Starting in 1918, railguns have long existed as experimental technology but the mass, size and cost of the required power supplies have prevented it from becoming practical military weapons. But in the last decades there have been significant efforts towards their developments as realizable military technology.

It comprises a pair of parallel conducting rails, along which a sliding armature is accelerated by the electromagnetic effects of a current that flows down one rail, into the armature and then back along the other rail. The rails are connected to a pulsed direct current power supply. (Fig. 1)

In contrast to explosive or gas expansion propulsion the muzzle velocity is only depending to the aerodynamic properties of the projectile and the energy of the power supply. The force, which is acting on the armature, is the Lorentz force. It appears through the magnetic field of the rails.

There are various problems for this technology. First is the mobility of the power supply. Second the abrasion of the rails due to the heat and friction. But with better materials this could be solved in the future.

The uses of the railgun are mostly military but it also can used as launch assist for an spacecraft and even for the initiation of a nuclear fusion.

Nowadays railguns are most known out of science fiction Series like Stargate or Movies like Transformers: Revenge of the Fallen. But it isn’t science fiction at all. It started nearly a century ago in 1918 in France where an early form of the railgun was invented. Even the German had testings with this kind of technology during World War 2, but they had no success.

A few decades ago, the first functional railguns were built, but only for one shot, then the rails were badly damaged and had to be replaced. Nowadays the US Army and Navy are the farthest in the research of this technology. The research goes mostly in the way of the materials of the rails and the power supply which hast to be enormous powerfull. Here I show the parts the railgun consists of and how a railgun works.

A railgun consists of two parallel metal rails connected to an electrical power supply. When a conductive projectile is inserted between the rails, it completes the circuit. Electrons flow from the negative terminal of the power supply up the negative rail, across the projectile, and down the positive rail, back to the power supply. This current makes the railgun behave as an electromagnet, creating a magnetic field inside the loop formed by the length of the rails up to the position of the armature. In accordance with the right-
hand rule, the magnetic field circulates around each conductor. Since the current is in the opposite
direction along each rail, the net magnetic field between the rails $B$ is directed at right angles to the
plane formed by the central axes of the rails and the armature. In combination with the current $I$
in the armature, this produces a Lorentz force which accelerates the projectile along the rails, away
from the power supply. (Fig. 2) There are also Lorentz forces acting on the rails and attempting to
push them apart, but since the rails are mounted firmly, they cannot move.

![Figure 2: Schematic function of a railgun](image)

In the next step I am going to show how the Force is calculated. The Lorentz force is given by the
average magnetic field $B$ on the railgun armature and is a result of the Biot-Savart-law.

$$B = \frac{\mu_0 I}{2\pi d} \ln \frac{r}{d} \quad [4]$$

$\mu_0$ is the permeability constant, $I$ is the current through the rails, $d$ is the distance between the centre
points of the rails and $r$ the radius of the rails. Now we insert the result for the magnetic field in the
Lorentz force law and we get following solution for the Lorentz force.

$$F = \frac{\mu_0 I^2}{2\pi} \ln \frac{r}{d} \quad [4]$$

Here we see that the force, which propels the projectile, is going in with the square of the current.
That means, the higher the current, the higher is the acceleration of the projectile.

Now that we now the theoretical background, we can go to the parts of the railgun starting with the
power supply. The power supply must be able to deliver large currents, sustained and controlled over
a useful amount of time. The most important gauge of power supply effectiveness is the energy it
can deliver. The most common forms of power supplies used in railguns are capacitors and
compulsators which are slowly charged from other continuous energy sources. There we have the
first problem for the common use of railguns. As a railgun should be mobile it’s not possible to have
such a power supply that’s mobile, and charged really fast.

Let’s go to the rails. The rails and projectiles must be built from strong conductive materials. The rails
need to survive the violence of an accelerating projectile, and heating due to the large currents and
friction involved. Some erroneous work has suggested that the recoil force in railguns can be
redirected or eliminated, careful theoretical and experimental analysis reveals that the recoil force
acts on the breech closure just as in a chemical firearm. The rails also repel themselves via a
sideways force caused by the rails being pushed by the magnetic field, just as the projectile is. The
rails need to survive this without bending and must be very securely mounted.
A long time it was not possible to fire a railgun multiple times in a row, because the rails were badly damaged after the first shot. Massive amounts of heat are created by the electricity flowing through the rails, as well as by the friction of the projectile leaving the device. The heat created by this friction itself can cause thermal expansion of the rails and projectile, further increasing the frictional heat.

Now we head to the uses of a railgun. First of all, it is researched for military use. Mainly as main weapon of tanks of the US Army it would replace the chemical main weapon of it. On ships of the US Navy it should replace the cruise missiles like the Tomahawk. The US Army and Navy have the farthest research on railguns.

A railgun also can be used as launch or launch assist of spacecraft. Here we have some key parameters for space launch. (Fig. 3)

<table>
<thead>
<tr>
<th>Key Parameters</th>
<th>Value</th>
<th>Units</th>
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<tr>
<td>Muzzle Velocity</td>
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Figure 3: Key parameters for space launch

There we can see that this would be only for unmanned spacecraft because of the very high acceleration.

Another use for that technology is to initiate a nuclear fusion. A particle would be accelerated to 200 km/s and as cause of the pressure and heat by the collision, a fusion reaction could be initiated.