6-30 in the Sphere

It's Almost Rocket Science

We simplified our machine gun jetpack model to a spherical point mass. The Sphere, with a radius of 1.5 meters, is large enough to contain the gun and bullets, complete with casings. We are assuming the sphere is massless: our model does not consider an additional mass for the sphere's structure. As soon as bullets leave the muzzle of the gun, they exit the system, reducing its total mass. We are modeling it as a point mass because we are not considering rotation in our model.



Our model considers the forces of gravity, drag, and thrust, and accounts for the loss of weight as the gun is fired. The model is similar to a rocket ejecting fuel to gain thrust.

Total system mass

$$F_g = Mg$$

Gravitational constant

Effective area of sphere; Drag coefficient of sphere

$$F_d = \tfrac{1}{2} A \rho C_D V^2$$

Density of air; Total system velocity

Rate of fire

$$F_t = m_b R v_m$$

Mass of one bullet; Muzzle velocity of bullet

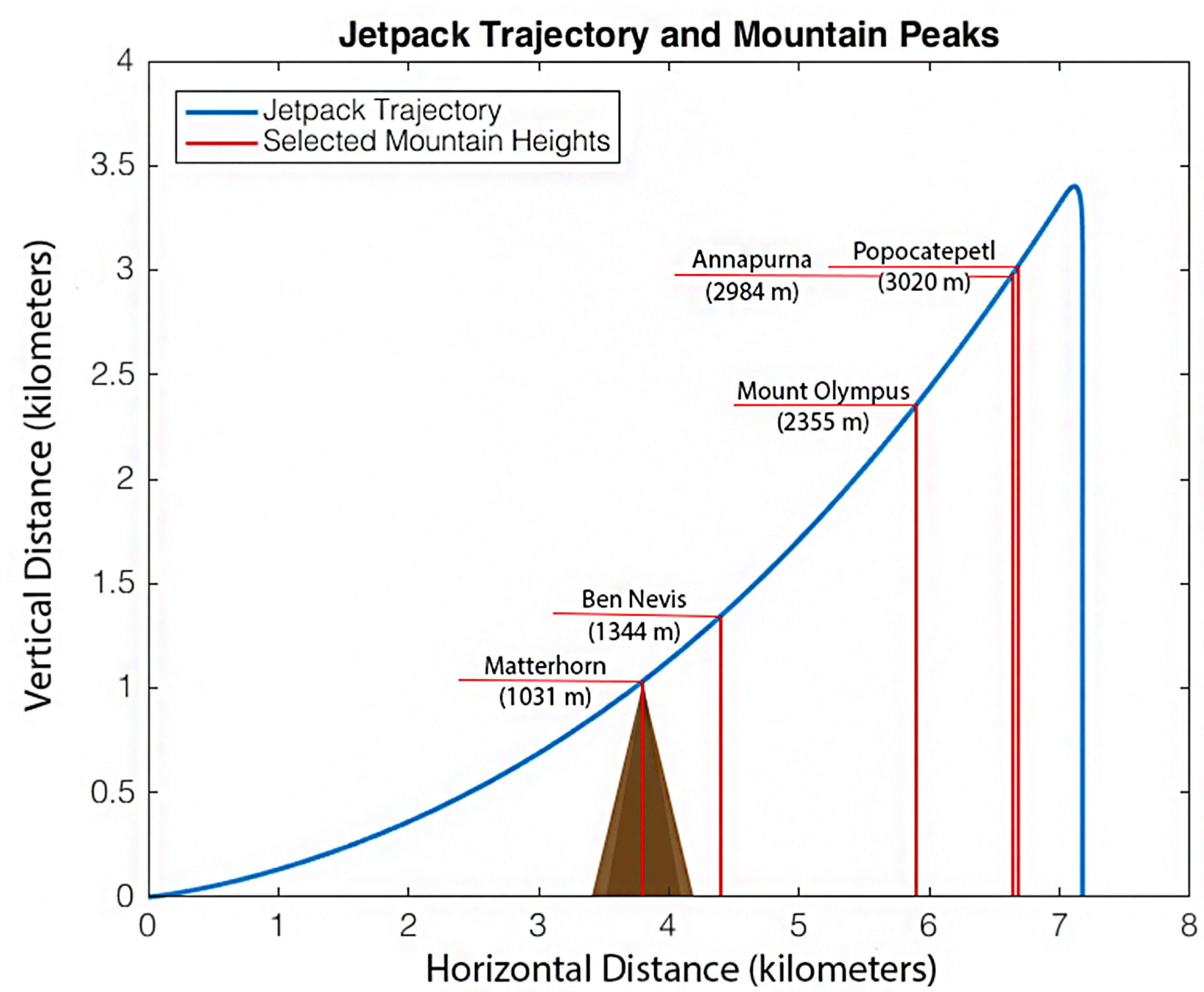
Change in total system mass; Mass of one bullet

$$\Delta M = R(m_b + m_c)$$

Rate of fire; Mass of bullet casing

A Mountainous Leap

According to our model, xkcd was right: the GSh-6-30 can jump mountains. But mountains come in a huge spectrum of heights and base distances. So specifically, which mountains can this thing jump?



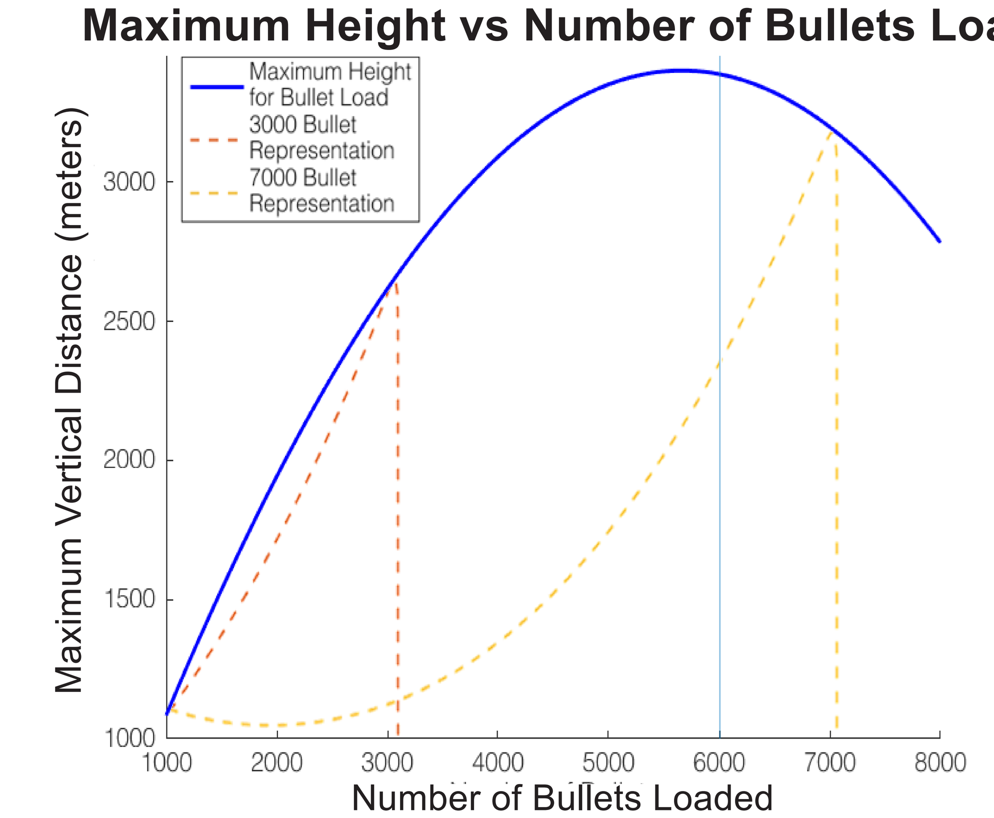
Jump Setup
To cover a wide variety of mountains, we fired the gun at an angle of 45 degrees, where it reaches its maximum vertical and horizontal distance. We also found that the ideal number of bullets to carry would be 5625 bullets, fired at 6000 rounds per minute. The resulting trajectory is shown in the graph above.

Jump Results
Our model shows that the gun can reach a maximum vertical distance of 3401 meters and a maximum horizontal distance of 7175 meters. The graph above shows the heights of various mountains that our gun can reach. However, the gun can't actually leap over most of these mountains; while it can reach the height of the mountain peak, in most cases, it cannot cover the massive horizontal distance of the mountain bases.

The above graph shows the points in the trajectory where these mountain's heights are reached. There is one rather famous mountain that our gun can fully cross: the Matterhorn. With a prominence of 1031 meters and a base ranging from 600 to 800 meters depending on which side of the mountain is considered, the Matterhorn falls well under the trajectory of our gun, as represented in the graph above.

Optimal Number of Bullets

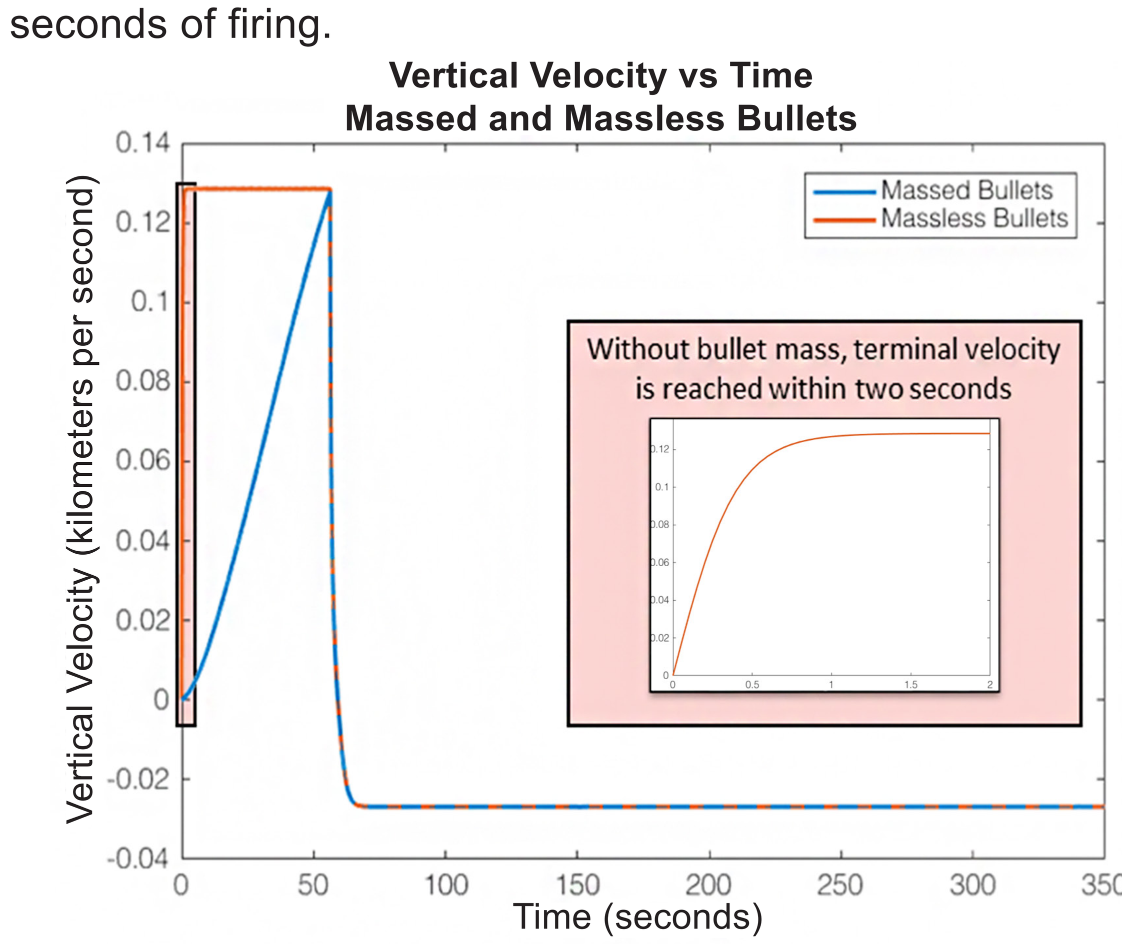
Loading more bullets has tradeoffs. More bullets provides more time with thrust and a higher maximum vertical position; at the same time, more bullets make the jetpack heavier, decreasing its initial vertical acceleration and lowering the maximum height.



5625 is the optimal number of bullets. At 6000 bullets and greater, the thrust force cannot overcome the weight of the jetpack, and the system cannot leave the ground until enough weight is shed for thrust to overcome gravity.

Mass Matters

To validate our loss of mass, we ran our model without the bullets' mass for comparison. The simulation with massless bullets has much less initial weight, causing much greater vertical acceleration. In the graph below, the massless-bullet jetpack reaches a constant terminal velocity within two seconds of firing.



As the massed-bullet jetpack sheds weight, it reaches the same mass as the gun alone. Consequently, the weight forces of the two systems are equal, causing both systems to achieve the same final terminal velocity and fall with identical velocities.

Next Up: An Actual Jetpack

Despite describing our model as a machine gun jetpack in the title, we evidently have not actually accounted for a human rider for the "jetpack." Future modelling will look into the survivability of the jetpack, rather than optimizing for height and distance as we have here. Our current model involves about 40 g's of acceleration, not to mention the extensive heating of the system, both of which are conditions that a human would not be able to survive. A machine gun jetpack optimized for survivability will be a very different modelling challenge.