USING RAILGUN (RELSOTRON) FOR PAYLOADS DELIVERY FROM THE MOON

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The ways to leave a planet

Chinese invented rockets: 9th century Chinese Taoist alchemists discovered black powder while searching for the Elixir of Life.

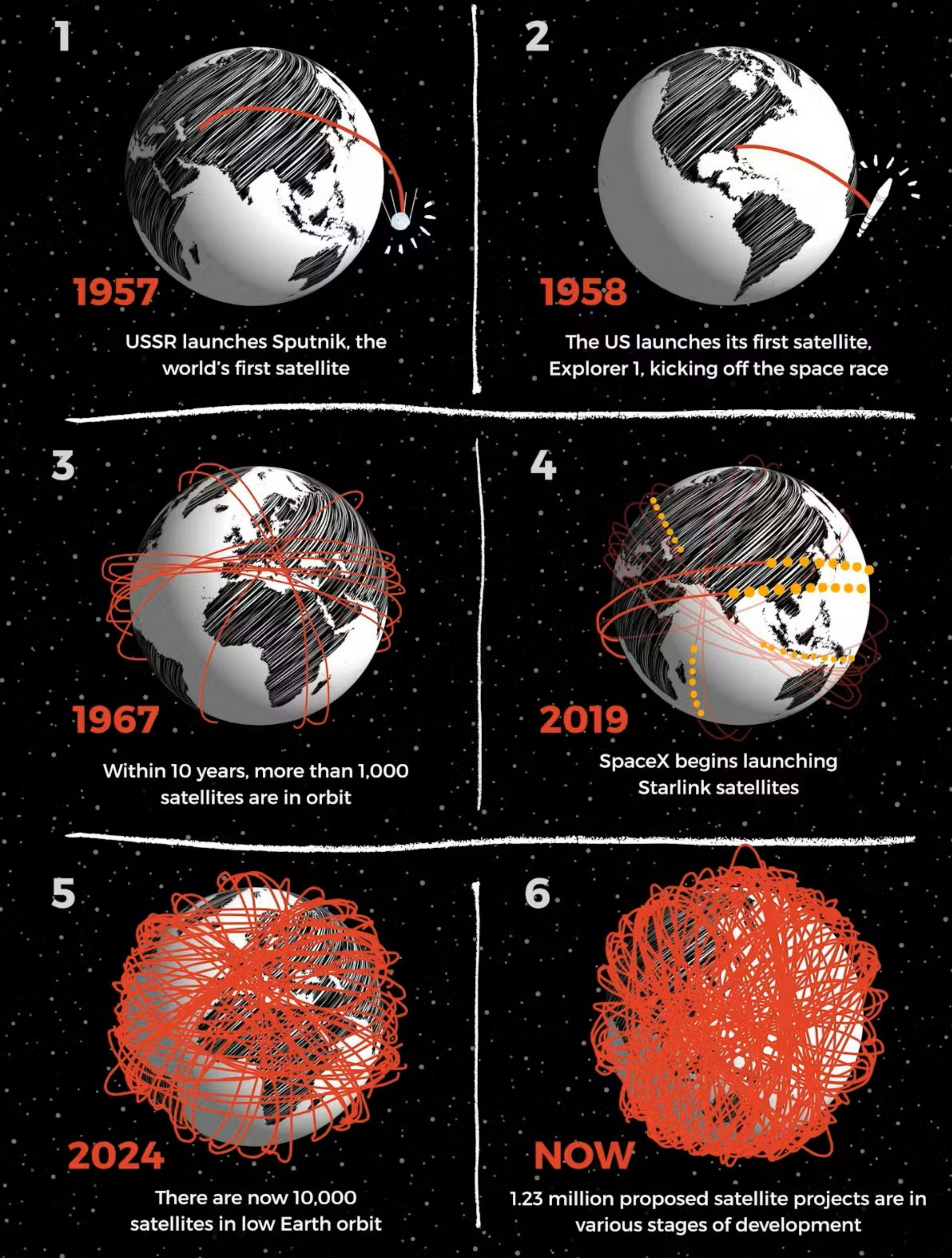
Tsiolkovsky suggested using them to go to space:

1903. К. Ціолковскій, *Изслѣдованіе мировыхъ пространствъ реактивными приборами (The Exploration of Cosmic Space by Means of Reaction Devices)* -- the first world's serious work on using rockets to go to space! Though he talked about rocket principle in space as early as 1883.

We on Earth are lucky

—Escape speed from the surface of the Earth is just around the speed limit attainable by the chemical propulsion. Amount of fuel required per payload to escape velocity scales as ~3.3 exp(g0). Chemical rocket launches on superEarths would need to use a sizable fraction of the planet mass as chemical fuel per launch (For a classical Apollo moon mission (45 t) on Kepler-20b (27.1 km/s), the rocket would need to weigh ~400,000 tons, *Hippke 2019).*

—Escape velocity from planets near dwarf stars, like Proxima b, into space is much higher than ours (42): ~65 km/s; to launch 1 kg CubeSat would take a thousand times more fuel than carried by the Space Shuttle (=1.7 mln kg of propellant at liftoff), *Loeb 2018.*



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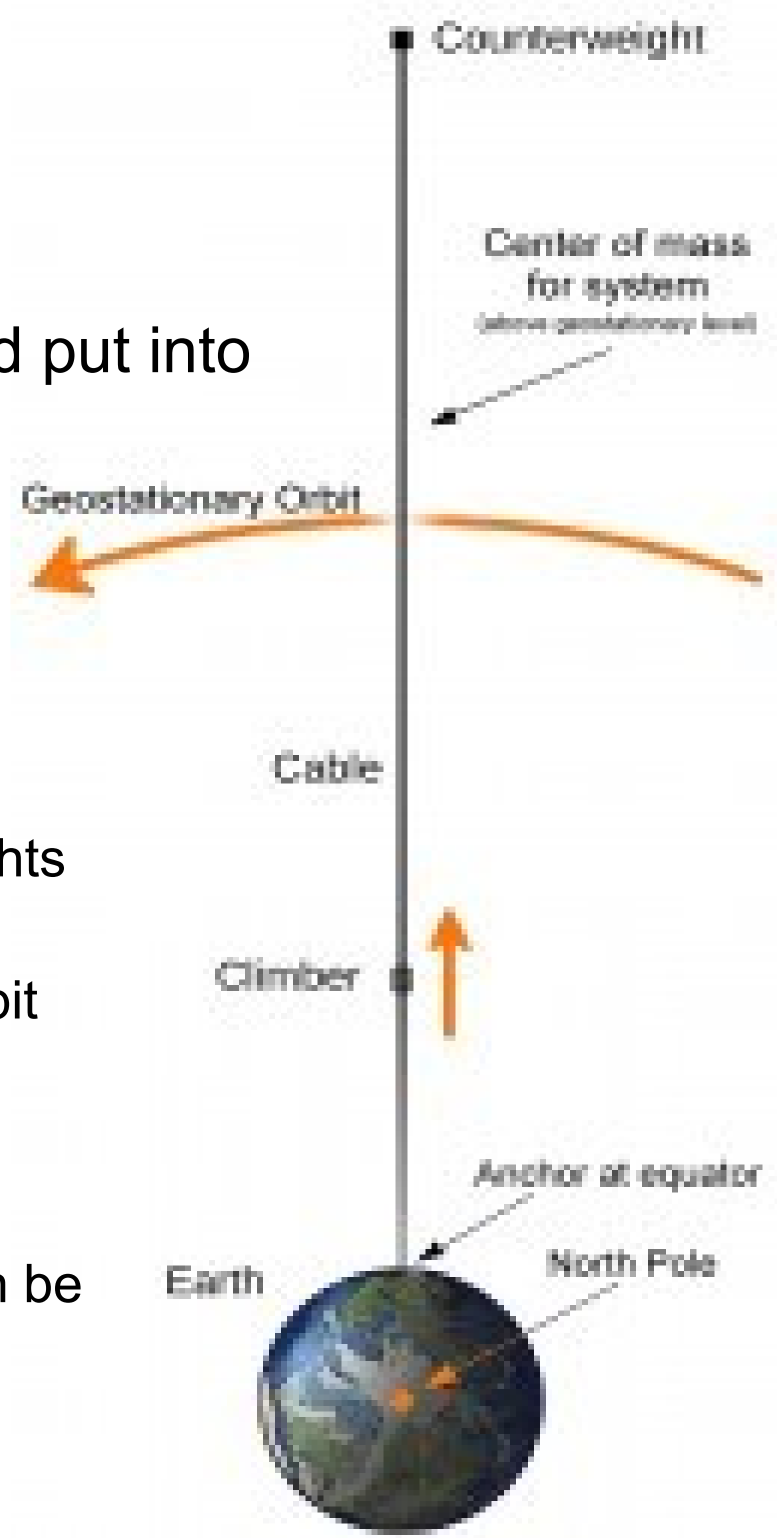


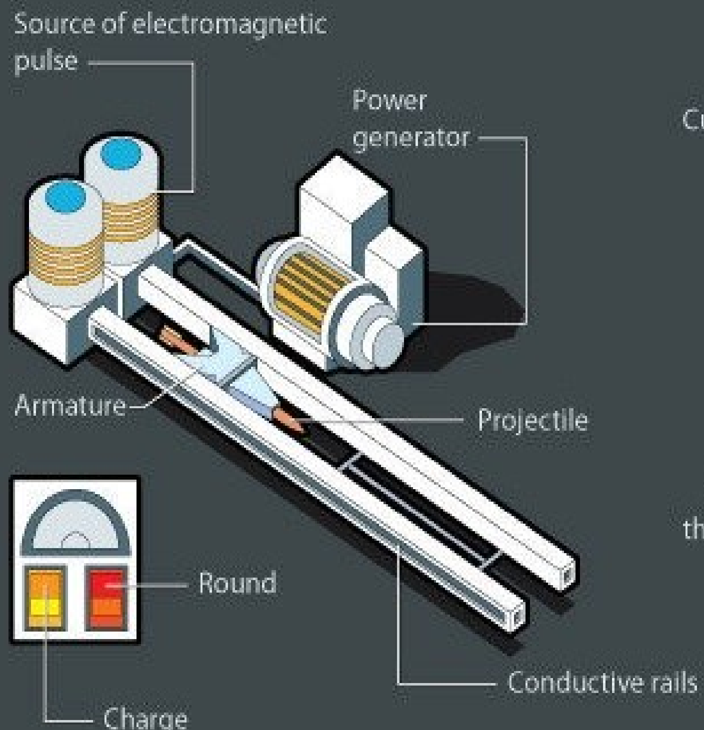
Electromagnetic launches

Railgun – a 21st-century weapon

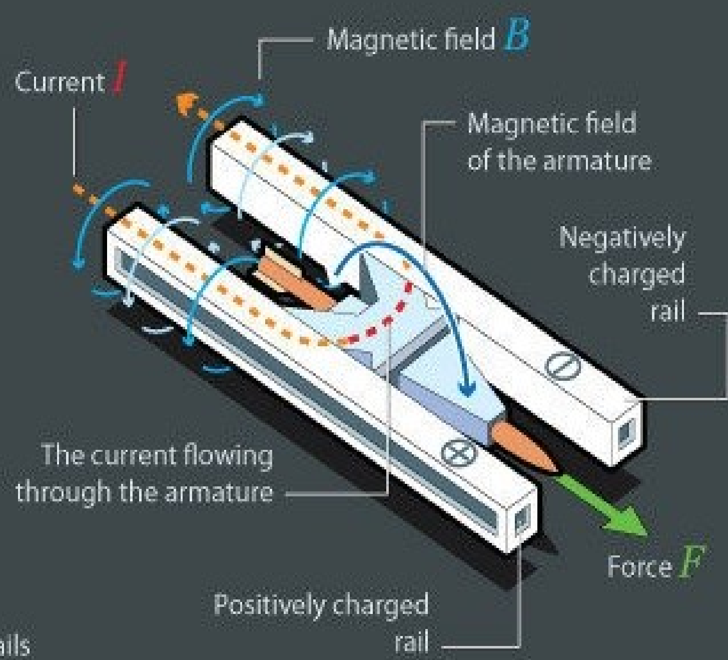
In the opinion of the U.S. military, electromagnetic weapons have the potential to replace conventional artillery in the near future

The most powerful railgun in the world was designed at the U.S. naval research laboratory in Dahlgren, Virginia. The energy of its rounds is 33 megajoules. Projectile velocity is five times the speed of sound and its firing range can reach 370 km

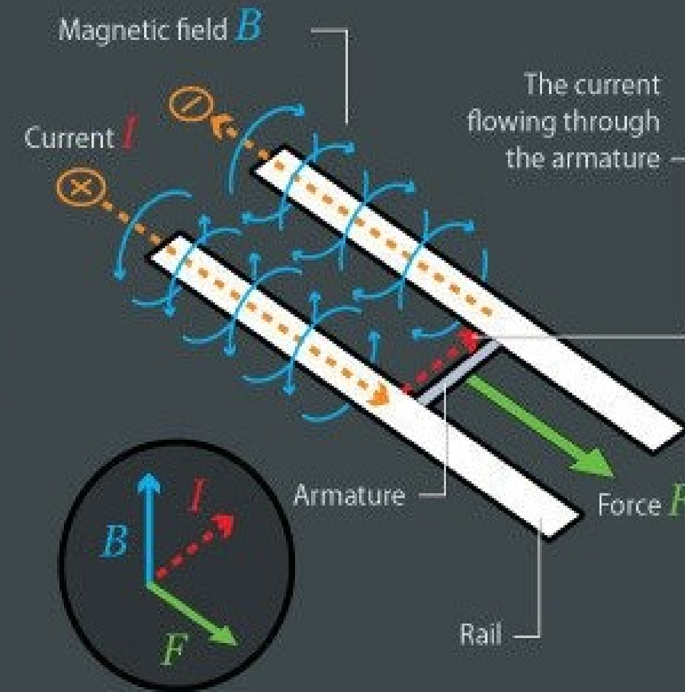
Railgun device



Interaction of magnetic fields

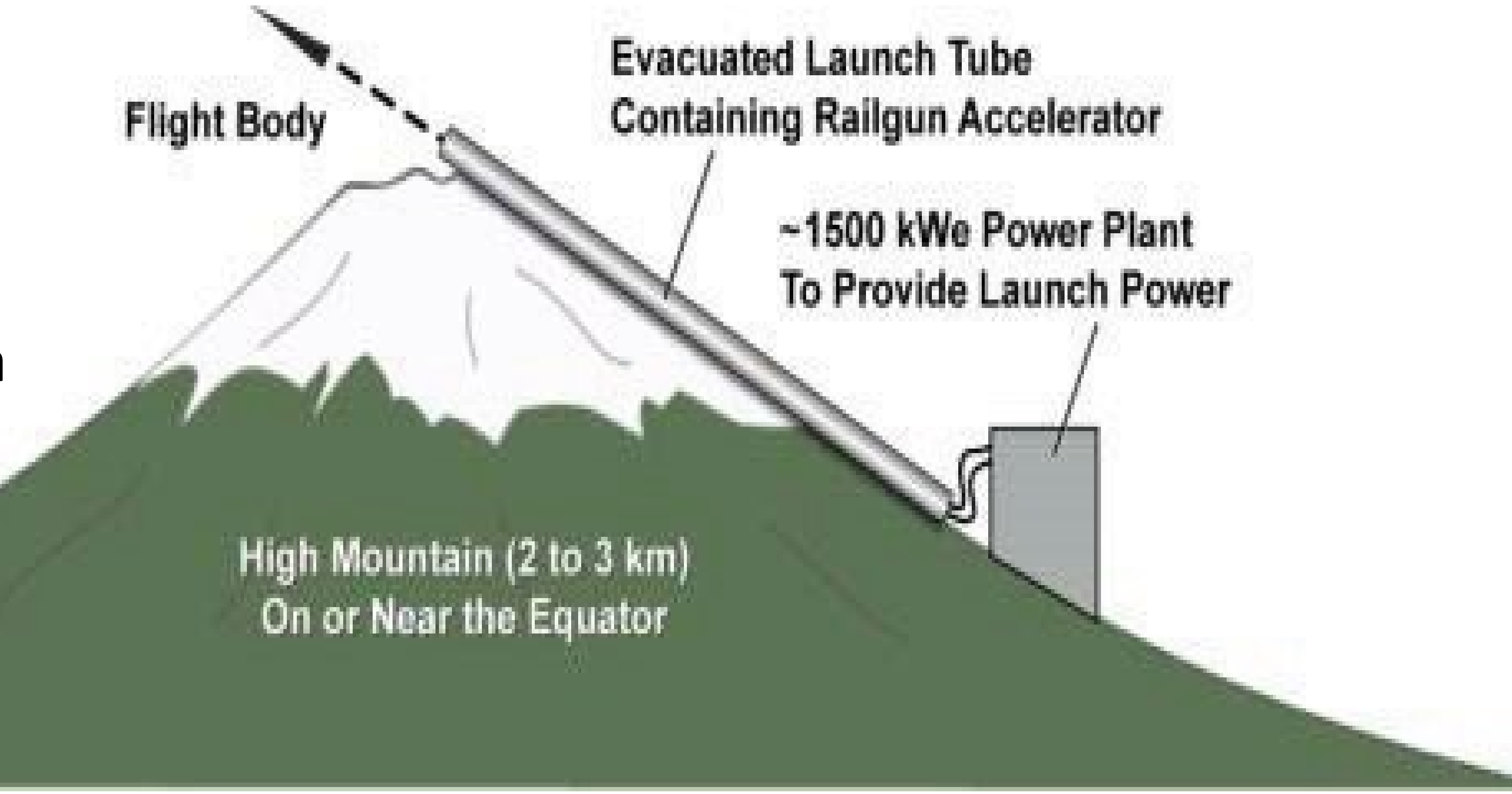


The principle behind Lorentz force

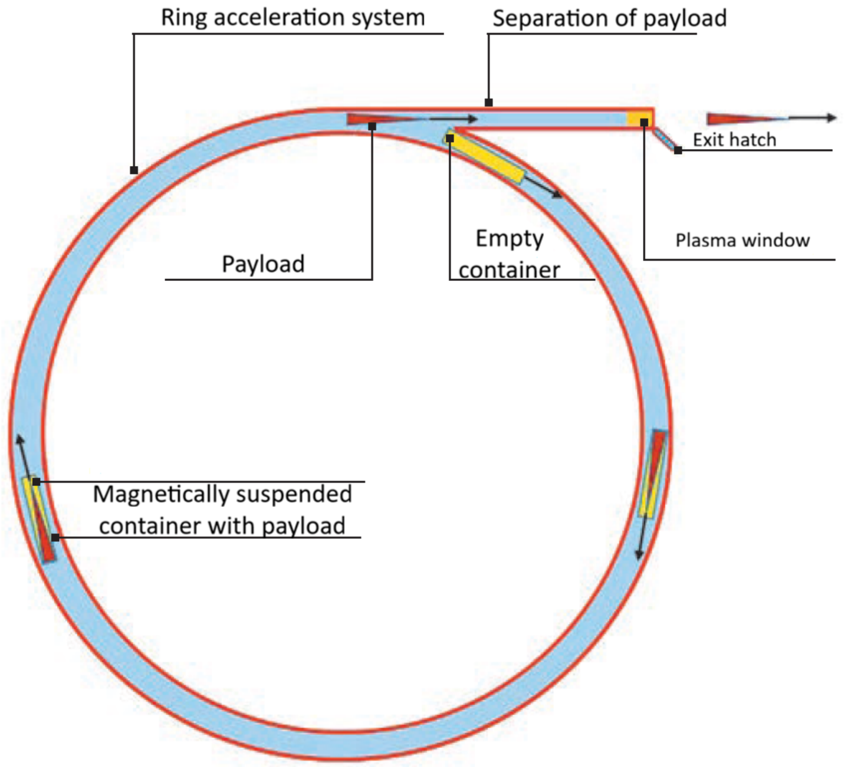


The railgun uses electromagnetic force (Lorentz force) to propel an electrically conductive projectile that is initially part of a chain. Current I, flowing through the rails, generates magnetic field B in the rails and armature. As a result, under the action of force F, the armature is pushed out of the magnetic field of the rails and the projectile accelerates

High in the mountains to reduce aerothermal heat load on the launched payload, and to place the rails into a vacuum tube (1.5-km long) to reduce friction losses.



Another configuration of a relsotron is a circular one with diameter of a few kms and also preferably built high in the mountains.



Moon avoids some of the terrestrial problems, like high gravity and atmosphere

For relsotron system UTSTAR from Earth to LEO (*McNab 1999, 2003*) it was estimated that the total energy cost to launch 1250 kg system (payload only 300 kg) to be ~44.6 GJ (most of the energy is spent on taking payload to the launch altitude, overcoming atmosphere resistance, etc.; thus, energy cost of taking 1 kg payload to LEO is just ~24% of the total energy expenditure).

Lunar conditions simplify the construction and reduce all costs, energy included, of such accelerator. The lunar regolith can be a local source of material to build the whole structure. The absence of the atmosphere removes the necessity of a vacuum tube, and there is no need of an aerodynamic container – an aeroshell: the container protecting the payload and its components from very high atmospheric aerothermal load.

EM launchers based on the Moon could be used to deliver mined materials to destinations such as Lagrange colonies, Earth or near-Earth locations, or to the orbiting NASA Gateway space station in support of Mars or Solar System explorations. Once emplaced on the Moon, such EM launchers could also serve other applications, like defense of lunar colonies against meteorite impacts, launches of sub-orbital or orbital lunar surface mapping and reconnaissance satellites, and launches of lunar communications satellites.

3 possible lunar orbital locations to launch:

- *LLO: say 50 km altitude*
- *Cislunar Space*
- *Earth-Moon L1 Lagrange point*

Consider 300 kg payload with the armature of 100 kg

1. Low Lunar Orbit (LLO)

first accelerate to the lunar orbital velocity V_{orb}=1.68 km/s

then additional to reach the final h=1788.2 km (R_{lunar} +50 km)

Total energy expenditure is 564.96 MJ

2. Cislunar Space

lunar escape velocity V_{esc}=2.38 km/s

The input energy to launch with this velocity is 798.15 MJ

3. Earth-Moon L1 Lagrange point

R_{L1} ~61,500 km from the Moon centre

initial velocity of the spacecraft should be V_{L1}=2.35 km/s

If the payload imparted the 778.15 MJ energy at the start,
it will reach the L1 point with zero velocity.

To launch a 300-kg payload from Earth surface to LEO requires 44 GJ total power, on the Moon for the same payload to LLO it is 78 times less energy.
The Earth-based launcher UTSTAR had the total length of 1.6 km, the length of the lunar relsotron to launch to lunar L1 is 157 m — a significant reduction in the construction cost (we do not even need to consider a circular design).

The relsotron can be built on the Moon using the local material and any necessary equipment from the Earth that needs to be delivered only once. The energy can be sourced using the solar batteries on the lunar surface, or even a nuclear power delivered from the Earth. In the foreseeable future, a thermonuclear power source can be used, for which the fuel – ^{3}He isotope – is abundantly available on the Moon.

Therefore, we are confident that using the linear railgun (relsotron) is a forward-looking (promising) and cost-effective way of launching payloads from the surface of the Moon into the cislunar space.

Artists’s concept on relsotron on the Moon. Wright, Kuznetsov & Kloesel, 2011.