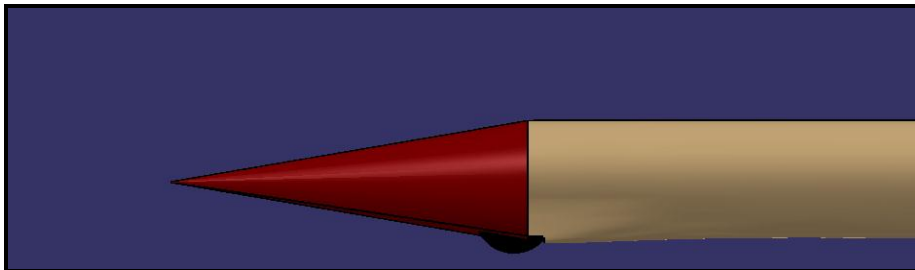
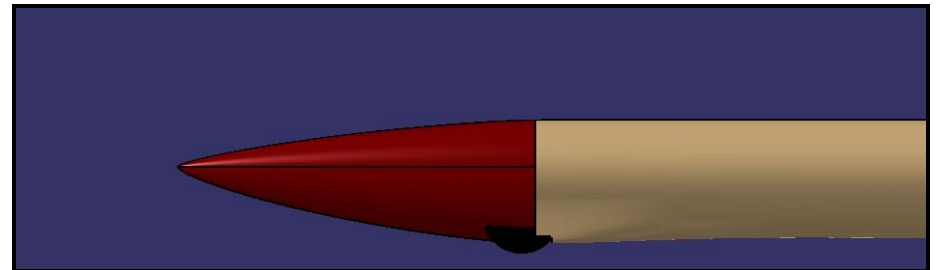


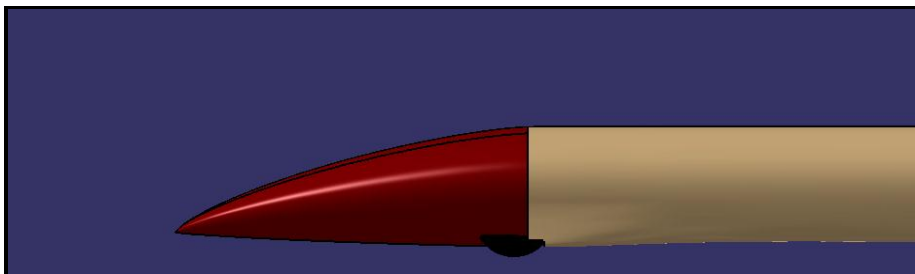
Nose 1



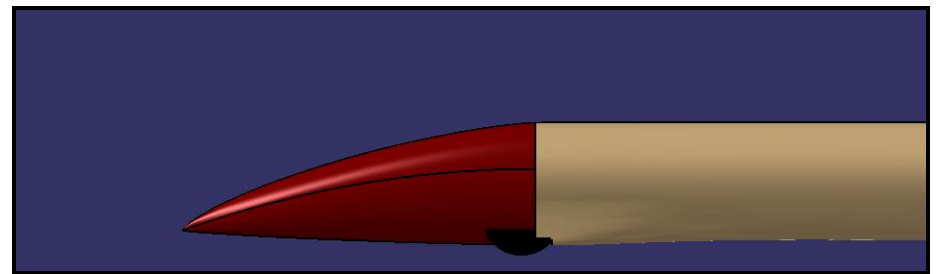
Nose 2



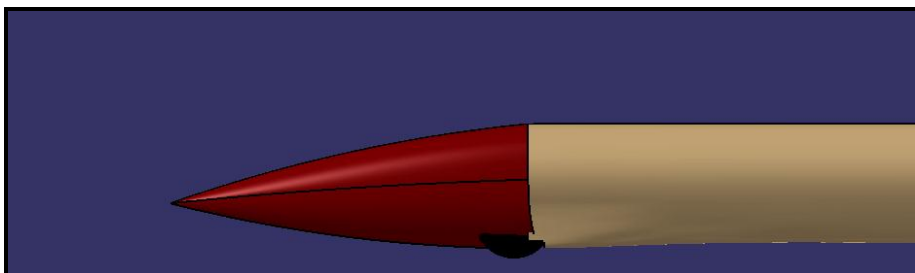
Nose 3



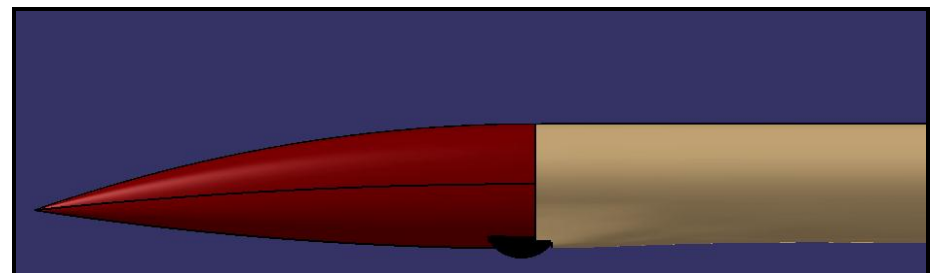
Nose 4



Nose 5



Nose 6

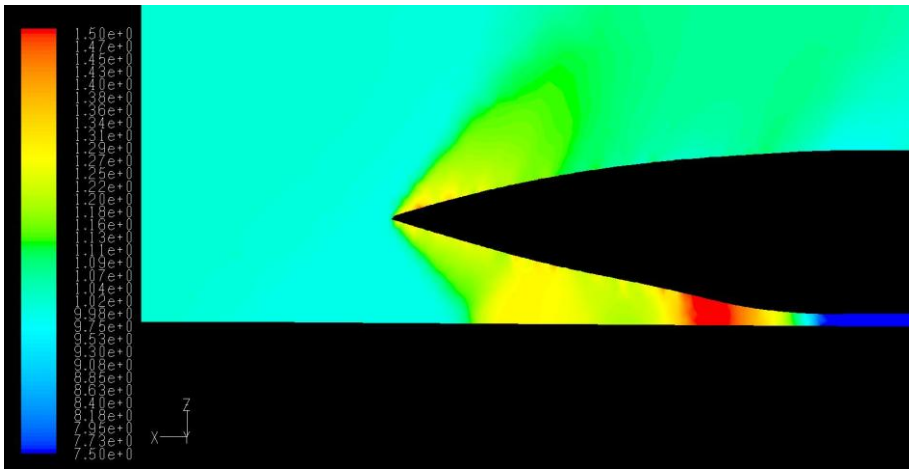


Nose 7

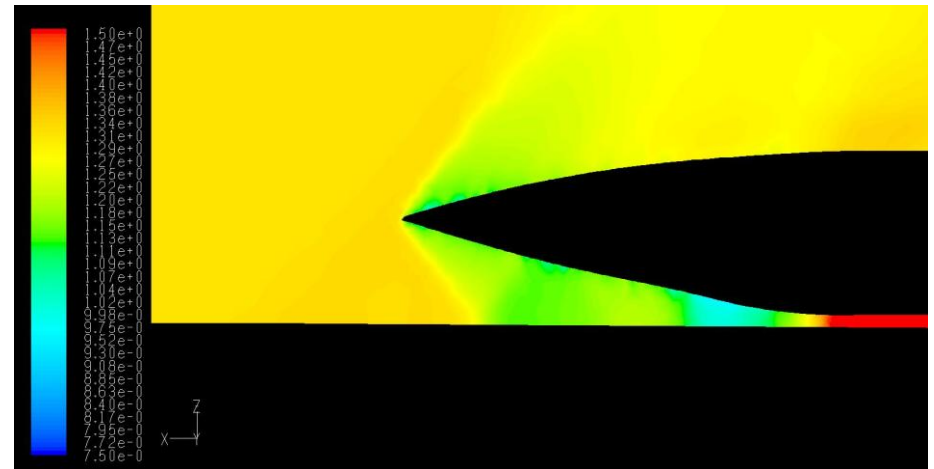
**Nose 1 - Existing design**

$C_L$  value = 0.044  
 $C_D$  value = -0.053

The existing design shows a high pressure region under the nose giving a lift value. A shock wave is experienced at the nose tip. The air speed slows as it approaches the minimal contraction point between body and floor before it goes through expansion and speeds up under the vehicle body. A high pressure band (red) occurs on the underside of the nose where a geometric change occurs between the nose shape and the body blend around the front wheel cover.



Pressure Contour Plot



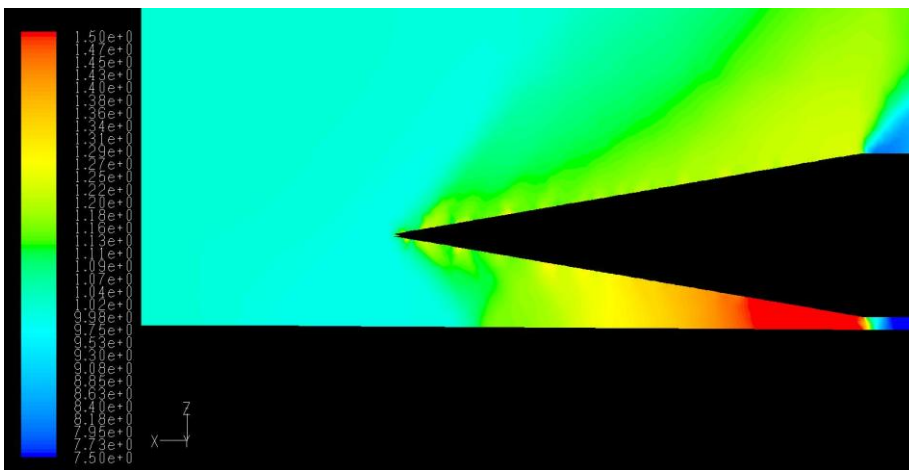
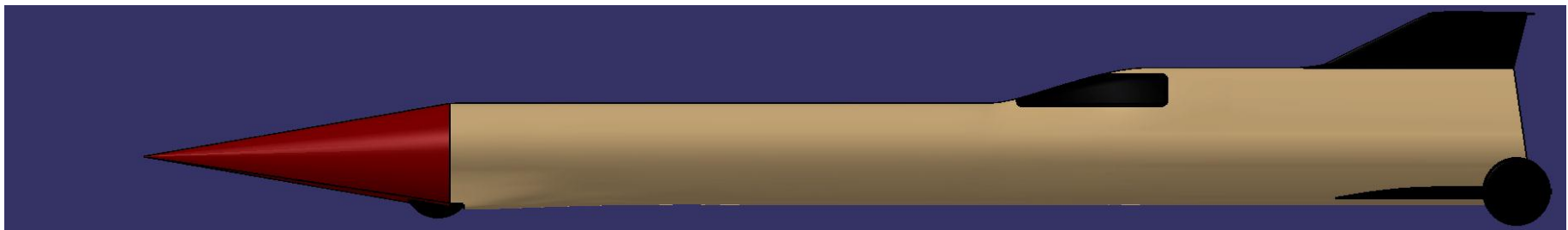
Velocity Contour Plot

## Nose 2 - Ideal conical based shape

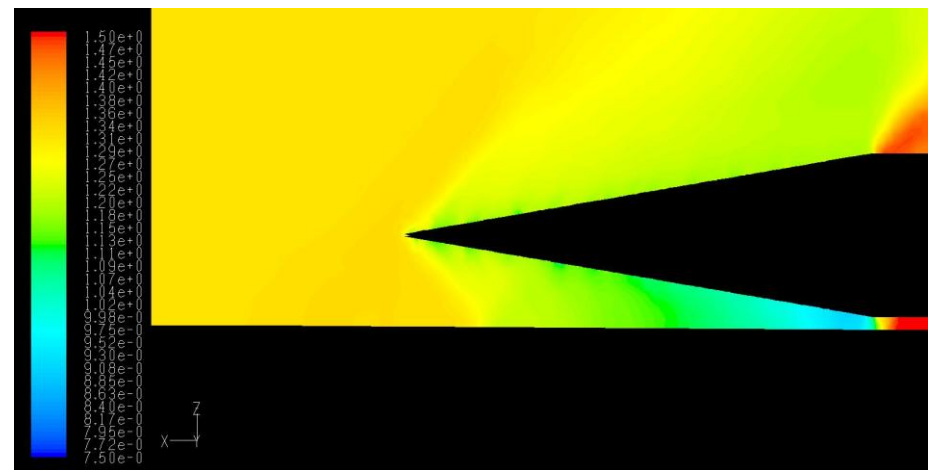
$C_L$  value = 0.146  
 $C_D$  value = -0.123

To give a baseline for all shapes, a simplistic idealistic cone was utilised. This is typically a supersonic shape although not for close to ground use. This was developed as a comparative shape.

The cone shows poor performance in close proximity to the ground. More high pressure is present under the nose cone (red in pressure plot below). This signifies a higher lifting force compared to the original design and is subsequently proved by the  $C_L$  value for this shape. The large angle change from cone to body produces a large expansion where a rapid velocity change occurs and flow is choked between the large angle of the cone and the small gap between floor and body. High drag is thus associated with this shape.



Pressure Contour Plot



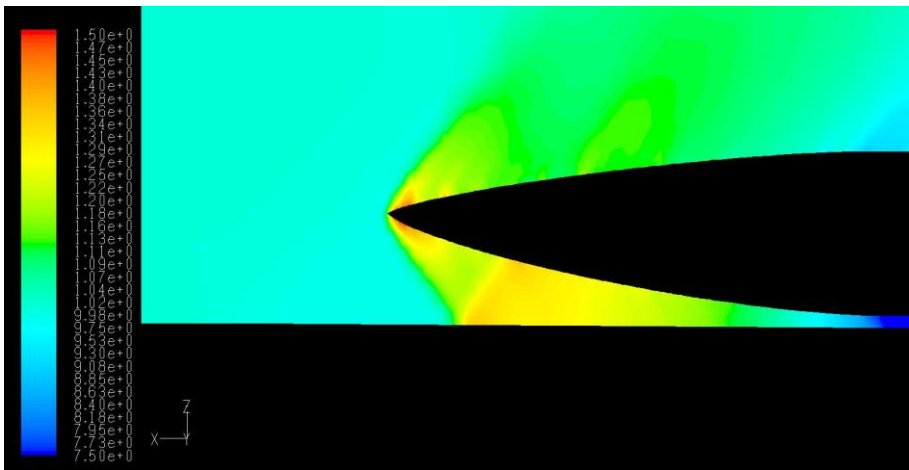
Velocity Contour Plot

### Nose 3 - Elliptical Haack based shape

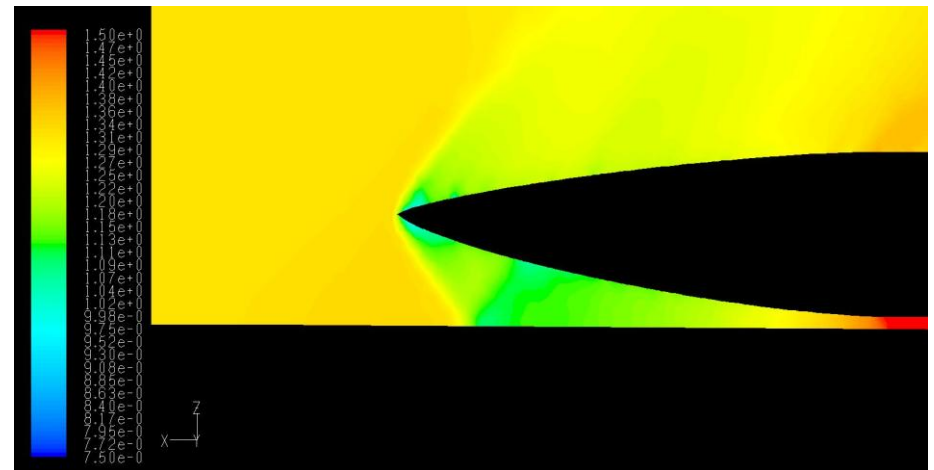
$C_L$  value = 0.027  
 $C_D$  value = -0.044

A Haack shape has been mathematically derived to provide a smoother transition between the nose tip and the underside of the shape. The previous two designs show due to significant shape changes along the lower curvature produce high pressure regions and a subsequent lifting force. To avoid this, a Haack shape is employed.

The Haack shape has the desired effect of removing any abrupt geometric changes on either the upper or lower surface. The gradual curvature from the tip to the underside of the body provides flow with a steady geometric change. Lift has been reduced compared to the two previous runs, with drag also being reduced.



Pressure Contour Plot



Velocity Contour Plot

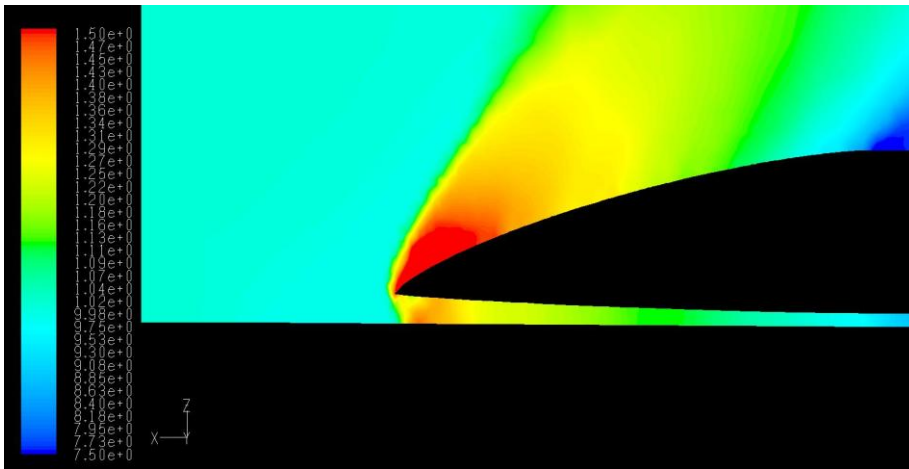
**Nose 4 - Wide low bi-von Karman based shape**

$C_L$  value = -0.097

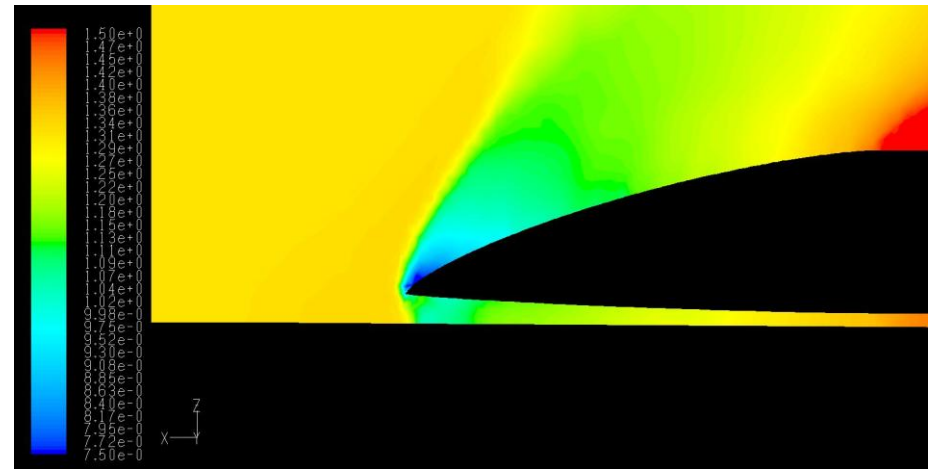
$C_D$  value = -0.116

Based on the chart in Appendix 1, the von Karman shape is suited for the approximate mach value the vehicle is aiming for. This shape is typically found on fighter jets for nose cone shapes. The von Karman shape is similar to the Haack shape in that it is mathematically derived and has been developed for low drag purposes. This particular shape is a bi-von Karman shape where two differing von Karman curves have been blended to provide a low tip with the intention of producing downforce. The von Karman derived curves have been maintained at the expense of fitting within the confines of the body width restrictions.

High pressure is seen on the upper leading edge of the nose which indicates the production of downforce. The geometric discontinuity between the upper curve and the body causes an expansion where flow speed increases (red in the velocity plot). The underside of the nose shows no such feature and flow progresses more uniformly from the tip to the underside of the body. The high drag value produced by this nose is associated to increased frontal area whilst maintaining the correct mathematical curvature.



Pressure Contour Plot

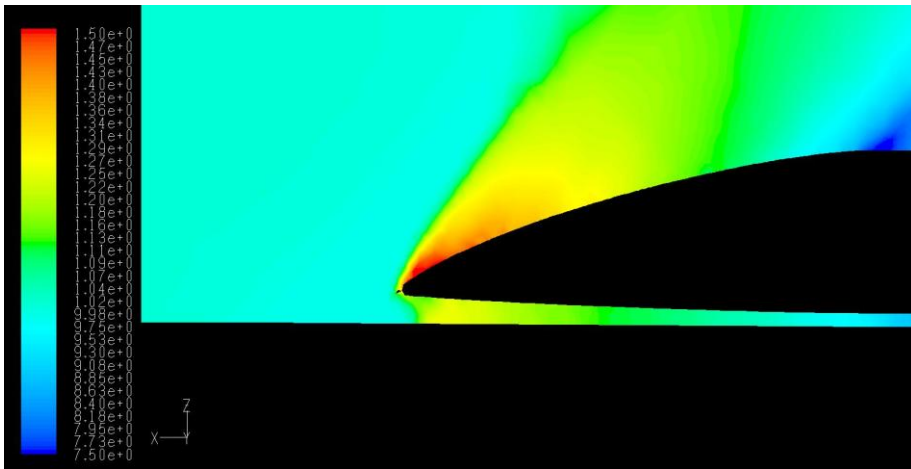


Velocity Contour Plot

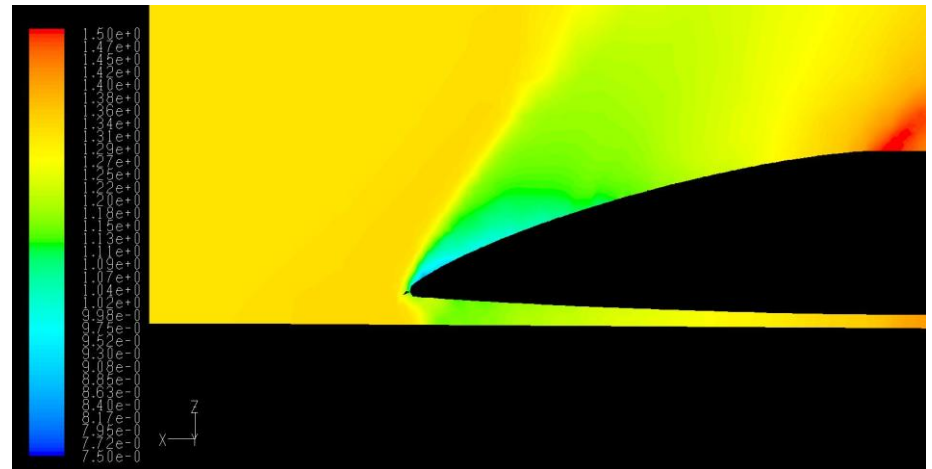
**Nose 5 - Narrow low bi-von Karman based shape**  $C_L$  value = -0.037  
 $C_D$  value = -0.049

The previous nose had the desired effect of producing downforce at the expense of increased frontal area due to maintaining the desired curvature. This shape utilises the same bi-von Karman mathematically derived curves from the previous shape but its blended curvature is compromised to enable it to fit more closely to the body dimensions.

Results show this shape has the same effect as the previous nose shape albeit at a reduced amount. The downforce is reduced (approximately 60%) although the drag value is also reduced (approximately 60%). Downforce is still generated by the high pressure on the upper leading edge of the nose and the velocity underneath the vehicle is generally more uniform.



Pressure Contour Plot



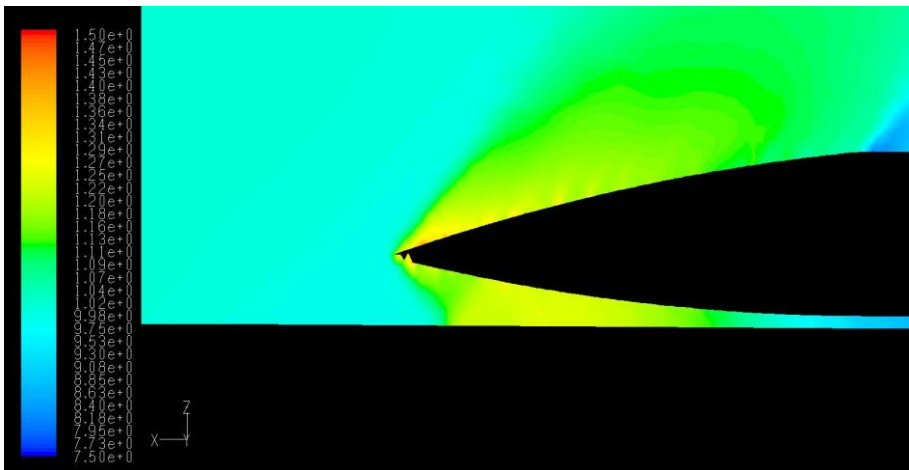
Velocity Contour Plot

**Nose 6 -  $x^{1/2}$  Power based shape**

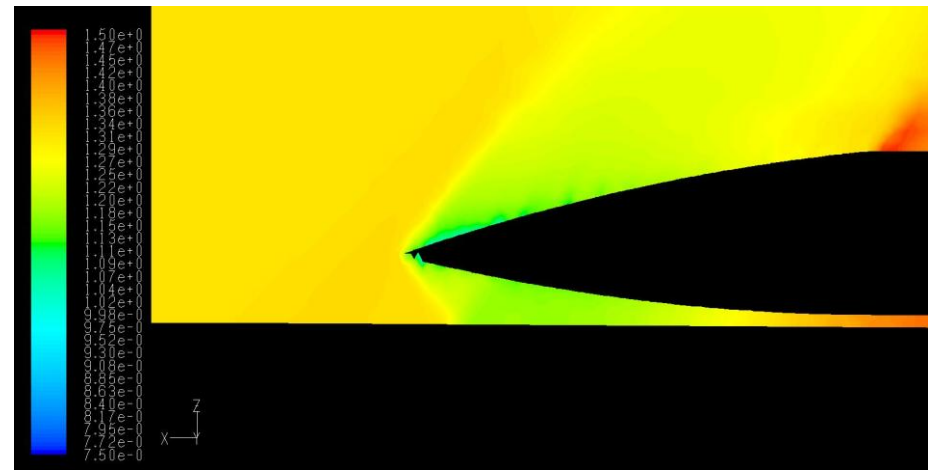
$C_L$  value = -0.024  
 $C_D$  value = -0.045

Again based on the information in Appendix 1, the  $x^{1/2}$  power based curvature, another mathematically based shape, is a suitable match for the intended vehicle speed. The intention of this shape was to reduce the high curvature at the leading edge of the previous nose geometry, and hence reduce generated downforce.

Pressure contour plots show no high pressure (red) on or near the nose suggesting a removal of large forces. Consequently, the plots show presence of less low pressure (dark blue) compared to previous shapes. Both high and low pressure removal is optimum as this suggests slowing/speeding of air is minimal. Velocity plots show uniform speed above and below the nose shape (once the initial shock has passed), until the body geometry is reached where expansion occurs.



Pressure Contour Plot



Velocity Contour Plot

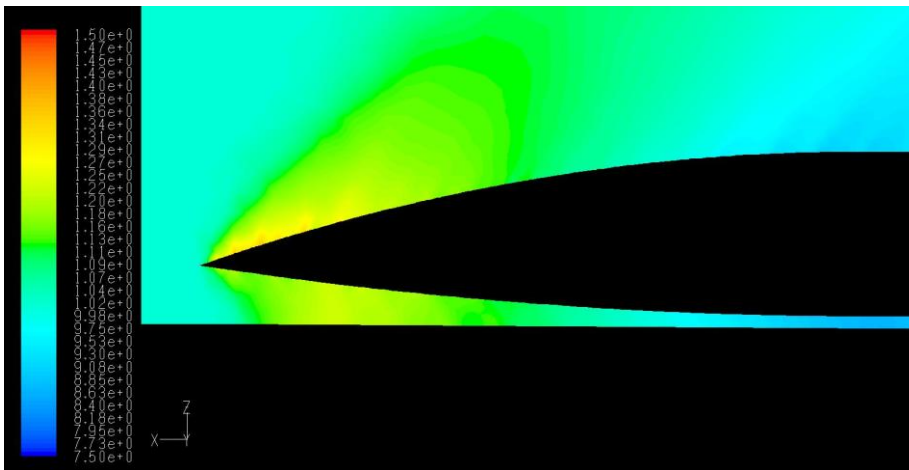
**Nose 7 -  $x^{1/2}$  Power based shape  
(Increased fineness ratio)**

$C_L$  value = -0.022  
 $C_D$  value = -0.031

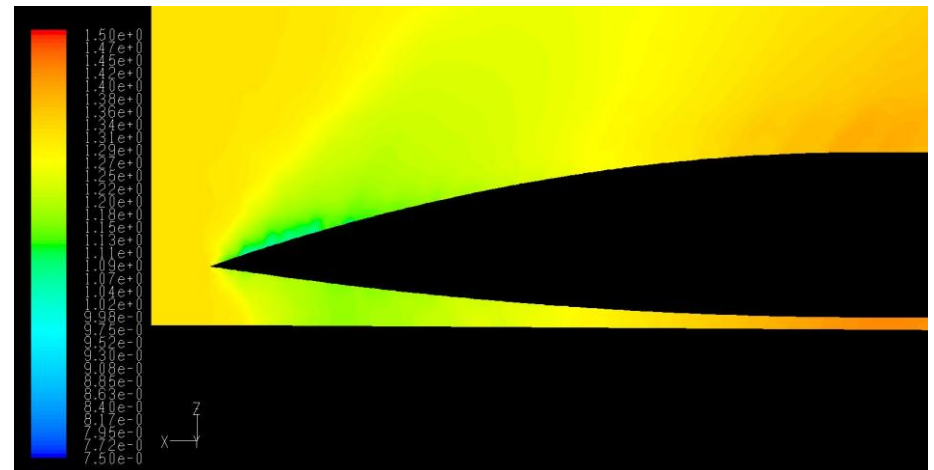
As nose 6, the  $x^{1/2}$  power based shape provided the best results from the series, both in terms of minimal lift and drag, a further design iteration on this shape was conducted. The chart in Appendix 2 shows the relationship between drag produced and the fineness ratio. The fineness ratio is essentially a ratio of the length to height and suggests that higher fineness ratios (up to a maximum of 5) are optimum for drag reduction. Nose 6 has a fineness ratio of 2.9 and has been restricted in length by the maintaining the original nose design length. Nose 7 has been extended 1.5m to produce a fineness ratio of 4.1.

Results show a similar lift value to nose 6, however the drag value has been reduced by an approximate 30%. This is backed up by the contour plots where in the pressure plot there is a reduction of low pressure on the upper surface. The velocity plot shows a uniform speed value along the length of the nose and body once the initial shock has been negotiated. Results have benefited from the clean transition from nose cone to body shape. The mach number difference between maximum and minimum is the smallest of all shapes on trial suggesting minimal flow disruption (resistance) occurs.

This nose shape is the best on trial from the CFD runs.



Pressure Contour Plot



Velocity Contour Plot



## CONCLUSION

Nose 7 has shown to be the best performing shape from all those trialed in the above CFD runs. Nose 7 possesses the lowest drag and lowest downforce, or lift, value along with the smallest mach number change between highest and lowest recorded flow speed. This shape is an  $x^{1/2}$  power based curve and is elongated to produce a fineness ratio of 4.1.

An important consideration of any nose cone design is that it must maintain a minimal shape discontinuity between nose and body. This is important to avoid expansion as flow crosses this section. Flow expansion results in a flow speed change.

Another feature that a nose should maintain is a gradual and steady curvature on the underside as it approaches the minimum ground height position. This will ensure flow is not unduly forced into a small area from a larger area and flow choking will be avoided.

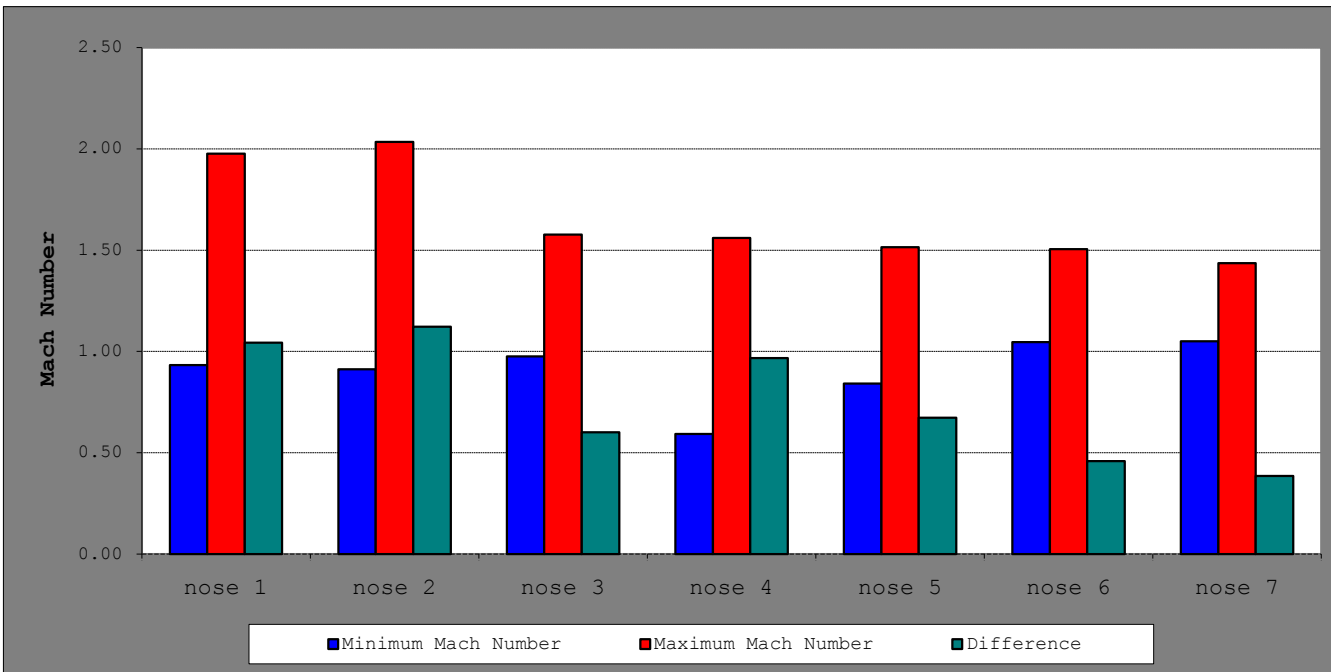
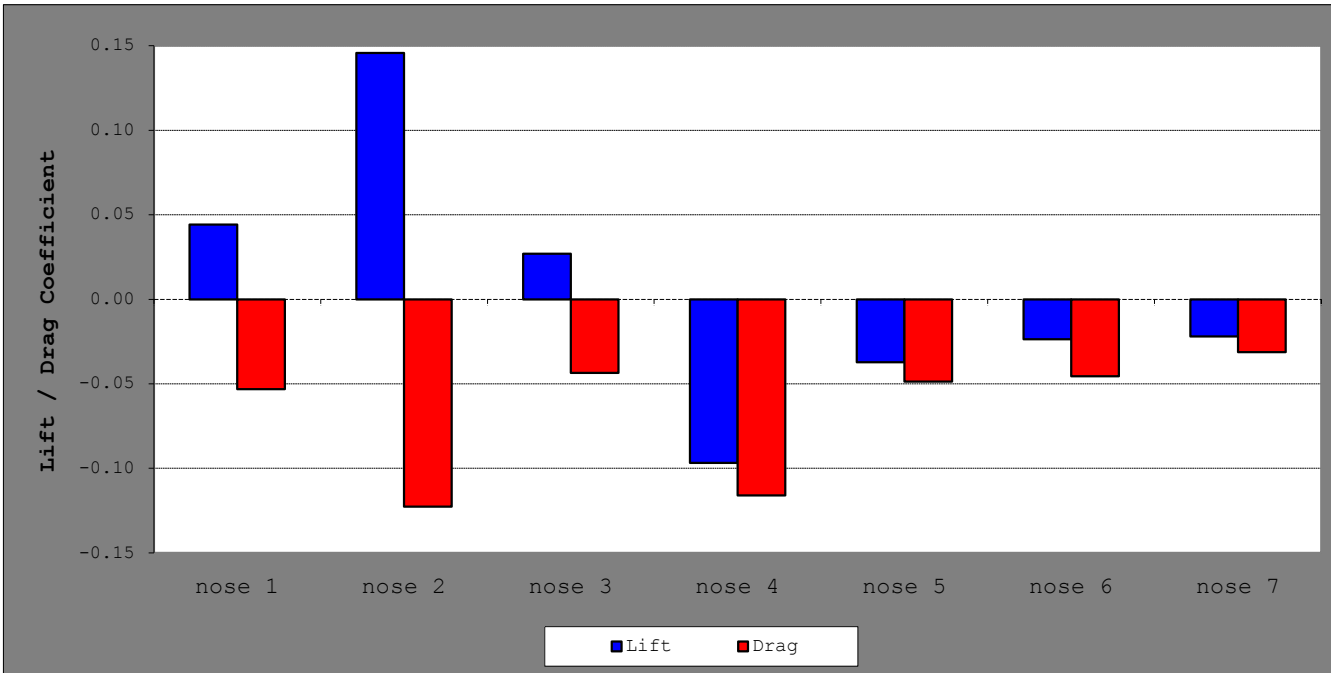
The sharp point on the nose cone tip has been shown to perform better than any curvature based tip, therefore should be maintained on any design.

The nose cone should be the widest part of the vehicle and shouldn't be wider than necessary as drag is a function of surface area.

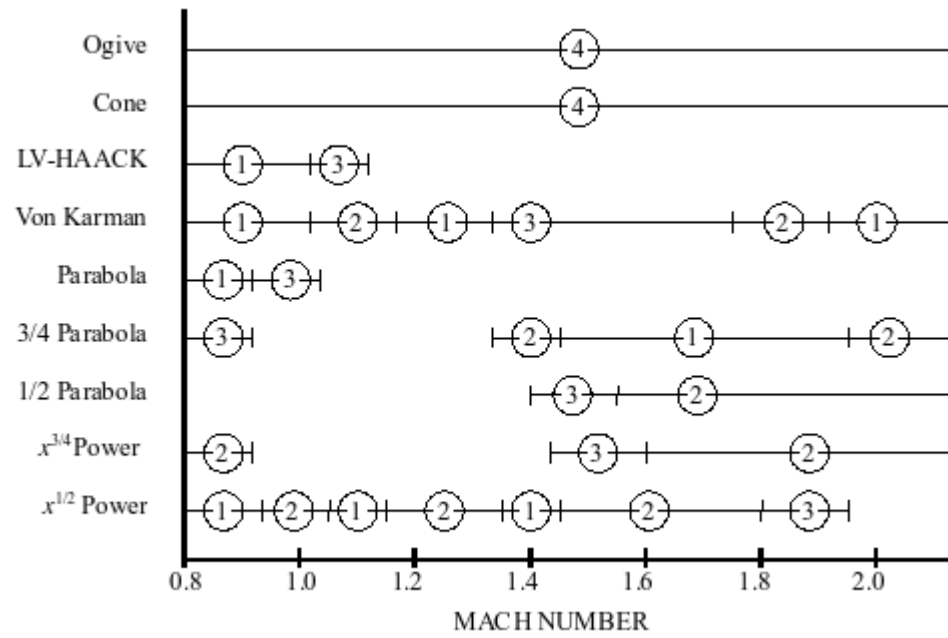
A decision will have to be made on whether lift or downforce is a requirement. Downforce will be a safer option in that this force will push the vehicle downwards into the ground in the event of issues arising. A neutral shape is likely to be the optimum shape, although as the rest of the vehicle design is yet to be signed off. Any excess downforce/lift can be counteracted and trimming of lifting surfaces is an easier option.

The best performing nose shapes provide a smaller speed change where the fluid is not having to expand or contract which will cause flow speed changes. These speed changes will be associated around geometrical features.

The graphs below outline the CFD runs. Graph 1 shows the lift and drag for each nose design. Lift is a positive value whereas downforce is a negative lift value. All drag values are negative due to sign convention. Graph 2 shows the maximum and minimum mach numbers along with the delta between the two.



APPENDIX 1



1 = Superior  
 2 = Good  
 3 = Fair

APPENDIX 2

