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Recovery Of Sounding Rockets Using Retractable Wings For Controlled Descend

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Abstract

The thesis aims at the recovery of sounding rockets under a controlled path without the use of extra propellant. This in turn will result in the safe recovery of the whole rocket and hence make them reusable.
The research was proceeded by studying various techniques of rocket recovery which included parachute and thruster based recovery. The data collected revealed that, either, only the essentials can be recovered using parachutes without any control over the route, or the rocket can be recovered with a defined route but with the use extra propellant.
The design proposed involves the use of retractable wings in order to recover the rocket in the form of a glider. The whole idea is inspired by a bird which retains its flight by opening its wings in the middle of a dive. Thus, the wings, controlled automatically or manually from a ground station, will help in gliding the rocket back to the desired destination.
The overall thesis will result in recovering the sounding rocket in a reusable condition and hence help save money, time, material and man power in building new rockets for new missions.

Keywords: sounding rocket, Glider, Wings, Parachute, Reusable, rocket, glider rocket, thruster rocket, openrocket, recovery, retractable wings.

1. Introduction

Sounding rockets also known as “research rockets” are one or two stage solid propellant rockets which are used for probing the upper atmospheric zones so that they can execute different space-related research. They also serve as easily affordable platforms to review or establish prototypes of new components or subsystems envisioned for use in launch vehicles and satellites. The sounding rocket has so far proved to be a productive tool in enlightening scientists in research of the earth’s atmosphere and its other geological features. Evidently, application of sounding rockets is growing in innumerable domains and is still to approach its pinnacle.

There are four crucial areas of consideration when it comes to rocket engineering; Reliability, Cost, Safety, and Reusability. Lately, despite many launch mandates for scientific research's using sounding rockets, the prospects of launches are regulated because of high-cost of rocket launches. The current total US market for high altitude sounding rockets with payloads in the 50 to 200-kilogram range and apogees in excess of 100 kilometres is roughly 100 launches annually at an average of one million dollars charged per launch. This research focuses on to cut down the cost factor by reusing the sounding rockets. While considering reusability, recovery system plays a major role in rocket engineering. Using parachutes is a most common method for recovery but the major disadvantage it offers is uncontrollable descent and thus parachute recovery on wind days makes it more difficult to locate the rocket after recovery. Also parachutes provides tremendous amount of drag which leads to very slow descent.

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2. Design

The rocket structure is designed such that it comprises of two nose cones, an experimental payload, a body tube, a pair of retractable wings and three trapezoidal fins.
The rocket also consists of an avionics bay, wing retraction mechanism, propulsion motor, body tube couplers, engine mounting ring, centring ring, parachute and two bulkheads.

2.1. Nose Cone

Nose cone is the foremost surface of a model rocket is generally tapered in shape. It reduces drag by directing airflow smoothly around rocket. The research lays emphasis on the recovery of a sounding rocket using retractable wings and hence is designed to have two nose cones, viz. one being the outer nose cone and the other being the inner nose cone. The two nose cones were incorporated to make sure that the experimental payload could eject off the rocket body to continue with its experimentation.

2.1.1. <u>Outer nose cone</u>

The outer nose cone is made using the parabolic series. It is designed such that it provides the rocket body with optimum lift-off and drag conditions. The height of the nose cone is 1190mm which encapsulates the inner nose cone and the experimental payload. Also, it has a 70 mm collar which makes sure that the nose cone fits properly over the outer surface of the body tube.

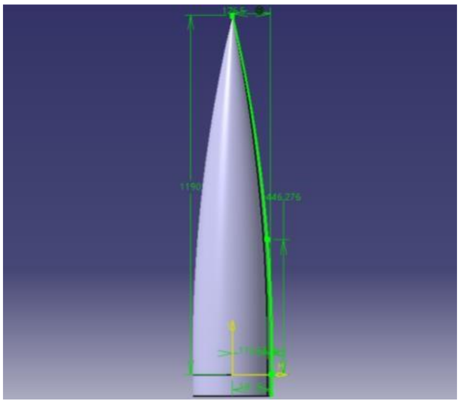

Figure 1: NoseCone Dimensions

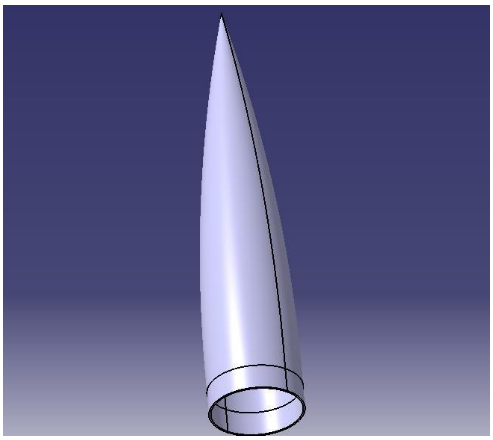

Figure 2: CAD model of Outer nosecone

<u>Working:</u>

The working of the outer nose cone is such that it ejects off the rocket body at the apogee and is recovered using a parachute. A small ejection mechanism is fixed on a plate that is placed right above the tip of the inner nose cone. Again, the payload is placed slightly above the top of the ejection mechanism within the space present in the hollow nose cone (which has a wall thickness of just 5 mm). Once, the rocket reaches the apogee, an electrical impulse triggers the ejection mechanism, which ejects the outer nose cone, therefore, leaving the payload free to release and the inner nose exposed to the air. The nose cone consists of a parachute which is deployed after ejection, making sure that the nose cone can be recovered in a good condition.

2.1.2. Inner nose cone

The inner nose cone is designed such that it fits the inner surface of the body tube. It is made following the ellipsoidal series with a height of 190mm and an external diameter of 253mm. It also consists of a collar of length 70mm. The inner nose cone is fixed with the body tube and provides an optimum surface for the rocket body to fly while it is being recovered as a glider.

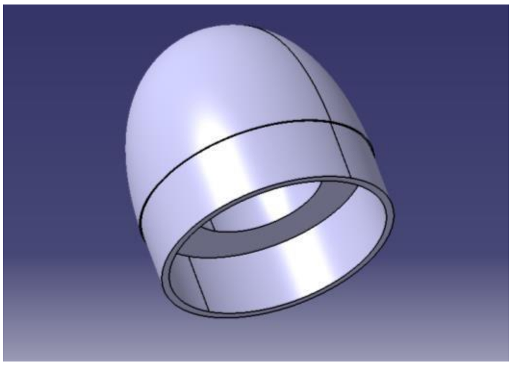

Figure 3: CAD model of inner nosecone

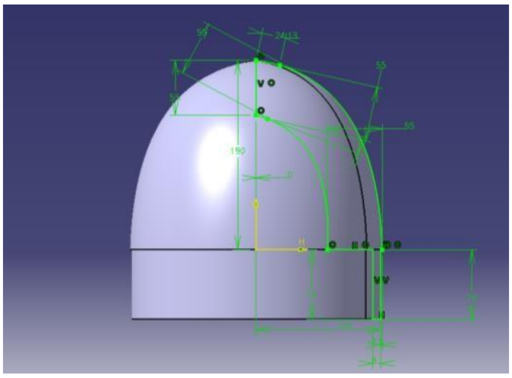

Figure 4: Dimensions of inner nosecone

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2.2. Body tubes

It is used to make the airframe of a model rocket to which all other parts are attached. It contains all the internal parts of the rocket and separates the fins from the nose cone The body tube has an outer diameter of 253mm, an inner diameter of 250mm and a length of 4060mm. It is designed to accommodate all the components required to make the rocket accomplish its mission objective. It has the avionics bay, the engine section, the wings and all of the electrical wiring.

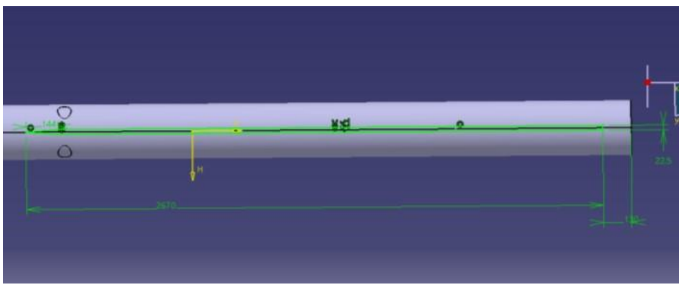

Figure 5: CAD model and dimensions of bodytube

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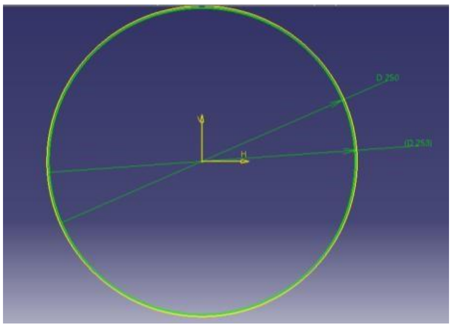


Figure 6: Cross-section of bodytube

2.3. Wings

A pair of retractable wings is hinged some distance below the centre of the body tube. These wings are made using the symmetrical S9026 airfoil. This airfoil makes sure that least rotating moment is generated while the wings are in the closed configuration and high lift is generated while the wings are in open configuration. The length of one wing is 2500mm and the chord length is 250mm. The wings have ailerons as their primary control surfaces to make recovery of the rocket body with controlled precision.

<u>Wing parameters selection:</u>

Research was done to calculate L/D ratios of various glider based airfoils. The selection criterion being an optimum L/D ratio and generation of least rotating moment due to the closed wing on the rocket body after lift-off. The total wing span is 5160mm which is approximately 1.214 times the entire length of the rocket. This gives the glider configuration an optimum glide ratio.

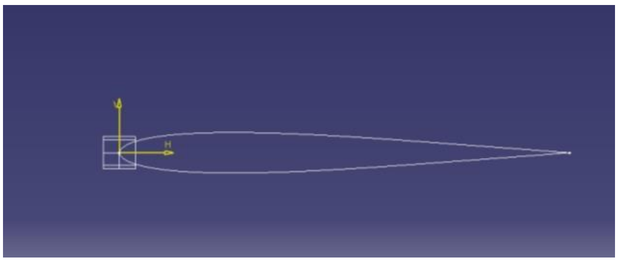


Figure 7: Airfoil cross-section of the wing

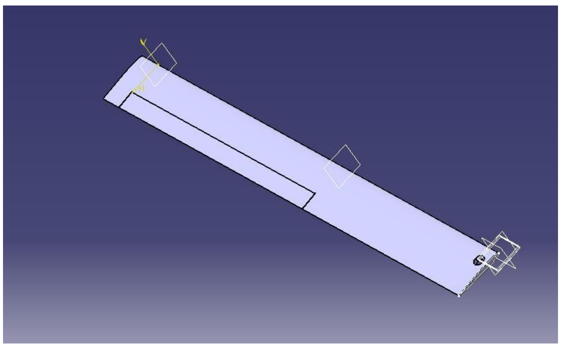


Figure 8: CAD model of wing and ailerons

2.4. Fins

It is the stabilizing and guiding unit of a model rocket. The aerodynamic surfaces projecting from the rocket body for the purpose of giving the rocket directional stability. Usually made of balsa wood or plastic, and located at the rear of the rocket. A tri-fin configuration is used in the rocket. These fins are given dimensions to provide stability to the rocket in both the closed-wing and the open-wing configurations. In the closed-wing configuration they provide rotational stability whereas in open-wing configuration, they work like the Y-tail configuration of an airplane.

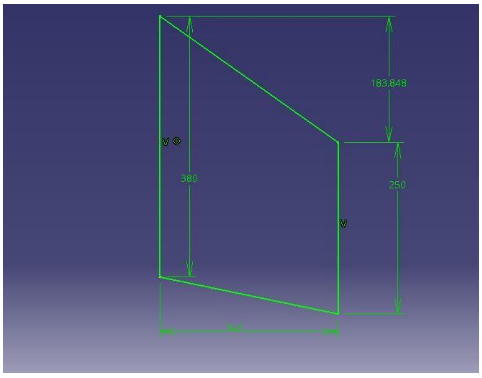


Figure 9: CAD model and dimensions of fins

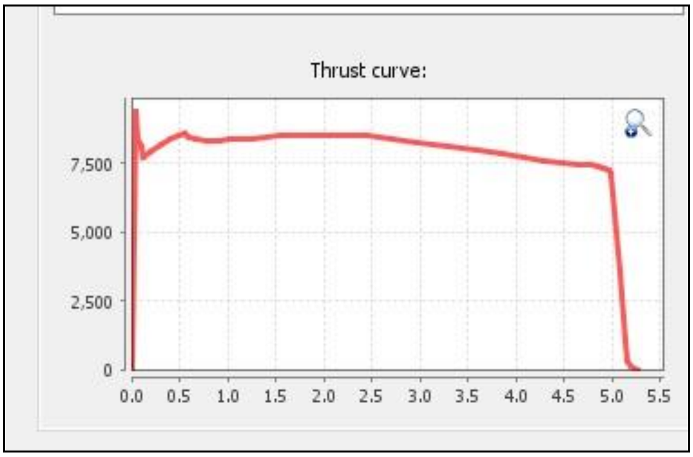
2.5. Motor

After many analysis we chose the motor O8000. This motor was best suited for our rocket structure. Its properties are given below.

Table 1: Motor Specifications

Total impulse:	41125 Ns (Over O)
Avg. thrust:	7980 N
Max. thrust:	9389 N
Burn time:	5.15 s
Launch mass:	32672 g
Empty mass:	14062 g
Data points:	38

Input by Tim Van Milligan for RockSim users.
Used John Coker's ThrustCruve
Tracer program. Thrust curve and engine data
from C.A.R. web site.



Graph 1: Thrust curve for motor O8000

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3. Recovery

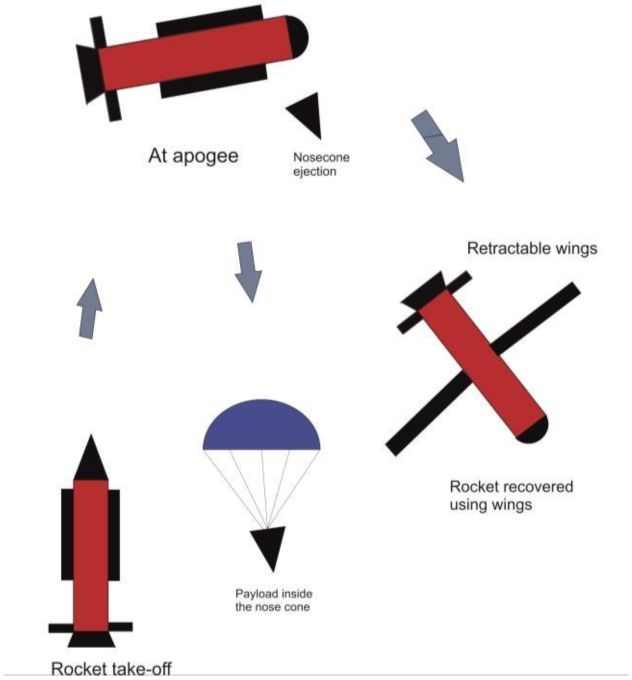

Figure 10: Summary of path of flight of rocket containing payload for experimentation purposes

Open wing and Closed wing configurations

- **Closed wing configuration**

  The rocket is kept in the closed wing configuration before lift-off. In this configuration, the wings are locked with their axis parallel to the axis of the bodytube. They are 120mm inside the body and 130mm outside the body. The trailing edge is kept outside the body and the leading edge in the inner portion of the same. The rocket motor is filled with the propellant which will decrease in proportion with time after lift-off.

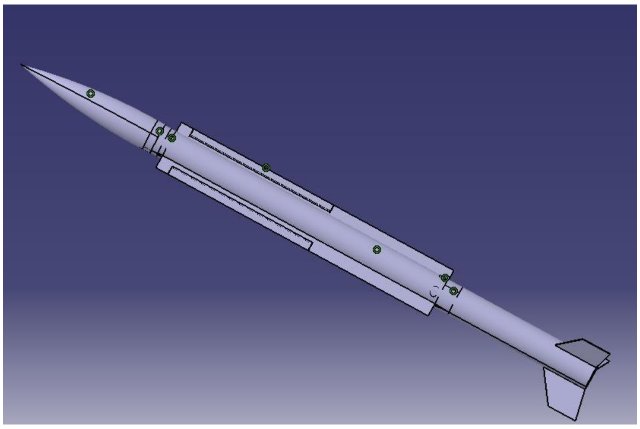

Figure 11: CAD model of Closed wing configuration of rocket

- **Open wing configuration**

  Once the rocket reaches the apogee, the outer nose cone is ejected and hence the payload is released. It also has an empty engine motor with no propellant left. As soon as the rocket starts the dive, the lock stopping the wings is released. The hinge comprises of springs and locks which allow the wing to easily open along the direction of the wind and lock once it is in position. Once the wings are locked, the ailerons are used to recover the rocket.

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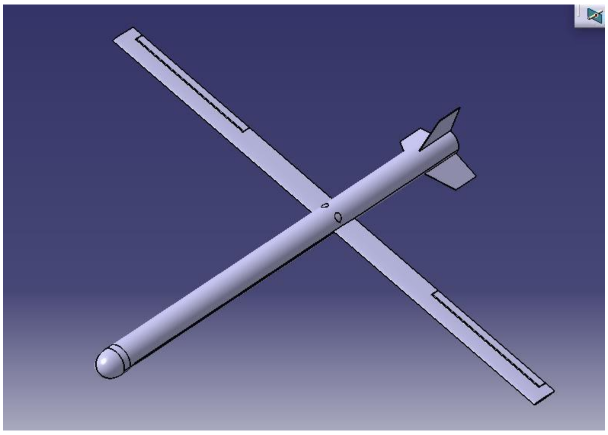

Figure 12: CAD model of open wing configuration of the rocket i.e. the glider mode

4. Simulations

ANSYS FLUENT allows us to plot contour lines or profiles superimposed on the physical domain. A profile plot draws these contours projected off the surface along a reference vector by an amount proportional to the value of the plotted variable at each point on the surface.
The Simulation of the rocket is done at 404 m/s to analyse the condition of the rocket in the most extreme conditions. At such high speed which is greater than Mach number 1 the rocket lies under the regime of supersonic.
In the figure below we can see the flow over the nose cone is such that the nose cone has the velocity very low as compared to the flow at some distance. This is due to skin friction drag acting on the rocket.

The maximum static pressure is at the tip of the nose come. The tip of the nosecone was therefore red in colour.

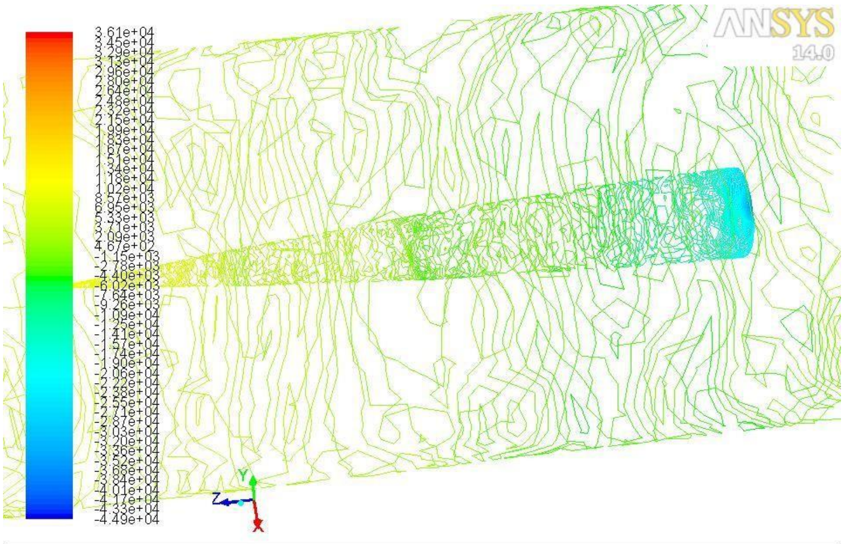

Figure 13: ANSYS analysis of outer nose cone

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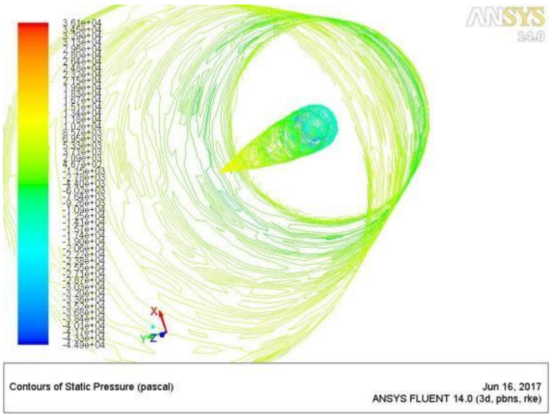

Figure 14: ANSYS analysis showing pressure contour for the outer nose cone

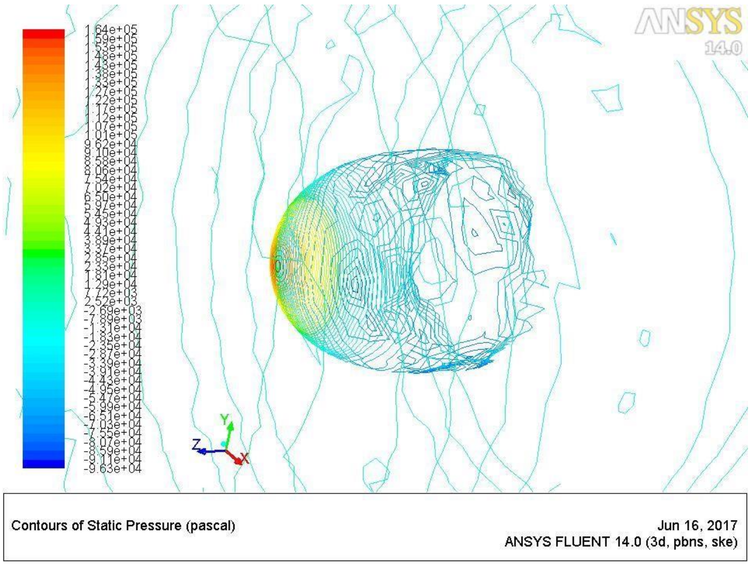

Figure 15:ANSYS analysis of inner nose cone using pressure contours

Analysis of Wings

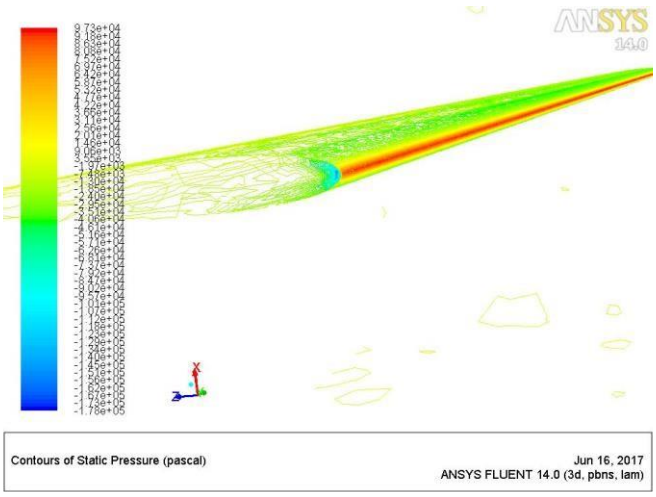

Figure 16:Pressure contour of Wing in Laminar flow

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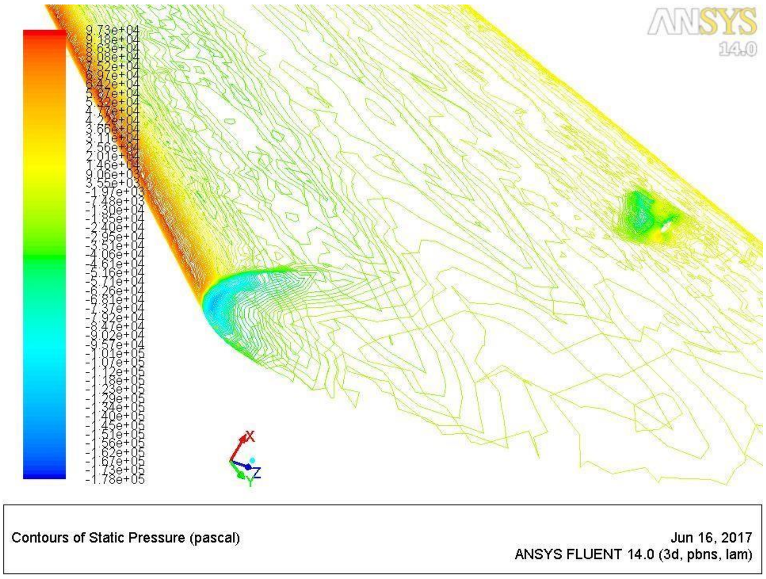


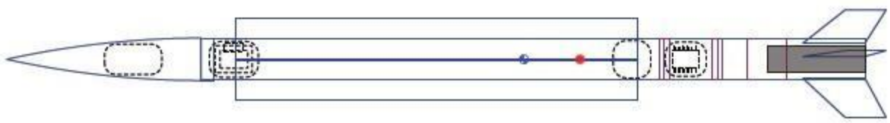
Figure 17:We can see that the red and orange areas have the maximum pressure, and after that pressure is evenly distributed.

A wing with a S9026 airfoil section is supported such that both the end is free. The analysis is done in Laminar mode were the inlet velocity is 404 m/s i.e the maximum velocity of the rocket. The wing is Aluminum 6061-T6. Find the first 6 modes of vibration of the airfoil using ANSYS Workbench.

5. Open Rocket Model and Simulation Results

Table 2: Rocket simulation results from open rocket

Rocket Design



Rocket

Stages: 1

Mass (with motor): 87226 g

Stability: 1.32 cal

CG: 316 cm

CP: 351 cm

Altitude	4808 m
Flight Time	70.4 s
Time to Apogee	30.1 s
Optimum Delay	24.9 s
Velocity off Pad	13.2 m/s
Max Velocity	404 m/s
Velocity at Deployment	N/A
Landing Velocity	209 m/s

Motor	Avg Thrust	Burn Time	Max Thrust	Total Impulse	Thrust to Wt	Propellant Wt	Size
O8000	7980 N	5.15 s	9389 N	41125 Ns	9.33:1	18610 g	161/597 mm

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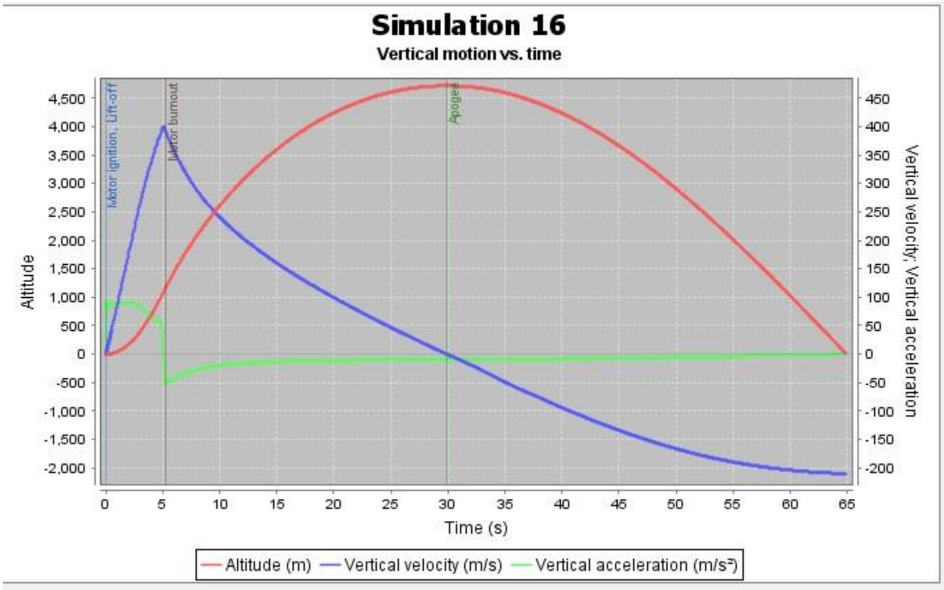

Table 3: Rocket Stuructural desription

Parts Detail

Sustainer

Nose cone	Carbon fiber (1.78 g/cm³)	Parabolic series	Len: 119 cm	Mass: 15700 g
Unspecified		Diaout 18.5 cm		Mass: 6000 g
Body tube 1	Carbon fiber (1.78 g/cm³)	Diain 24.7 cm Diaout 25 cm	Len: 283 cm	Mass: 5899 g
glider mech		Diaout 22 cm		Mass: 700 g
Bulkhead	Aluminum (2.7 g/cm³)	Diaout 24.7 cm	Len: 0.2 cm	Mass: 259 g
locking mechanism		Diaout 23 cm		Mass: 500 g
Body tube 2	Carbon fiber (1.78 g/cm³)	Diain 24.7 cm Diaout 25 cm	Len: 33 cm	Mass: 688 g
Tube coupler	Carbon fiber (1.78 g/cm³)	Diain 24.7 cm Diaout 24.7 cm	Len: 6 cm	Mass: 0 g
avionics		Diaout 21 cm		Mass: 1500 g
Bulkhead	Aluminum (2.7 g/cm³)	Diaout 24.7 cm	Len: 0.2 cm	Mass: 259 g
Trapezoidal fin set (2)	Carbon fiber (1.78 g/cm³)	Thick: 2.5 cm		Mass: 20000 g
Tube coupler	Carbon fiber (1.78 g/cm³)	Diain 24.7 cm Diaout 24.7 cm	Len: 6 cm	Mass: 0 g
Body tube 3	Carbon fiber (1.78 g/cm³)	Diain 24.7 cm Diaout 25 cm	Len: 90 cm	Mass: 1876 g
Trapezoidal fin set (3)	Carbon fiber (1.78 g/cm³)	Thick: 0.25 cm		Mass: 1108 g
Engine block	Aluminum (2.7 g/cm³)	Diain 24.7 cm Diaout 24.7 cm	Len: 0.5 cm	Mass: 0 g
Centering ring	Cardboard (0.68 g/cm³)	Diain 0 cm Diaout 24.7 cm	Len: 0.2 cm	Mass: 65.2 g

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6. Conclusions

The research led to results which suggested that a pair of retractable wings can lead to reusability of sounding rockets. This research laid emphasis on the wings which are presented as an alternative method of recovering sounding rockets. These wings will result in recovery of descending rockets in a precisely controlled manner. The wings have ailerons installed in them which may either be automatically piloted by an APM unit which will make it reach its destination or they may be controlled manually from the ground station. This will in turn, save a lot of manufacturing cost that is incorporated in building sounding rockets every year. Further research is being done to improve the glide ratio and compactness of the wings.

7. Appendix

List of Figures-

8. References

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