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Launch System for CUBESAT STRaND-I Satellite Prototype Development

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ABSTRACT
The launch of rocket is considered to be very tedious and risky process and also requires a hefty price. Rockets carrying satellites are heavy and a cautious design procedure has to be followed. Failure may get occur at engines, fuel tank or in any other component. Any failure may result in heavy losses. To overcome all the above stated shortcomings we come up with the solution of launching the satellites from the ground without using the traditional rockets or rocket launch vehicles. To achieve this, two techniques have been adopted which is vacuum gun and magnetic levitation. Implementing this idea we could launch satellites with low cost and very less failure probability. Thus we integrate them both and a prototype model is created and analyzed.

Keywords
Rocket;Satellite; Vacuum Gun; Magnetic Levitation;

1. INTRODUCTION
An artificial object placed into a particular orbit with the help of rockets is known as a satellite which will help put forth the global scenario of a country. Those satellites placed serve as helper in communication, identifying the resources, weather details, defense purpose etc. Satellites are placed with the help of rockets which are very risky to handle and use. Even the cost of constructing a rocket is not less. In this project report, we integrate a technology that can be implemented to launch cubesat into the orbit from earth itself with low cost.

2. EXISTING TECHNOLOGY
2.1 Rockets
A rocket engine in the form of missile, spacecraft or aircraft is used in rocket to obtain the thrust. The propellants are carried within the rocket. They obtain the forward motion by throwing their exhaust backwards extremely fast. Rockets are not reliant on the atmosphere but they work well in space.Significant scientific, interplanetary and industrial use did not occur until the 20th century, when rocketry was the enabling technology for the Space Age, including setting foot on the moon. Rockets are now used for fireworks, weaponry, ejection seats, and launch vehicles for artificial satellites, human spaceflight, and space exploration.Chemical rockets are the most common type of rocket and they typically create their exhaust by the combustion of rocket propellant. Chemical rockets store a large amount of energy in an easily released form, and can be very dangerous. However, careful design, testing, construction and use minimize risks.

2.2 Design
A rocket design can be as simple as a cardboard tube filled with black powder, but to make an efficient, accurate rocket or missile involves overcoming a number of difficult problems. The main difficulties include cooling the combustion chamber, pumping the fuel (in the case of a liquid fuel), and controlling and correcting the direction of motion.

2.3 Components
Rockets consist of a propellant, a place to put propellant (such as a propellant tank), and a nozzle. They may also have one or more rocket engines, directional stabilization device(s) (such as fins, engine gimbals for thrust vectoring, gyroscopes) and a structure (typically monocoque) to hold these components together. Rockets intended for high speed atmospheric use also have an aerodynamic fairing such as a nose cone, which usually holds the payload. As well as these components, rockets can have any number of other components, such as wings (rocket planes), parachutes, wheels (rocket cars), even, in a sense, a person (rocket belt). Vehicles frequently possess navigation systems and guidance systems that typically use satellite navigation and inertial navigation systems.

2.4 Engine
Rocket engines employ the principle of jet propulsion. The rocket engines powering rockets come in a great variety of different types. Most current rockets are chemically powered rockets (usually internal combustion engines, but some employ a decomposing (monopropellant) that emit a hot exhaust gas. A rocket engine can use gas propellants, solid propellant, liquid propellant, or a hybrid mixture of both solid and liquid. With combustive propellants achemical reaction is initiated between thefuel and the oxidizer in the combustion chamber, and the resultant hot gases accelerate out of a rocket engine nozzle (or nozzles) at the rearward-facing end of the rocket. The acceleration of these gases through the engine exerts force ("thrust") on the combustion chamber and nozzle, propelling the vehicle (according to Newton's Third Law). This actually happens because the force (pressure times area) on the combustion chamber wall is unbalanced by the nozzle opening; this is not the case in any other direction. The shape of the nozzle also generates force by directing the exhaust gas along the axis of the rocket.

2.5 Propellant
Rocket propellant is mass that is stored, usually in some form of propellant tank or casing, prior to being used as the propulsive mass that is ejected from a rocket engine in the form of a fluid jet to produce thrust. For chemical rockets often the propellants are a fuel such as liquid hydrogen or

kerosene burned with an oxidizer such as liquid oxygen or nitric acid to produce large volumes of very hot gas. The oxidizer is either kept separate and mixed in the combustion chamber, or comes premixed, as with solid rockets. Sometimes the propellant is not burned but still undergoes a chemical reaction, and can be a 'monopropellant' such as hydrazine, nitrous oxide or hydrogen peroxide that can be catalytically decomposed to hot gas.Alternatively, an inert propellant can be used that can be externally heated, such as in steam rocket, solar thermal rocket or nuclear thermal rockets. For smaller, low performance rockets such as attitude control thrusters where high performance is less necessary, a pressurized fluid is used as propellant that simply escapes the spacecraft through a propelling nozzle.

3. SCOPE OF CURRENT WORK

In the current date there are important needs to develop a system which can be eco-friendly. Thus if the concept is implemented it results in a reduction in the cost and chances of launch failure. In the current era ourconcept results in decreasing the cost effectiveness caused due to launch failure and in implementing this.

4. CONSTRUCTION

Out technology is a combination of two existing techniques which are combined and has inspired a lot. Those two technologies are Magnetic levitation and vacuum gun.

4.1 Magnetic Levitation

This is a technique where an object is suspended with no other object other than magnetic fields. It is method of propulsion which helps to propel the vehicle using magnets. Using Maglev, a vehicle is levitated a short distance away from a guide way using magnets generating both lift and thrust. Here in our concept we use electrodynamicsuspension method in order to achieve the levitation. Electrodynamic suspension work with the principle of Faradays law and Lenz law where the relative motion between the conductor and magnet induces Eddy current in the conductor which creates a magnetic field in the conductor and this repels the magnetic field produced by the magnet and hence levitation is achieved. Electrodynamic suspension uses strong permanent magnets or superconducting electromagnets. Here, we took the satellite shroud as conductor and superconducting magnets are arranged and lined inside the vacuum tube.The tube is lined with two sets of superconducting magnets for Maglev application in it.

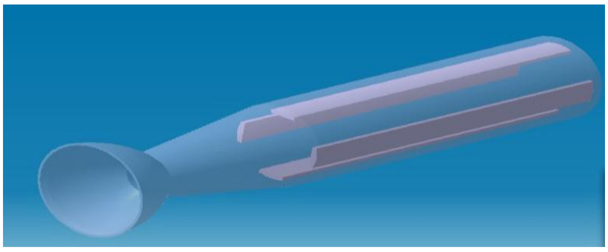

Fig 1: Proposed design for Maglev System

4.2 Vacuum Gun

This technology is inspired by a experimental toy called Ping-Pong gun where, Ping-Pong balls are fired at high speed using vacuum gun. In our application we basically take a cylindrical tube that is sealed on both the ends after placing the required payload. A vacuum of 99.99% is achieved inside it. When one end of the seal is broken, air rushes inside the tube and thus accelerated the payload breaking the seal on the other end at higher speed. The exit velocity can be improved using a good design of C-D Nozzle and providing a pressurized air at the inlet.

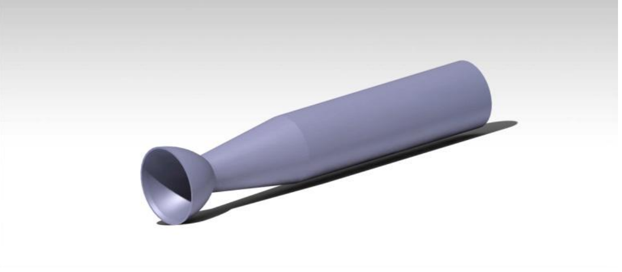

Fig 2 : Proposed design for Vacuum Tube

4.3 Definition

By combining both the technologies described above we propose a new technology for launching vehicles/rockets. Since we are unsure of the power that can be obtained from this new system, it's better to be on the safer side and use this technology mainly in satellite carrying rockets.Here, no propulsion system (conventional) is required. Hence all the lower stages of the rocket can be discarded. Thus the weight of the rocket can be plummeted down to earth. Only the shroud is required to carry the satellite.

4.4 Construction

As we are incorporating both the technologies into a single one, the maglev superconductors lining will be placed inside the vacuum tube. The vacuum tube is thick walled with specific dimension for the C-D Nozzle and barrel length. The barrel diameter is adjusted in order to fit the satellite with a protective body or shell. As no fuel is required the lower portion of rocket is omitted and shroud or head of the rocket is used in carrying payload(satellite). The barrel is of around 7m diameter which has a capacity of holding a shroud of 4-5m diameter. Exact dimensions for C-D Nozzle have to be maintained to produce Mach speed of air. The tube is also provided with a drain pipe to remove the air from the tube. A 4 way doors is used at both ends of the cylindrical tube to seal the tube with vacuum tight. These doors must be light and strong enough to withstand high vacuum pressure

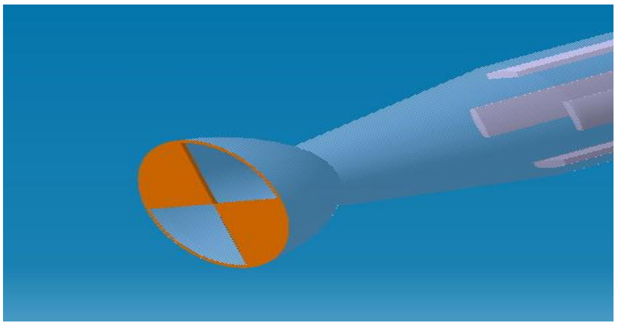

Fig 3: Proposed design for 4 way doors

The head or shroud of the body which is used can be in a bullet shaped structure which helps in decreasing the drag acting upon it.

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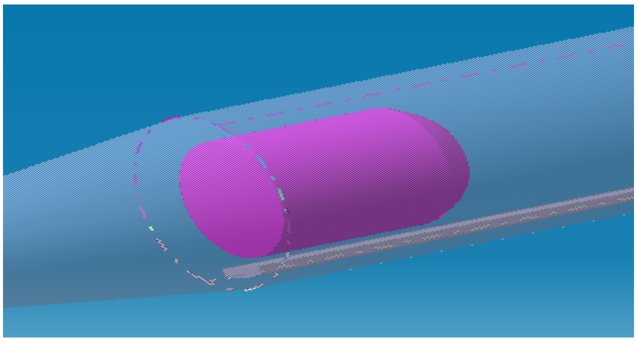

Fig 4: Proposed design for rocket Shroud

5. SELECTION OF SATELLITE

We have compared various kind of satellite and it is observed that an ordinary satellite is very much larger when compared with a special kind of satellite called CUBESAT.

5.1 Cubesat

A cubesat is a satellite used for space research which has usually a volume of exactly one liter has a mass of not more than 1.33 kilograms and uses commercial off-the-shelf components for its electronics. Encapsulation of the launcher-payload interface takes away the prohibitive amount of managerial work that would previously be required for mating a piggyback satellite with its launcher. Based on a research we have selected cubesat named STRaND-1(Survey Training, Research and Nanosatellite Demonstrator- 1). The 4.3 kg nanosatellite was launched from a PSLV Rocket from India on February 25, 2013. It is operated by two computers. They are Cubesat computer and Google Nexus one smartphone for android.

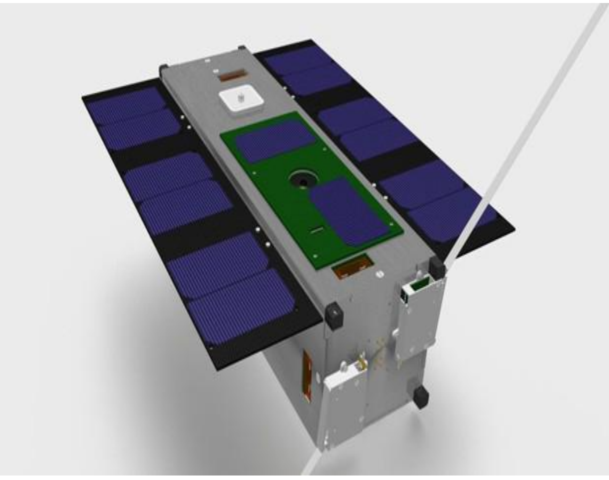

Fig 5 : A 3U CubesatSTRaND- 1

5.2 Specification

Width	=	0.43434m
Height	=	0.12954m
Depth	=	0.6477m
Mass	=	4.3kg

This STRaND – 1 Cubesat is now placed inside a spherical body, which can provide the outer protective covering for the satellite. This works in a way similar to the shroud of a satellite in case of the conventional Rockets.

6. CALCULATION

6.1 Maglev

Maglev technology in this prototype is used in order to maintain stability of cubesat while launching. The calculation is as follows.

Levitation force

$$FL=\frac{3\mu_0(m*d)^2}{32\pi h^4}$$

Where

FL- Levitating force (N)

μ0- Permeability of free space = 4π*10-7NA-2

m- Magnetic pole strength (Am)

d- Length of the magnet (m)

h- Levitation Air gap (m)

Length of the body (d) = 3m

Levitation height (h) = 0.03m

On substitution

$$6*9.81=\frac{3*4\pi*10^{-7}*(m*3)^2}{32\pi*0.03^4}$$

m= 11.88Am

A superconducting magnet of magnetic pole strength m= 240Am is required to achieve the levitation. Thus superconducting magnet such as YBCO and BSCCO are used to achieve this levitation.

6.2 Vacuum gun

Based on a research of Mark French, straight forward dynamics gives the velocity as a function of distance x down the tube as

$$V=\sqrt{\frac{2PAx}{m}}$$

Where

V- Velocity (m/s)

P- Air pressure in Pa

A- Area in m^2

X- Length of the tube in m

m- Mass of the payload in Kg

On substitution

P= 105 Pa

A= 1.247 m2

m= 6 Kg

x= 4m

$$V=\frac{455.88}{330}= 1.38 \text{ Mach}$$

With the introduction of Convergent- Divergent Nozzle, the velocity can be increased. As maglev is also used this propulsive force is amplified as no friction occurs.

For the length x=5m; V= 1.68 Mach

This states that by varying the length of tube the Mach can be increased and even hypersonic speed is achieved.

6.3 Escape Velocity

The escape velocity of satellite is calculated as

$$Ve=\sqrt{\frac{2GM}{r}}$$

The Gravitational constant (G) = 6.67x10-11m3kg-1s-2

Mass of the earth (M) =5.9736x1024kg

Radius (R) = 6371 km

Ve =11.2km/s

The escape velocity is inversely proportional to the radius of the earth. Thus increase in radius will decrease in escape velocity.

6.4 Launch Inclination

In order to achieve the successful launch of the satellite it has to be launched at an certain angle. The angle is calculated as

Initial velocity (v) = 685 m/s

Vertical Distance (y) = 450km

Horizontal Distance (x) = 160km

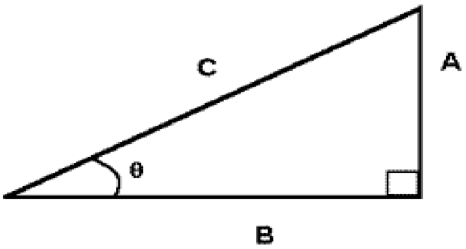

Fig 6 :Illustration for finding the angle of launch

A= y= 450000m

B= x= 160000m

By using Pythagoras theorem

AC2= AB2+BC2

We get the side value C = 477.6 km

Thus using these the angle is observed as 70.430. Thus at this angle the launch will be successfully.

7. DIMENSIONAL CAD MODEL

For the purpose of analysing the model is designed in CATIA V5 and is analysed in CFD. The model of the launch is as,

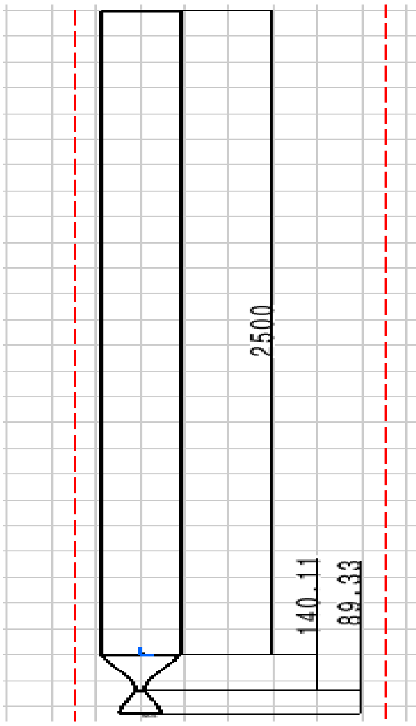

Fig 7: Dimensions of the launch tube

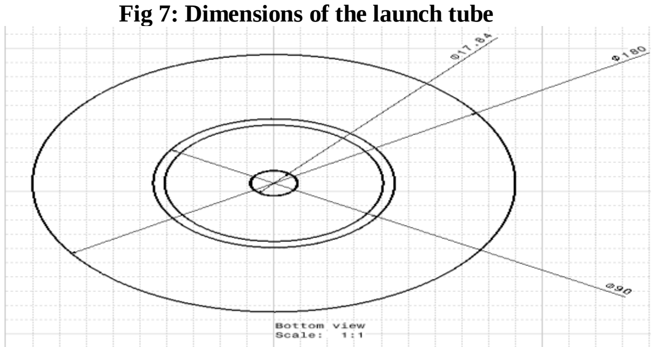

Fig 8: Dimensions of the launch tube

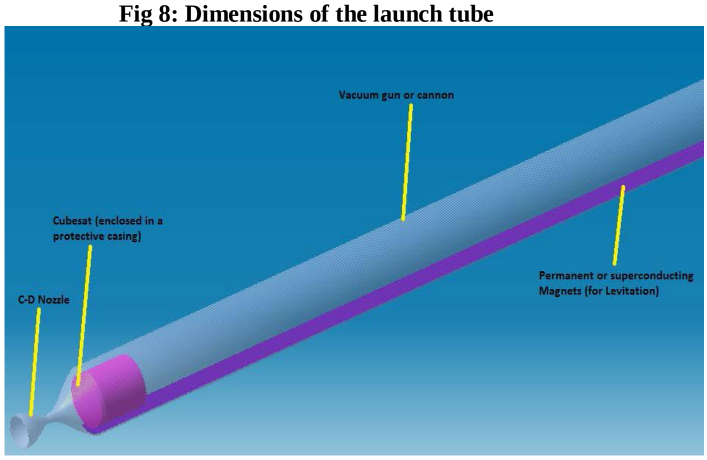

Fig 9: Finalised model- Inner Structure

8. ANALYSIS AND RESULTS

For analysis computational fluid dynamics, ANSYS CFX is used to provide the flow analysis of the model.

For obtaining the results the inlet and outer portions are defined. We have completely evacuated the air inside the tube. The pressure inside the tube is assumed to be very low at 0.04

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bar. The inlet conditions for the Convergent- Divergent nozzle is provided as

Inlet area ratio= 28.94

Mach number= 0.2

Entry Pressure= 1 bar

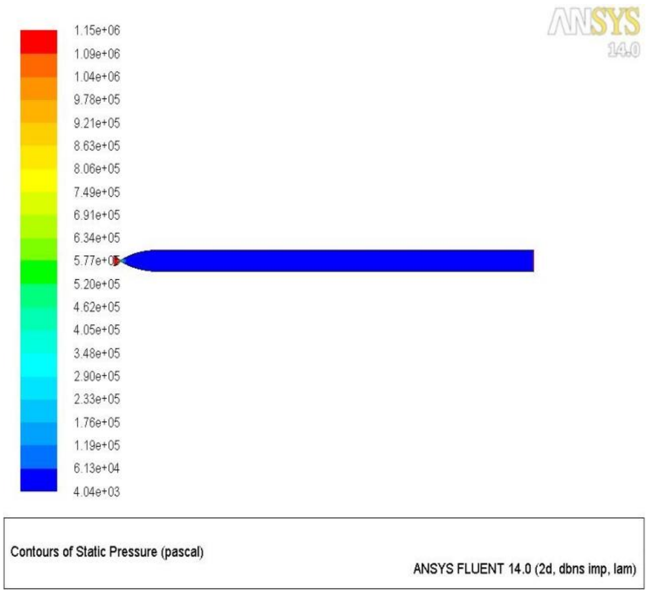

Fig 10: Pressure distribution along the tube

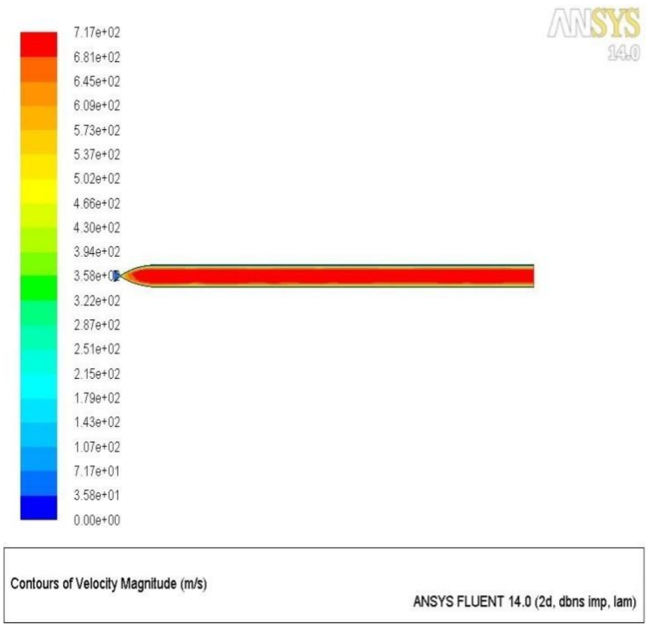

Fig 11: Velocity along the tube

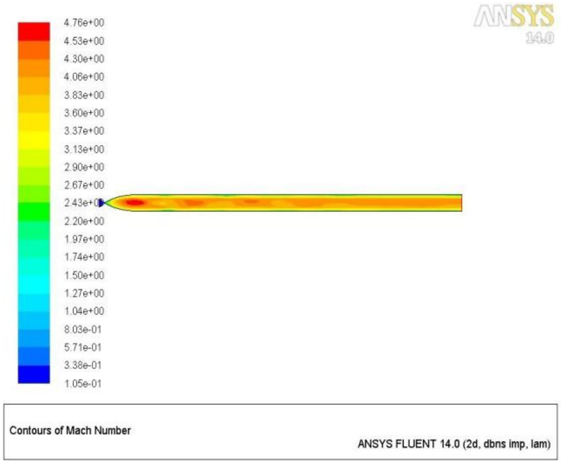

Fig 12:Diagram showing the contour of Mach number along the tube

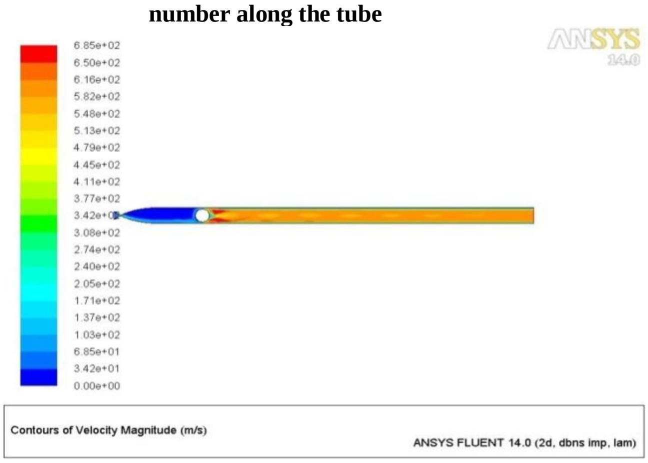

Fig 13: Picture showing the velocity with a ball inside the tube

9. CONCLUSION

Rocket technology has always been an advent, which has led engineering to vast improvements in both functionality and effectiveness of launching satellite into orbits. The cost is a very important parameter which is now cut down by the combination of the Vacuum gun and Maglev technique. Efficiency has also been improved by these technologies. As this a new technology, the nano satellites or cubesat are mainly focused in this project. If this technology is furthermost advanced the model can be used for larger satellites. Here we have provided a basic design, theoretical analysis and simulated analysis for the new proposed launch system for cubesat.

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