Abstract

Space exploration is the next big scientific frontier, but rocket launch costs are astronomically high. Current fuel boosters cost too much and accomplish too little. Rockets must use so much fuel to even just achieve orbit that there isn't much space for anything else. Therefore, the solution is a better launching method. Instead of using fuel to create thrust, electromagnets can be used to accelerate a pod to high speeds. This will take a long time and a long distance to achieve, so we will make a circular loop, similar to a particle accelerator. That way, the pod will have an infinite distance to travel. Once the desired velocity is reached, the pod will be launched upwards, essentially skipping the first stage of a booster rocket. It may cost a lot to build, but will be better for the environment and cheaper in the long run.

Mag-Launcher: Magnetic Repulsion Rocket Launcher

Today, the cheapest method for launching rockets is using reusable boosters. Still, boosters, like the Falcon 9, cost a tremendous $22 million USD to build and $4 million USD for refurbishing[1]. The exorbitant price for launching rockets limits space exploration. The proposed technology will use magnetic repulsion to reduce the cost of launching rockets, increase space exploration, and be better for the environment.

Present Technology

One major currently used solution to reduce the cost of sending rockets into space is reusable boosters. Companies such as SpaceX have designed and built reusable boosters to be placed on the bottom of rockets. Such rockets make it possible to reuse the first-stage booster of the rocket for multiple flights before needing to discard it, ergo eliminating the need for building a new booster for each flight. Implementing this kind of reusable technology for space travel allows for the cost of building and launching rockets to be reduced by several million dollars[2].

Rockets with reusable boosters, such as the one on SpaceX's Falcon 9, for instance, have pre-determined flight plans. After launch, the reusable first-stage booster carries the cargo and potentially a second-stage booster to an altitude of about 100 kilometers. Once the rocket has reached this specified altitude, the first-stage booster detaches, leaving the cargo and a second booster to complete the trip. This first-stage booster will then, instead of simply falling to the bottom of the ocean like normal boosters, touch down safely on a landing barge and then be shipped back to where it needs to be reused. This process is quite meticulous though. The first step after the booster separates from the second-stage booster is that small thrusters around the

[1] https://cosmosmagazine.com/space/launch-land-repeat-reusable-rockets-explained/
[2] https://www.pressreader.com/uk/how-it-works/20180419/283386242473371

booster begin to activate to rotate the booster, keeping it upright. Then, the engines of the first-stage booster, along with the grid fins and the onboard computer, guide the booster down to ensure a smooth touchdown. Part of this process includes the reactivation of some of the boosters, slowing down the rocket's velocity and thus keeping the booster unscathed and ready to use again[3].

Furthermore, there have been several minor improvements. One of which is fuel efficiency. NASA currently uses liquid hydrogen as a propellant. This extremely light and efficient propellant helps reduce the cost of space missions[4]. Additionally, there have been discoveries and improvements in rocket design. Most notably, the nose cone and fins reduce drag and increase stability. Thus, resulting in a rocket that requires less fuel for thrust and stability[5].

Although these solutions reduce the cost of launching rockets, they can be improvements. For example, reusable boosters are not a flawless solution because re-fuel is required for every mission[6]. This caveat inspired the proposed solution — one that works in conjunction with the reusable rocket technology. It features a reusable magnetic repulsion launch system that will reduce the number of boosters and fuel necessary for a successful and sufficiently powerful launch. Rather than using tons of gallons of fuel, the proposed solution intends to use a very minimal amount of fuel and instead primarily use electromagnetic repulsion to launch the rocket. Although it may not be possible for such a launch to occur with no fuel at all, the proposed solution will still save significantly more fuel than the current solution we have: reusable boosters.

[3] https://cosmosmagazine.com/space/launch-land-repeat-reusable-rockets-explained/
[4] https://www.nasa.gov/topics/technology/hydrogen/hydrogen_fuel_of_choice.html
[5] https://www.sciencelearn.org.nz/resources/392-rocket-aerodynamics
[6] https://www.pressreader.com/uk/how-it-works/20180419/283386242473371

History

In around 400 B.C.E, Archytas developed one of the first devices that employed principles crucial to the main integrity of a rocket flight. In the model, escaping steam propelled the bird attached to wires. Around 300 years later, Hero of Alexandria created a similar steam propelled device. A sphere suspended over a kettle of boiling water would rotate. Steam would enter through two L-shaped tubes and provided thrust for the design. In the starting century of the Common Era, the Chinese attached gunpowder filled tubes to arrows. They soon realized that the tubes could be fired on their own, creating the first true modern rocket. For centuries, rockets were mainly used for weaponry until Wan-Hu. He wanted to create a flying chair with rockets, but it is assumed that he blew up and failed in around 1500 C.E. Through the end of the 18th and start of the 19th century, rockets were again used again before the start of modern rocketry. In 1898, Konstantin Tsiolkovsky proposed the idea of exploring space by utilizing rockets. Early in the 20th century, Robert H. Goddard conducted experiments in rocketry. His first design used a solid propellant. He concluded that solid propellants would be too heavy leading to the change of using liquid propellants. On March 16, 1926, his liquid oxygen and gasoline-powered rocket launched only 12.5 meters into the air. As rockets were studied and became more advanced throughout the duration of World war II, scientists believed more that they could be used for space exploration. The Soviet Union U.S.A formed separate space programs. On October 4, 1957, the Soviet Union successfully launched satellite Sputnik I into the Earth's orbit. Within the next few decades, robots, humans, and the ISS were launched and sent into space[7].

[7] https://www.grc.nasa.gov/www/k-12/TRC/Rockets/history_of_rockets.html

One-time use boosters were utilized for space missions. These one-time boosters allowed for sending loads into space without having to worry about retrieving the boosters after they detach from the rest of the rocket. This method, however, was wasteful and expensive. An abundance of materials are needed to build new boosters for each launch. In addition, around a million more dollars are required to purchase enough fuel needed for each launch. This made every rocket launch into space very expensive, costing hundreds of millions of dollars.

One-time boosters are jettisoned at a pre-determined altitude. Once the desired altitude is reached by the rocket, the first-stage one-time use boosters are detached. After detachment, the boosters fall back to Earth. Rockets have a set flight path which is mostly over an ocean. Therefore, boosters would fall into the ocean after detachment. Unlike newer, reusable boosters, one-time boosters would not be retrieved and are permanently disposed of in the ocean[8].

The high cost of having to build new boosters for each space mission is the catalyst for the creation of reusable boosters. Although fuel was still an extraordinary expense, the new, reusable boosters were separated into stages. Once each stage was complete, it would detach and land back on Earth, where it could be refurbished and reused. This was much more efficient than building new boosters, both cost and time-wise. Not all the parts could be recovered, but it was still an improvement. However, the first stage required tremendous amounts of lift to propel the rest of the rocket. Over time, rockets have slowly grown more efficient with advances in technology and design. Newer engines, more powerful internal computers, cheaper fuel, and materials have all helped revolutionize the modern rocket. Yet although such advancements have

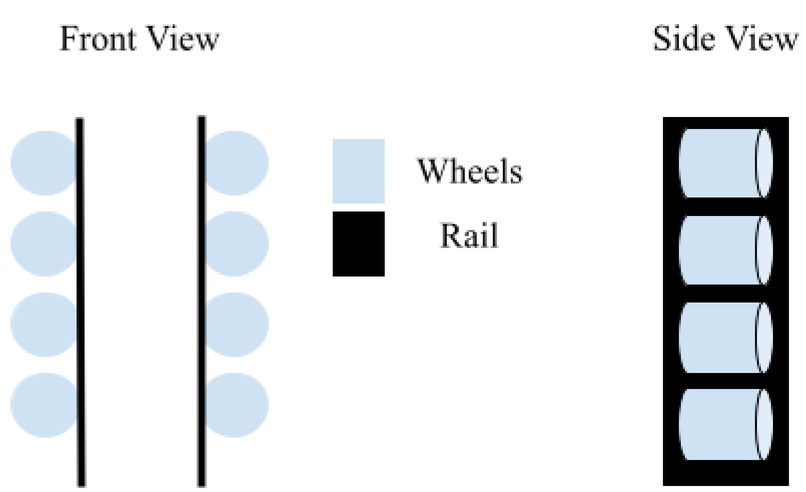
[8] https://youtu.be/P1wMn8g7lW8

been made, it becomes clear that the major problems have remained mostly the same: a lack of efficiency and still a much too high cost of launching rockets.

Future Technology

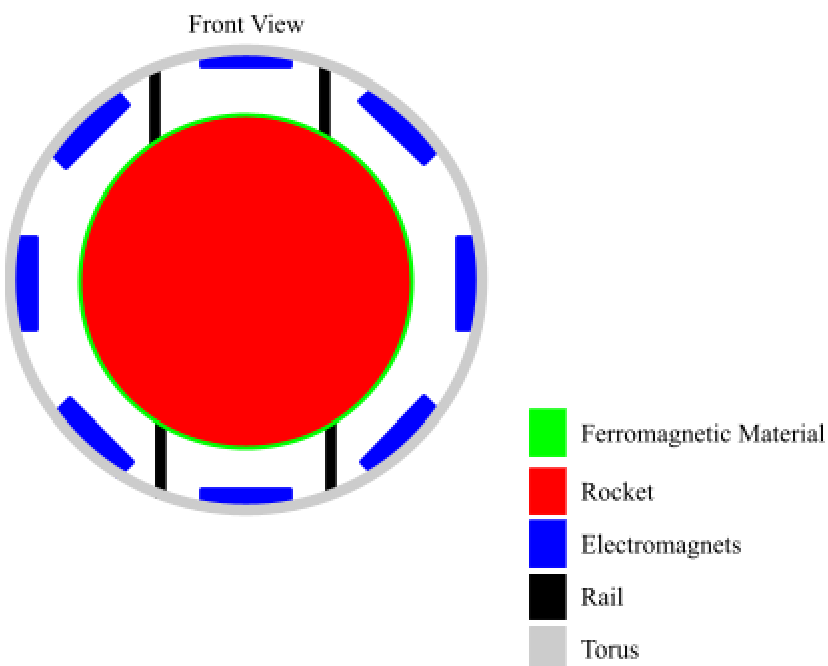
Our solution, the Mag-Launcher, is a reusable electromagnetic repulsion system. Our plan for a fuel-efficient method of shipping cargo to space is to create a torus-shaped structure — one that incorporates a lot of advanced technologies. These technologies, including advanced electromagnetic repulsion systems, will be used to accelerate a rocket to exceptional speeds. Our hope is to remove most of the cost for fuel, as well as reduce the size or eliminate the need for a first-stage booster.

As previously mentioned, rockets will be placed inside a large torus. The torus will be titled at a specific angle and will be big enough so rockets can fit. Upon further testing and experimentation, the circumference of the torus will be determined. Further information about a small-scale experiment will be provided in the Breakthroughs section. The interior of the structure will be kept in a vacuum, reducing air resistance to virtually nothing, and will speed up the process of acceleration.



Additionally, rockets would be attached to a rail inside the torus. The rail will help guide rockets as they are being accelerated. The rocket will be attached to the rail by using multiple sets of wheels placed in the orientation of the diagram shown. This will ensure that the rocket cannot move in any direction while accelerating. Electromagnets will be lined up distant from each other on all sides of the torus.

By altering which magnets turn on at specific times, the magnetic repulsion will generate a great enough force to accelerate the rocket. The rocket will continue spinning around the torus until the required speed for launch is reached. The spinning of the rockets creates G-forces that would be unbearable for humans, limiting our current design to cargo. Once the desired speed has been reached, the magnets will generate enough force so that the speed remains constant until launch. A hatch near the top of the torus will open and the rocket will detach from the rail for launch. At this stage, boosters on the rocket will turn on to stabilize the rocket for its journey into space. Doing this will give it a forceful boost, essentially getting rid of the need for a traditional first stage booster.



This is virtually the same concept as the maglev trains of today, except the magnetic force is being exerted on all sides at greater strengths. The basic technology required to build a functional model of our design is already in place, but the technology is not as advanced as hoped. For our solution to work, the electromagnets need to consistently exert a large amount of force for longer periods of time. A large, efficient power source that is preferably environmentally friendly is also required. However, developing more efficient methods of space travel is certainly a hot research topic and will most likely develop to fit the Mag-Launcher's needs in ten years, thus potentially making the Mag-Launcher the standard device used for rocket launches.

Breakthroughs

As previously mentioned, a small-scale experiment has been designed to determine the optimal circumference of the Mag-Launcher system. The experiment will aim to observe the rotations and time required for a rocket to accelerate to a desired speed. Additionally, observations on the structural integrity of the rails will be recorded. The recorded data and observations will then be used to make improvements and perfect the Mag-Launcher.

All components of the Mag-Launcher system will be scaled down so that 1 foot represents 10,600 feet or 2 miles. The independent variable will be the circumference of the torus. The quantifiable dependent variables will be the rotations and time necessary to accelerate to a set speed. The structural integrity of the rails will be a qualitative dependent variable. Finally, the control group will be a torus with a circumference of 40 feet which represents 20 miles. The procedures of the experiment are as follows:

1. Design and build a model with a circumference 0.75 and 1.25 of the base model. When starting, the base model will be the control group and have a circumference of 40 feet.
2. Once built, test the 2 new models while ensuring all variables other than the circumference are constant.

3. Observe and record data for the 2 models.
4. Use the data to compare the 2 models with each other as well as the control model.
5. Select the model with the best results.
6. Repeat steps 1 - 5 until the difference between the data of each model is nearly equal with the best model from the previous 2 being the new base model.
7. Re-run the selected model so ensure the results are in accord with the original test. If not, repeat steps 1-6.
8. Complete further testing with the selected model to eradicate any possible imperfections in the design.

Once the testing is complete, the measurements for the optimal dimensions of the Mag-Launcher will be determined. Scaling up the measurements will provide a design for a life-size system.

Design Process

Prior to the selection of the proposed torus shaped Mag-Launcher design, other designs were discussed. One of them being a vertical tower magnetic repulsion launch system. It would work in a similar fashion to the Mag-Launcher. A rocket would be placed inside of a tower and electromagnets would vertically launch. Although the rocket would be directly launched upwards, the height of the tower would be too great to build. In order to reach a speed in which a rocket will launch a 100 kilometers using electromagnets, it would require a tower several kilometers high. With current building techniques and materials, it would be impossible to build a robust tower that high. The Mag-Launcher, however, allows for multiple rotations for accelerating. This is ultimately the reason the Mag-Launcher was selected over a tower design.

Another discussed idea was using a large curved rail. This rail would be lined with electromagnets. A rocket would be attached onto a rail which would steadily curve until it was near vertical. At that point, the rocket would detach and launch. Similar to the tower design, it would be extremely long in order to reach desired speeds. Additionally, maintaining it would be difficult as the rail would be subject to weathering. The Mag-Launcher overcomes the challenge of weathering as it has an outer shell protecting the technology. Thus, the rail idea was not selected as it would be infeasible in reality.

Lastly, using solar powered turbines was another idea considered for the project. Instead of boosters, turbines would be used to launch rockets. The turbines would be powered using a previously charged solar powered battery. The drawbacks of this system were that turbines are not currently powerful enough to launch rockets and they would be useless once the rocket exits the Earth's atmosphere. Whereas the Mag-Launcher works in conjunction with boosters to launch a rocket. The impracticality led to its rejection as the proposed solution to the problem.

Consequences

The proposed solution has numerous consequences, several of which are major advantages. One of the major advantages of the Mag-Launcher is the reduction of cost. The main reduction of cost comes primarily from the smaller size of rockets. With the Mag-Launcher providing most of the force needed for launch, the first-stage booster size will be reduced or completely eliminated. To supplement this, less fuel will be needed to complete each launch. The reduction of fuel, in turn, leads to less greenhouse gasses being emitted during the process of the launch. Therefore, making the Mag-Launcher more environmentally friendly compared to traditional launch methods. Furthermore, the Mag-Launcher is a reusable system. Consequently, the cost, in the long term, will be significantly less than current methods. Lastly, the Mag-Launcher can be used for a wide variety of rockets. The total control over the magnets allow for the Mag-Launcher to optimize itself for numerous types of rockets.

But the consequences are not all positive. Despite the benefits, the Mag-Launcher does have some limitations. For instance, there still is the possibility of a malfunction. In addition, because the Mag-Launcher uses electromagnetic repulsion rather than the traditional method of getting a rocket up to high velocities, it is likely that launch times will be longer. This is because magnets don't exert as much force as traditional boosters. This, however, is outweighed by the fact that using electromagnets helps save a plethora of fuel. Also, although in the long run the Mag-Launcher will help save a lot of money when launching rockets, initially, the one-time cost to build the Mag-Launcher will be fairly expensive. Not only will it be expensive, but it will also take a while to complete. With more launches, the cumulative cost will be less than those of traditional methods. Finally, the Mag-Launcher will be subject to weathering. However, the outer shell will be made of a strong alloy to prevent major weathering. Ultimately, however, the benefits of the Mag-Launcher certainly eclipse the negative aspects of it.

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