

## Magnetic Journey of Space Shuttle

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### Abstract

In order to make launching, cost efficient, highly reliable, and the consumption of propellant minimum, an idea to accelerate and launch the space shuttle magnetically is proposed in this paper. This proposal involves simultaneous use of both propellant and the magnetic field throughout its journey, along with change in the complete structural and material design of the space shuttle, to suite the conditions being discussed. Under the principle of magnetic levitation, space shuttle is launched and is directed towards North Pole or South Pole. The contributing factors for magnetic launch discussed are magnetic field strength, the location of the launch and the structural design of the space shuttle. The location for the launch of the space shuttle is the area with least gravitational force, helping in achieving extra velocity, with the minimum usage of propellant. This proposal summarizes the possible results of this initiative and would address the development of this idea in the future space programs.

**Keywords:** Magnetic base of space shuttle; fuel efficient; magnetic repulsion phenomena.

### 1. Introduction

In the present world of space exploration, the cost involved in launching a space shuttle is very high. In order to make launching, cost efficient, highly reliable, and the consumption of propellant minimum, an idea to accelerate and launch the space shuttle magnetically is proposed in this paper. This proposal involves simultaneous use of both propellant and the magnetic field throughout its journey, along with change in the complete structural and material design of the space shuttle, to suite the conditions being discussed. Under the principle of magnetic levitation, space shuttle is launched and is directed towards North Pole or South Pole. The base of the space shuttle is made

magnetically active with the same polarity as that of earth's magnetic field. Due to the repulsion force, the space shuttle will reach the lower earth orbit easily and in a short period of time. The magnets used in the space shuttle are temporary magnets and made active only at the required time. While landing the space shuttle, the magnetic field of space shuttle will have opposite polarity to that of the other planet or natural satellite, on which it is to be landed, enabling attraction towards the planet. This criterion is used for the landing procedure of the space shuttle on the other planets or natural satellites. The contributing factors for magnetic launch discussed are magnetic field strength, the location of the launch and the structural design of the space shuttle. The location for the launch of the space shuttle is the area with least gravitational force, helping in achieving extra velocity, with the minimum usage of propellant.

## 2. Launching Site

For a launch to take place in a desired manner as efficient as possible the choice of the launching site is important. For the magnetic launching the desired or the most efficient position considered is the earth's equator. The earth's equator has a minimum 'g' value (acceleration due to Gravity) due to which the energy required for the launch would be less, besides that it offers even greater velocity. The various places of the equator will be considered out of which the place with minimum 'g' value will be taken as the launching site.

The following places located in the equator are considered for the launching site,  
 Indonesia (Jakarta)  $\rightarrow 9.781\text{m/s}^2$   
 Brazil  $\rightarrow 9.783\text{m/s}^2$   
 Kenya  $\rightarrow 9.781\text{m/s}^2$

Among these places Indonesia which has a g value of 9.781 is considered to be a suitable position for the launching, being a remote place, away from highly populated area as the place is nearby to the ocean.

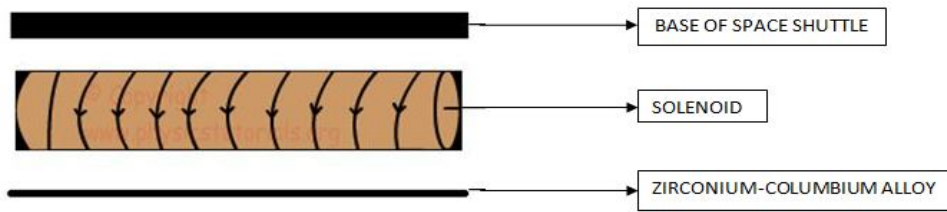
At the equator, the radius of earth is 6384km, as a result when a space shuttle is launched from this position at equator it gains a velocity of 1667km per hour (463.6m/s).

It is better to launch rockets closer to the equator because the earth rotates at a greater speed here than that at either pole. This extra speed at the equator means a rocket needs less thrust (and therefore less fuel) to launch into orbit. In addition, launching at the equator provides an additional 1667km/hr. (463.6m/s) of speed once the vehicle reaches orbit. This speed bonus means the vehicle needs less fuel, and that speed can be used to carry more loaded. If a spaceship is launched from equator it goes up into space, and it is also moving around the earth at the same speed it was moving before launching. This is because of inertia. This speed will help the space shuttle keep up a good enough speed to stay in orbit.

### 3. Space Shuttle Design

As the launching of space shuttle is to be done by the means of magnetic field, this necessitates the need for the modification of the space shuttle, magnetically, according to the requirement. Due to the introduction of magnetic launching procedure, the space shuttle needs to be magnetically active for the launch to take place efficiently and effectively.

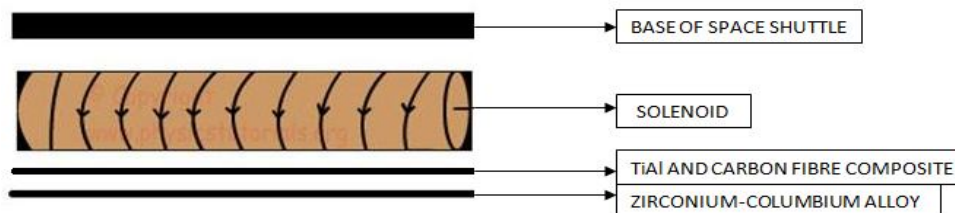
The addition of solenoids to this structure will help in achieving this magnetic property for the space shuttle. The solenoids are to be located at the base of the space shuttle. The core of the solenoid is made up of pure iron and the coil wound around it will be made up of  $Nb_3Sn$  (Niobium-Tin). The combination of combined pure iron and coil can produce high magnetic field of about 30T (Tesla). We will place many solenoids of the same arrangement according to the requirement. The solenoids are to be fixed parallel to the base of the space shuttle in such a way that the solenoids can be deflected manually, making an inclination with the base as and when required.



**Figure 1:** Base of Space Shuttle fixed with Solenoids.

The solenoids require electricity for producing magnetic field which is provided by the battery fixed inside the space shuttle. That battery will be charged by solar panels will be explained in next topic. The solenoids are covered with the layer of Zirconium –Columbium Alloy which in turn covers the complete base of the space shuttle. This Alloy layer is a super conductor of magnetic field and also protects the solenoid from getting damaged.

During Re-entry the a layer which is the combination of TiAl and Carbon fibre composite will be detached between solenoid and Zirconium – Columbium alloy which will protect the solenoid from damaging due to the excessive high temperature conduction of heat from the base.



**Figure 2:** Base of Space Shuttle during Re-entry.

#### 4. Power Generation

The important aspect of the functioning of the solenoid is the source of electric power. A reliable power source which could operate the generation of magnetic field has to be used. Solar panels are the best device for the generation of electricity by photovoltaic effect. In fact the temperature increases as you go beyond 85km. Thermosphere is the region above 85km where suns radiation have very high intensity. This light will fall on the solar panels and charge the battery with will in return provide electricity to the solenoid to produce magnetic field. Solar arrays will be placed at an angle equal to the site latitude with no bias to produce low voltage (Direct Current) - usually 6 to 24 volts and can produce an average 360 watt per hours of power per day.

When the space shuttle reaches the height above 400 km than this solar panel will be detached from the shuttle body and will provide power to the avionics system and also to the solenoid attached at the bottom of the shuttle.

##### 4.1 Arrangement

In order to achieve a Magnetic field of 20T, direct current of 50 Amp gets extracted from the solar panel, considering the solenoids with equal length and equal number of turns in the same direction.

**Formulae:**

$$B = \mu_o N I / L$$

$\mu_o$  = Permeability of Iron Core

N = No. of turns

I = current flowing in the wire

L= length of solenoid

**Design calculation for solenoid:**

Number Of turns = 5000

Length = 8 m

Radius = 7 cm

Current = 50 Amp

Permeability Of iron = 0.0002512

The net magnetic field: 7.85 T

Hence, two solenoids attached to the base of the space shuttle produces a magnetic field of 15.7 T.

##### 4.2 The boost up thrust for the shuttle

The mass of the maglev train is 385 tons which is 385000kg , hence the weight is 3776850 N.

The magnetic field required to lift 3776850 N weight is 5 Tesla Accordingly , the magnetic field being produced for this shuttle launch is about 15.7 Tesla, Comparing the Magnetic field of both maglev train and the space shuttle, the weight of the space shuttle comes out to be three times the weight of the maglev train.

Hence, the thrust produced by the magnetic field of 15.7 Tesla is 11330550 N.

### 4.3 The weight of the space shuttle at launch site

The Space Shuttle weighed 165,000 pounds empty. Its external tank weighed 78,100 pounds empty and its two solid rocket boosters weighed 185,000 pounds empty each. Each solid rocket booster held 1.1 million pounds of fuel. The external tank held 143,000 gallons of liquid oxygen (1,359,000 pounds) and 383,000 gallons of liquid hydrogen (226,000 pounds). The fuel weighed almost 20 times more than the Shuttle. At launch, the Shuttle, external tank, solid rocket boosters and all the fuel combined had a total weight of 4.4 million pounds. The Shuttle could also carry a 65,000 payload.

### 4.4 The weight of the space shuttle at an orbit of 400km from Earth's surface

The magnetic field of space shuttle at 400km orbit is 15.7 Tesla, which is allowed to interact with the magnetic field of the Earth allowing it to repel, producing additional thrust.

The Space Shuttle weighs 2.015 million pounds at 400 km orbit, inclusive of the fuel. Its external tank weighed 78,100 pounds empty. The external tank held 143,000 gallons of liquid oxygen (1,359,000 pounds) and 383,000 gallons of liquid hydrogen (226,000 pounds). The fuel weighed almost 20 times more than the Shuttle. At launch, the Shuttle, external tank, solid rocket boosters and all the fuel combined had a total weight of 2.015 million pounds which is 8984170 N

Considering the magnetic field, the boost up thrust is about  $11330550 - 8984170 = 2346380$  N which is about 2.35 MN thrust. This boost up thrust allows the space shuttle to move at a higher velocity.

## 5. Launching Procedure



**Figure 3:** Magnetic Vertical Launch.

The launching location includes the tunneling of the mountain situated near the water source. This tunnel is vertically magnetized for launching. The magnetic launching is for projecting the space shuttle approximately up to 5km in the

atmosphere. The magnetic base is polarized North, with similar polarization on the space shuttle, at the time of launch. The magnetic disc attached to the space shuttle will propel the shuttle upward due to repulsion between base and the disc. Once the shuttle leaves the mountain top the disc is detached and the shuttle is further propelled using the rocket boosters. This launch procedure is considered to be cost efficient, less polluting, fuel efficient.

## 6. Orbit Manoeuvring

After launching, the space shuttle is put to lower retrograde circular orbit at altitude of 400km with Earth at the centre. The orbit is inclined at an angle of  $101.5^\circ$  (retrograde orbit). The Right Ascension and argument of perigee will be 90 degree.

The earth's magnetic South Pole lies at the inclination of 11.5 degree to geometric North Pole, as the earth rotates the magnetic field will make an angle of  $101.5^\circ$  with equator (same as 1<sup>st</sup> orbit of space shuttle at height of 400km).

Velocity of space shuttle at 400km =  $\sqrt{\mu/r}$  where r=radius of earth + altitude=6778km

So velocity,  $V_1=7.668\text{km/sec}$

The second orbit of the space shuttle should be at an altitude of 20,000km. The orbit will be a prograde orbit with an inclination of  $78.5^\circ$ .

Velocity of space shuttle at 20,000km =  $\sqrt{\mu/r}$  where r=radius of earth + altitude=26,378km

So velocity,  $V_2=3.887\text{km/sec}$

$\Delta V_1 = \sqrt{[(V_1)^2 + (V_2)^2 - 2V_1V_2 \cos \Theta]}$  where  $\Theta$ =angle between two orbits= $11.5^\circ+11.5^\circ=23^\circ$

So,  $\Delta V_1 = 4.3635 \text{ km/sec} = 15,708.54\text{km/hr}$

Velocity of space shuttle at 35,786km =  $\sqrt{\mu/r}$  where r=radius of earth + altitude=42,164km

so velocity,  $V_3=3.0746\text{km/sec}$

$\Delta V_2 = \sqrt{[(V_2)^2 + (V_3)^2 - 2V_2V_3 \cos \Theta]}$  where  $\Theta$ =angle between two orbits= $11.5^\circ+11.5^\circ=23^\circ$

So,  $\Delta V_2 = 1.6 \text{ km/sec} = 5761.575\text{km/hr}$ .

The time taken by the spacecraft from earth to moon

$$(\text{Time period})^2 = 4\pi^2 a^3 / \mu$$

For an altitude of 400km

$$a=400+6378=6778\text{km}$$

$$T^2=4 \pi^2 (6778)^3 / 398600$$

$$T=5563.458975\text{sec} = 1.54263\text{hrs}$$

For an altitude of 20000km

$$a=20000+6378=26378\text{km}$$

$$T^2=4 \pi^2 (26378)^3 / 398600$$

$$T=42635.7608\text{sec} = 11.8433\text{hrs}$$

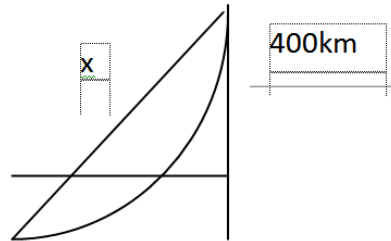
For an altitude of 36000km

$$a=36000+6378=42378\text{km}$$

$$T^2=4 \pi^2 (42378)^3 / 398600$$

$$T = 24\text{hrs}$$

The estimation of time taken to travel from Earth's surface to an orbit at an altitude of 400km is done below:



The path followed by the spacecraft makes an angle of  $60^\circ$  from the horizontal travelling from the Earth's surface to the orbit at an altitude of 400km from the surface.

The path traced by the spacecraft is in the form of a curve which can be approximated to a straight line for the purpose of calculation.

Hence using the triangle properties

$$\sin 60^\circ = 400/x$$

$$\text{where } x = 478.66\text{km}$$

similarly The distance covered in travelling from an orbit of 400km to an orbit of 20000km estimated from the Earth's surface :

The angle projected by the spacecraft traveling from the orbit of 400km to the orbit of altitude 20000km estimated from the surface of the Earth is about  $45^\circ$

Using the Triangle properties, the distance covered by the spacecraft from 400km orbit to the 20000km orbit can be estimated :

$$\sin 45^\circ = 19600/x$$

$$x = 27718.5858\text{km}$$

similarly The distance covered in travelling from an orbit of 400km to an orbit of 20000km estimated from the Earth's surface :

The angle projected by the spacecraft traveling from the orbit of 20000km to the orbit of altitude 35786km estimated from the surface of the Earth is about  $45^\circ$

Using the Triangle properties, the distance covered by the spacecraft from 20000km orbit to the 35786km orbit can be estimated :

$$\sin 45^\circ = 15786/x$$

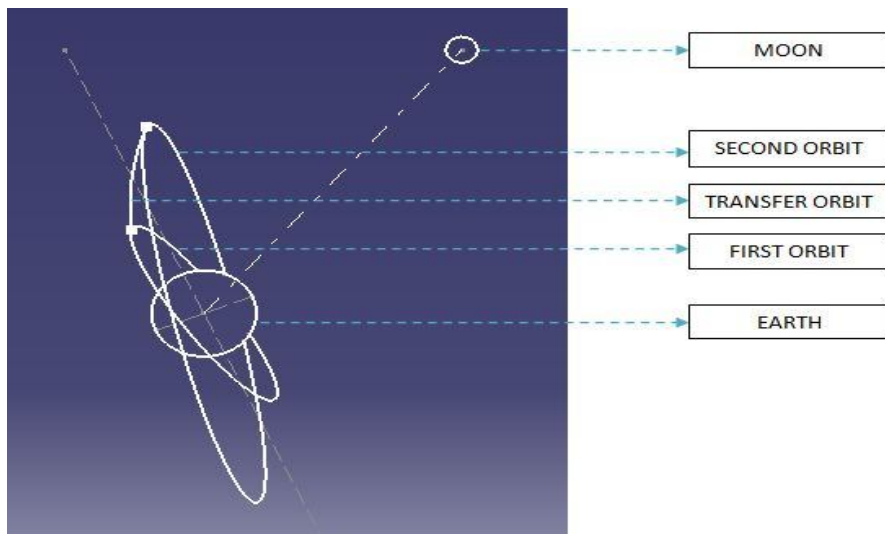
$$x = 22324.7753\text{km}$$

The change of the orbit takes place with the help of magnetic field resulting in less amount of propellant used. We have to locate the position till the time the space shuttle is exactly at the top of the magnetic south pole of earth, as the earth's magnetic field shifts from extreme west to east during earth's rotation, space shuttle will start with orbit transfer. The magnetic field will be produced by solenoids in the space shuttle.

The solenoids should be inclined at an angle of  $10.9^\circ$  to the base of the space shuttle. The solenoids end facing to the earth should produce South Pole polarity. This inclination will exactly coincide with the axis of the magnetic field lines of the earth. The solenoids require electricity for producing magnetic field which is provided by the

photovoltaic cells. These cells are charged by the solar panels attached to the space shuttle. The solar panels absorb the sun's radiation and in return charge the photovoltaic cells. The earth's magnetic field will repel the space shuttle and helps in orbit transfer by repelling the space shuttle. Hence, the space shuttle is put to a prograde orbit with an inclination of  $79.5^\circ$ .

The  $\Delta V$  required for the transfer from retrograde to prograde orbit will be provided by both magnetic repulsion and propellant used hence reducing the amount of propellant required.

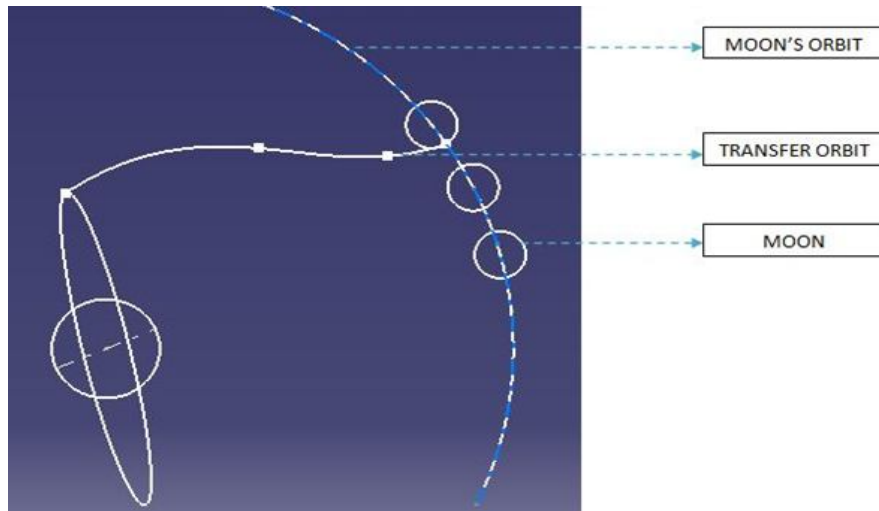


**Figure 4:** Earth with its Orbits.

## 7. Transfer Orbit

Finally, the time has come to transfer the space shuttle from earth's orbit to moon's orbit. The transfer orbit from earth to moon will be from prograde orbit to the orbit of moon at an altitude of 200km. As the earth's magnetic field has effect till  $10R$  ( $R$ =radius of earth), it will constantly repel the space shuttle. The magnetic field of the space shuttle will be ON throughout the path. This space shuttle will also change its inclination from  $79.5^\circ$  to  $28.7^\circ$  (moon's inclination).

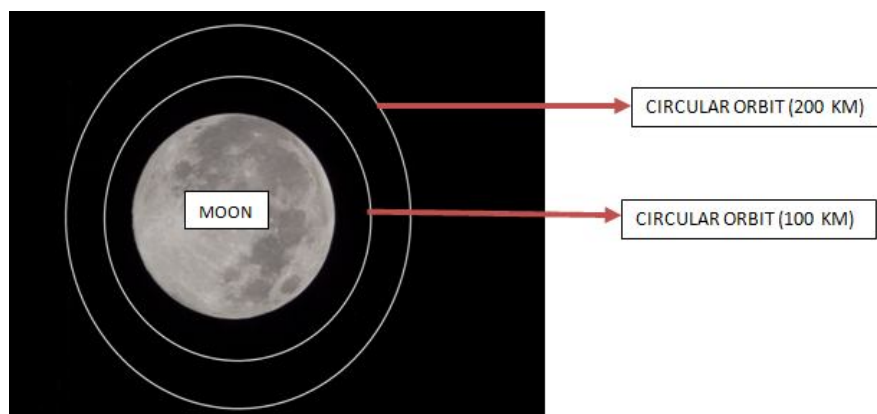
This will take place with the help of magnetic field plus propellant used. As the earth's magnetic field is cusp shaped due to solar wind, this will help to change the inclination. Hence, the amount of propellant used will be less for the transfer of the orbit.



**Figure 5:** Transfer of Space Shuttle from Earth to Moon.

### 8. Orbits of Moon

As the space shuttle enters the moon's gravity, first it will be put to the orbit at height of 200km. The orbit of space shuttle will be circular in shape as shown in the figure below. As rotating objects in the universe have their magnetic field, the Moon, being a natural satellite of the Earth, has external magnetic field but very weak in comparison to that of the Earth. The entirely crustal of the moon is covered with the magnetic particles. Those can be used to transfer the orbit around moon from 200km to 100 km. Then according to the appropriate atmospheric conditions the space shuttle will be launched on the moon's surface. So, with less amount of propellant we are able to reach moon.



**Figure 6:** Moon with its Orbits.

## **9. Conclusion**

The study of magnetic field of the earth has been of immense utilization for years, making it one of the reliable sources of force. The use of magnetic field of the earth for the space transportation would revolutionize the launching procedure of the space shuttle, which would in turn improve the efficiency and the reliability of the launching procedure. This application of magnetic field would decrease the use of propellant.

The application of magnetic field for space exploration is not only restricted to earth but is also utilized in other planets. Considering the results of study of earth's magnetic field, it has been found the magnetic field can be used as a source of energy for propelling the space shuttle, substituting the typically used propellants. Hence, reducing the use of propellant.

The magnetic field is used for both landing and launching process, making use of both attraction and repulsion characteristics of the magnetic field. As the principle of the magnetic levitation is under major application for the railway transportation, the use of Earth's magnetic field for the space exploration would revolutionize the space programs in a completely efficient way.

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