



Executive Summary

The current method of transporting payloads from low earth orbit (LEO) to low lunar orbit (LLO) have excessively high fuel consumption rates and squander our natural resources.

The normal spacecraft used to launch payloads to the moon have many different stages; the part we propose to improve is the earth departure stage (EDS). The purpose of the EDS is to perform trans-lunar injection (TLI) which is a burning of fuel that will set the spacecraft or small payload on course for the moon.

We propose that the EDS be replaced with a railgun on any reusable spacecraft. The railgun would not only conserve fuel but it would be able to run on complete solar energy, thus the fuel would not have to be transported into LEO. Additionally, because of the use of solar power the railgun would not drain our country's limited natural resources.

Since the railgun could be placed on any spacecraft its use would help move moon exploration to private industry. This move would not only help companies that want to be involved in moon exploration, but it would also utilize space tourism because private companies could use the railgun on space tourism flights.

Furthermore, the use of a railgun could help launch much needed resources to a moon base; and provides a much cleaner and simpler way to do it. And when used on a private flight a railgun could help the private industry be more involved with a government sponsored moon base.



Background

Moving from LEO to TLI

The current proposed method NASA plans to use for the new Constellation program involves launching two different spacecrafts into LEO. The second bigger spacecraft called Ares V will take the EDS into LEO. Then the EDS will rendezvous and dock with the lunar Lander, Altair. The crew will be in the command module Orion and lunar Lander. The EDS will then make a burn and perform TLI. The crew will arrive to the moon in 3 days.

The proposed EDS will use 228519.836 kilograms of LOX/LH2 to perform TLI. LOX/LH2 is liquid oxygen and liquid hydrogen.

Railguns

There are three parts to a railgun: a power supply, two sets of charged parallel rails and a moving armature.

The power supply on a railgun is simply a supply of electrical current, for a large railgun, the power supply is normally in the millions of amps. Because of this, when solar panels are used to power a railgun a large amount of capacitors is needed to store the collected energy. Then all that energy needs to be released at once.

The two rails on a railgun are simply two rails of a conductive metal. One is given a positive charge and the other is given a negative charge. When used for high power launches the metal that the rails are made out of need to be able to with stand large amounts of heat.



The armature is the thing that bridges the gap between the two rails. It can be a solid piece of metal or it could be used as housing for a larger projectile. The armature is the thing that is launched when the railgun is fired.

When the railgun is used an electric current runs from the positive terminal of the power supply, up the positive rail, across the armature, and down the negative rail back to the power supply. The magnetic field now created across the positive rail is counter clockwise and clockwise around the negative rail. The net magnetic field is directed vertically. The force experienced by the armature is called Lorentz force, this force is perpendicular to the magnetic field and to the current flowing across the armature. (see image 1.1 in appendix)

Uses for Railguns

There are many different uses for railguns, however the most commonly used and most modern uses are mainly for weapons. Additionally, railguns are used on the superman ride at Six Flags Magic Mountain. They have never been used in space. Many people want to launch small payloads or projectiles from earth into LEO, however they must get an enormous amount of energy to successfully go into LEO. Plus, they must find very good rails, because every time they would accelerate something fast enough to make it into space, the intense heat would fry the rail. So, a railgun on earth can only be used once. However, if a railgun was used in space then it could easily be reused.



Concept Details

Materials

There are many decisions that need to be made when making a railgun, one of those decisions is what material should be used. The rails have to sustain their form while conducting a ton of electricity and being heated up. Therefore, to make the rails reusable, a strong, highly conductive, metal alloy, with a high melting point must be chosen. The rails must stay in the same shape they started with, so the alloy must be strong. Plus, the rails must conduct the electric current well. If it does not there will be a lot of friction and the rails will heat up even more. So to withstand this intense heat the rails must have a very high melting point, that way they will not melt when the projectile is launched and they will keep their form. The less friction there is, the less the rails will heat up, so everything should be done to reduce the friction to the lowest amount possible.

Speed

To correctly perform TLI the payload or projectile must be accelerated. The ΔV must be at least 10,000 feet/second or 3048 meters/second to leave LEO and be on course for the moon. Therefore, the railgun must accelerate the payload to 10,000 feet/second.

Energy Used

To power the railgun will use a huge amount of electricity. However this is still good because electricity is a clean and renewable source of energy. It will not waste fuel to send the payload to LLO. Plus, all the electricity can be acquired from solar panels mounted on top of the



spacecraft. The energy will be stored in large capacitors and then released when needed. When the solar panels are not being used to power the railgun they can power just about anything else on the spacecraft.

To find the energy needed the formula $F = \frac{(\mu_0)(I^2)}{2} \ln\left(\frac{d-r}{r}\right)$. In this equation "d" is the distance between the center points of the rails and "r" is the radius of the rails. "F" is the force needed to get to space, and "I" is the current needed.

If there is a 500lbs payload a force of 8640935.22N would be needed, if there is a 1000lbs payload a force of 17281870.44N would be needed. If the rails are a set of ten 40ft rails mounted like a telescoping ladder, and the radius of the rails is 5in and the distance is 15in then a force of 7895009.307 amps would be needed for 500lbs and for 1000lbs the current would need to be 11165229.24 amps.

Energy Collection

The energy needed to power the railgun could be collected using solar panels. This would help reduce launch costs and would not use up the limited natural resources on earth.

In LEO a solar panel gets 230 watts/m². So, with very little paneling and lots of capacitors the railgun would be charged and ready for use in very little time. If the capacitors had a charge before the spacecraft was launched then the railgun would be ready for launch even faster.

How it is attached to the Spacecraft

The railgun must accelerate the payload to a very fast rate. Therefore the railgun will be quite large, however it will be significantly smaller than the current rockets that are used. The



railgun will need to have an opening into space where the payloads are released and launched. Otherwise it could go almost anywhere. It will likely be on a side of the craft (however not on the outside during launch). It should additionally be contained so it will not affect the crew. There will be heat from the railgun when something is launched, so the railgun should be in a contained tube or outside of the craft. The heat from the railgun can be used to heat the spacecraft, conserved to power something else or realized out into space. Additionally because the railgun armature will carry a charge the armature will be used to push the actual payload, the side of the armature that will touch the payload would be insulated so the payload would not be effected by the electorcal current needed to power the railgun.

What is launched

The railgun can launch small payloads of just about anything to LLO. Most likely, food and water will be launched to the lunar outpost that NASA is scheduling for 2020. This way the food gets to the outpost, yet very little fuel is used. Plus, there is no spacecraft that has to be returned to Earth, again eliminating fuel use. The food will be in containers or small spacecrafts that will use small rocket engines to gently touch down on the lunar surface. Plus, airbags can inflate around the payload to ensure a good landing. However, the food will be good no matter what, unless it is significantly damaged, and the container breaks. Then the materials from the container and airbags can be used in the lunar outpost and even the empty rockets can be made into something else. Everything from the payload can be recycled.

This method could also be used to launch lunar lenders, it would be especially useful in a scenario like the Google Lunar Xprize. Because of the railgun's reusability and the easy of



placing it on any spacecraft, a railgun would enable and encourage private exploration of the moon.

When to launch

"For every action there is an equal and opposite reaction." (Sir Isaac Newton) Newton's third law of motion applies to everything and especially affects things in space. When the railgun launches a payload, the spacecraft will have an equal and opposite reaction. Taking into account the fact that the railgun is very powerful and will send the payload into TLI at 10,000 feet/second, there is the obvious conclusion that the spacecraft will be hurtled out of LEO. There are two ways to solve this.

The first way is to launch the payload out of the railgun when it is time to go back to Earth. That way the railgun will give the spacecraft an initial push and start it on its way to Earth. But this must be done at the correct time and angle to make sure that the payload will travel to LLO and the spacecraft will enter the Earth's atmosphere. Also, if the spacecraft is oriented so that when the railgun shoots the payload, the opposite reaction will send the spacecraft in the same direction as LEO, it will just keep continuing in LEO. However the payload must still be launched at the moon and into LLO.

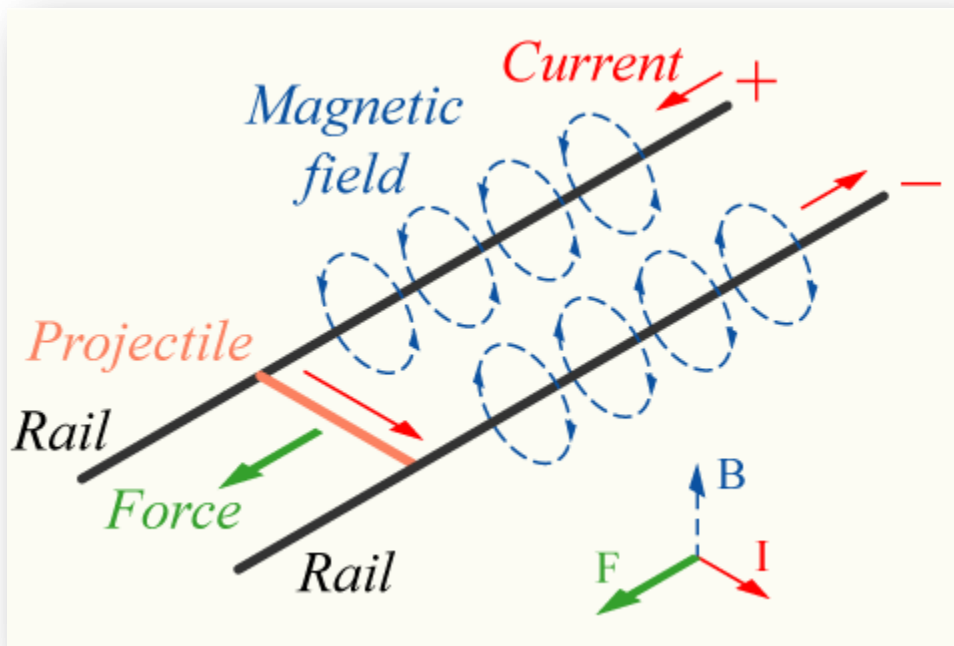
The other method of solving this problem is to have two railguns of equal power on each side of the spacecraft. If the two railguns fired an equal amount of mass at the same time the spacecraft would stay in the same place, one of the payloads would be in TLI and the other would enter the earth's atmosphere and burn.

Advantages over fuel

There are many advantages to the use of solar power in a railgun over the use of fuel in a traditional rocket. One major advantage is that solar power is renewable and a clean source of energy. Using solar power will save fuel and it can power anything else on the spacecraft. It has many uses. Plus, using solar power means that no power has to be carried on a spacecraft into LEO, it is collected and stored while in space. There is no need for an EDS for the small payloads, just the railgun and solar panels to charge it. Eliminating the EDS and all the fuel needed for it will reduce the weight of the spacecraft. And since most spacecrafts already have solar panels, adding a few more will not add that much weight.

Appendix

Image 1.1





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