Analysis Report

Multiple Fin Assembly Analysis Report

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1) Introduction

This report; going beyond the classical rocket designs, which have now become a standard in the rocketry industry, preferred due to its practicality and various advantages, designed as four equal-sized fins attached to the lower body; the effect of a larger number of additional winglets positioned in different places than the standard fins on the general flow and flight was examined, and the analyzes obtained through Openrocket and Ansys applications were shared on the basis of these examinations.

2) Openrocket Analysis

First stage, the preliminary analysis of the possible rocket designs to be compared were tested through the Openrocket program, and if successful results are obtained from the tests, which of the designs that give successful analysis results after the reasons are stated, which of the designs that give the successful analysis result are desired to be taken to the next stages, proceed to the next stages with the selected designs and proceed to the reporting processes has been continued.

In the preliminary analyzes made over the Openrocket program, rocket designs were examined by dividing them into 3 basic classes:

A. Additional Fin Analysis Added to the Rear Fuselage
B. Analysis of Additional Fins Added to the Front Body Without Engine
C. Analysis of Additional Fins Added to the Front Body With Engine

The basic conditions that the designs must meet in order to pass the Openrocket tests are listed as follows:

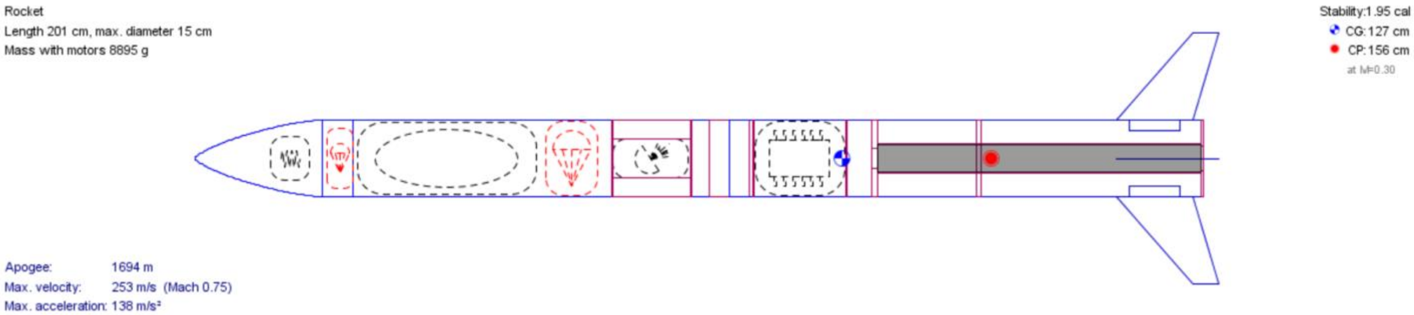
-1 kg payload should be able to be increased up to 1500-2000 meters altitude.
-The average wind speed should be 2 m/s.
-The launch pad must be 3 meters and the launch angle must be 5 degrees.
-The minimum ramp speed should be 20 m/s.
-The stability value during flight should not exceed 1.5-3 cal range.
-The properties of the materials to be used are also specified as follows:

Payload height 350 mm, diameter 143 mm.
Main Parachute height 100 mm, diameter 146 mm, weight 500 g.
Drogue Parachute height 50 mm, weight 100 g.
Avionics Box height 150 mm, diameter 75 mm, weight 600 g.

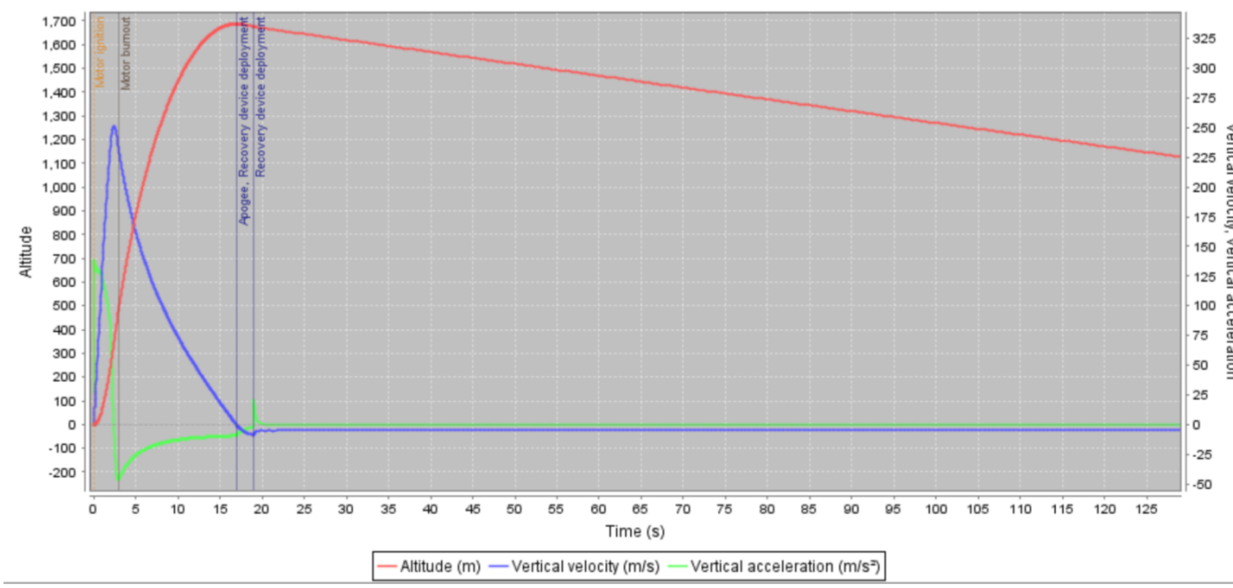
A. Analysis of Additional Fins Added to the Rear Body In the

In the rocket designs used in this article, 4 fins have been added in addition to the standard rocket structure and the shapes of all the fins used are designed to provide the necessary conditions, especially the necessary stability during the flight.

Our additional wingless rocket design and flight simulations, which we refer to in the comparisons, are as follows:

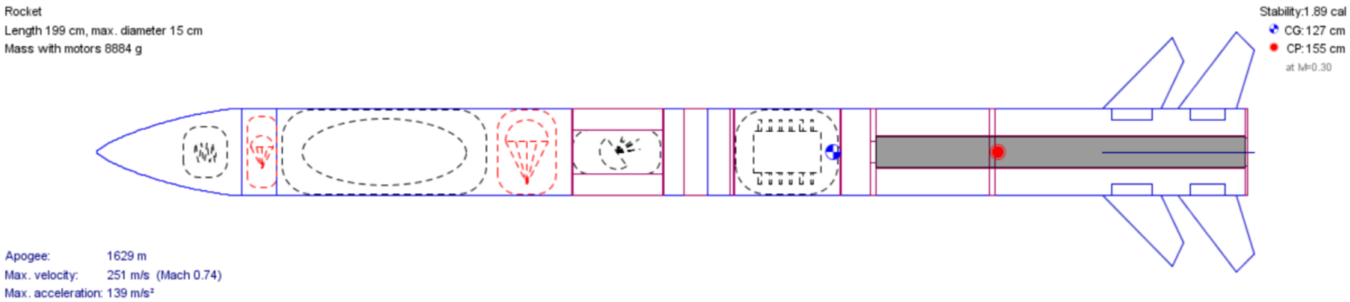


Reference Rocket Design and Flight Simulation

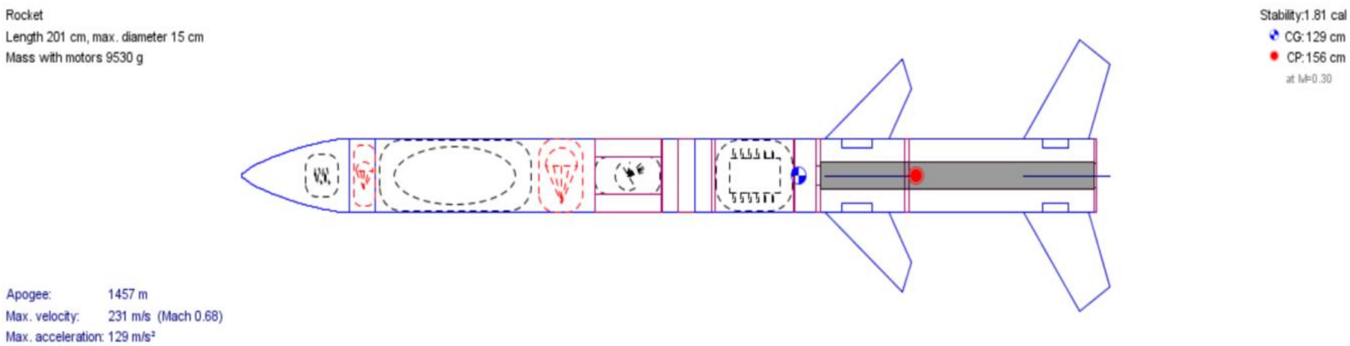


In the first design trials, in addition to the current number of 4 fins, which is considered standard, it was mounted to the lower fuselage and subjected to various tests by adding 2 and 3 additional fins in different positions in separate trials, but as a result of these tests, it was observed that the rocket could not provide a stable flight during flight. In the new design trials that were continued afterwards, it was observed that a smooth and stable flight was at the highest efficiency with 4 additional fins to be added. As the main reason for this situation, we have argued that the arrangement of the fins in different numbers has different geometries, and therefore the fins in the front will direct air currents in a way that is not suitable for the fins at the rear, causing an uneven distribution of forces.

The trial tests of the next item A were made to see whether adding the fins to the rear part of the rocket body, or the front part, would yield more efficient results. 4 different test rocket designs were created. In the first and second rockets, the fins were designed to have surface areas close to each other and close to the rear part of the first rocket and close to the front of the fuselage in the second rocket.



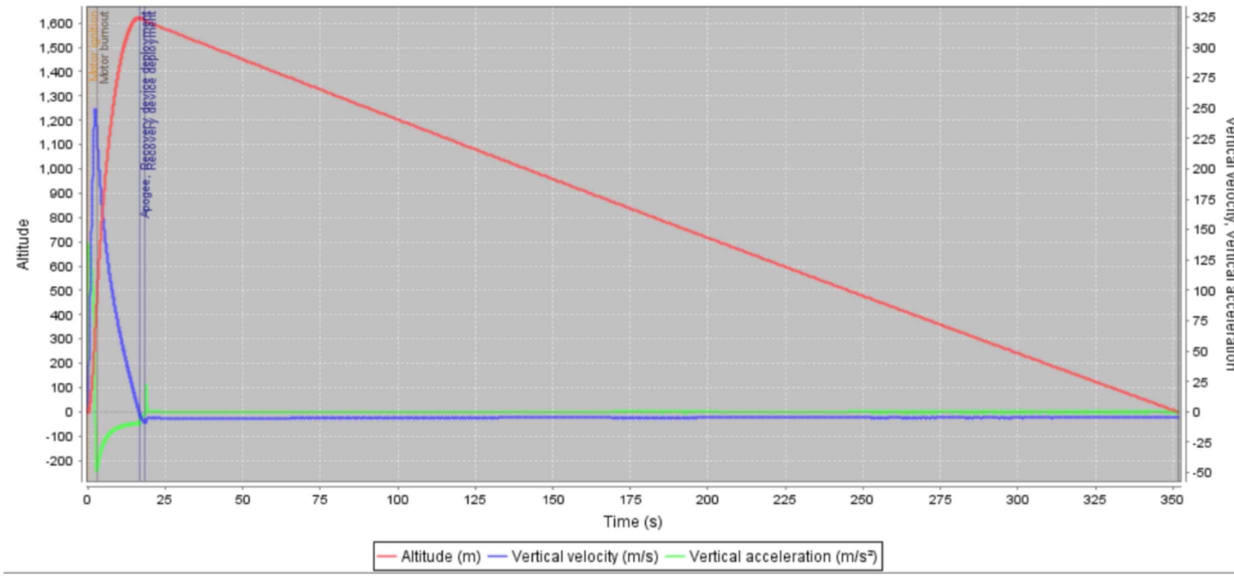
Rocket-1



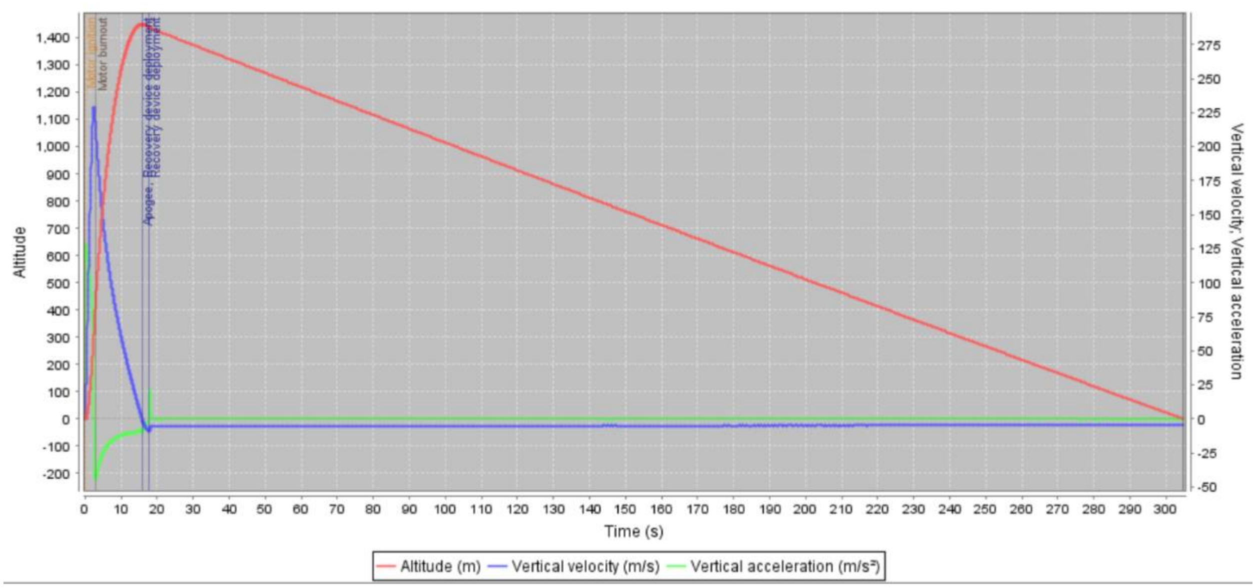
Rocket-2

Although the stability of the first two test rockets gave an uneventful result between 1.5 and 3 cal during their flight, it was observed that the stability and the maximum height expected to be reached decreased significantly as the fins were moved from the rear to the front. Fins forward

As carrying reduces stability, the fins need to be further enlarged in order to compensate for this. Since the growing fins are also made of aluminum, the net weight of the rocket has increased by about 700 g after the changes. As a result of this increase in mass for the sake of stability, the maximum height has decreased by approximately 170 m and similar decreases have been experienced in the estimated maximum speed and acceleration to be reached.

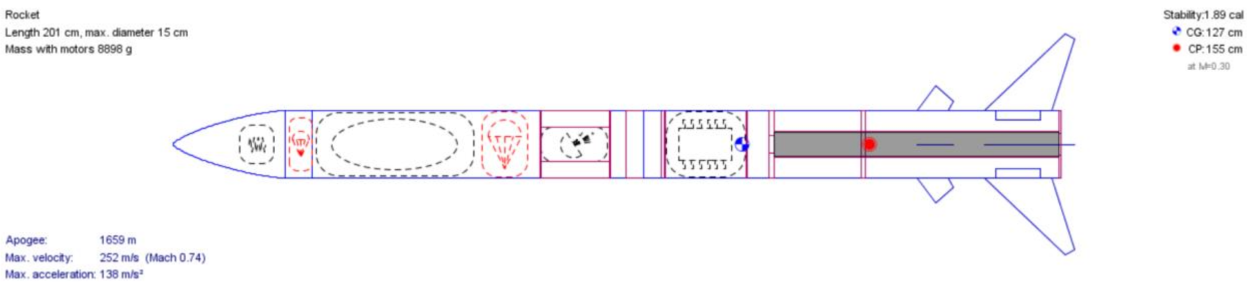


Rocket-1 Flight Simulation

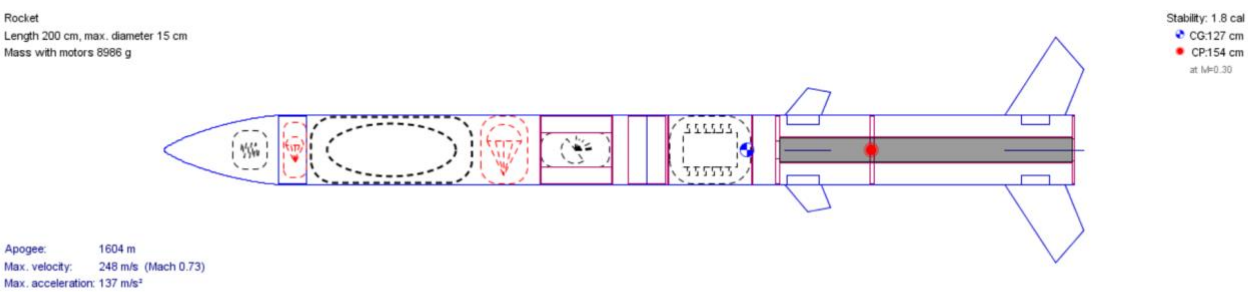


Rocket-2 Flight Simulation

Following the results obtained in rockets with close surface areas, the 3rd and 4th rockets, whose surface areas are far apart, that is, carrying 4 large and 4 small fins, were also subjected to similar tests and simulations.



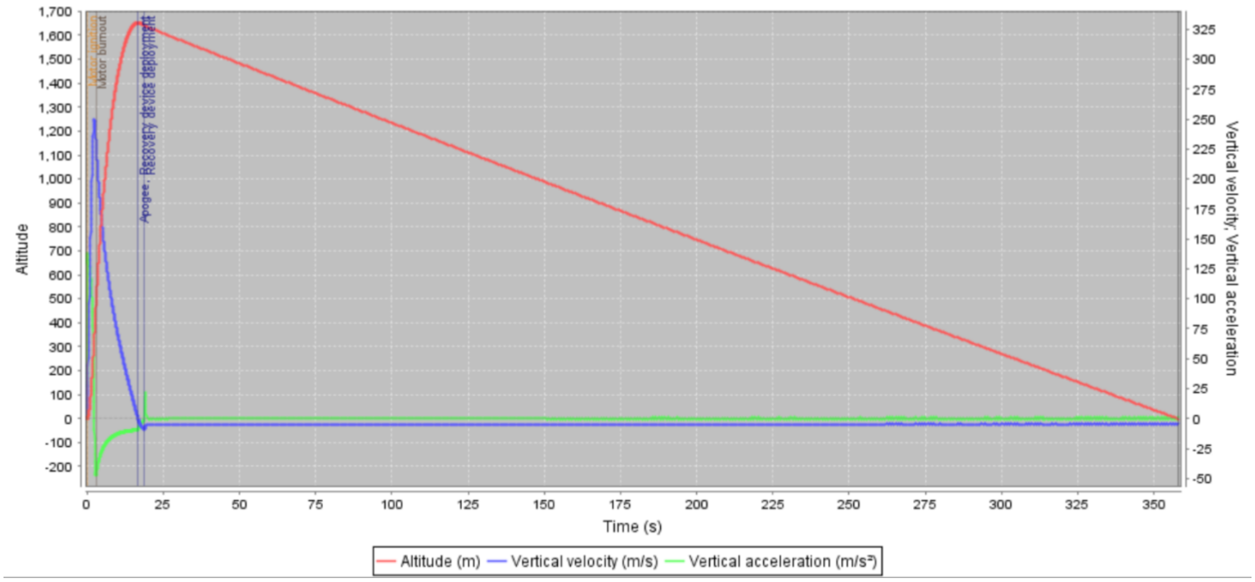
Rocket-3



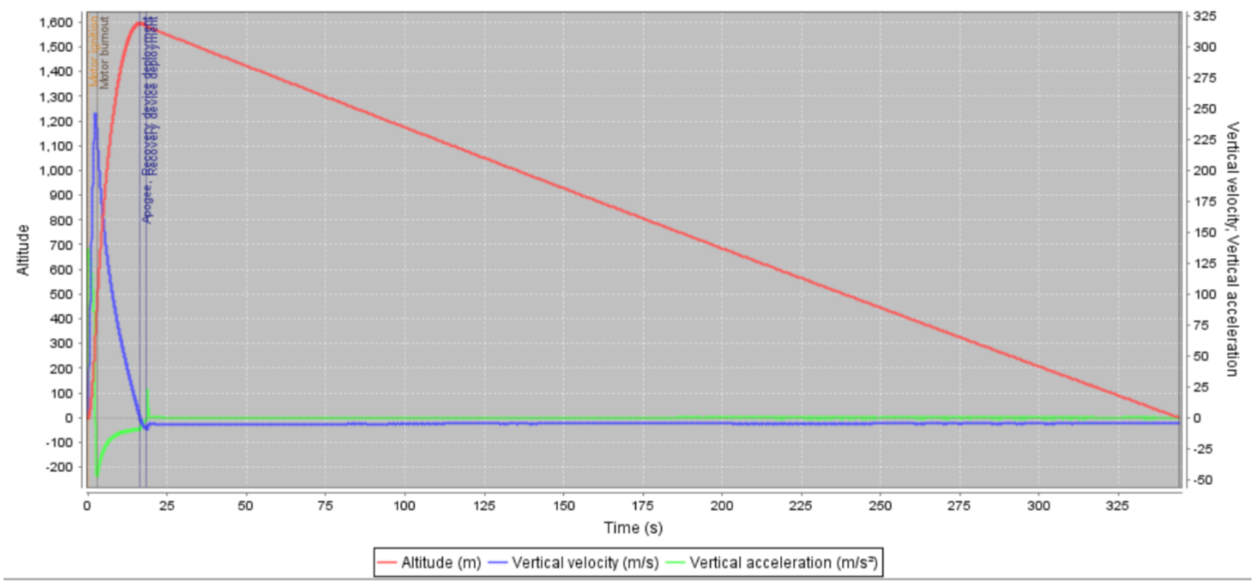
Rocket-4 In the

In the simulations, the 3rd and 4th rockets, which were designed with winglets with four large and four small surface areas, were able to reach higher altitudes than the 1st and 2nd rockets with similar large surface areas. Again, as we noticed when comparing the first two rockets, there was a decrease in stability in these simulations as a result of the fins moving away from the rear, but since the fins were smaller and naturally lighter than the previous one, it was not necessary to enlarge the second winglet much. The price of the stability provided by the change of the second aileron areas with small differences in this way was a loss of altitude of only 55 meters. There were also smaller decreases in maximum velocity and acceleration compared to the first two rockets.

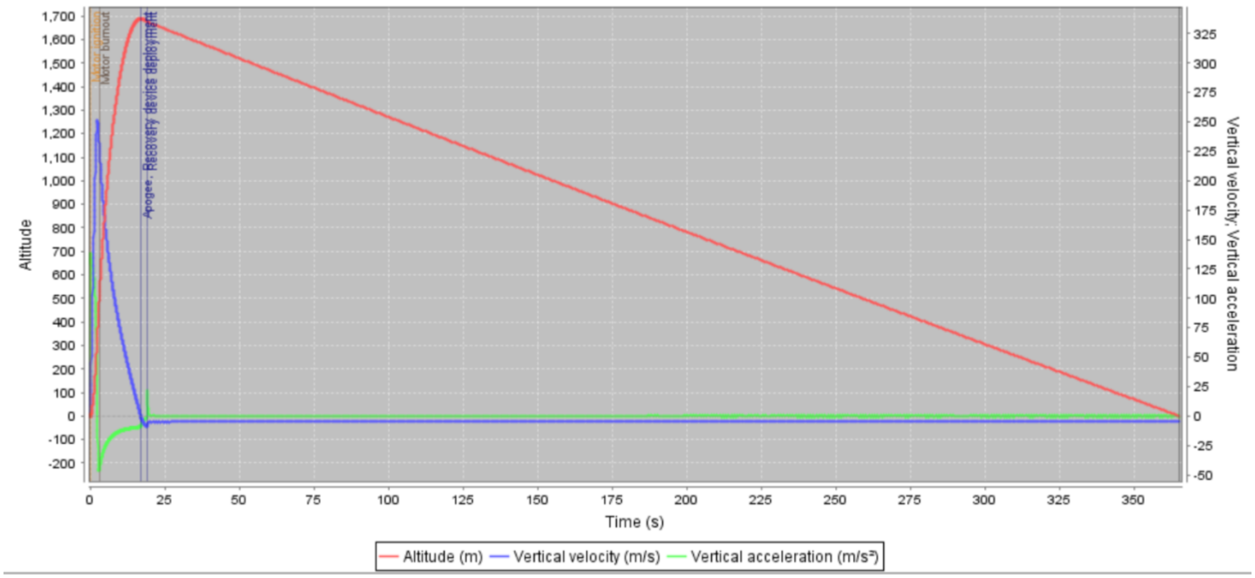
To evaluate the results in general; In line with simulations, it is possible to add fins to the rear fuselage without adding an engine and to fly under these conditions. In order not to disturb the flight stability of the number of fins and their geometry, 4 or more fins can be used provided that they are mounted at equal angles. However, the use of more than 4 fins is not recommended as it will be a serious additional weight for the rocket, and it should be examined whether there is a problem in the flow with deeper analysis. It is important that the size of the fins to be added is smaller than the original fins and that these added fins are positioned as close as possible to the main fins and correctly at the rear of the rocket, for the sake of stability, both altitude and speed of the rocket are lost at a minimum level. The most important result observed in all these trials is that the addition of a different fin to the lower body of the rocket, under any circumstances, could not provide as efficient flight as the normal rocket design without any additional fins. In other words, designing a rocket by attaching an additional wing to the rear fuselage in addition to the standard rocket design is a superfluous task unless there is a special reason, it is inefficient. It is possible to see this result visually in the flight simulations given below.



Rocket-3 Flight Simulation



Rocket-4 Flight Simulation

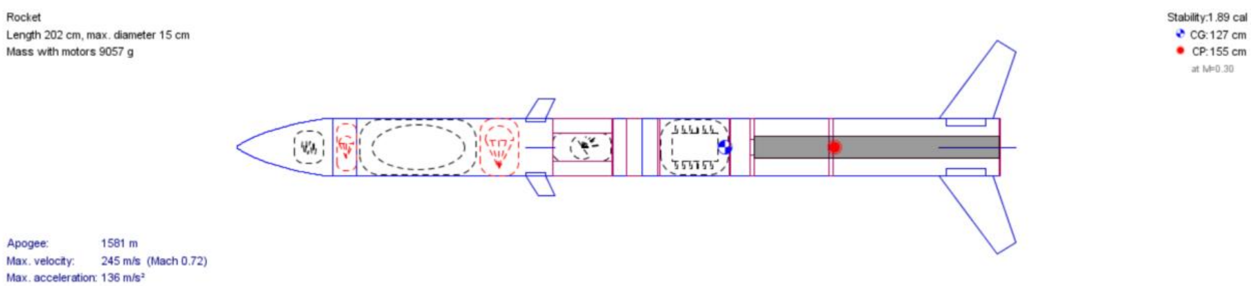


Flight Simulation of Basic Rocket with No Additional Fins (Reference Rocket)

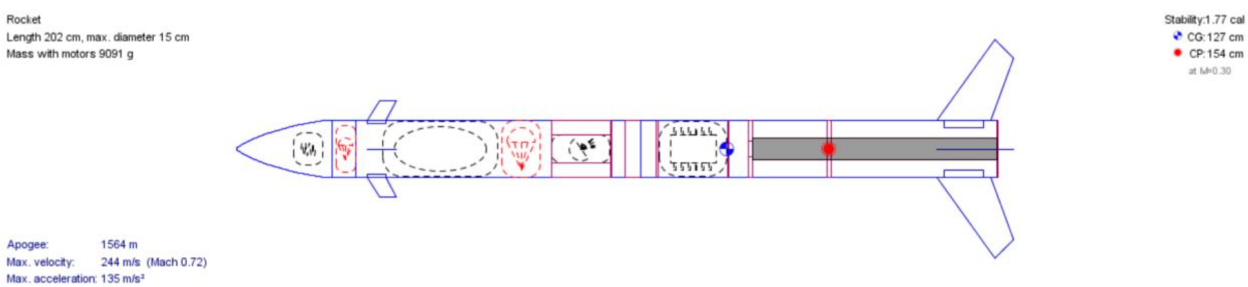
B. Analysis of Additional Fins Added to the Front Body Without Engine

In this item, as in item A, simulations were continued by using 4 additional fins. As the name suggests, in this article, fins were added to the upper rocket body without using an additional engine. In other words, it can be thought of as 4 fins that are additionally mounted on the upper body of a standard rocket.

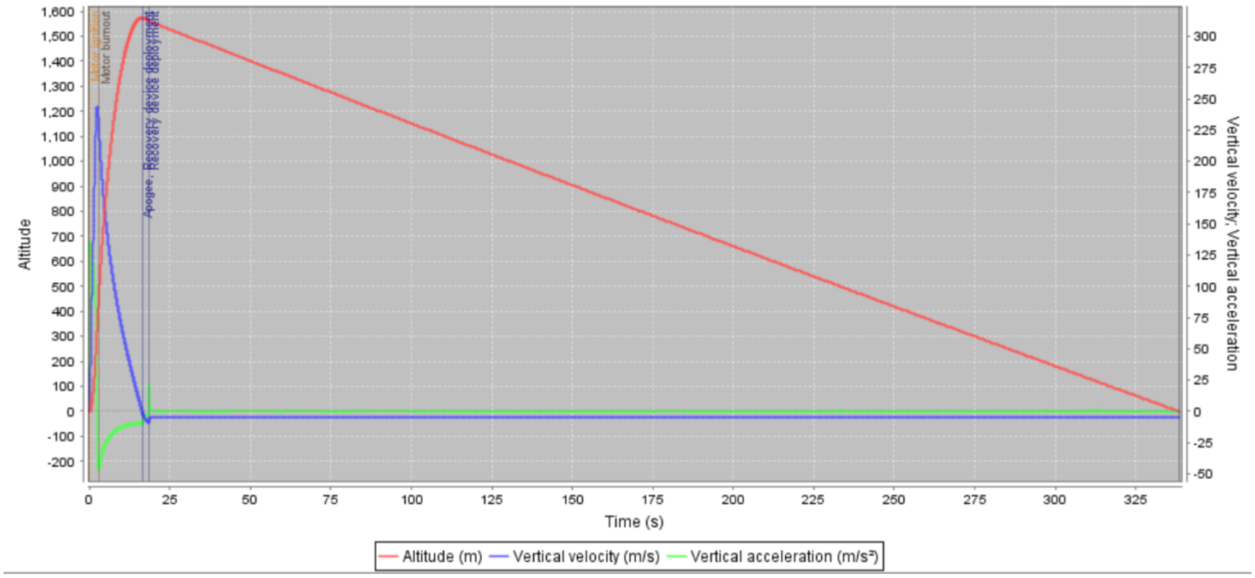
As noticed in the experiments; The fins added to the upper body of the rocket significantly reduce the stability by changing the center of gravity and pressure center. If this front-mounted wing is too large, stability values may even drop below 1, and to compensate for this, we need to design the rear fin in huge dimensions. Of course, this choice should be avoided, as the growing fin will have more weight. For these reasons, only small fins and draft tests were made on the front fuselage in the simulation trials and the results were analyzed according to these. Two test rockets and flight simulations with these rockets are as follows:



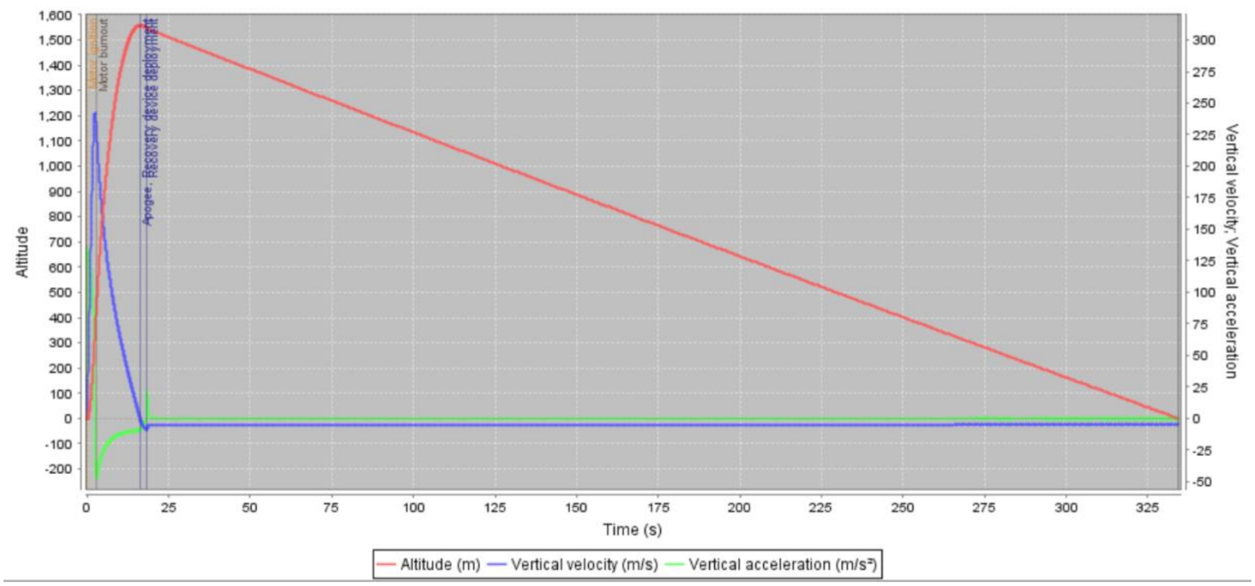
Rocket-1B



Rocket-2B



Rocket-1B Flight Simulation



Rocket-2B Flight Simulation As

As can be seen, there is no significant difference in the result between the two paintings and the two rockets. Compared to the differences between the rockets in item A, the altitude difference of the rockets in item B is a very small value, such as 17 meters. In item A, this loss was simulated as the lowest 55 meters. The rockets with additional fins designed in this article also seem to be designed successfully in real life, as seen from the simulations. However, the results show that the rocket designs in item B are more inefficient than the characteristics of a rocket with no additional fins, as in item A. You will not need to use such an additional fin unless you have a goal of tampering with the rocket's center of pressure.

According to the general experience obtained as a result of the tests, if you are sure to install additional fins, you should attach these additional fins to the front body to reduce stability and to the rear body to increase it. Considering these conditions, special designs can be made that have sufficient qualifications and can successfully perform the flight, although they do not have absolute efficiency.

The design of the SpaceX Starship rocket, which was successfully launched at the end of 2020, was exactly the type of rocket mentioned in article B. The main differences from item B are that this rocket has a very large nose cone, the mentioned additional fins are placed 2 on top of this nose cone, and there are only 2 fins in the lower body, that is, in the basic position. There is a critical reason for making this interesting design, which is very difficult to manufacture: soaring. We see that the rocket flies calmly towards a certain height during its flight, then when the target point is reached, the rocket engines are turned off, the Starship rocket moves to a horizontal position and starts to glide. to the landing area

This floating rocket is designed to make a vertical landing again. The rocket engines are re-ignited, the rocket is brought to a vertical position with the propellant forces and begins to make a vertical descent. However, due to the failure of one of the engines, the landing is attempted only with the remaining rocket engines and the Starship rocket, which cannot slow down naturally enough, crashes to the ground and explodes.

SpaceX Starship Rocket And Gliding Moment

C. Analysis of Additional Fins Added to the Front Body Without Engine

The most critical item, item C, is based on a multi-engine system. In other words, while the main rocket engine is working up to a certain altitude, after the main engine is exhausted, the separation between the bodies occurs and the second rocket engine is activated and our rocket continues its flight. Apart from the difficulty of the design, the high synchronization requirement and the low success rate compared to the classic, we can also analyze this structure in terms of aerodynamics. The experiment we did

We also succeeded in obtaining successful results in the simulations of their designs.

Since adding fins in A and B items did not give us the desired result in terms of altitude, we explained that it was unnecessary unless there were special conditions and requests. However, there is no altitude loss when an extra engine is involved. Although the weight of the extra rocket and additional fins reduces the maximum speed and maximum acceleration, our altitude values are

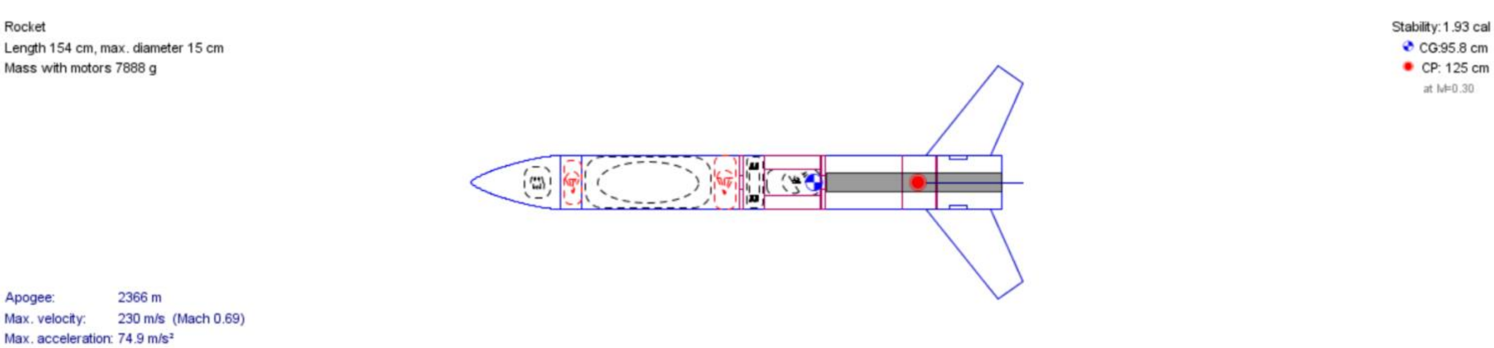
these designs are above normal values.

The fins to be added to the rocket must be as far from the nose cone as possible and as close to the engines as possible. If the additional fins are close to the nose cone, it will affect the flight of the rocket in two stages:

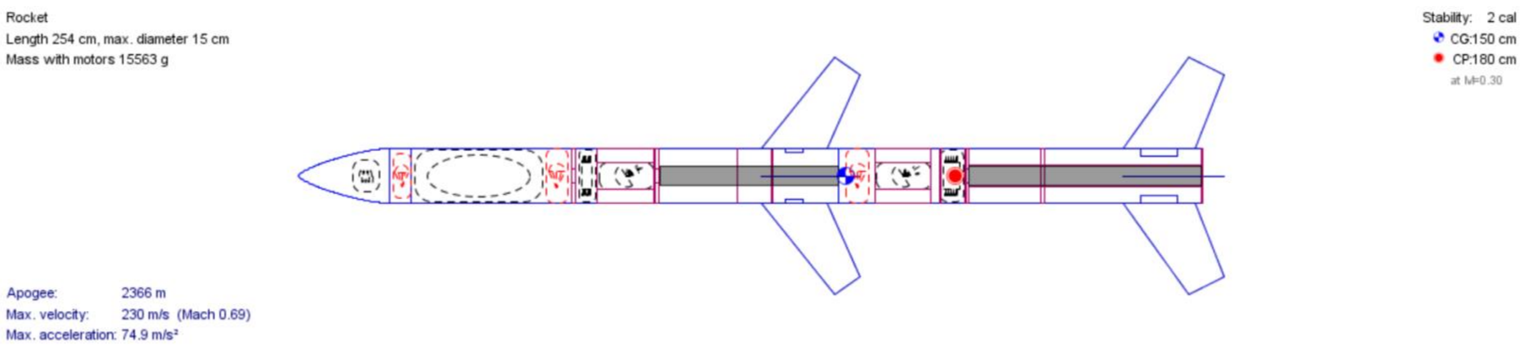
The first stage is the stage in which the rocket flies as a whole, at which the position of the fin will decrease the stability values of the rocket and to balance it,

the fins will need to be designed even larger. This will reflect to us as extra weight and altitude loss.

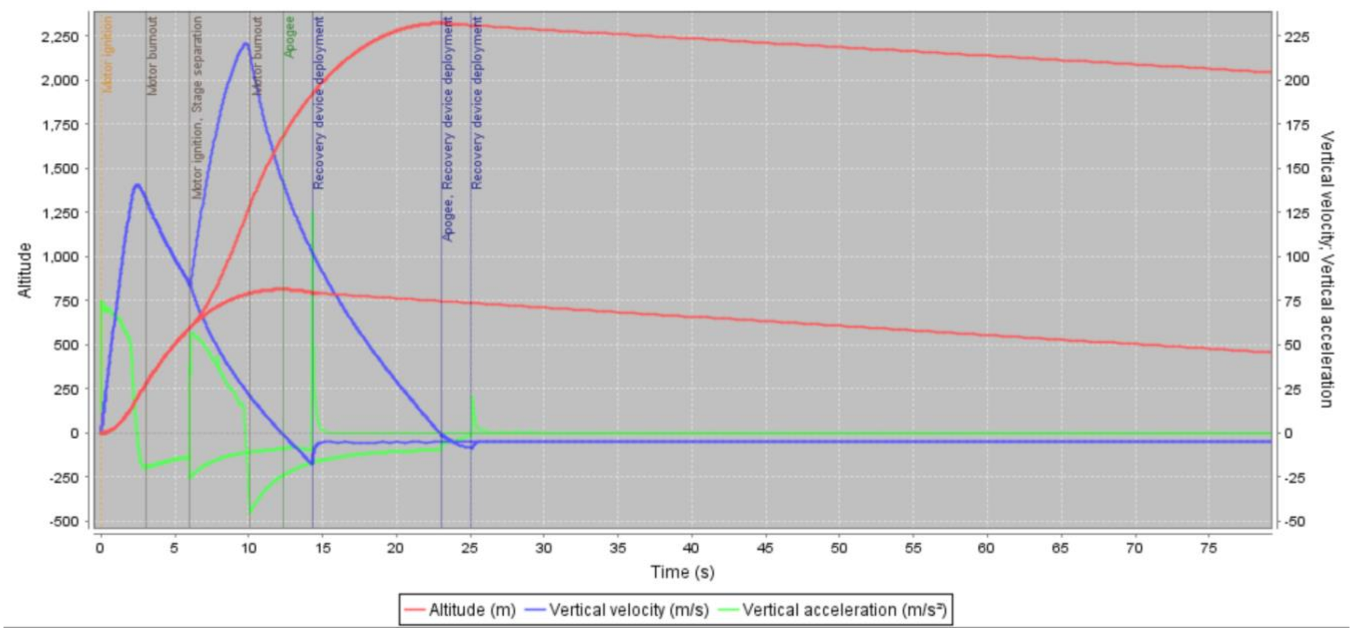
The second stage is the post-departure flight process. After the rocket has successfully disengaged, only the upper body and nose cone will remain. So the upper body will actually act like any other rocket. If we position the fins close to the nose cone, the center of gravity and the center of pressure will change position significantly and the stability of the rocket after separation may even decrease to values below zero. This means that the rocket starts somersaults and crashes into the ground unsuccessfully. For these reasons, additional fins should be as small as possible and adequately sized for post separation stability, and should be positioned as close as possible to the rocket engine and as far away from the nose cone as possible. When these conditions are met, a successful flight and landing is of course possible.



Rocket-1C Stage-1



Rocket-1C Stage-2



Rocket-1C Flight Simulation

As can be seen, the main task of a rocket to be designed in accordance with the C clause should be focused on high altitude. As a matter of fact, the system in space shuttles is also based on this logic. Extra rocket engine, extra fuel spent, extra parts, in short, a bigger rocket; means more expense.

D. Determined for the Next Stage

As a result of all our Openrocket analyzes, the rockets that are planned to be transferred to the Solidworks drawing stage in order to carry out detailed analyzes on Ansys and their types, along with their reasons, are as follows:

-Reference Rocket has been selected. In order to make a comparison, it was deemed appropriate to examine the flow of our reference rocket. In addition, the flow analysis of the reversed fins of the reference rocket was also carried out.

- Rocket-1C Stage-2 version has been selected. In order to compare the flow on it and to find the optimum blade mounting position; It has been deemed appropriate to make the designs with the position where the main fins and the additional fins will be parallel to each other and the position with an angle of 45 degrees between them, to be made over the Solidworks program and then to be subjected to Ansys analysis.

Other analyzed rocket designs were not selected for various reasons mentioned in their articles.

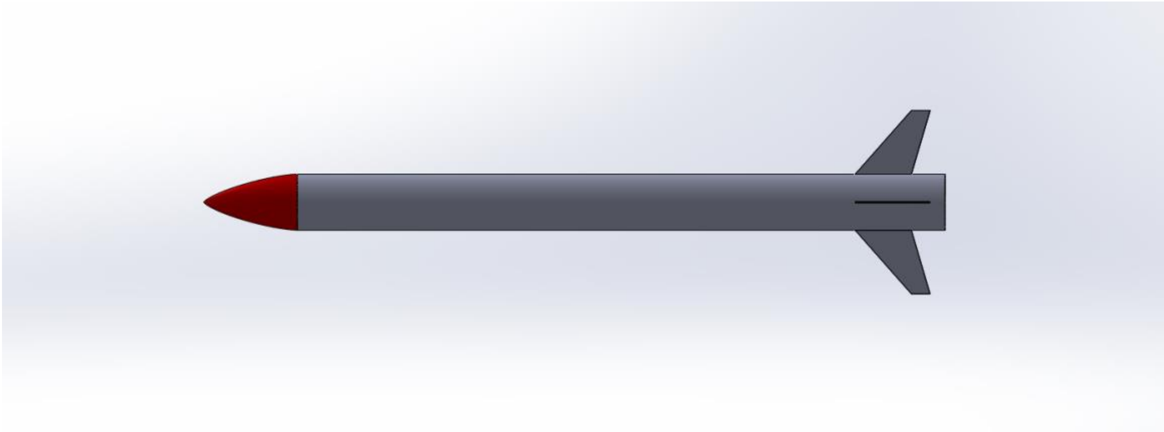
3) Solidworks Designs

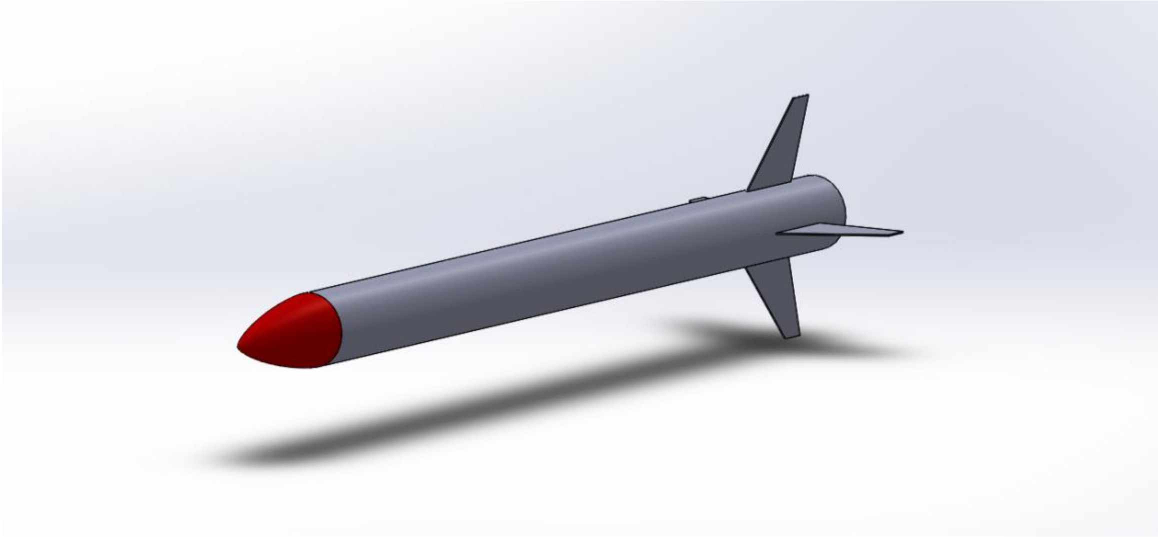
Our Solidworks designs have been designed in accordance with the outlines of Openrocket designs and transferred to Ansys geometry with the "Parasolid" format so that we can use them in our Ansys analysis.

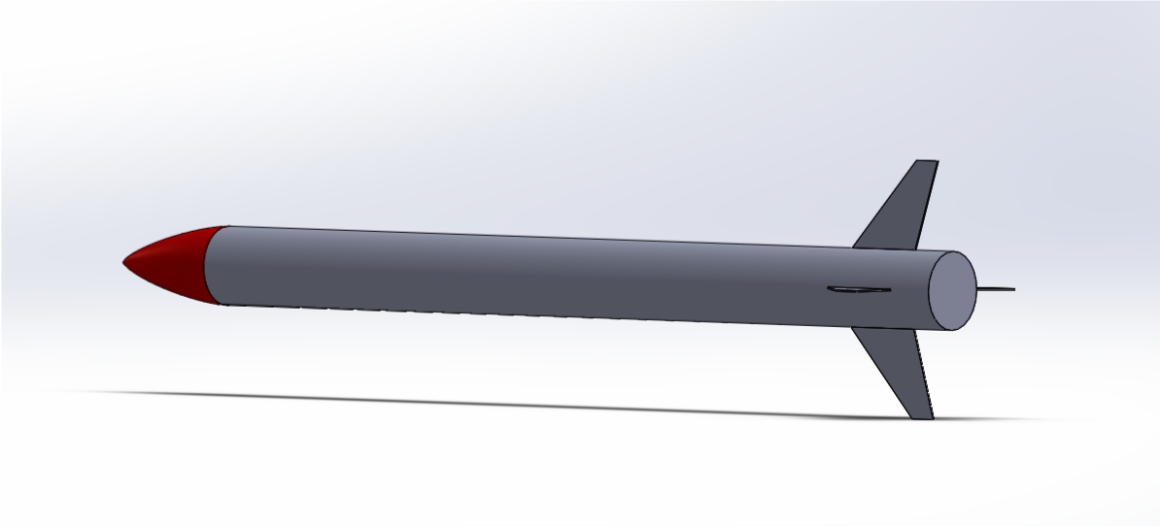
A minor careless issue was encountered while importing designs into Ansys:

During the assembly of the fins in Solid, the fins were not fully seated on the fuselage and millimetric errors occurred in the assembly of the straight cut fins to the curved fuselage. Solidworks drawings were reviewed in detail and necessary adjustments were made to the drawings. In this way, we did not have any problems while transferring our Solidworks designs to Ansys. Our Solidworks designs are shared as images below:

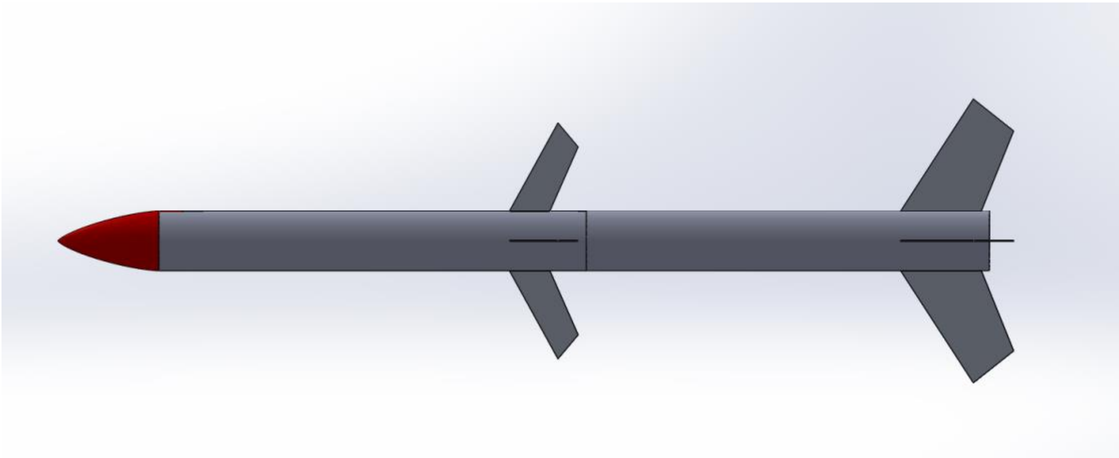
- Reference Rocket Solidworks Design:

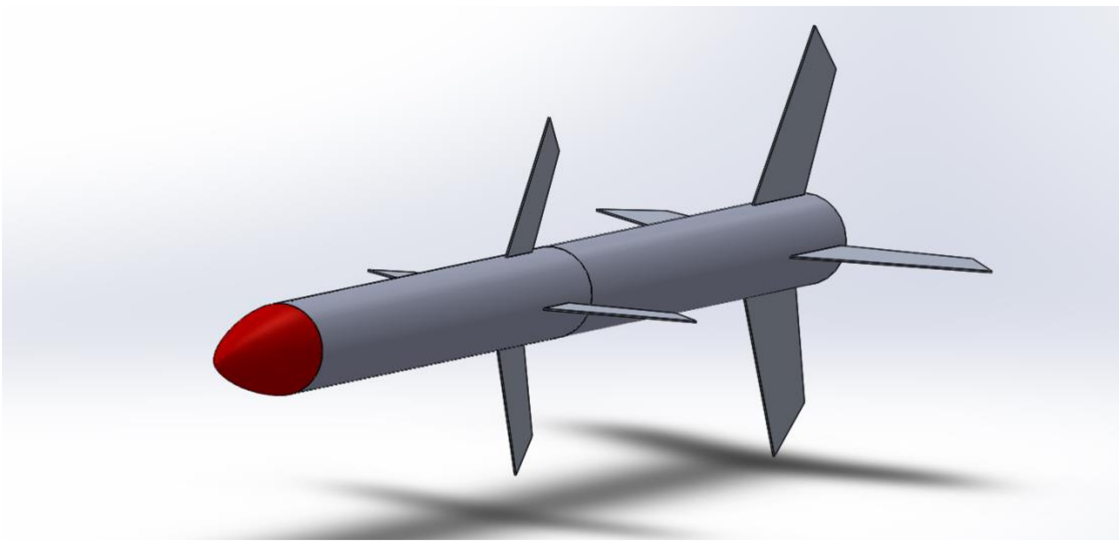


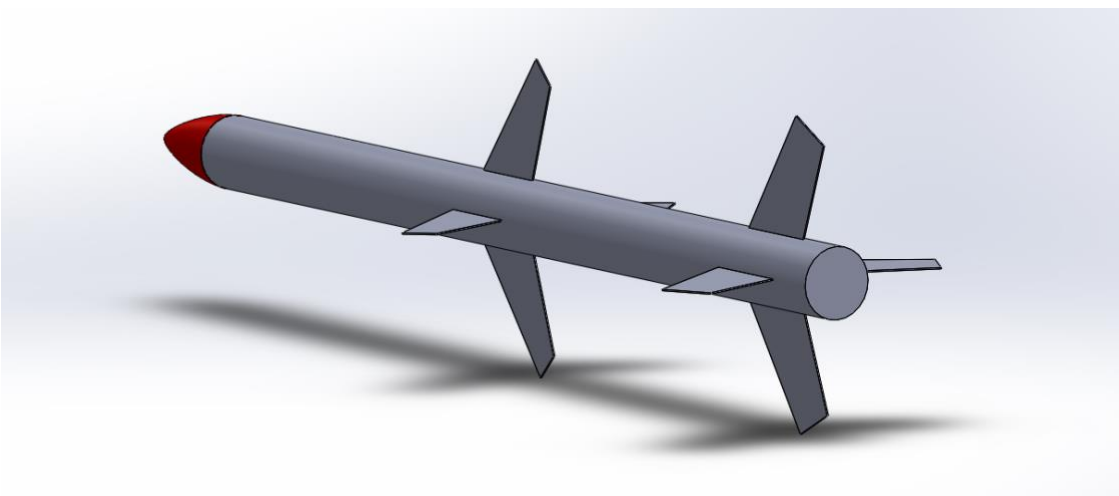




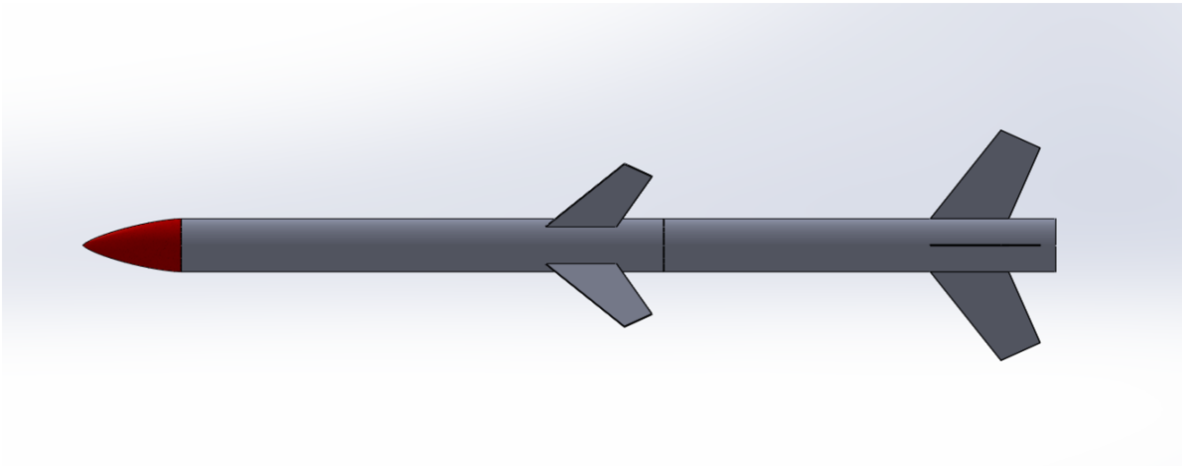
- Multistage Rocket 1-C Solidworks Design:

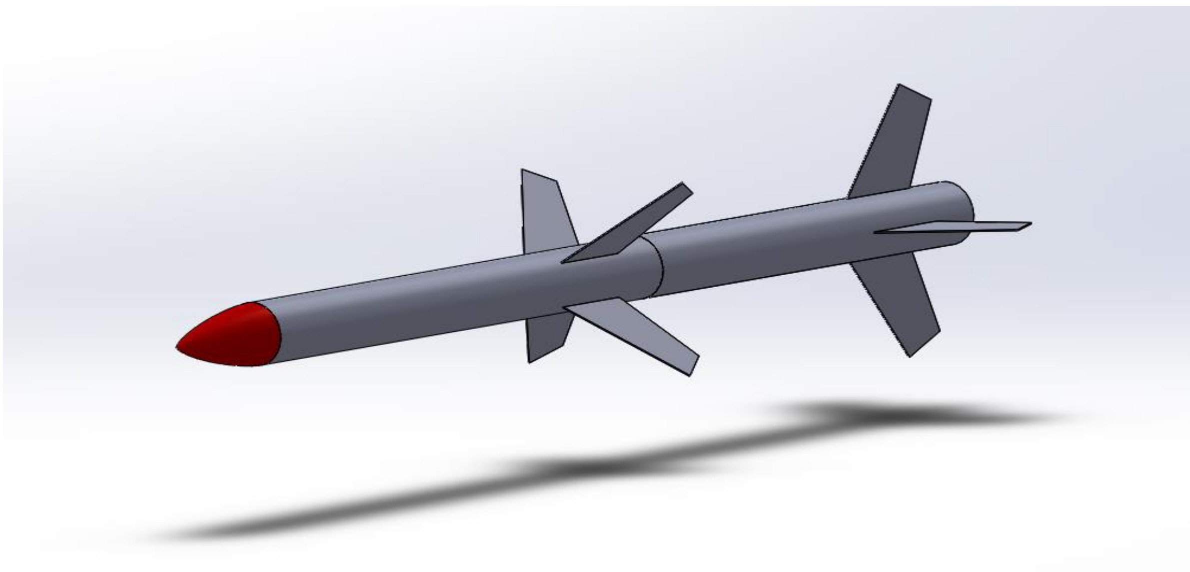


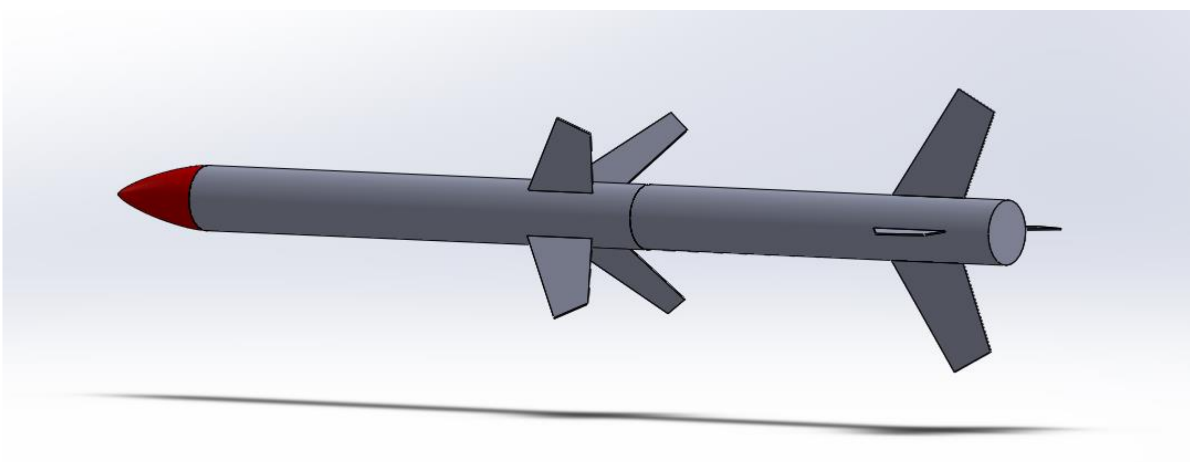




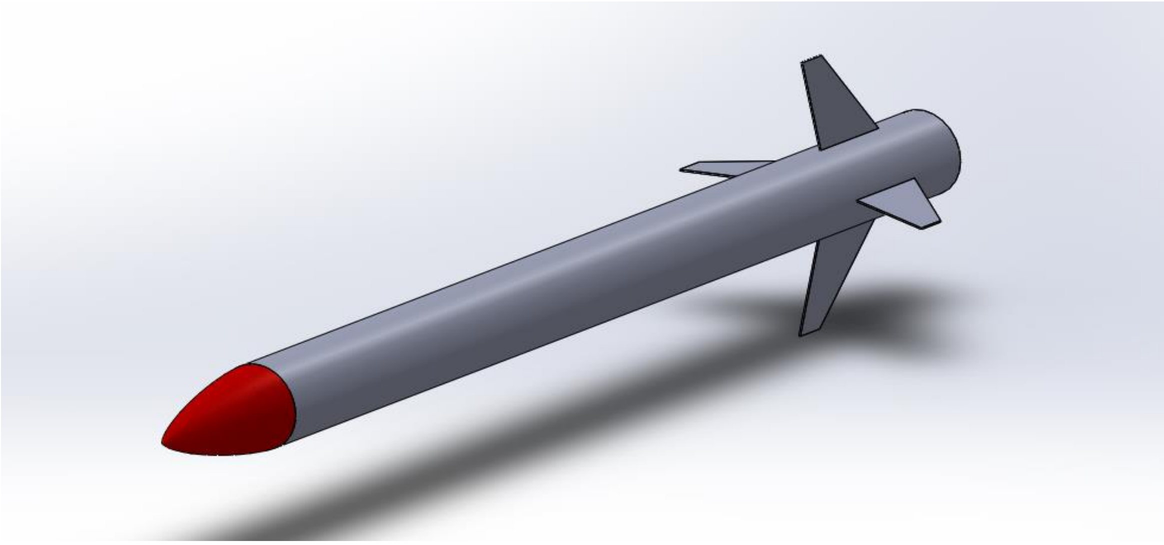
- Multistage Rocket 1-C (Rotated 45 Degrees) Solidworks Design:

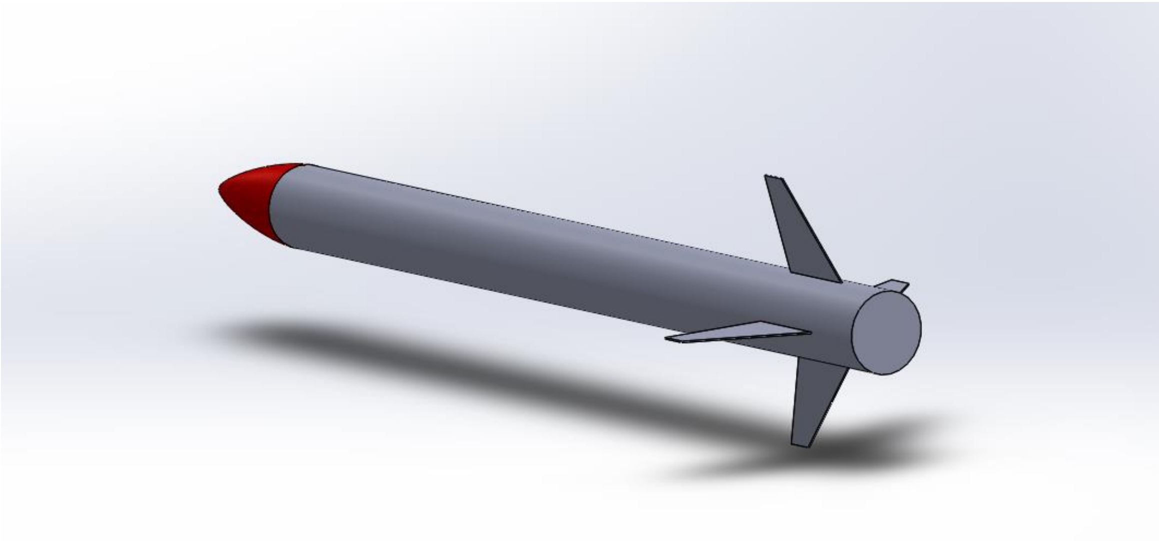






- Reference Rocket (With Inverted Fins) Solidworks Design:





4) ANSYS Analysis

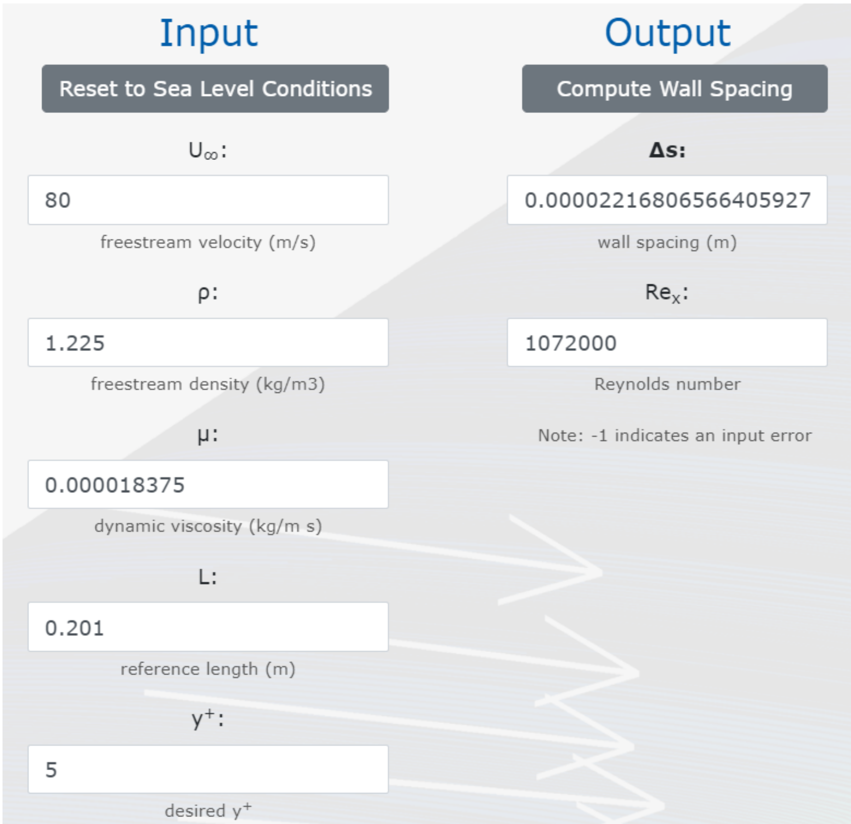
In our ANSYS analyzes, our flow analyzes were performed over Fluid Flow (Fluent). Necessary data and information were determined via Openrocket and air was used as the fluid. Geometry is drawn with a single control volume, designated as the Parasolid (.x_t) extension of Solidworks designs. However, when drawn with a single control volume, the meshing process was quite problematic. The computer, which rebuilt the entire rocket for a sizing given to the fins, started to make poor quality and long-lasting meshes. Therefore, the single control volume has been increased to two control volumes and the second control volume has been plotted to coincide exactly with the fins. In this way, when sizing is given, the processes are accelerated and a mesh suitable for the solution is obtained by giving a small amount of sizing.

Although the mesh quality was tried to be ensured by deleting zero from the First Layer Thickness value before changing the control volume, it was abandoned because this would affect the solution and could not solve the mesh problem fundamentally.

In addition to these, the rockets were transferred to the Ansys environment in a reduced ratio of 1/10 of the original, and in this way, the mesh and solution process was accelerated. In shrinking rockets, the flow velocity also changed in the ratio of the square root of the length ratio, and appropriate solutions were assigned to these shrunken rockets with their own reduced velocity values in Ansys calculations. Our First Layer Thickness values together with our Openrocket data, via the Y+ Calculator over the internet
calculated.

The visuals and explanations regarding the analyzes of the rockets are given below in detail, separately:

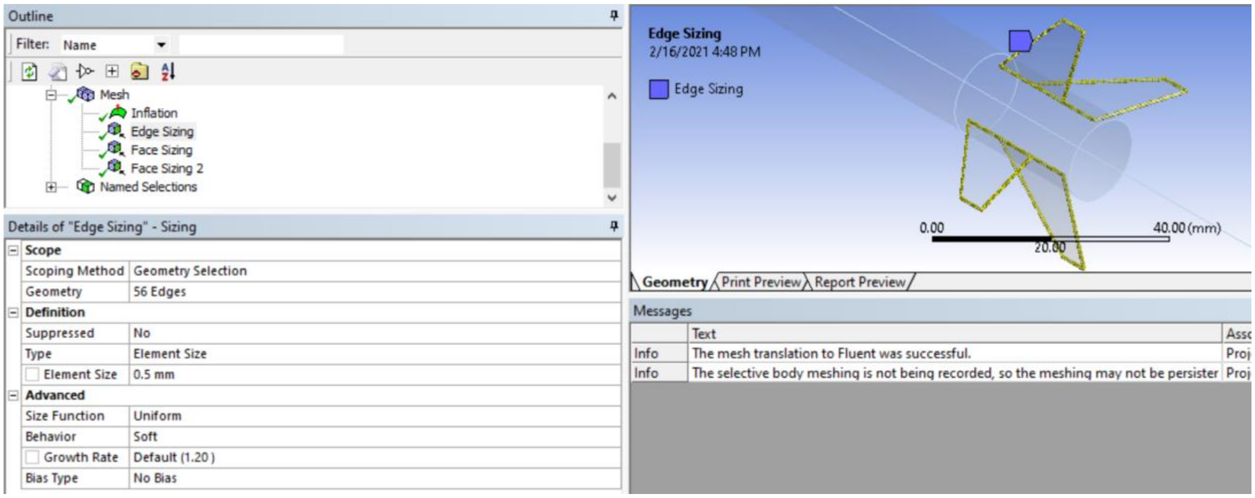
a) Reference Rocket Ansys Analysis

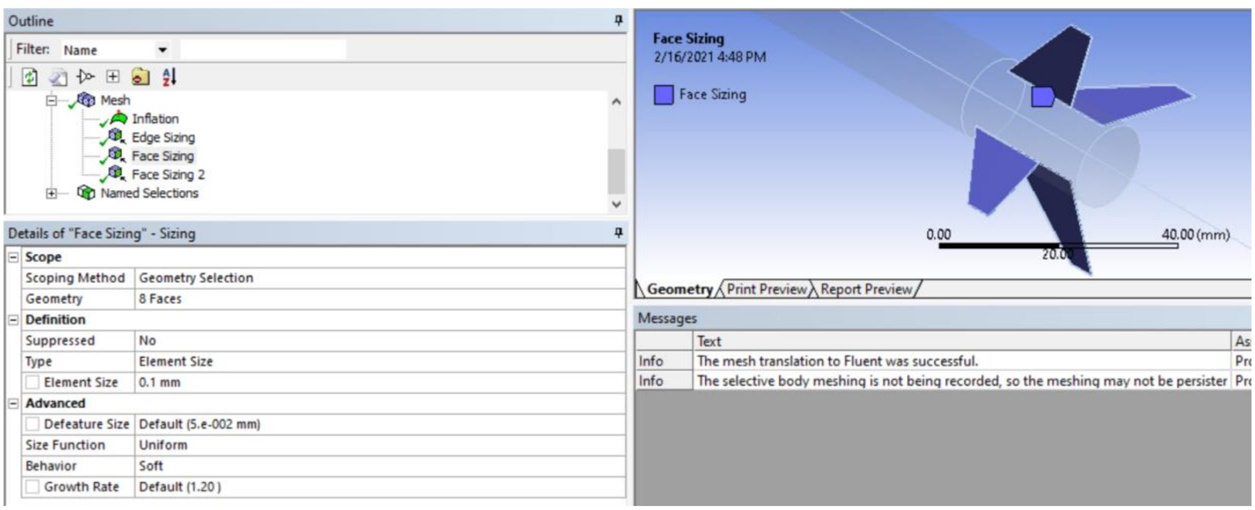


- Mesh

Details of "Inflation" - Inflation

Scope	
Scoping Method	Geometry Selection
Geometry	2 Bodies
Definition	
Suppressed	No
Boundary Scoping Method	Named Selections
Boundary	wall
Inflation Option	First Layer Thickness
First Layer Height	2.216e-002 mm
Maximum Layers	10
Growth Rate	1.2
Inflation Algorithm	Pre


Outline
Filter: Name
Mesh
Inflation
Edge Sizing
Face Sizing
Face Sizing 2
Named Selections
Details of "Edge Sizing" - Sizing
Scope
Scoping Method | Geometry Selection
Geometry | 56 Edges
Definition
Suppressed | No
Type | Element Size
Element Size | 0.5 mm
Advanced
Size Function | Uniform
Behavior | Soft
Growth Rate | Default (1.20)
Bias Type | No Bias
Edge Sizing
2/16/2021 4:48 PM
Edge Sizing
0.00
20.00
40.00 (mm)
Geometry
Print Preview
Report Preview
Messages
Text
Info | The mesh translation to Fluent was successful.
Info | The selective body meshing is not being recorded, so the meshing may not be persister


Outline
Filter: Name
Mesh
Inflation
Edge Sizing
Face Sizing
Face Sizing 2
Named Selections
Details of "Face Sizing" - Sizing
Scope
Scoping Method | Geometry Selection
Geometry | 8 Faces
Definition
Suppressed | No
Type | Element Size
Element Size | 0.1 mm
Advanced
Defeature Size | Default (5.e-002 mm)
Size Function | Uniform
Behavior | Soft
Growth Rate | Default (1.20)
Face Sizing
2/16/2021 4:48 PM
Face Sizing
0.00
20.00
40.00 (mm)
Geometry
Print Preview
Report Preview
Messages
Text
Info | The mesh translation to Fluent was successful.
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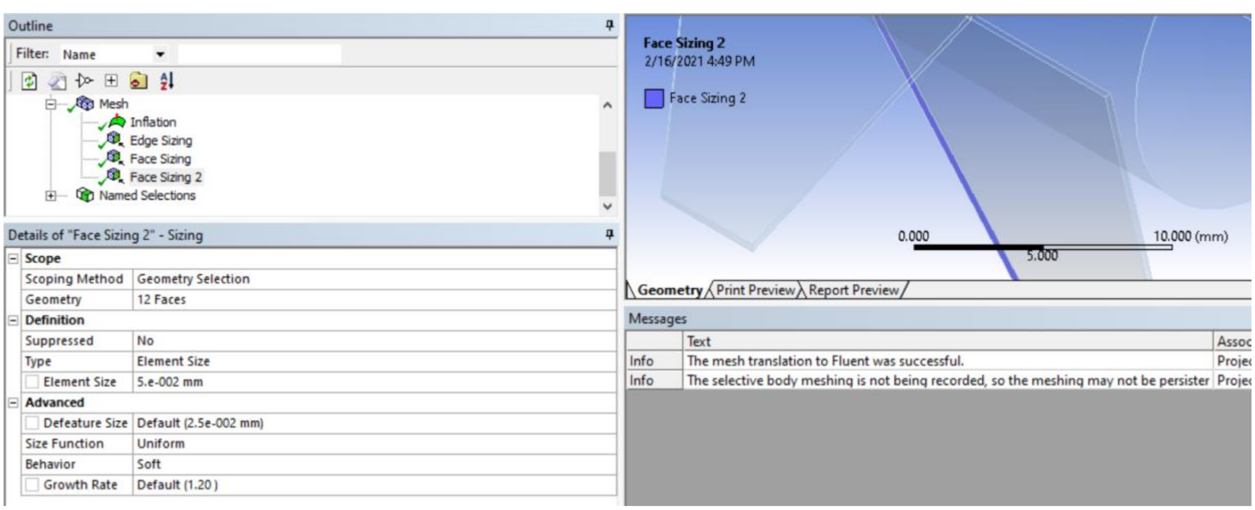

Outline
Filter: Name
Mesh
Inflation
Edge Sizing
Face Sizing
Face Sizing 2
Named Selections
Details of "Face Sizing 2" - Sizing
Scope
Scoping Method | Geometry Selection
Geometry | 12 Faces
Definition
Suppressed | No
Type | Element Size
Element Size | 5.e-002 mm
Advanced
Defeature Size | Default (2.5e-002 mm)
Size Function | Uniform
Behavior | Soft
Growth Rate | Default (1.20)
Face Sizing 2
2/16/2021 4:49 PM
Face Sizing 2
0.000
5.000
10.000 (mm)
Geometry
Print Preview
Report Preview
Messages
Text
Info | The mesh translation to Fluent was successful.
Info | The selective body meshing is not being recorded, so the meshing may not be persister

What we have obtained after all your reviews and which are the basic evaluation criteria for us; Aspect Ratio, Skewness and OQ our values are as follows:

Quality	
Check Mesh Quality	Yes, Errors
Target Skewness	0.6
Smoothing	Medium
Mesh Metric	Aspect Ratio
Min	1.1731
Max	417.37
Average	3.4837
Standard Deviation	7.7117

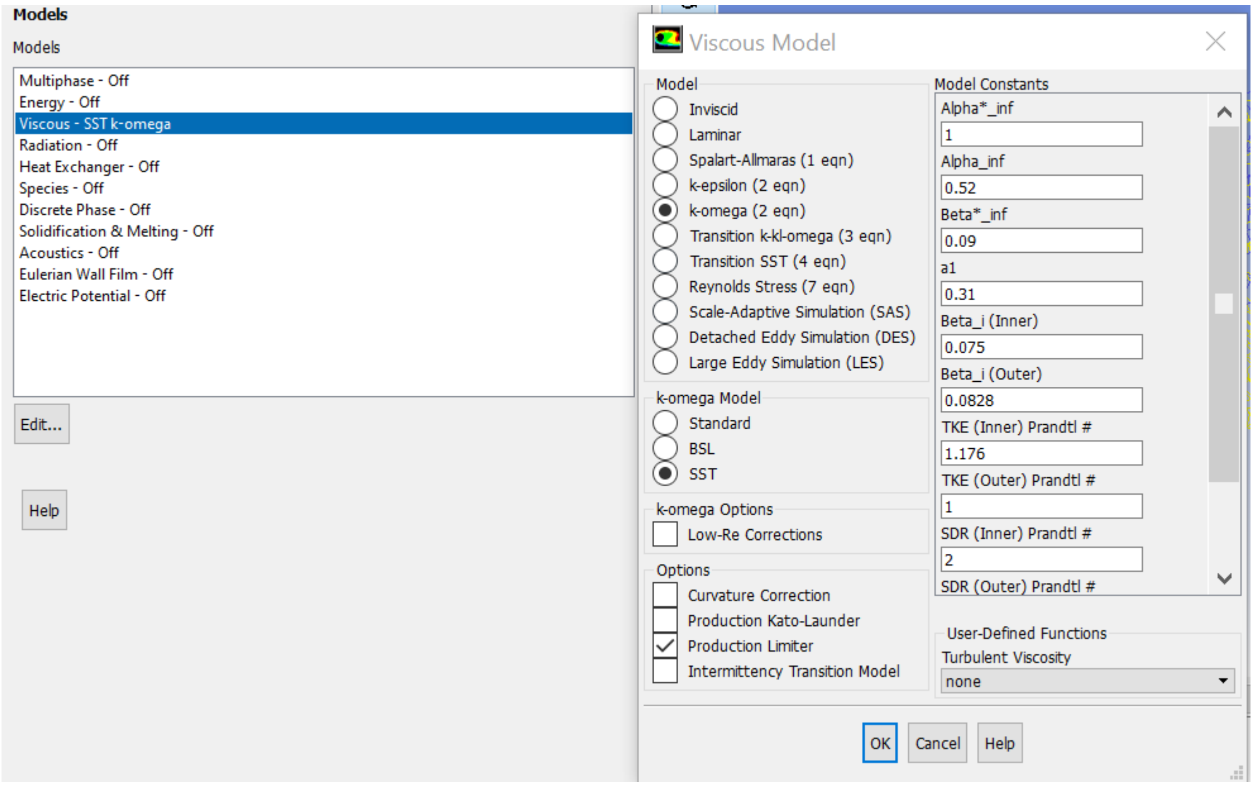
Mesh Metric	Skewness
Min	2.4539e-004
Max	0.92175
Average	0.26455
Standard Deviation	0.14777

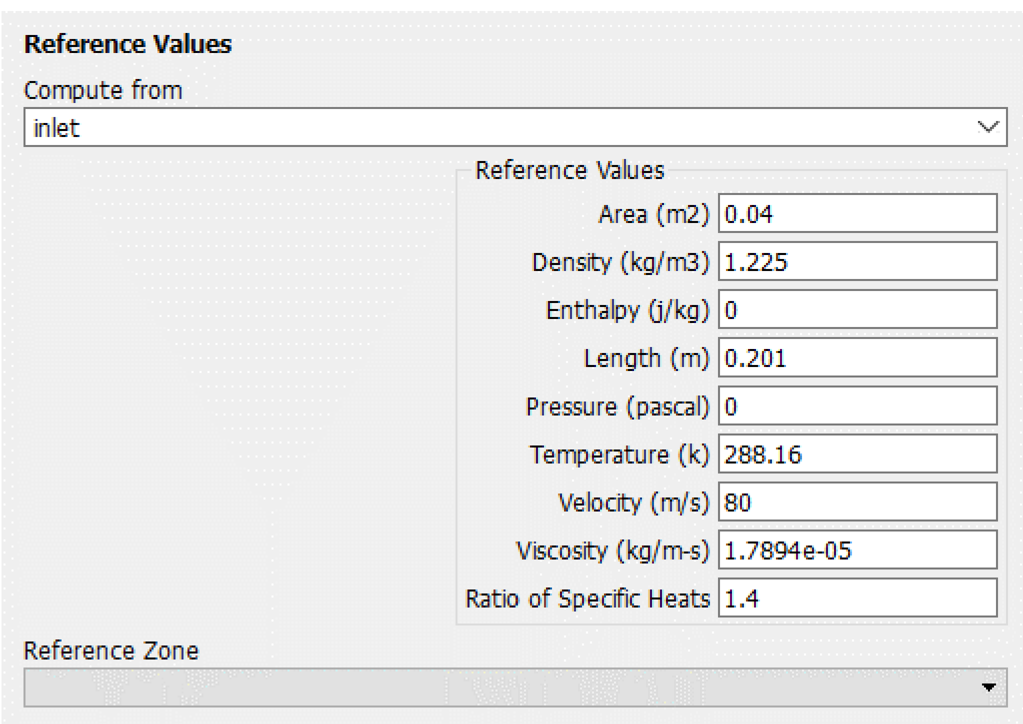
Mesh Metric	Orthogonal Quality
Min	2.7778e-002
Max	0.99934
Average	0.73465
Standard Deviation	0.14828

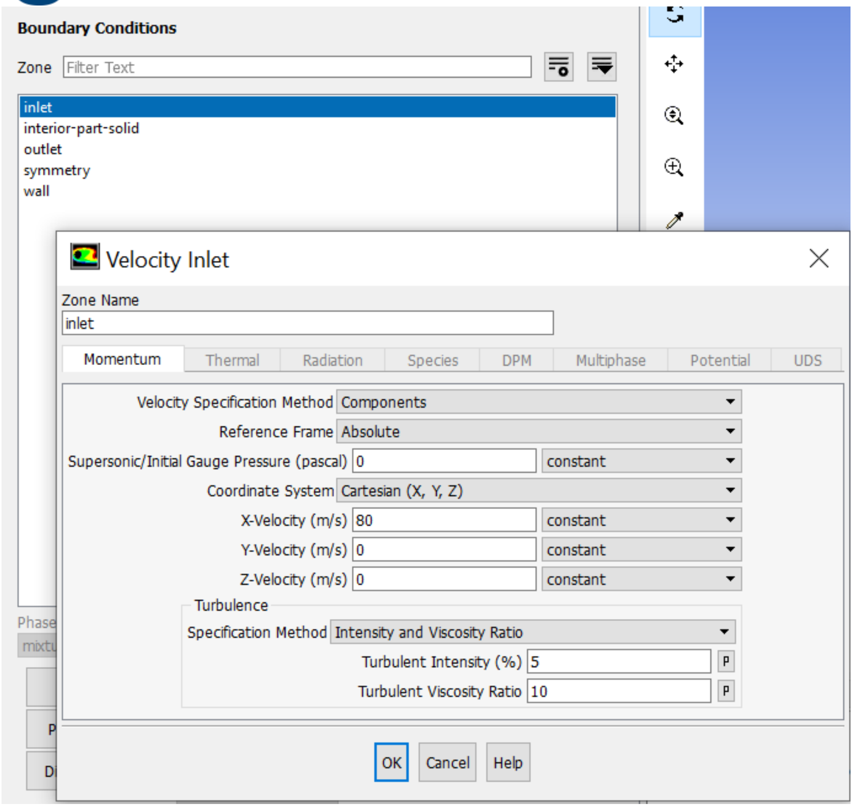
The number of the elements are as follows:

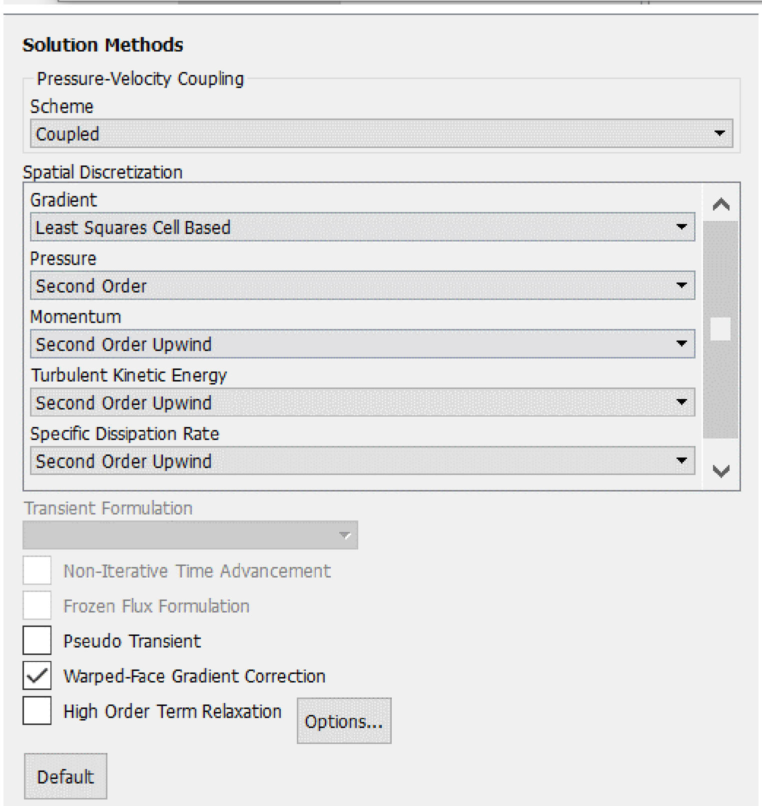
Statistics	
Nodes	1455083
Elements	3788746

-setup


Models
Models
Multiphase - Off
Energy - Off
Viscous - SST k-omega
Radiation - Off
Heat Exchanger - Off
Species - Off
Discrete Phase - Off
Solidification & Melting - Off
Acoustics - Off
Eulerian Wall Film - Off
Electric Potential - Off
Edit...
Help
Viscous Model
Model
Inviscid
Laminar
Spalart-Allmaras (1 eqn)
k-epsilon (2 eqn)
k-omega (2 eqn)
Transition k-kl-omega (3 eqn)
Transition SST (4 eqn)
Reynolds Stress (7 eqn)
Scale-Adaptive Simulation (SAS)
Detached Eddy Simulation (DES)
Large Eddy Simulation (LES)
k-omega Model
Standard
BSL
SST
k-omega Options
Low-Re Corrections
Options
Curvature Correction
Production Kato-Launder
Production Limiter
Intermittency Transition Model
Model Constants
Alpha*_inf
1
Alpha_inf
0.52
Beta*_inf
0.09
a1
0.31
Beta_i (Inner)
0.075
Beta_i (Outer)
0.0828
TKE (Inner) Prandtl #
1.176
TKE (Outer) Prandtl #
1
SDR (Inner) Prandtl #
2
SDR (Outer) Prandtl #
User-Defined Functions
Turbulent Viscosity
none
OK
Cancel
Help

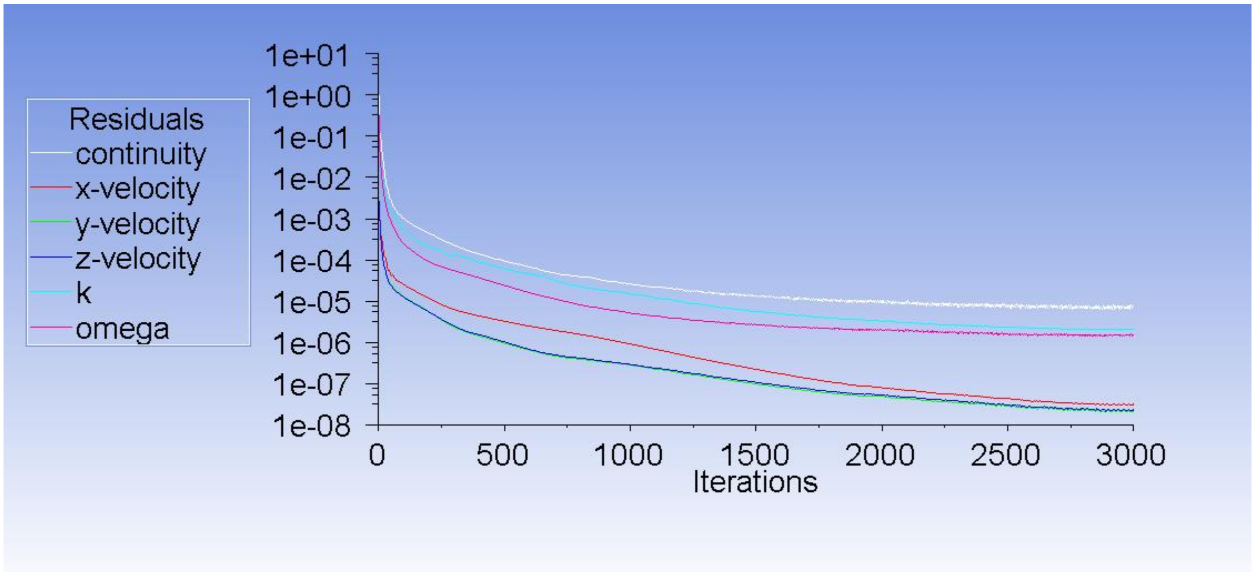

Reference Values
Compute from
inlet
Reference Values
Area (m2) 0.04
Density (kg/m3) 1.225
Enthalpy (j/kg) 0
Length (m) 0.201
Pressure (pascal) 0
Temperature (k) 288.16
Velocity (m/s) 80
Viscosity (kg/m-s) 1.7894e-05
Ratio of Specific Heats 1.4
Reference Zone

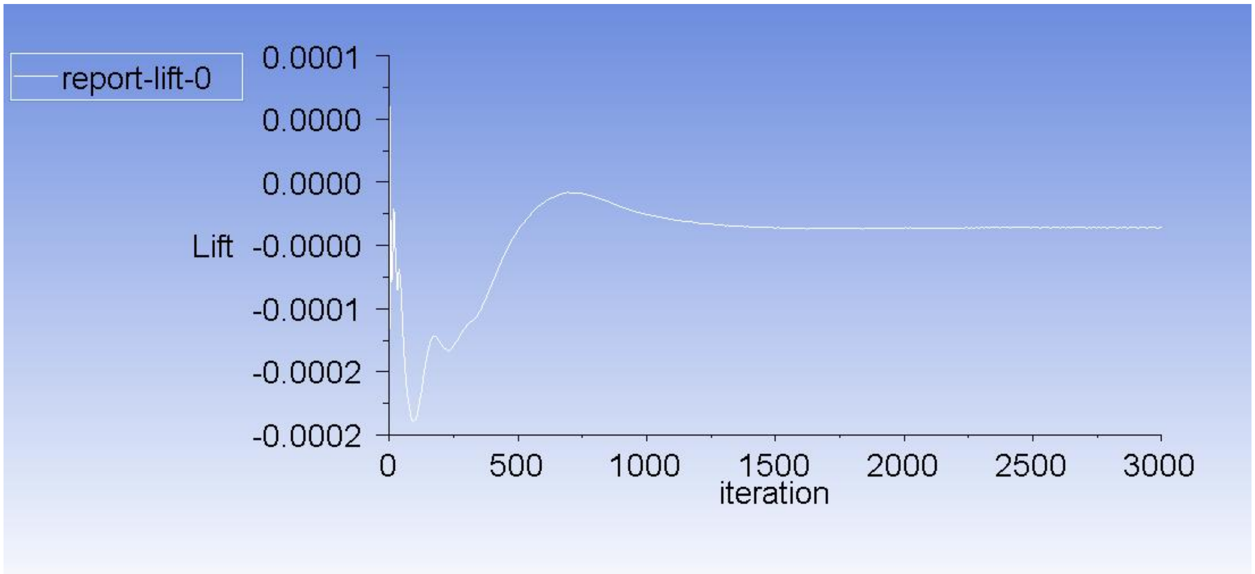

Boundary Conditions
Zone
Filter Text
inlet
interior-part-solid
outlet
symmetry
wall
Velocity Inlet
Zone Name
inlet
Momentum
Thermal
Radiation
Species
DPM
Multiphase
Potential
UDS
Velocity Specification Method Components
Reference Frame Absolute
Supersonic/Initial Gauge Pressure (pascal) 0 constant
Coordinate System Cartesian (X, Y, Z)
X-Velocity (m/s) 80 constant
Y-Velocity (m/s) 0 constant
Z-Velocity (m/s) 0 constant
Turbulence
Specification Method Intensity and Viscosity Ratio
Turbulent Intensity (%) 5
Turbulent Viscosity Ratio 10
OK
Cancel
Help

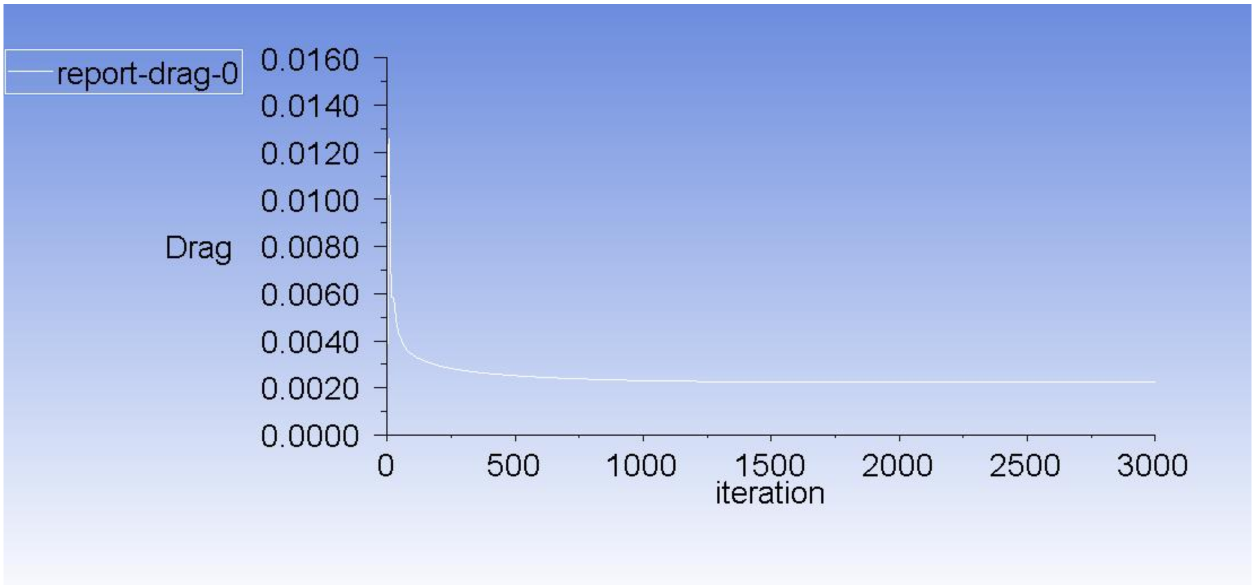

Solution Methods
Pressure-Velocity Coupling
Scheme
Coupled
Spatial Discretization
Gradient
Least Squares Cell Based
Pressure
Second Order
Momentum
Second Order Upwind
Turbulent Kinetic Energy
Second Order Upwind
Specific Dissipation Rate
Second Order Upwind
Transient Formulation
Non-Iterative Time Advancement
Frozen Flux Formulation
Pseudo Transient
Warped-Face Gradient Correction
High Order Term Relaxation
Options...
Default

-Results

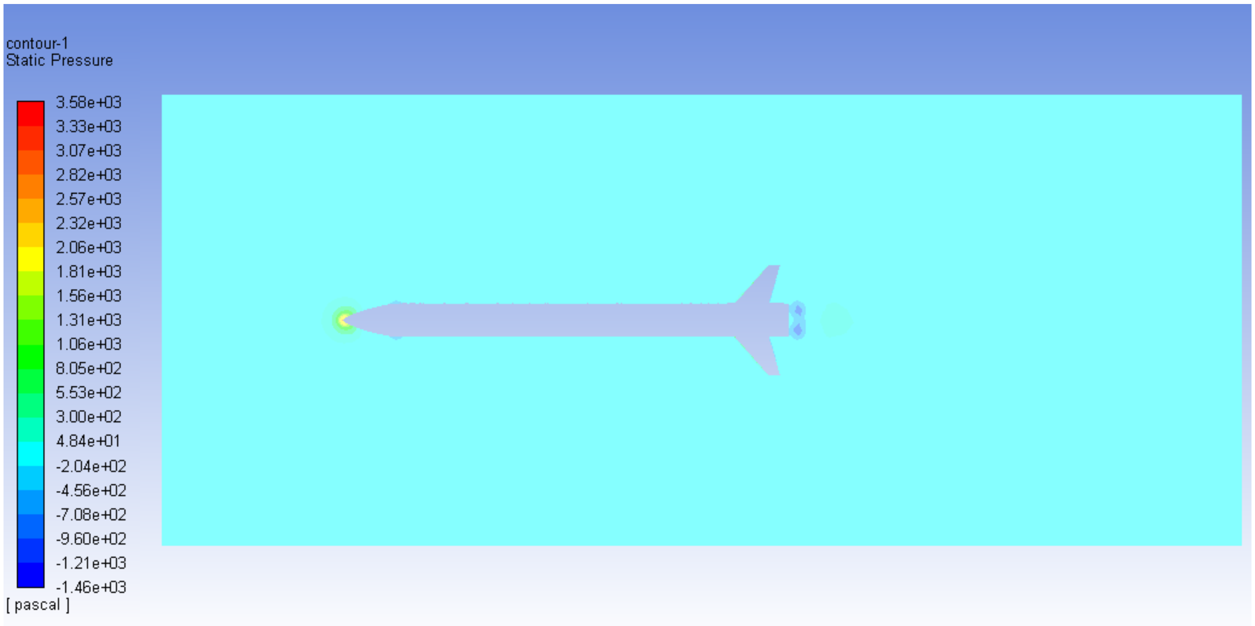
And finally hybrid initialization has switched to the stage of making a solution. Our solution graphics have been reached by giving approximately 4100 iterations. Drag and lift values were plotted simultaneously.

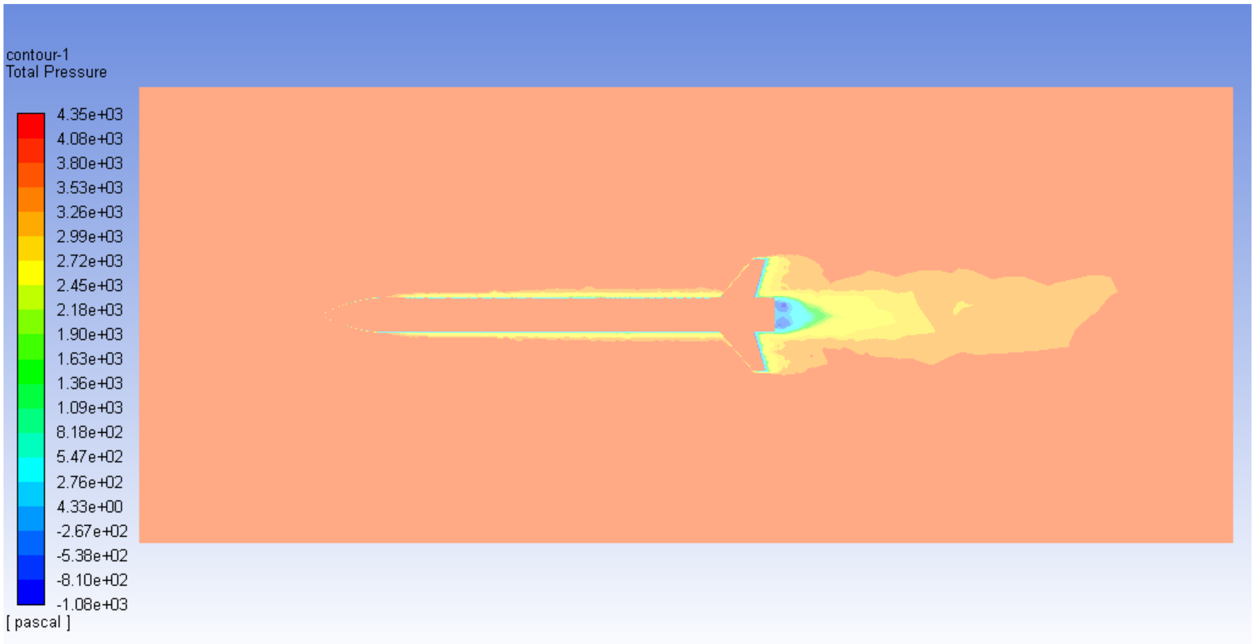




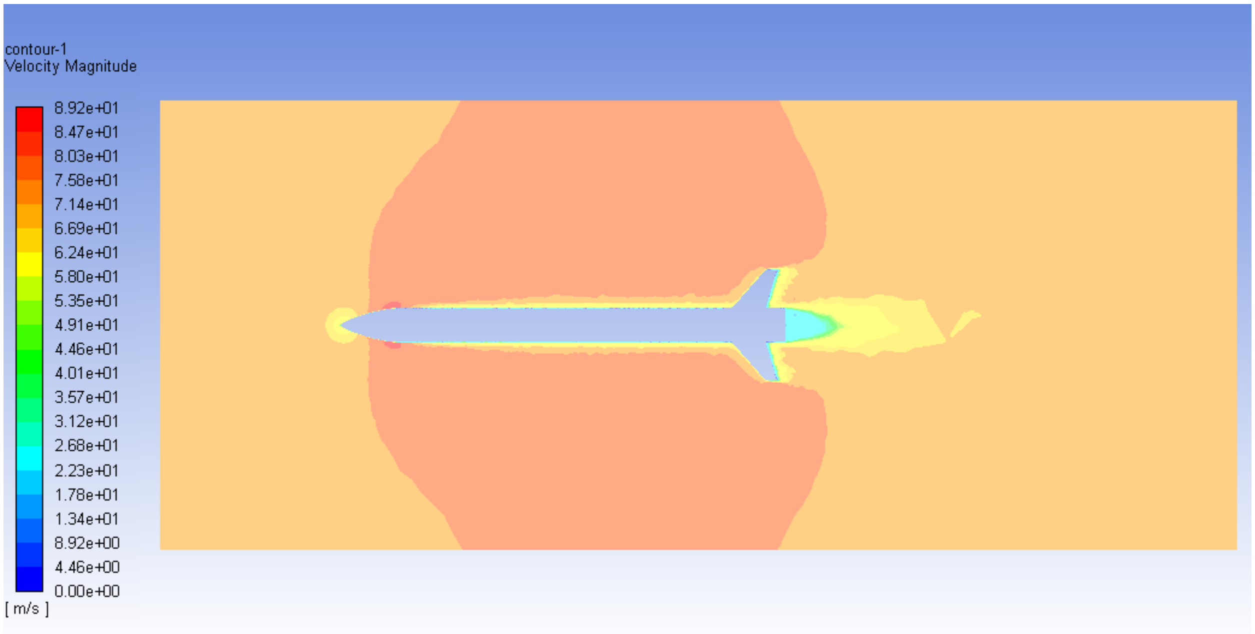


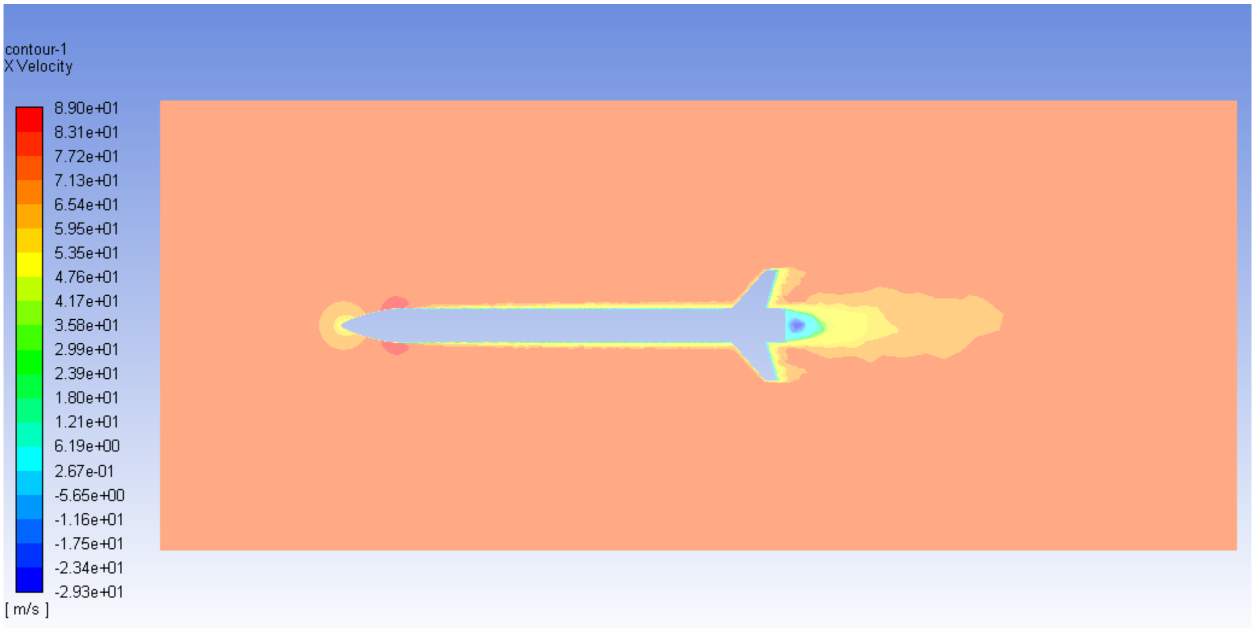
Pressure contours:





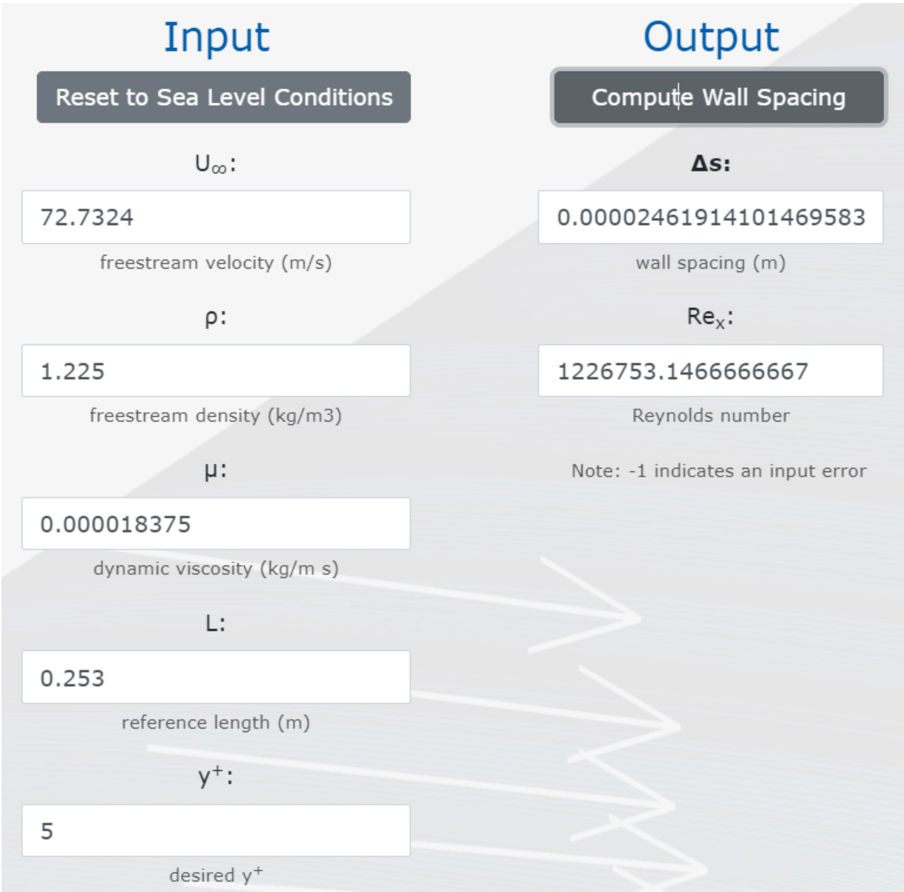
Velocity contours:





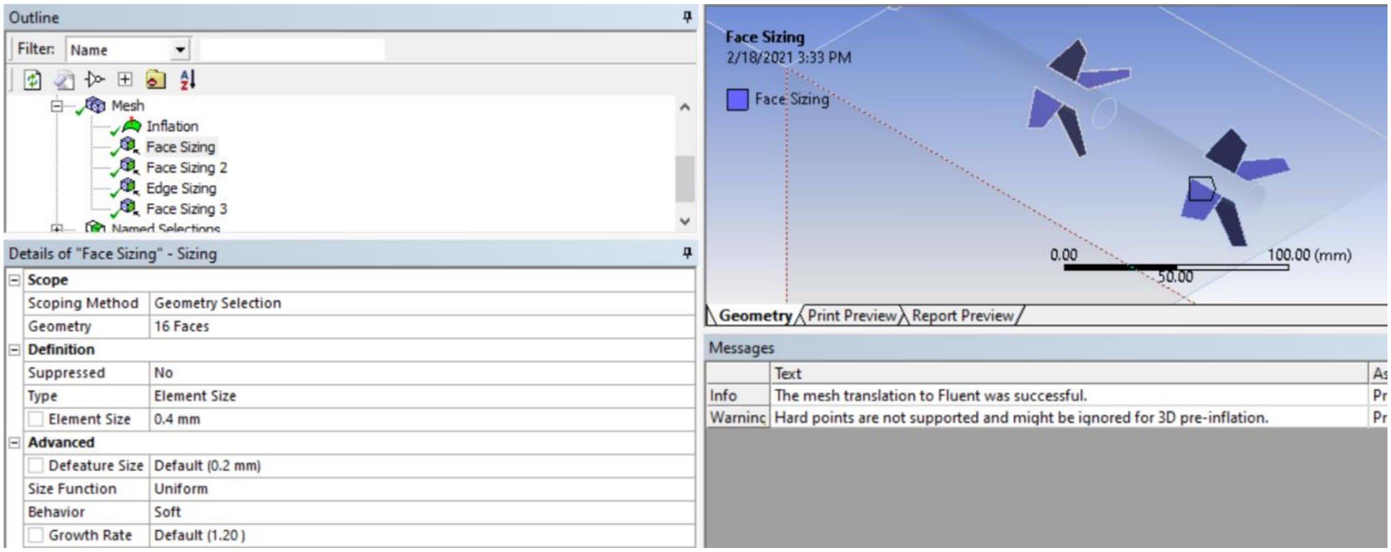
And thus, the analysis of our reference rocket was finished, and the analysis of the rockets we wanted to see started.

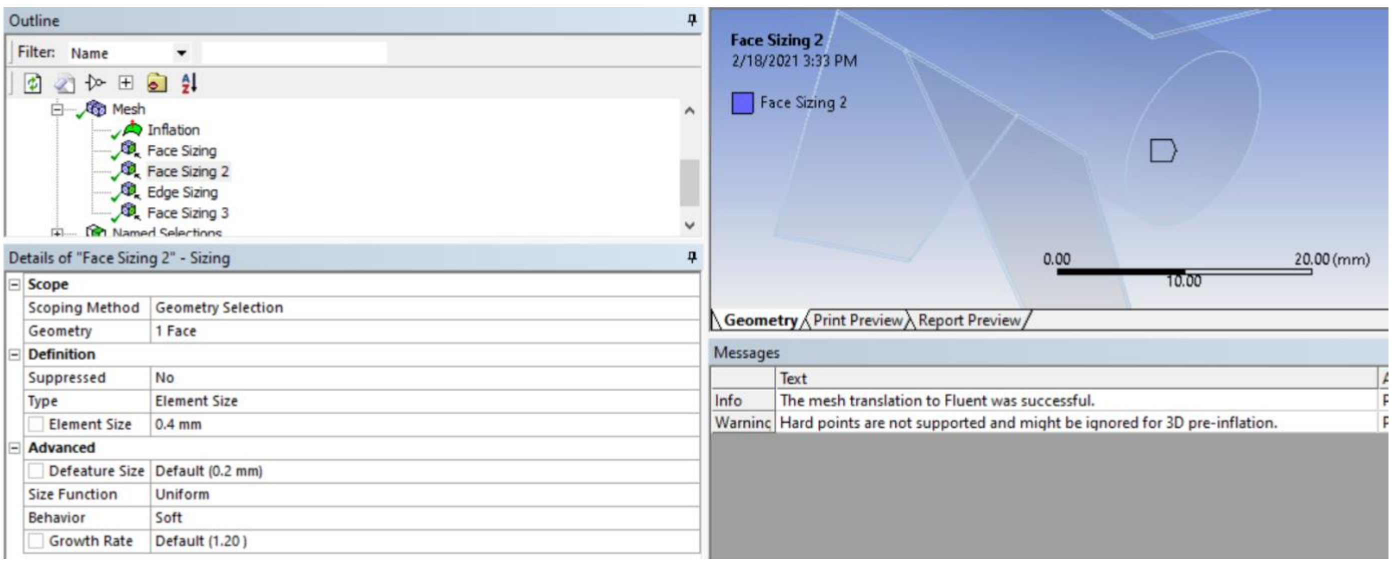
b) Multistage Rocket 1-C Ansys Analysis

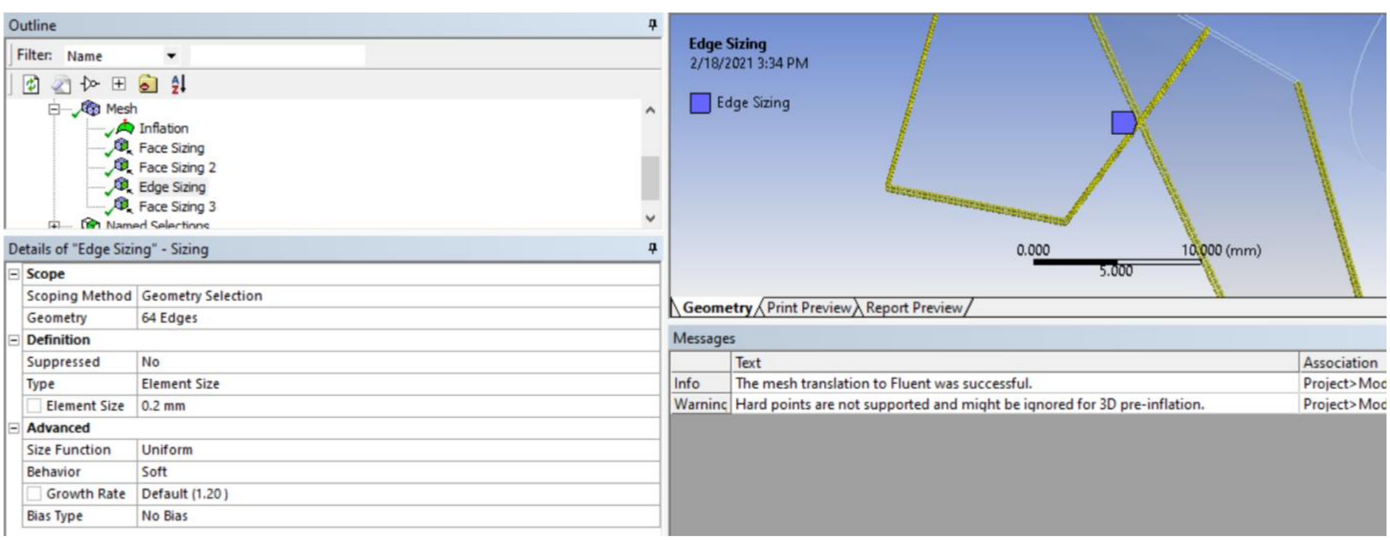


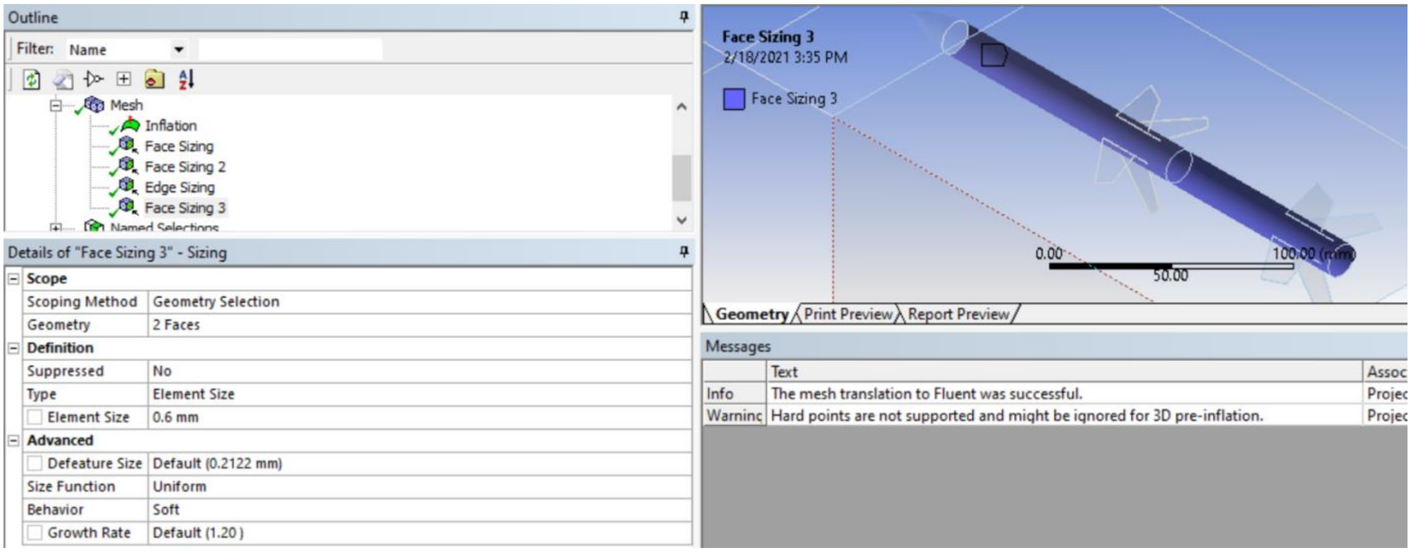
-Mesh

Details of "Inflation" - Inflation	
Scope	
Scoping Method	Geometry Selection
Geometry	2 Bodies
Definition	
Suppressed	No
Boundary Scoping Method	Named Selections
Boundary	wall
Inflation Option	First Layer Thickness
First Layer Height	2.4626e-002 mm
Maximum Layers	10
Growth Rate	1.2
Inflation Algorithm	Pre


Outline
Filter: Name
Mesh
Inflation
Face Sizing
Face Sizing 2
Edge Sizing
Face Sizing 3
Named Selections
Details of "Face Sizing" - Sizing
Scope
Scoping Method | Geometry Selection
Geometry | 16 Faces
Definition
Suppressed | No
Type | Element Size
Element Size | 0.4 mm
Advanced
Defeature Size | Default (0.2 mm)
Size Function | Uniform
Behavior | Soft
Growth Rate | Default (1.20)
Face Sizing
2/18/2021 3:33 PM
Face Sizing
0.00
50.00
100.00 (mm)
Geometry
Print Preview
Report Preview
Messages
Text
Info | The mesh translation to Fluent was successful.
Warninc | Hard points are not supported and might be ignored for 3D pre-inflation.


Outline
Filter: Name
Mesh
Inflation
Face Sizing
Face Sizing 2
Edge Sizing
Face Sizing 3
Named Selections
Details of "Face Sizing 2" - Sizing
Scope
Scoping Method | Geometry Selection
Geometry | 1 Face
Definition
Suppressed | No
Type | Element Size
Element Size | 0.4 mm
Advanced
Defeature Size | Default (0.2 mm)
Size Function | Uniform
Behavior | Soft
Growth Rate | Default (1.20)
Face Sizing 2
2/18/2021 3:33 PM
Face Sizing 2
0.00
10.00
20.00 (mm)
Geometry
Print Preview
Report Preview
Messages
Text
Info | The mesh translation to Fluent was successful.
Warninc | Hard points are not supported and might be ignored for 3D pre-inflation.


Outline
Filter: Name
Mesh
Inflation
Face Sizing
Face Sizing 2
Edge Sizing
Face Sizing 3
Named Selections
Details of "Edge Sizing" - Sizing
Scope
Scoping Method | Geometry Selection
Geometry | 64 Edges
Definition
Suppressed | No
Type | Element Size
Element Size | 0.2 mm
Advanced
Size Function | Uniform
Behavior | Soft
Growth Rate | Default (1.20)
Bias Type | No Bias
Edge Sizing
2/18/2021 3:34 PM
Edge Sizing
0.000
5.000
10.000 (mm)
Geometry
Print Preview
Report Preview
Messages
Text
Association
Info | The mesh translation to Fluent was successful.
Warninc | Hard points are not supported and might be ignored for 3D pre-inflation.



What we have obtained after all your sizing and which are the basic evaluation criteria for us; Our Aspect Ratio, Skewness and OQ values are given below:

Quality	
Check Mesh Qua...	Yes, Errors
Target Skewn...	0.6
Smoothing	Medium
Mesh Metric	Aspect Ratio
Min	1.1677
Max	735.67
Average	6.1101
Standard Devi...	7.9879

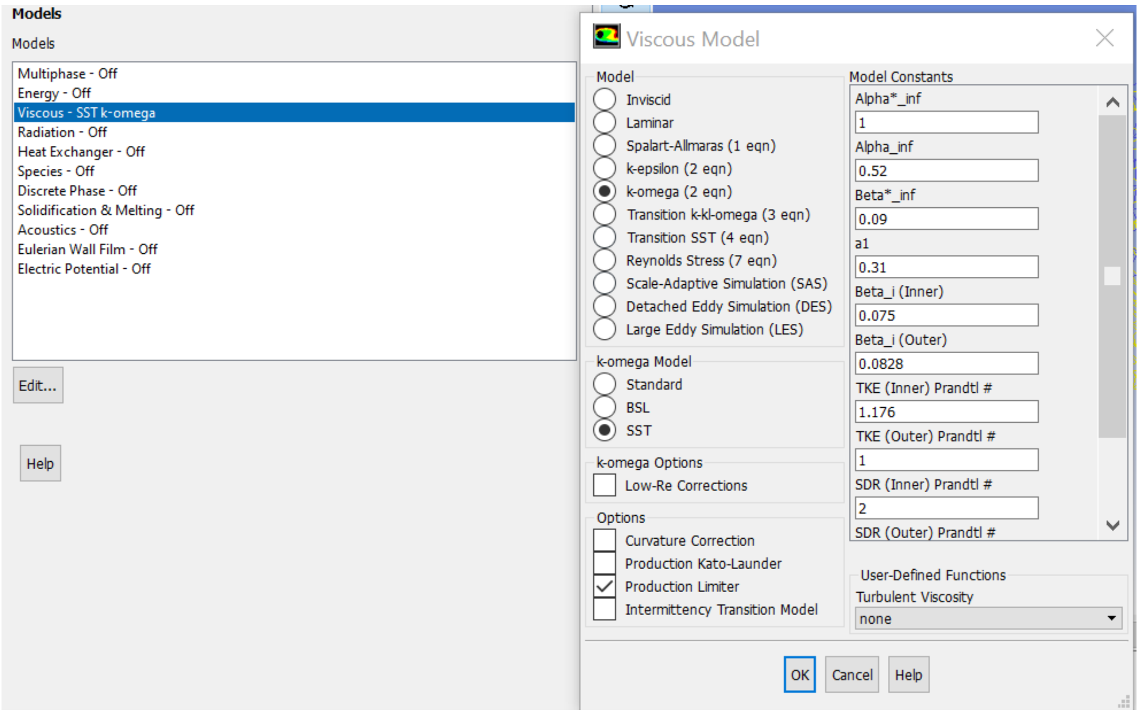
Mesh Metric	Skewness
Min	1.9412e-004
Max	0.74883
Average	0.25318
Standard Deviation	0.15373

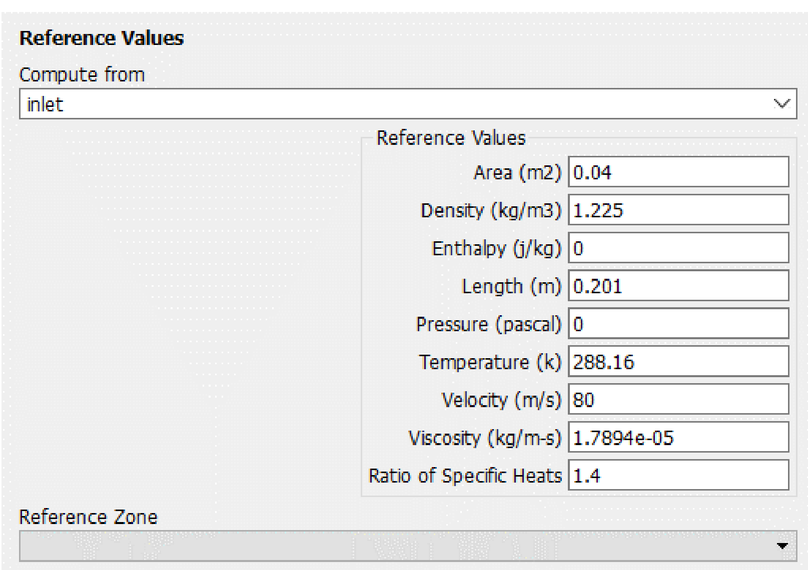
Mesh Metric	Orthogonal Quality
Min	4.8477e-002
Max	0.99836
Average	0.7434
Standard Deviation	0.15786

Our element count is as follows:

Statistics	
Nodes	1334446
Elements	4225210

-Setup





We could not add the Setup section to the report as a screenshot because we got an Ansys Workbench error at the end of our analysis. However, we were able to recover the images of our analysis results.

There are only minor differences with the reference rocket in the setup section:

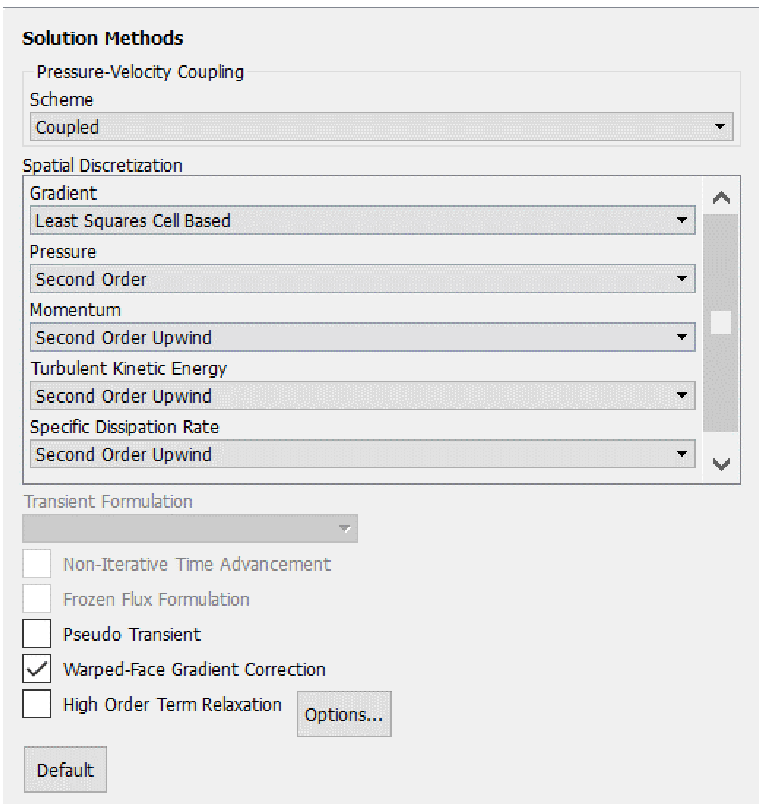
- In the Reference Values section;

Area: 0.1
Velocity: 72.7324
Length: 0.253

- In the Boundary Conditions section;

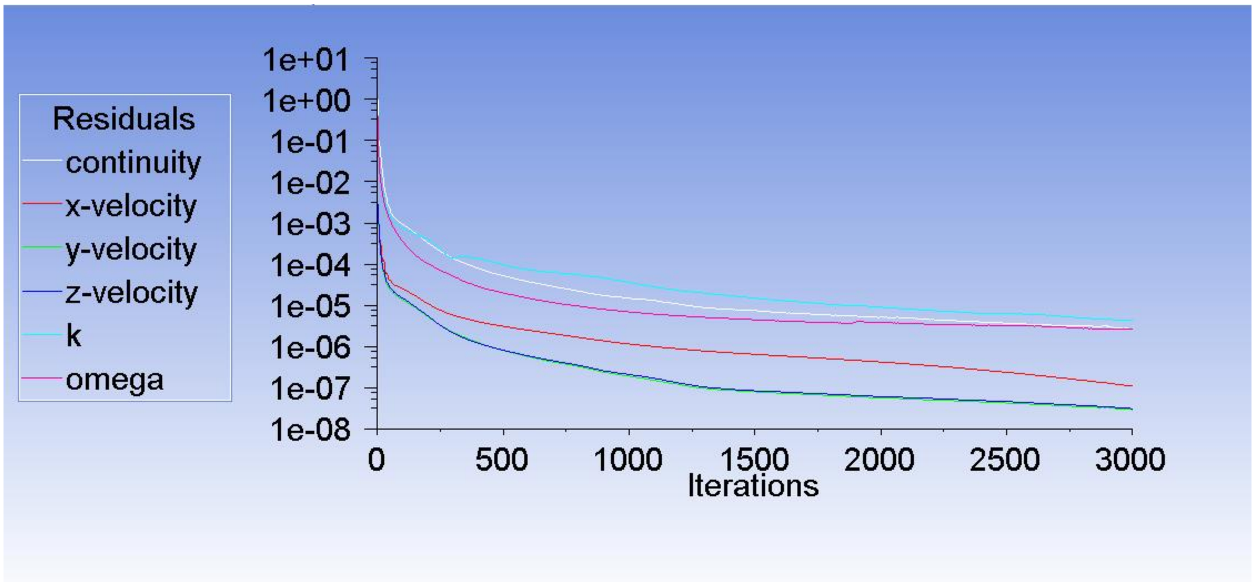
Velocity Inlet, X-Velocity: 72.7324

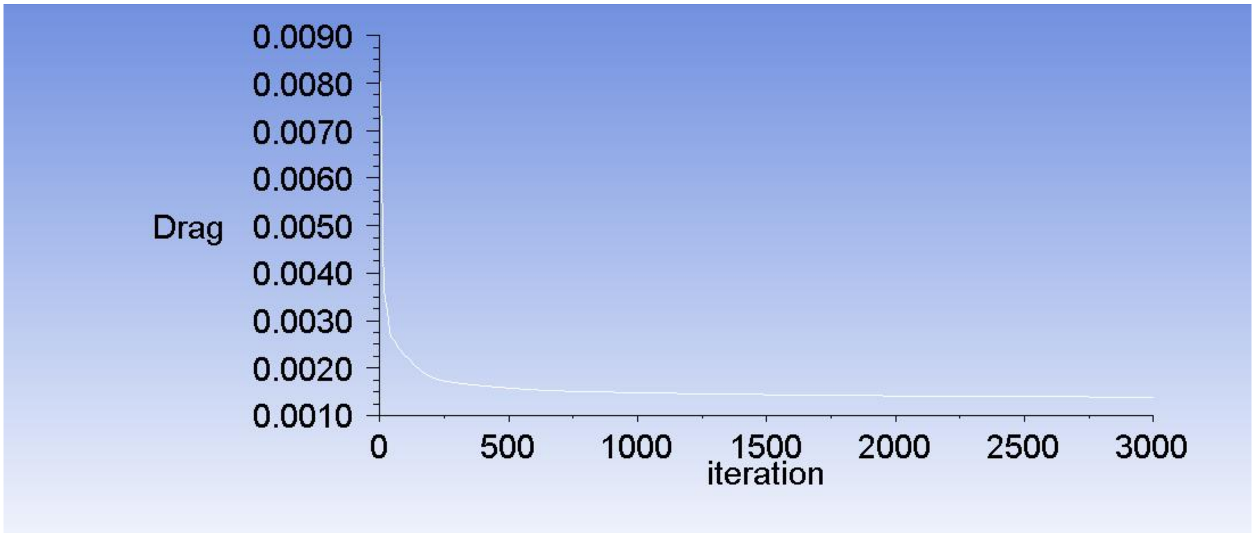
Adjustments were made to be as follows, the remaining values remained the same as our reference rocket.

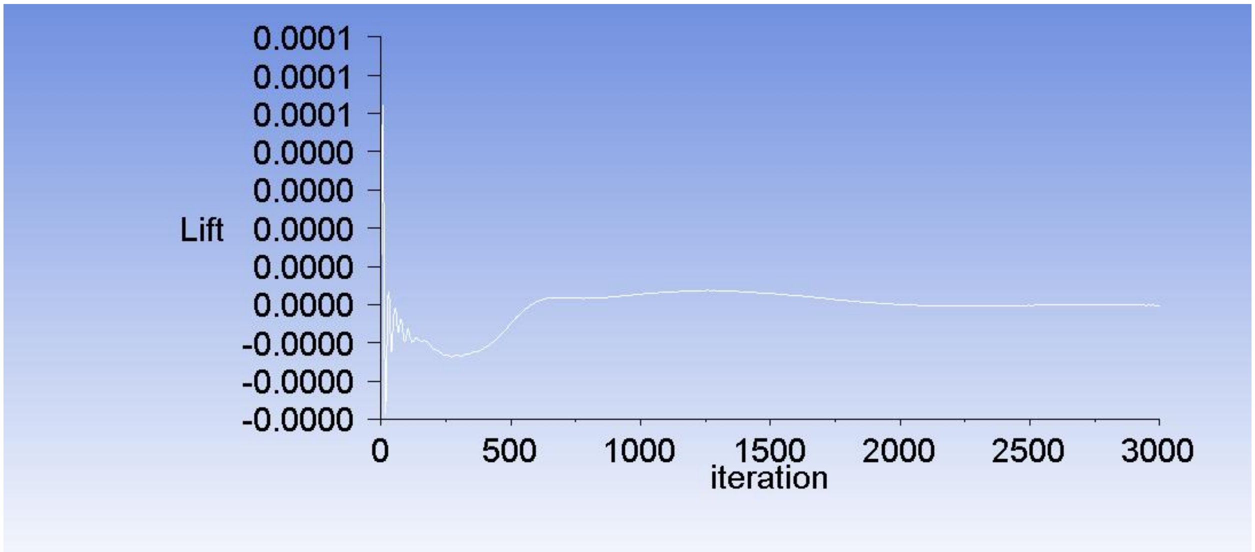


-Results

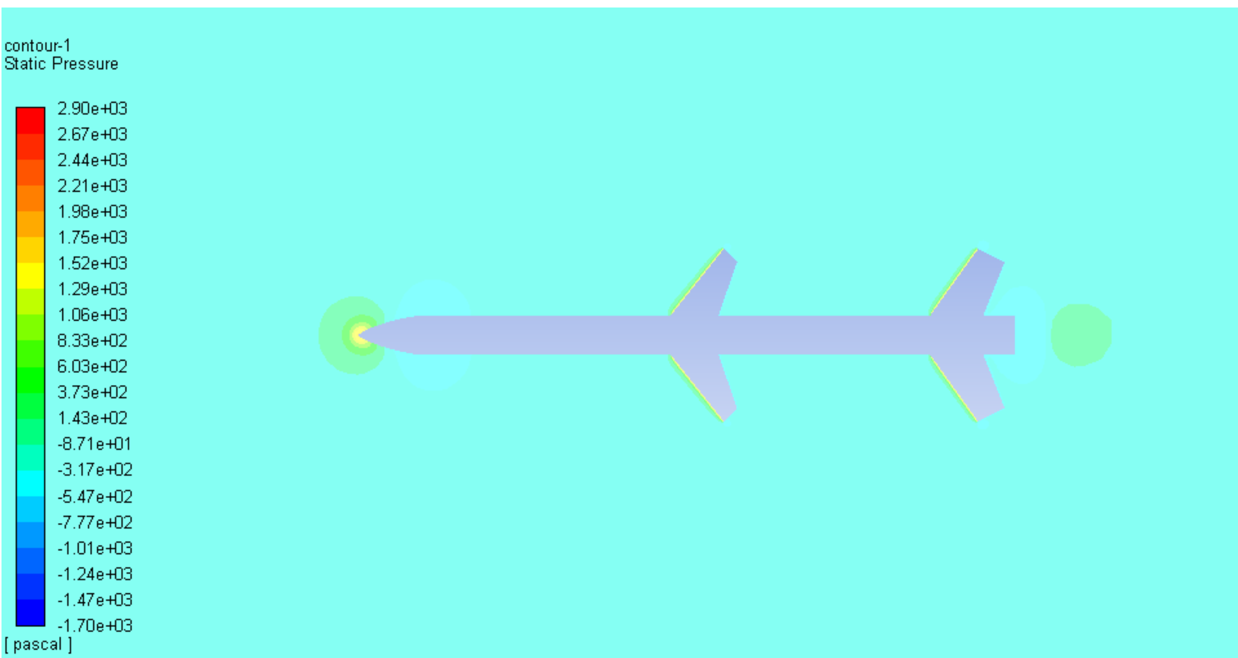
Before proceeding to the Results section, hybrid initialization was performed and the solution stage was started. Our solution graphics have been reached by giving approximately 3000 iterations. Drag and lift values were plotted simultaneously.

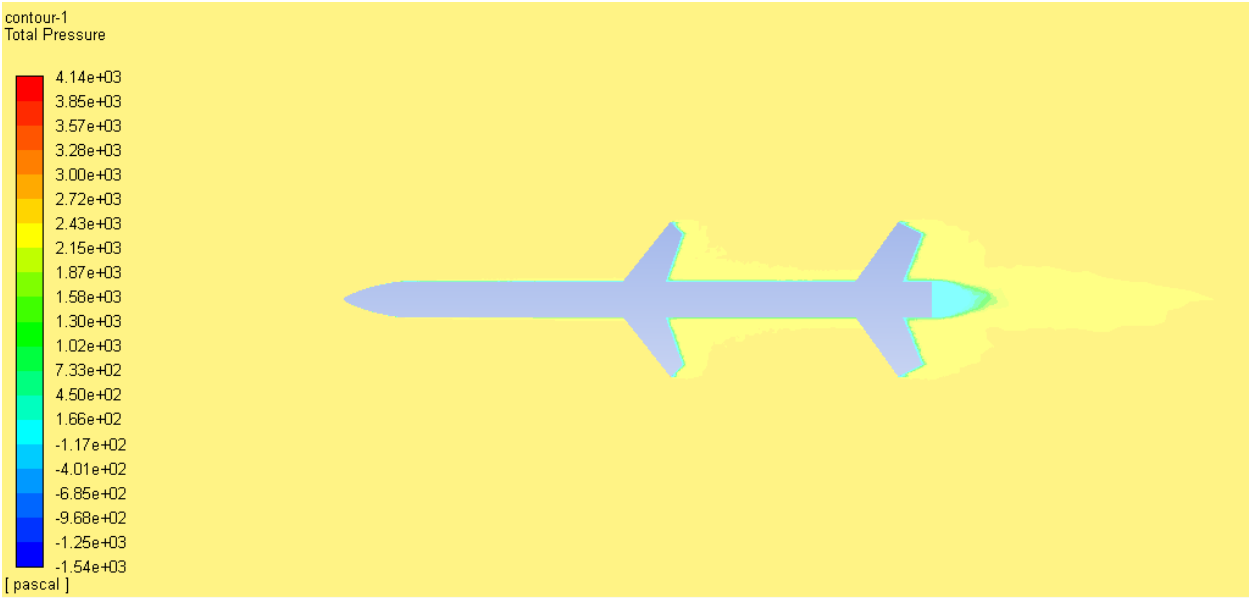




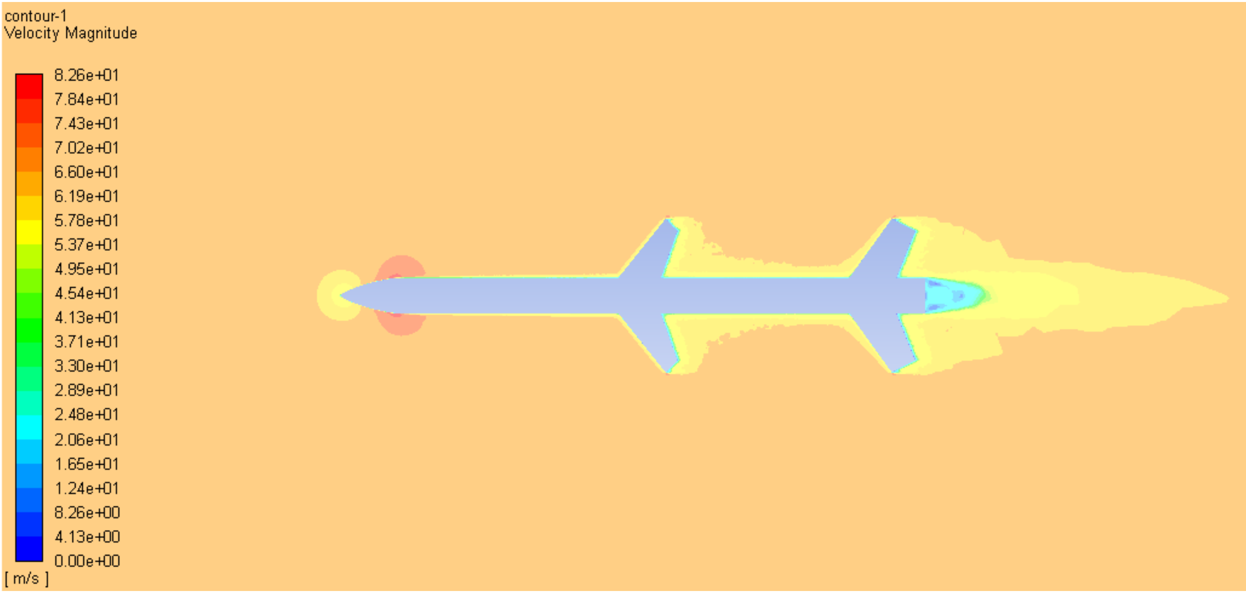


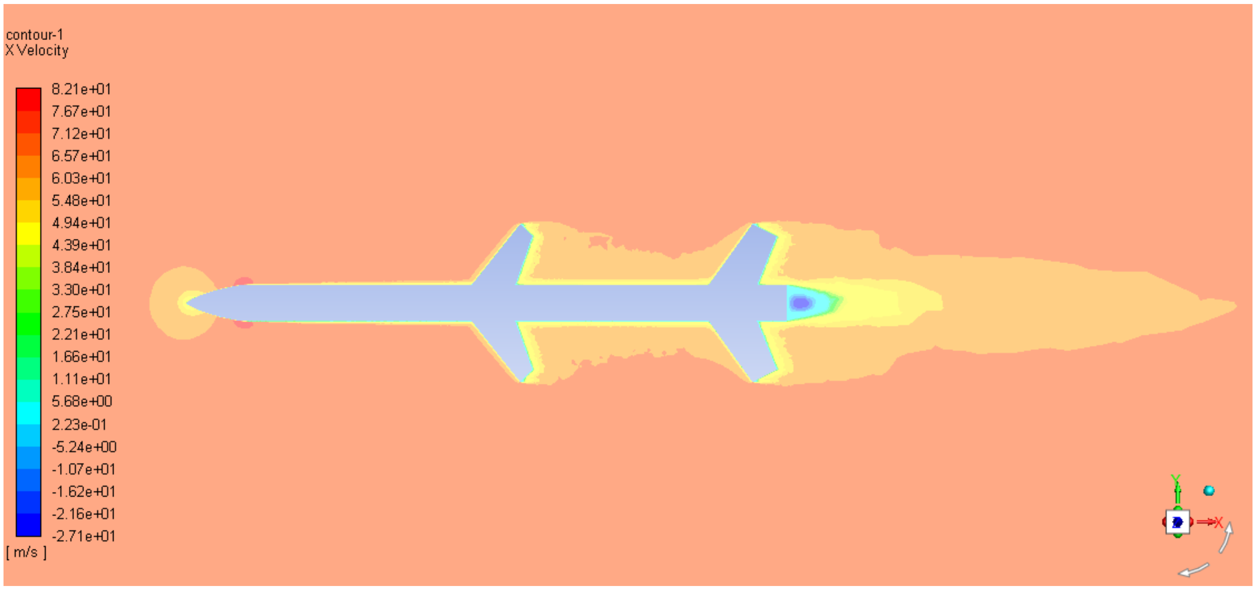
Pressure contours:





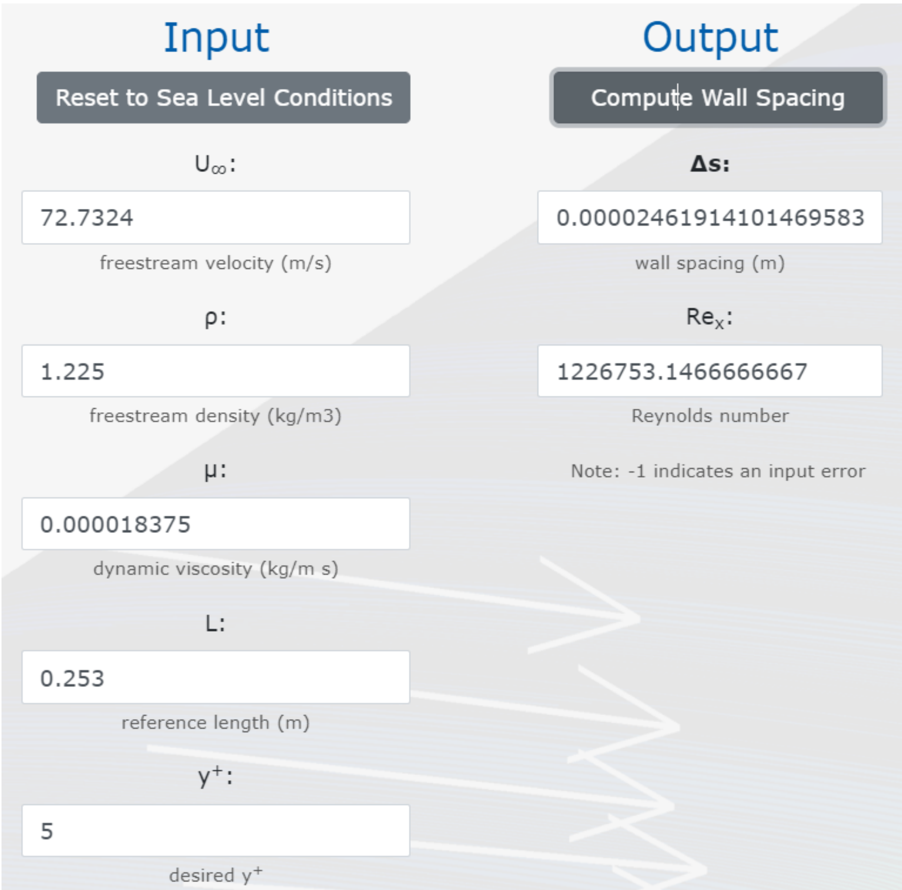
Velocity contours:





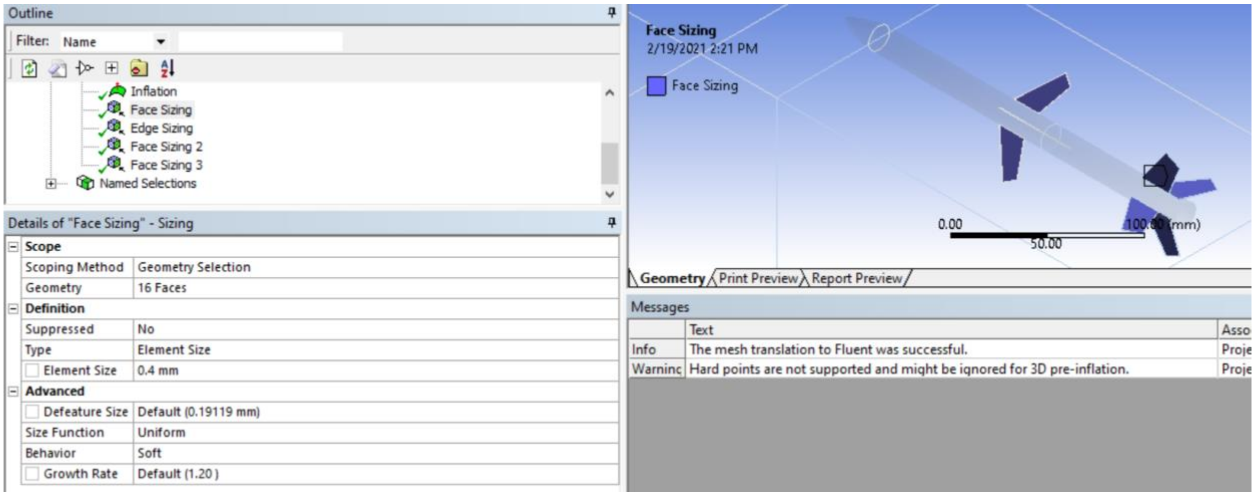
Thus, our Rocket 1-C analysis is completed.

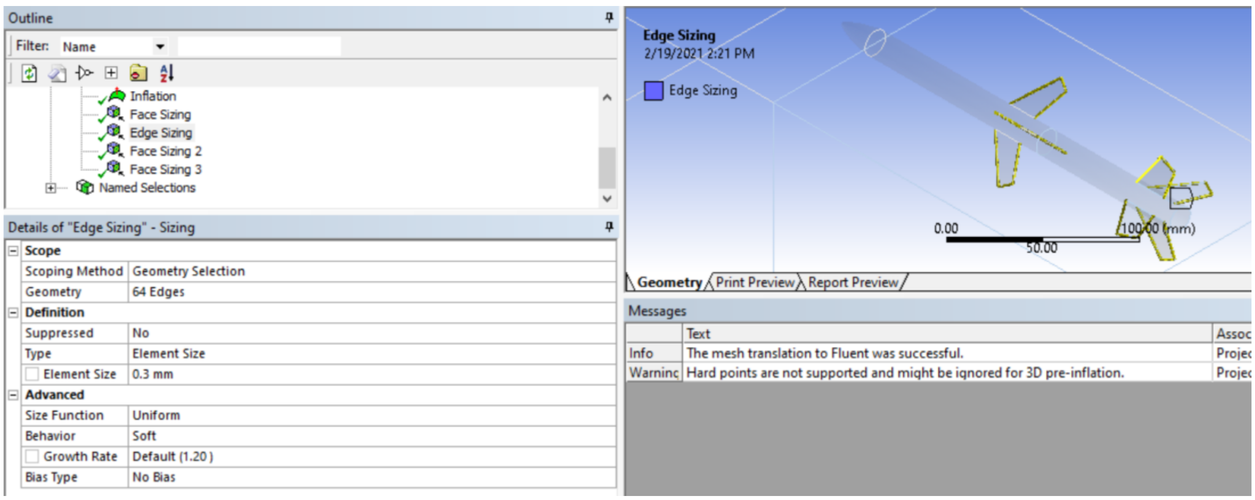
c) Multistage Rocket 1-C (Rotated 45 degrees) Ansys Analysis

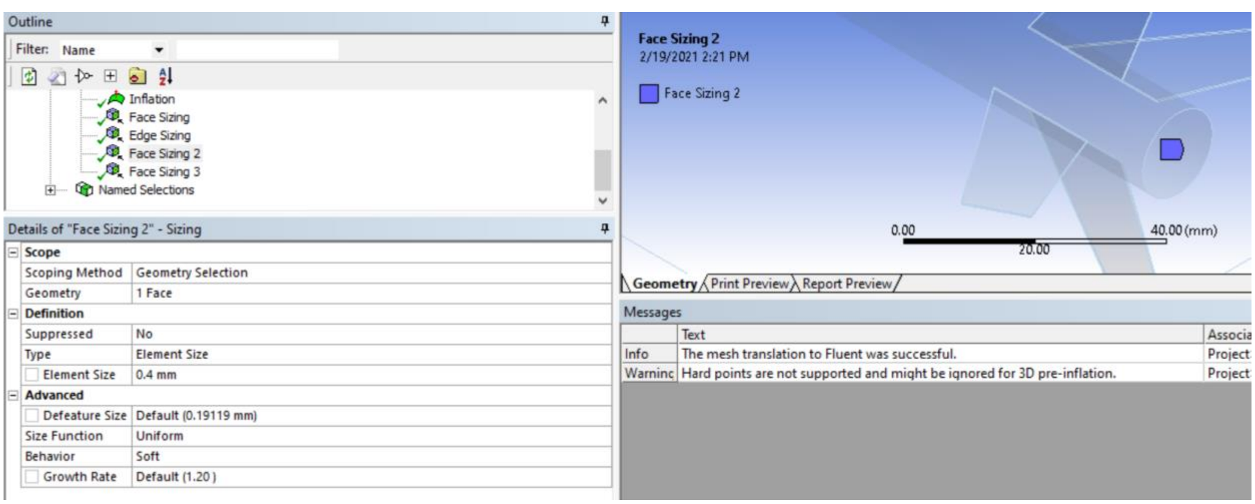


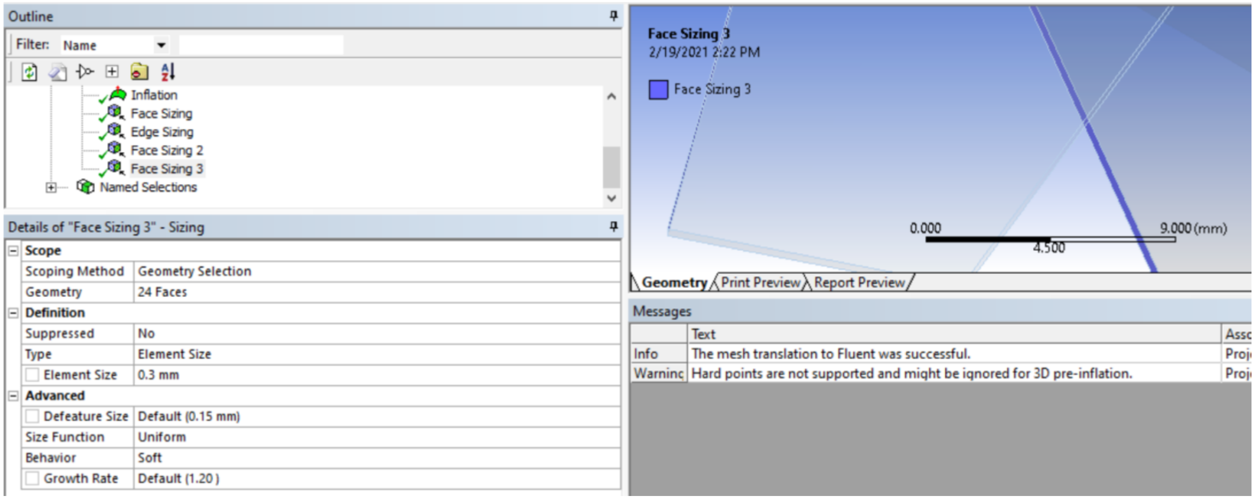
-Mesh

Details of "Inflation" - Inflation	
Scope	
Scoping Method	Geometry Selection
Geometry	2 Bodies
Definition	
Suppressed	No
Boundary Scoping Method	Named Selections
Boundary	wall
Inflation Option	First Layer Thickness
First Layer Height	2.4626e-002 mm
Maximum Layers	10
Growth Rate	1.2
Inflation Algorithm	Pre


Outline
Filter: Name
Inflation
Face Sizing
Edge Sizing
Face Sizing 2
Face Sizing 3
Named Selections
Details of "Face Sizing" - Sizing
Scope
Scoping Method | Geometry Selection
Geometry | 16 Faces
Definition
Suppressed | No
Type | Element Size
Element Size | 0.4 mm
Advanced
Defeature Size | Default (0.19119 mm)
Size Function | Uniform
Behavior | Soft
Growth Rate | Default (1.20)
Face Sizing
2/19/2021 2:21 PM
Face Sizing
0.00
50.00
100.00 (mm)
Geometry
Print Preview
Report Preview
Messages
Text
Info | The mesh translation to Fluent was successful.
Warninc | Hard points are not supported and might be ignored for 3D pre-inflation.


Outline
Filter: Name
Inflation
Face Sizing
Edge Sizing
Face Sizing 2
Face Sizing 3
Named Selections
Details of "Edge Sizing" - Sizing
Scope
Scoping Method | Geometry Selection
Geometry | 64 Edges
Definition
Suppressed | No
Type | Element Size
Element Size | 0.3 mm
Advanced
Size Function | Uniform
Behavior | Soft
Growth Rate | Default (1.20)
Bias Type | No Bias
Edge Sizing
2/19/2021 2:21 PM
Edge Sizing
0.00
50.00
100.00 (mm)
Geometry
Print Preview
Report Preview
Messages
Text
Info | The mesh translation to Fluent was successful.
Warninc | Hard points are not supported and might be ignored for 3D pre-inflation.


Outline
Filter: Name
Inflation
Face Sizing
Edge Sizing
Face Sizing 2
Face Sizing 3
Named Selections
Details of "Face Sizing 2" - Sizing
Scope
Scoping Method | Geometry Selection
Geometry | 1 Face
Definition
Suppressed | No
Type | Element Size
Element Size | 0.4 mm
Advanced
Defeature Size | Default (0.19119 mm)
Size Function | Uniform
Behavior | Soft
Growth Rate | Default (1.20)
Face Sizing 2
2/19/2021 2:21 PM
Face Sizing 2
0.00
20.00
40.00 (mm)
Geometry
Print Preview
Report Preview
Messages
Text
Info | The mesh translation to Fluent was successful.
Warninc | Hard points are not supported and might be ignored for 3D pre-inflation.



What we have obtained after all your sizing and which are the basic evaluation criteria for us; Our Aspect Ratio, Skewness and OQ values are given below:

Quality	
Check Mesh Qua...	Yes, Errors
Target Skewn...	0.6
Smoothing	Medium
Mesh Metric	Aspect Ratio
Min	1.1683
Max	665.2
Average	7.5994
Standard Devi...	14.36

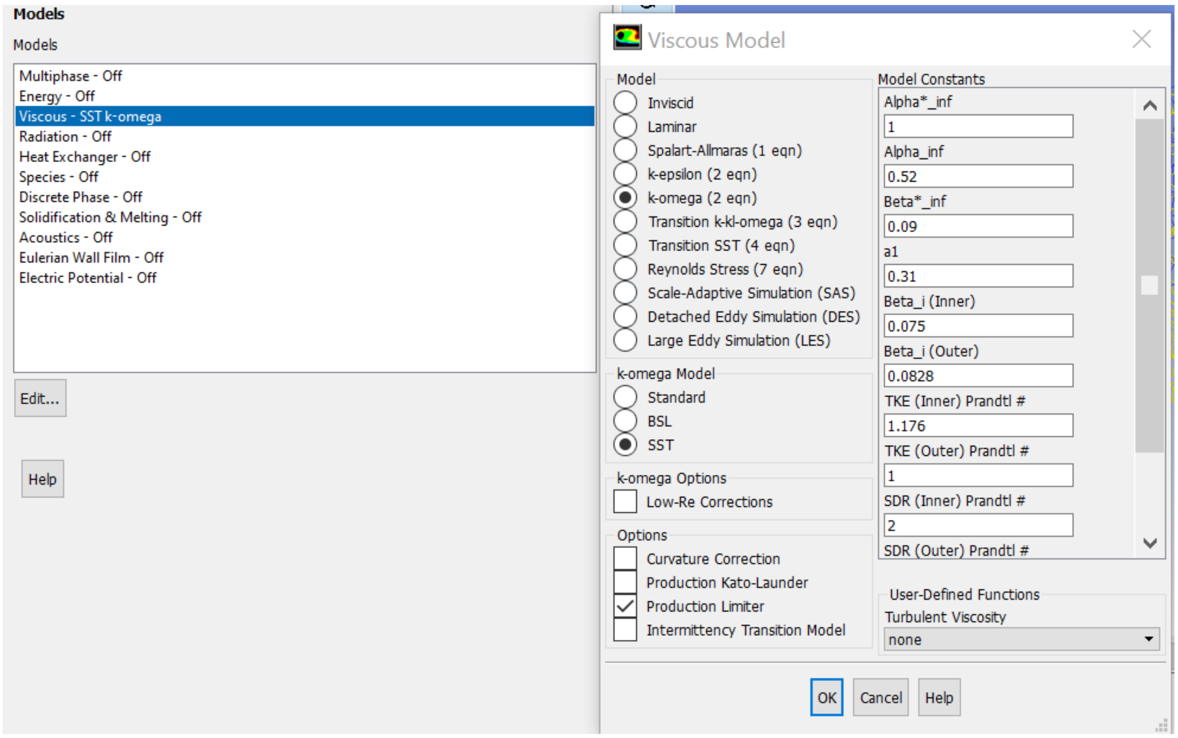
Mesh Metric	Skewness
Min	5.6867e-004
Max	0.79455
Average	0.27122
Standard Deviation	0.14701

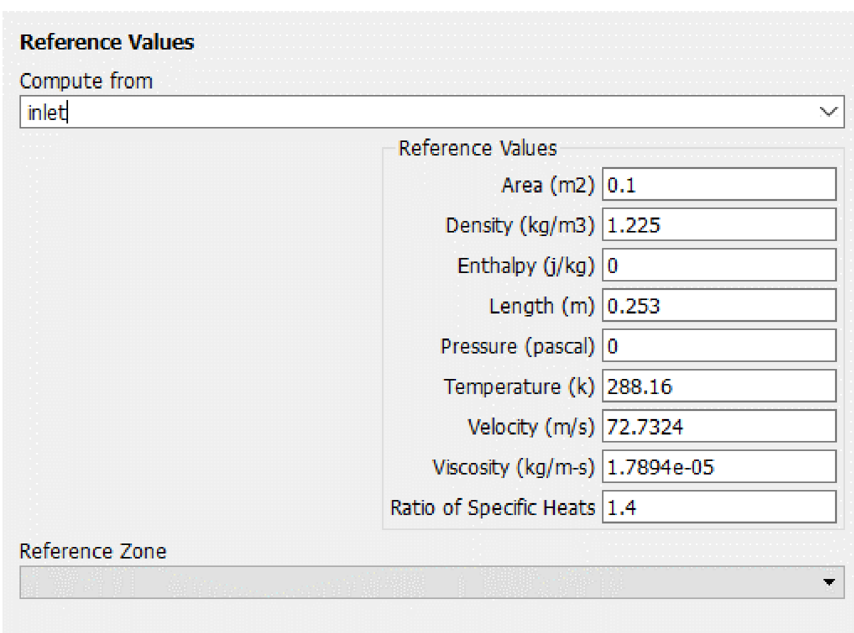
Mesh Metric	Orthogonal Quality
Min	2.1451e-002
Max	0.9989
Average	0.72152
Standard Deviation	0.16166

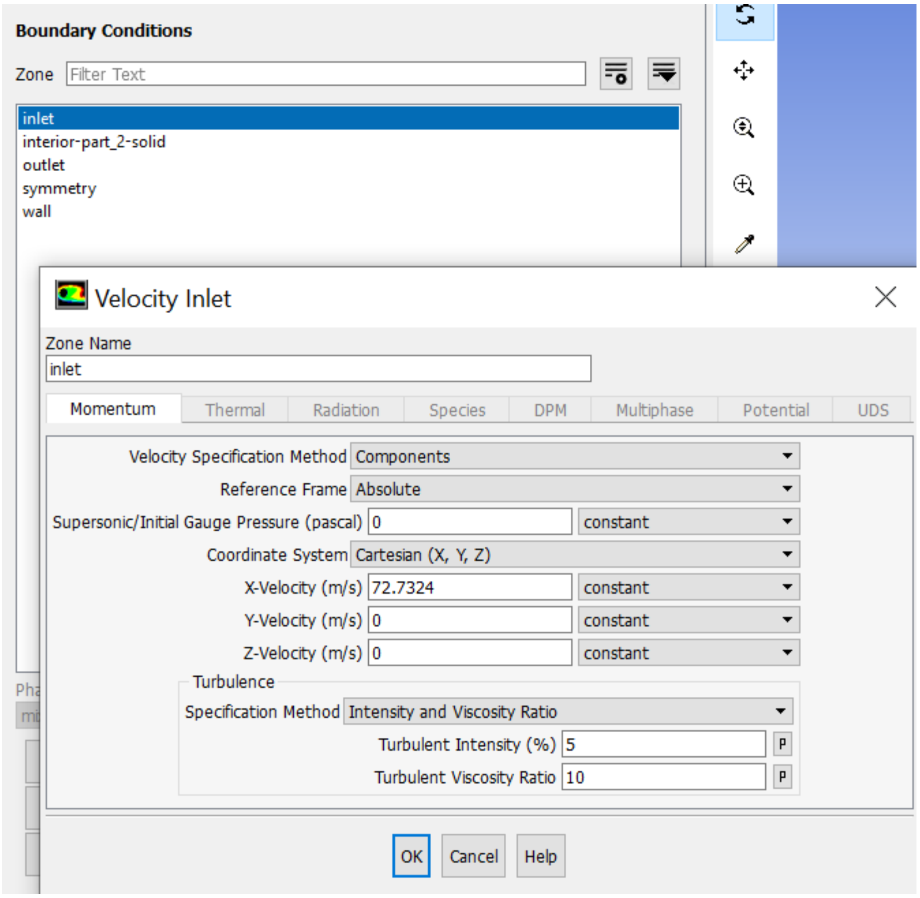
Our element count is as follows:

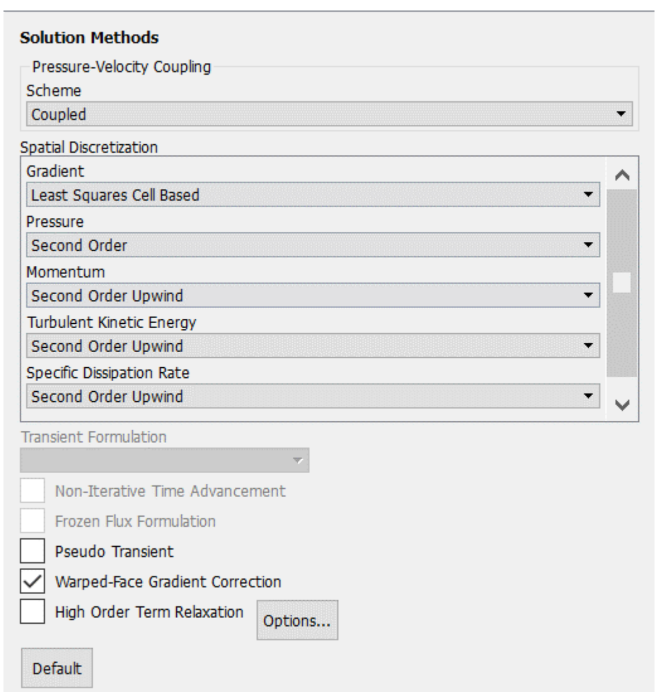
Statistics	
Nodes	821610
Elements	2621531

-Setup


Models
Models
Multiphase - Off
Energy - Off
Viscous - SST k-omega
Radiation - Off
Heat Exchanger - Off
Species - Off
Discrete Phase - Off
Solidification & Melting - Off
Acoustics - Off
Eulerian Wall Film - Off
Electric Potential - Off
Edit...
Help
Viscous Model
Model
Inviscid
Laminar
Spalart-Allmaras (1 eqn)
k-epsilon (2 eqn)
k-omega (2 eqn)
Transition k-kl-omega (3 eqn)
Transition SST (4 eqn)
Reynolds Stress (7 eqn)
Scale-Adaptive Simulation (SAS)
Detached Eddy Simulation (DES)
Large Eddy Simulation (LES)
k-omega Model
Standard
BSL
SST
k-omega Options
Low-Re Corrections
Options
Curvature Correction
Production Kato-Launder
Production Limiter
Intermittency Transition Model
Model Constants
Alpha*_inf
1
Alpha_inf
0.52
Beta*_inf
0.09
a1
0.31
Beta_i (Inner)
0.075
Beta_i (Outer)
0.0828
TKE (Inner) Prandtl #
1.176
TKE (Outer) Prandtl #
1
SDR (Inner) Prandtl #
2
SDR (Outer) Prandtl #
User-Defined Functions
Turbulent Viscosity
none
OK
Cancel
Help

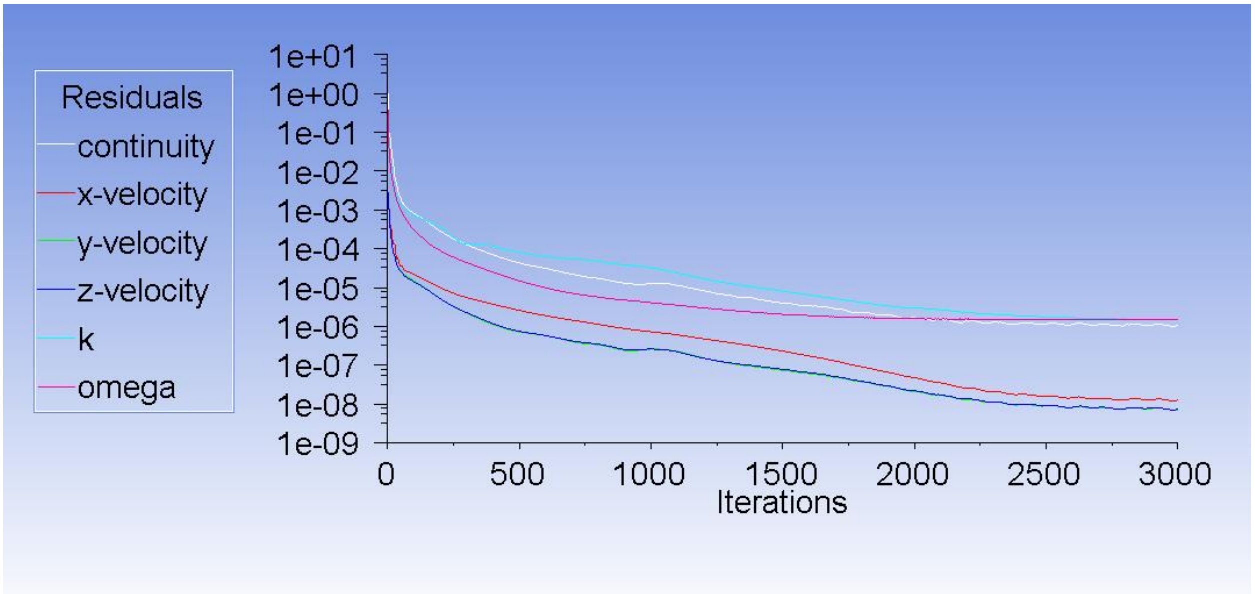

Reference Values
Compute from
inlet
Reference Values
Area (m2) 0.1
Density (kg/m3) 1.225
Enthalpy (j/kg) 0
Length (m) 0.253
Pressure (pascal) 0
Temperature (k) 288.16
Velocity (m/s) 72.7324
Viscosity (kg/m-s) 1.7894e-05
Ratio of Specific Heats 1.4
Reference Zone

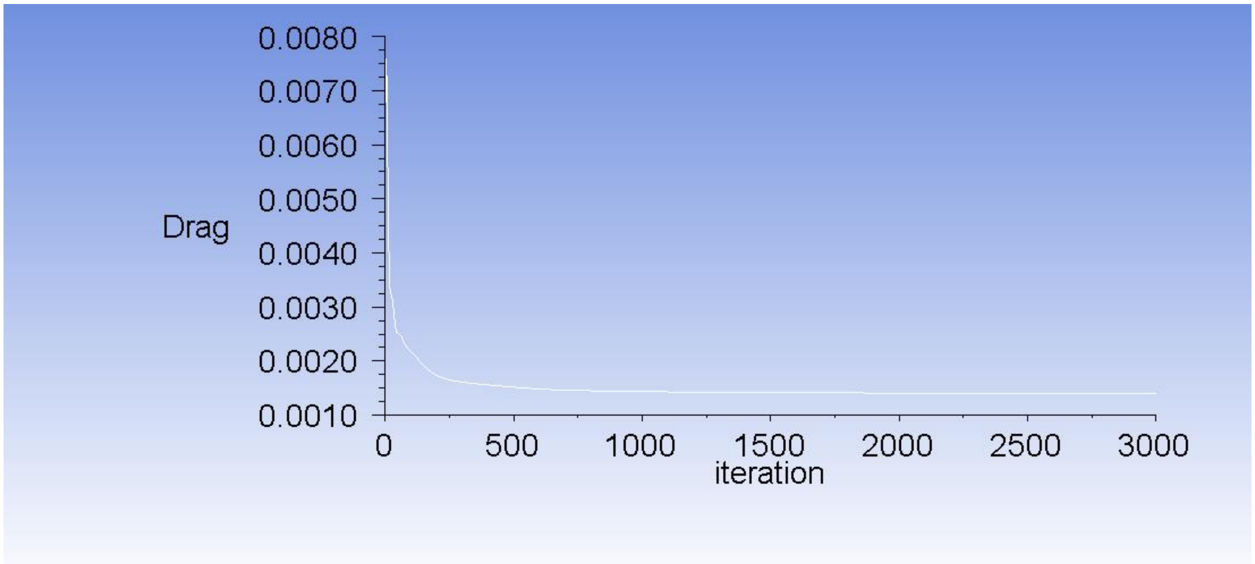

Boundary Conditions
Zone
Filter Text
inlet
interior-part_2-solid
outlet
symmetry
wall
Velocity Inlet
Zone Name
inlet
Momentum
Thermal
Radiation
Species
DPM
Multiphase
Potential
UDS
Velocity Specification Method
Components
Reference Frame
Absolute
Supersonic/Initial Gauge Pressure (pascal)
0
constant
Coordinate System
Cartesian (X, Y, Z)
X-Velocity (m/s)
72.7324
constant
Y-Velocity (m/s)
0
constant
Z-Velocity (m/s)
0
constant
Turbulence
Specification Method
Intensity and Viscosity Ratio
Turbulent Intensity (%)
5
Turbulent Viscosity Ratio
10
OK
Cancel
Help

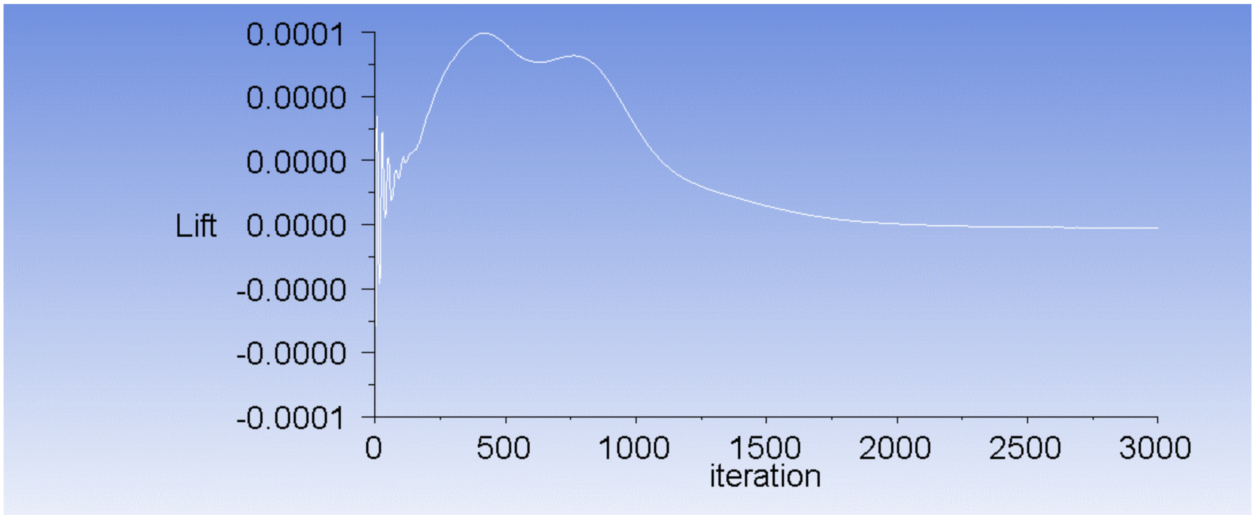

Solution Methods
Pressure-Velocity Coupling
Scheme
Coupled
Spatial Discretization
Gradient
Least Squares Cell Based
Pressure
Second Order
Momentum
Second Order Upwind
Turbulent Kinetic Energy
Second Order Upwind
Specific Dissipation Rate
Second Order Upwind
Transient Formulation
Non-Iterative Time Advancement
Frozen Flux Formulation
Pseudo Transient
Warped-Face Gradient Correction
High Order Term Relaxation
Options...
Default

-Results

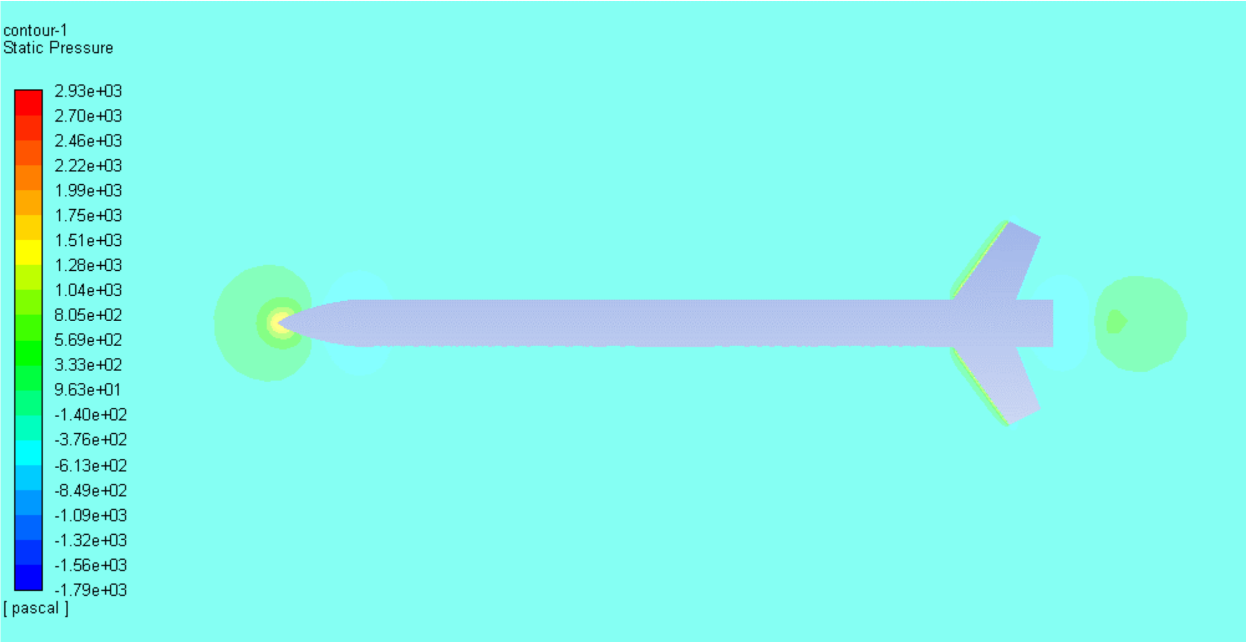
Before proceeding to the Results section, the solution phase was started by performing hybrid initiation. Our solution graphics were reached by giving approximately 3000 iterations. Drag and lift values were plotted simultaneously.

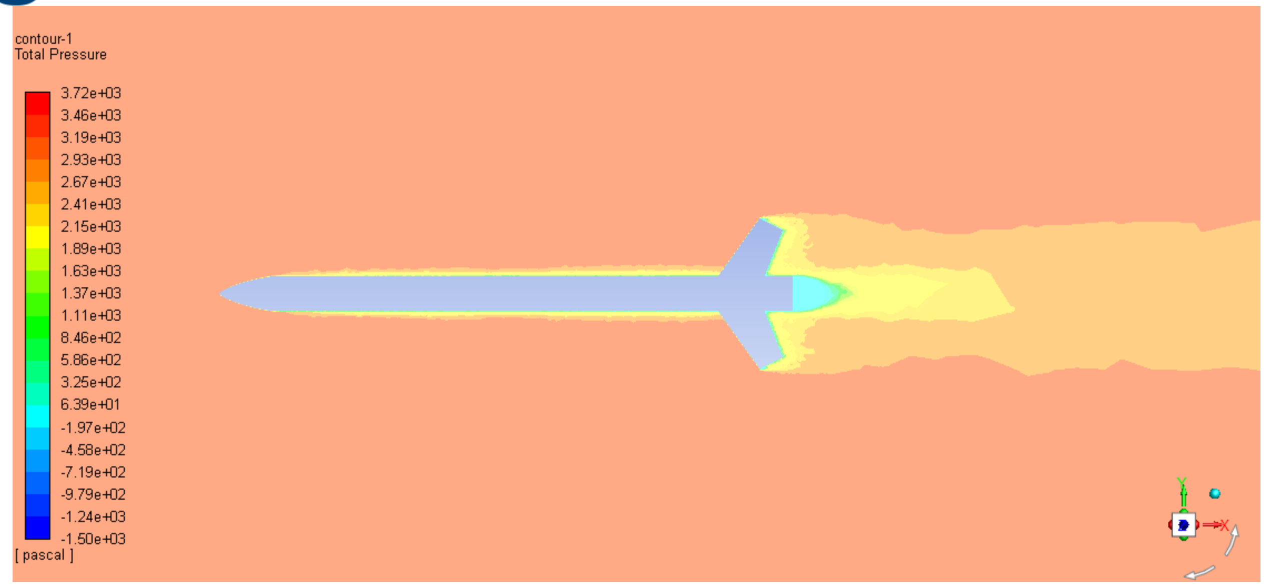




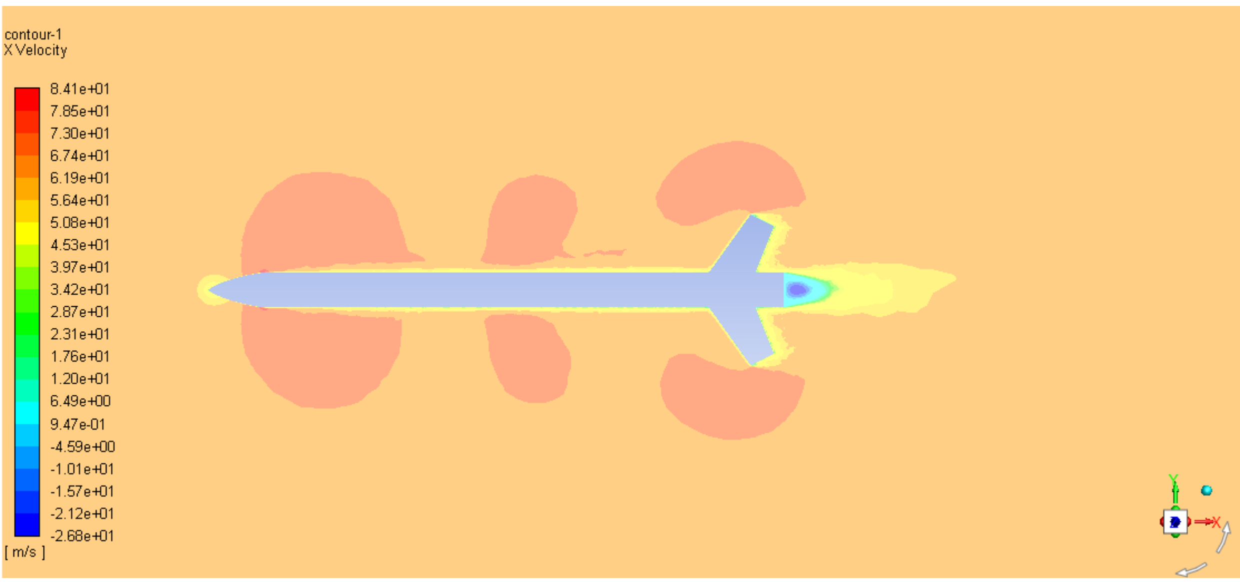


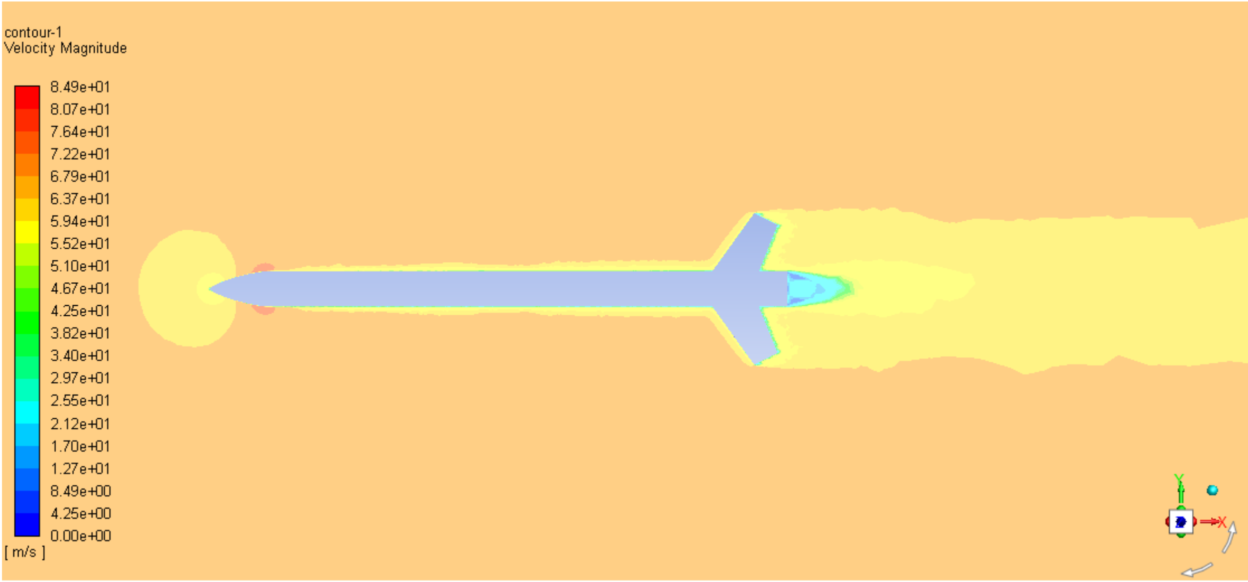
Pressure contours:





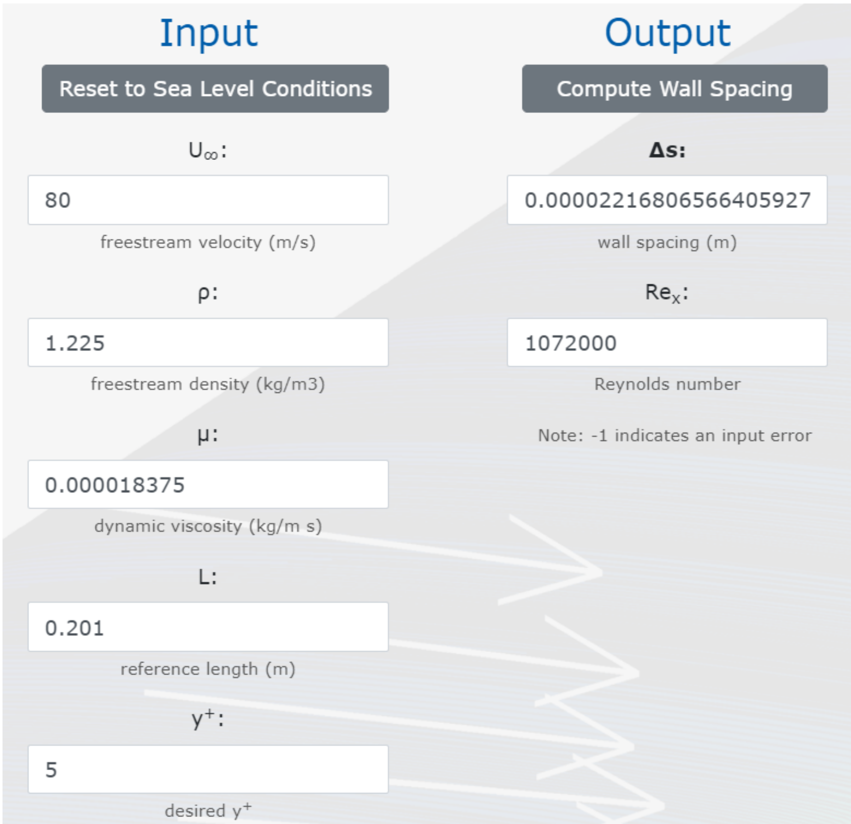
Velocity contours:





Rocket 1-C (Rotated 45 Degrees) analysis is complete.

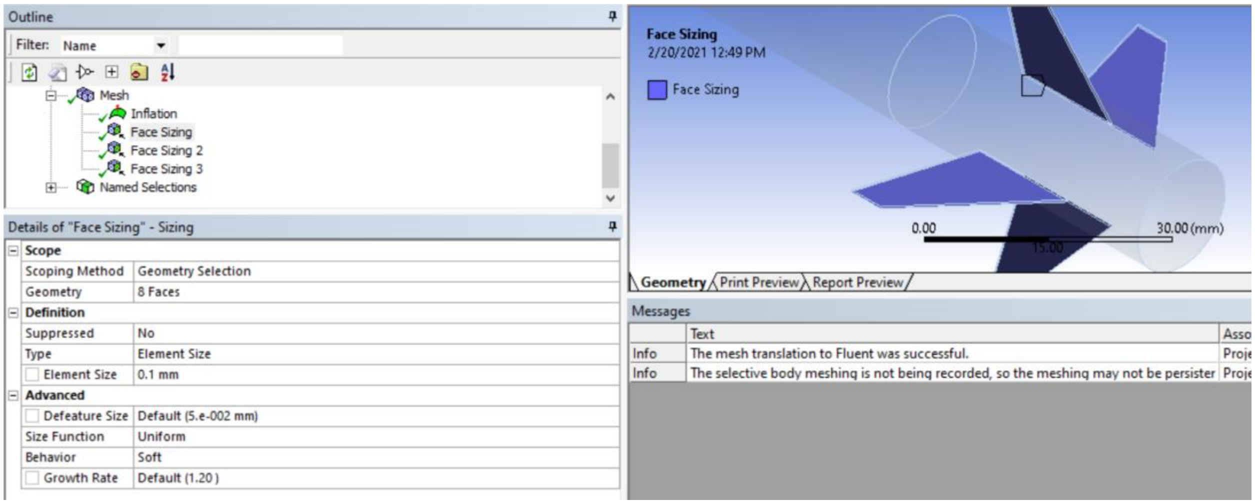
d) Reference Rocket (Inverted Fins) Ansys Analysis

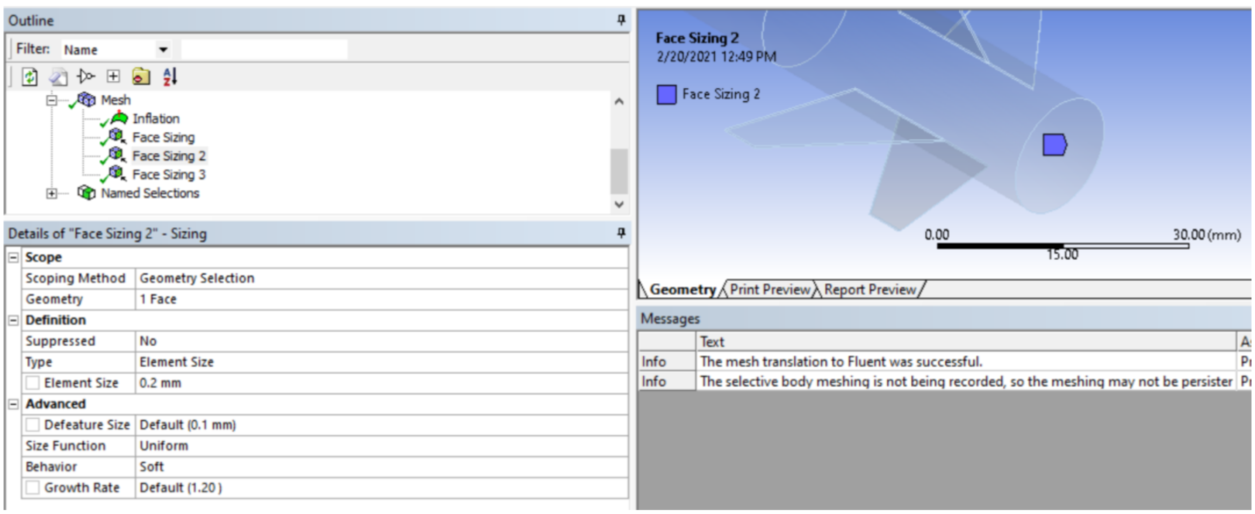


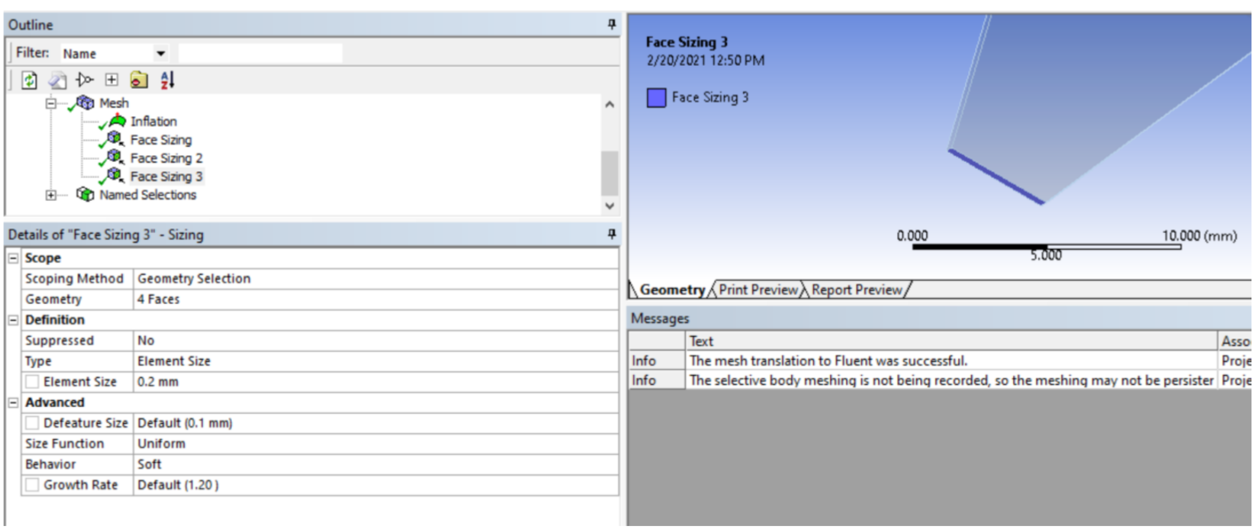
- Mesh

Details of "Inflation" - Inflation

Scope	
Scoping Method	Geometry Selection
Geometry	2 Bodies
Definition	
Suppressed	No
Boundary Scoping Method	Named Selections
Boundary	wall
Inflation Option	First Layer Thickness
First Layer Height	2.216e-002 mm
Maximum Layers	10
Growth Rate	1.2
Inflation Algorithm	Pre


Outline
Filter: Name
Mesh
Inflation
Face Sizing
Face Sizing 2
Face Sizing 3
Named Selections
Details of "Face Sizing" - Sizing
Scope
Scoping Method Geometry Selection
Geometry 8 Faces
Definition
Suppressed No
Type Element Size
Element Size 0.1 mm
Advanced
Defeature Size Default (5.e-002 mm)
Size Function Uniform
Behavior Soft
Growth Rate Default (1.20)
Face Sizing
2/20/2021 12:49 PM
Face Sizing
0.00
15.00
30.00 (mm)
Geometry
Print Preview
Report Preview
Messages
Text
Info The mesh translation to Fluent was successful.
Info The selective body meshing is not being recorded, so the meshing may not be persister


Outline
Filter: Name
Mesh
Inflation
Face Sizing
Face Sizing 2
Face Sizing 3
Named Selections
Details of "Face Sizing 2" - Sizing
Scope
Scoping Method Geometry Selection
Geometry 1 Face
Definition
Suppressed No
Type Element Size
Element Size 0.2 mm
Advanced
Defeature Size Default (0.1 mm)
Size Function Uniform
Behavior Soft
Growth Rate Default (1.20)
Face Sizing 2
2/20/2021 12:49 PM
Face Sizing 2
0.00
15.00
30.00 (mm)
Geometry
Print Preview
Report Preview
Messages
Text
Info The mesh translation to Fluent was successful.
Info The selective body meshing is not being recorded, so the meshing may not be persister


Outline
Filter: Name
Mesh
Inflation
Face Sizing
Face Sizing 2
Face Sizing 3
Named Selections
Details of "Face Sizing 3" - Sizing
Scope
Scoping Method Geometry Selection
Geometry 4 Faces
Definition
Suppressed No
Type Element Size
Element Size 0.2 mm
Advanced
Defeature Size Default (0.1 mm)
Size Function Uniform
Behavior Soft
Growth Rate Default (1.20)
Face Sizing 3
2/20/2021 12:50 PM
Face Sizing 3
0.000
5.000
10.000 (mm)
Geometry
Print Preview
Report Preview
Messages
Text
Info The mesh translation to Fluent was successful.
Info The selective body meshing is not being recorded, so the meshing may not be persister

What we have obtained after all your sizing and which are the basic evaluation criteria for us; Our Aspect Ratio, Skewness and OQ values are given below:

Quality	
Check Mesh Qua...	Yes, Errors
Target Skewn...	0.6
Smoothing	Medium
Mesh Metric	Aspect Ratio
Min	1.1608
Max	955.84
Average	3.5682
Standard Devi...	7.315

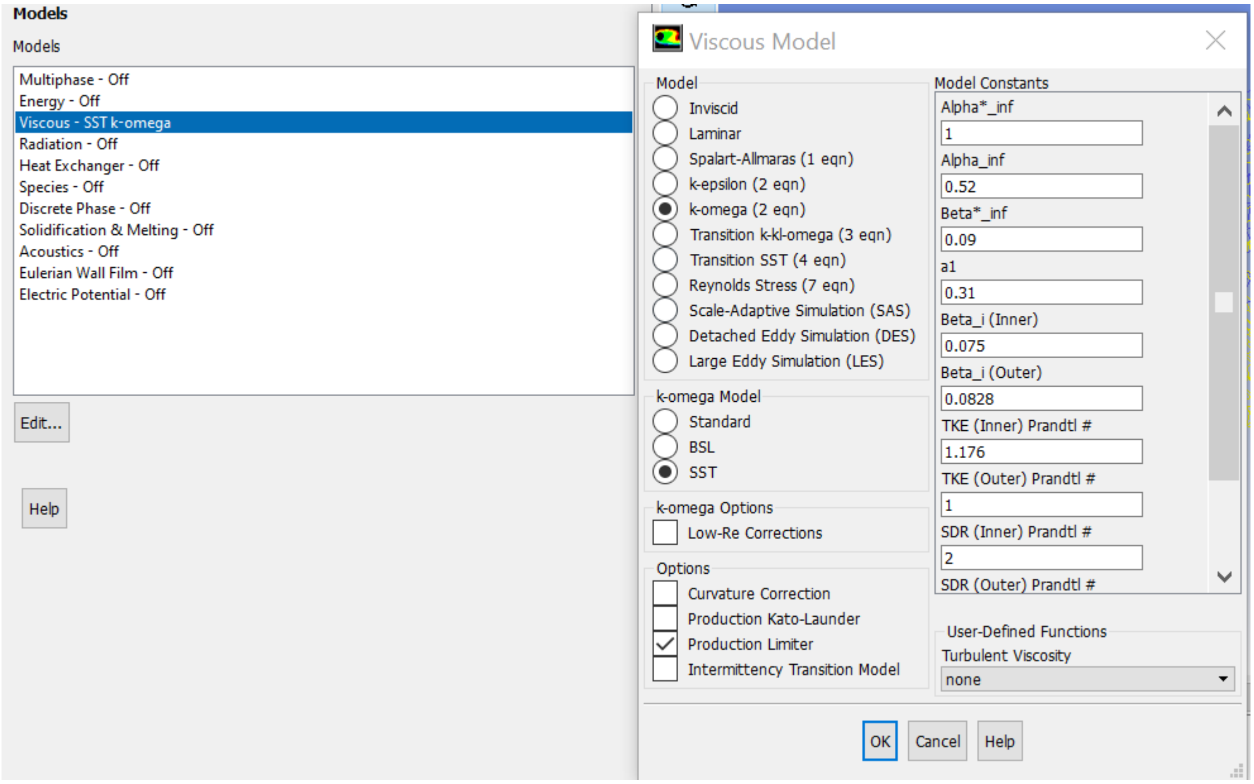
Mesh Metric	Skewness
Min	1.6528e-005
Max	0.94277
Average	0.25003
Standard Deviation	0.14373

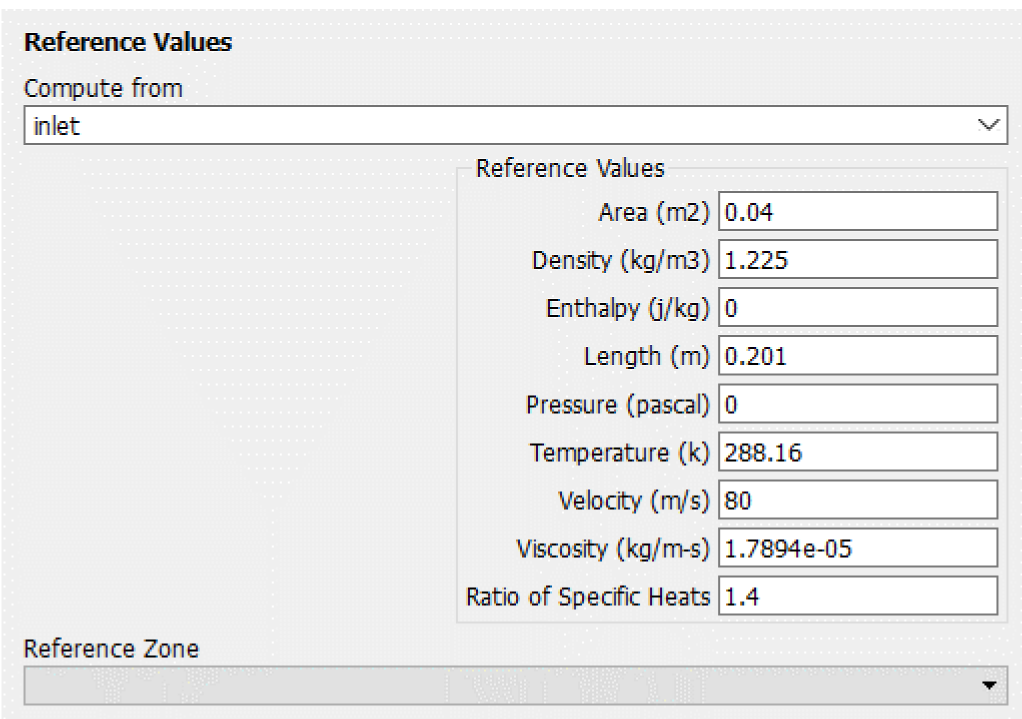
Mesh Metric	Orthogonal Quality
Min	1.2538e-002
Max	0.9994
Average	0.74938
Standard Deviation	0.14379

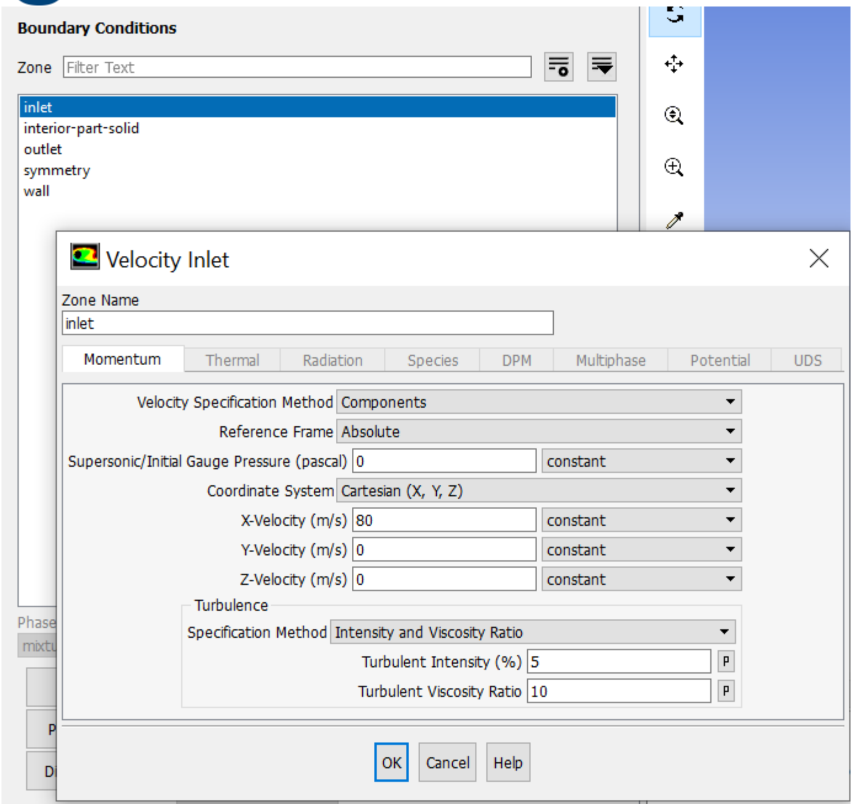
Our element count is as follows:

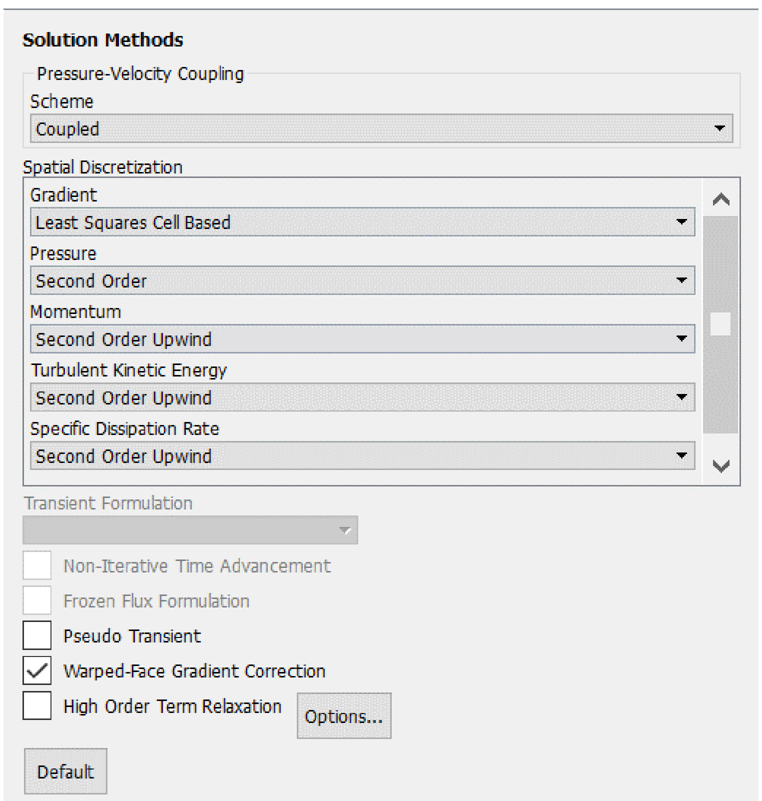
Statistics	
Nodes	1685019
Elements	4343587

-Setup


Models
Models
Multiphase - Off
Energy - Off
Viscous - SST k-omega
Radiation - Off
Heat Exchanger - Off
Species - Off
Discrete Phase - Off
Solidification & Melting - Off
Acoustics - Off
Eulerian Wall Film - Off
Electric Potential - Off
Edit...
Help
Viscous Model
Model
Inviscid
Laminar
Spalart-Allmaras (1 eqn)
k-epsilon (2 eqn)
k-omega (2 eqn)
Transition k-kl-omega (3 eqn)
Transition SST (4 eqn)
Reynolds Stress (7 eqn)
Scale-Adaptive Simulation (SAS)
Detached Eddy Simulation (DES)
Large Eddy Simulation (LES)
k-omega Model
Standard
BSL
SST
k-omega Options
Low-Re Corrections
Options
Curvature Correction
Production Kato-Launder
Production Limiter
Intermittency Transition Model
Model Constants
Alpha*_inf
1
Alpha_inf
0.52
Beta*_inf
0.09
a1
0.31
Beta_i (Inner)
0.075
Beta_i (Outer)
0.0828
TKE (Inner) Prandtl #
1.176
TKE (Outer) Prandtl #
1
SDR (Inner) Prandtl #
2
SDR (Outer) Prandtl #
User-Defined Functions
Turbulent Viscosity
none
OK
Cancel
Help

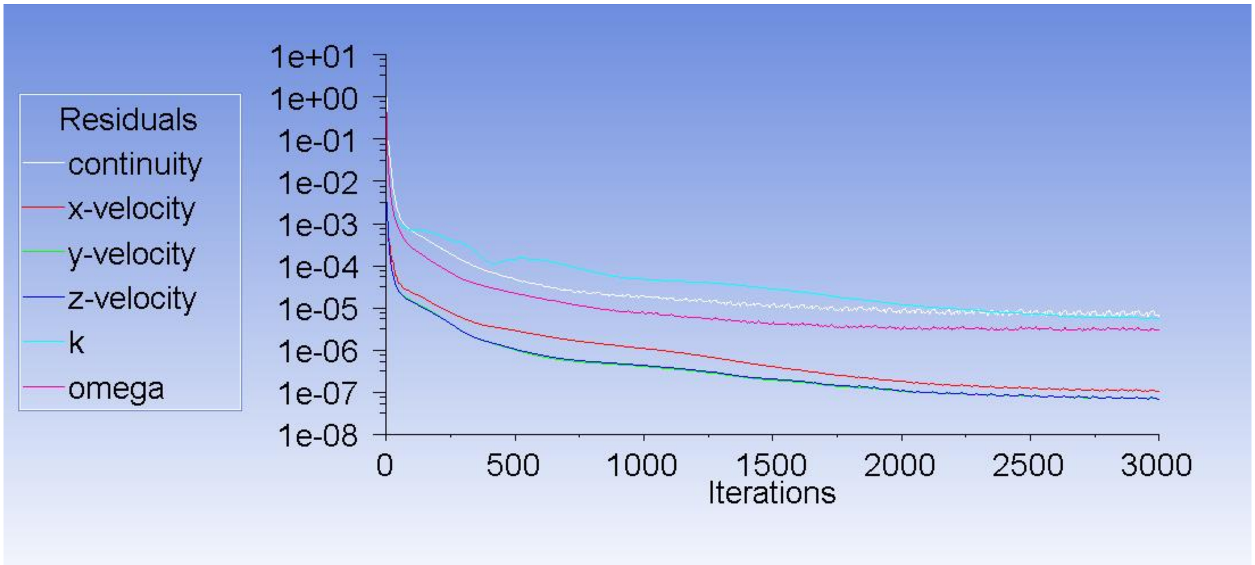

Reference Values
Compute from
inlet
Reference Values
Area (m2) 0.04
Density (kg/m3) 1.225
Enthalpy (j/kg) 0
Length (m) 0.201
Pressure (pascal) 0
Temperature (k) 288.16
Velocity (m/s) 80
Viscosity (kg/m-s) 1.7894e-05
Ratio of Specific Heats 1.4
Reference Zone

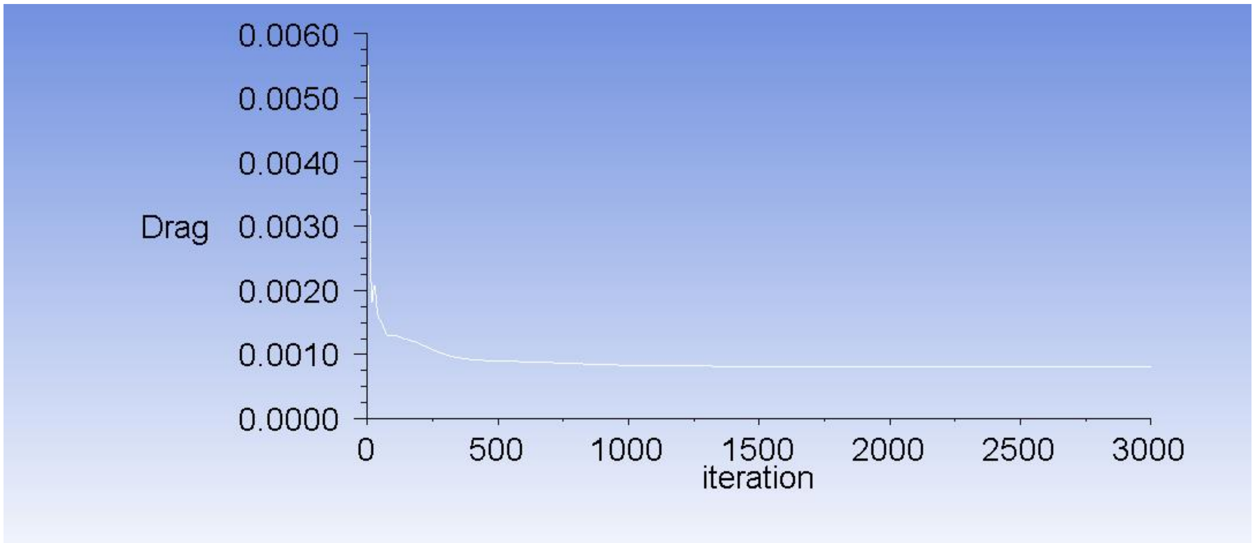

Boundary Conditions
Zone
Filter Text
inlet
interior-part-solid
outlet
symmetry
wall
Velocity Inlet
Zone Name
inlet
Momentum
Thermal
Radiation
Species
DPM
Multiphase
Potential
UDS
Velocity Specification Method Components
Reference Frame Absolute
Supersonic/Initial Gauge Pressure (pascal) 0 constant
Coordinate System Cartesian (X, Y, Z)
X-Velocity (m/s) 80 constant
Y-Velocity (m/s) 0 constant
Z-Velocity (m/s) 0 constant
Turbulence
Specification Method Intensity and Viscosity Ratio
Turbulent Intensity (%) 5
Turbulent Viscosity Ratio 10
OK
Cancel
Help

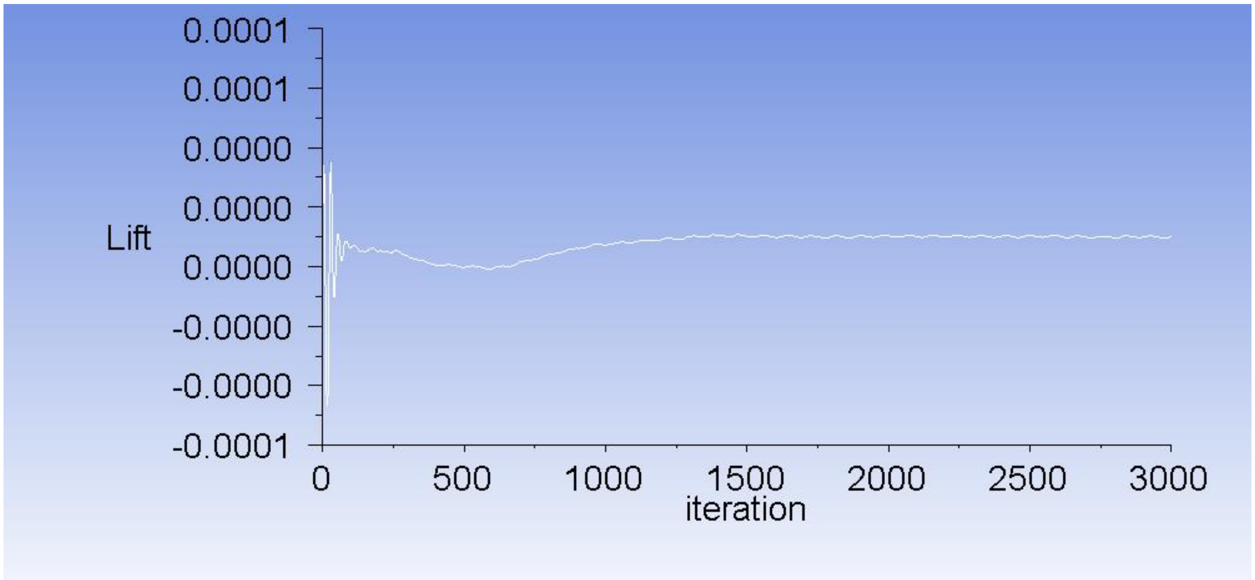

Solution Methods
Pressure-Velocity Coupling
Scheme
Coupled
Spatial Discretization
Gradient
Least Squares Cell Based
Pressure
Second Order
Momentum
Second Order Upwind
Turbulent Kinetic Energy
Second Order Upwind
Specific Dissipation Rate
Second Order Upwind
Transient Formulation
Non-Iterative Time Advancement
Frozen Flux Formulation
Pseudo Transient
Warped-Face Gradient Correction
High Order Term Relaxation
Options...
Default

-Results

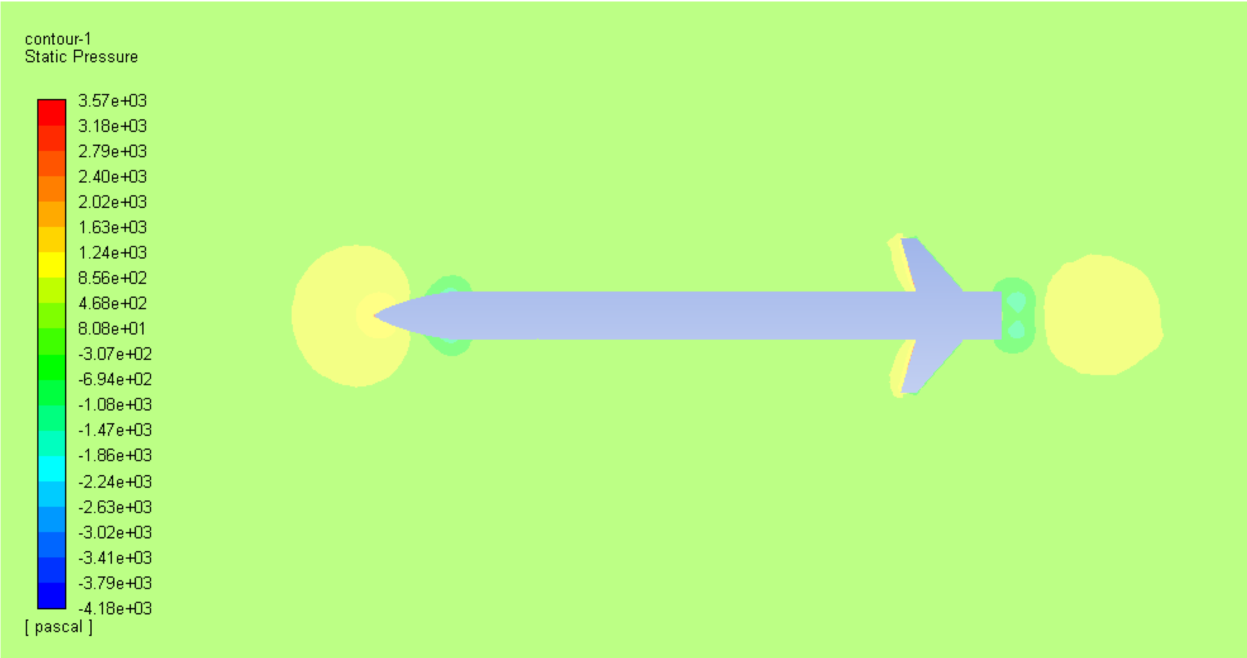
Before proceeding to the Results section, the solution phase was started by performing hybrid initiation. Our solution graphics were reached by giving approximately 3000 iterations. Drag and lift values were plotted simultaneously.

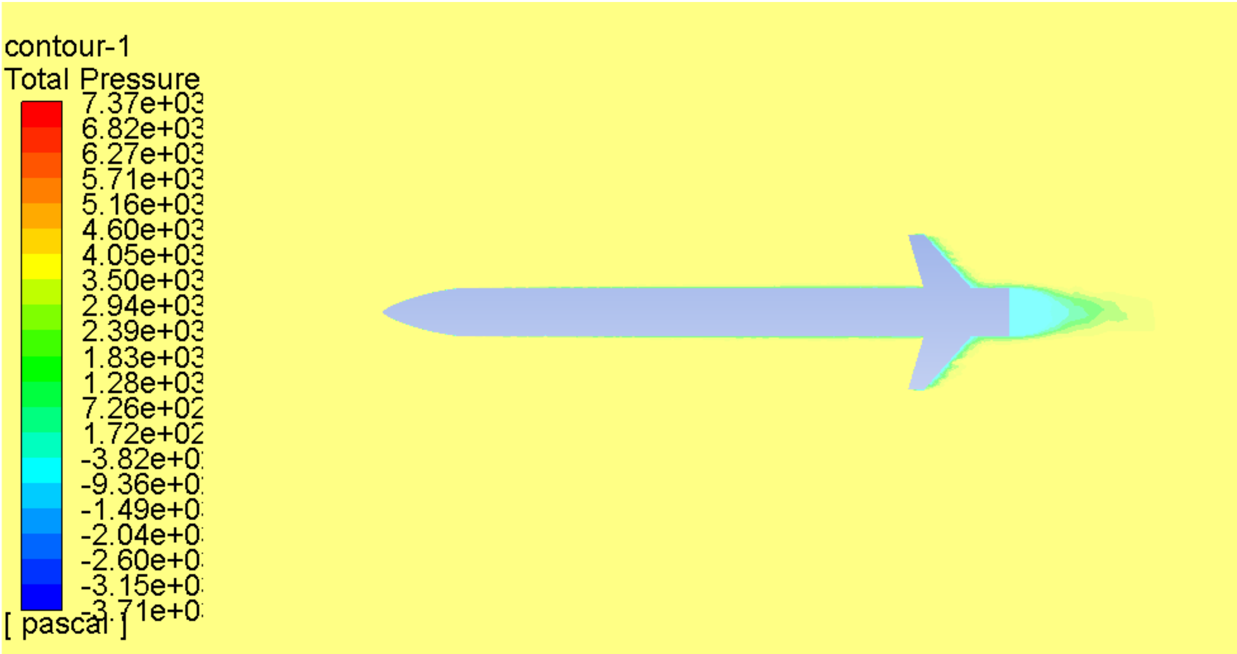




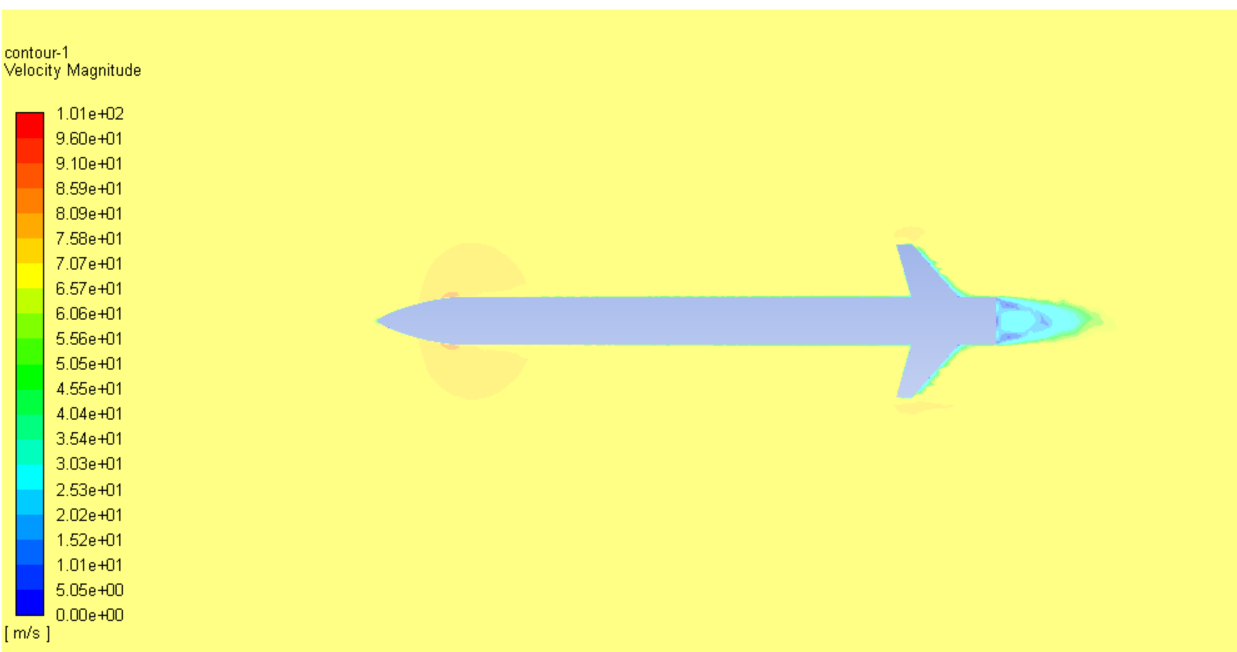


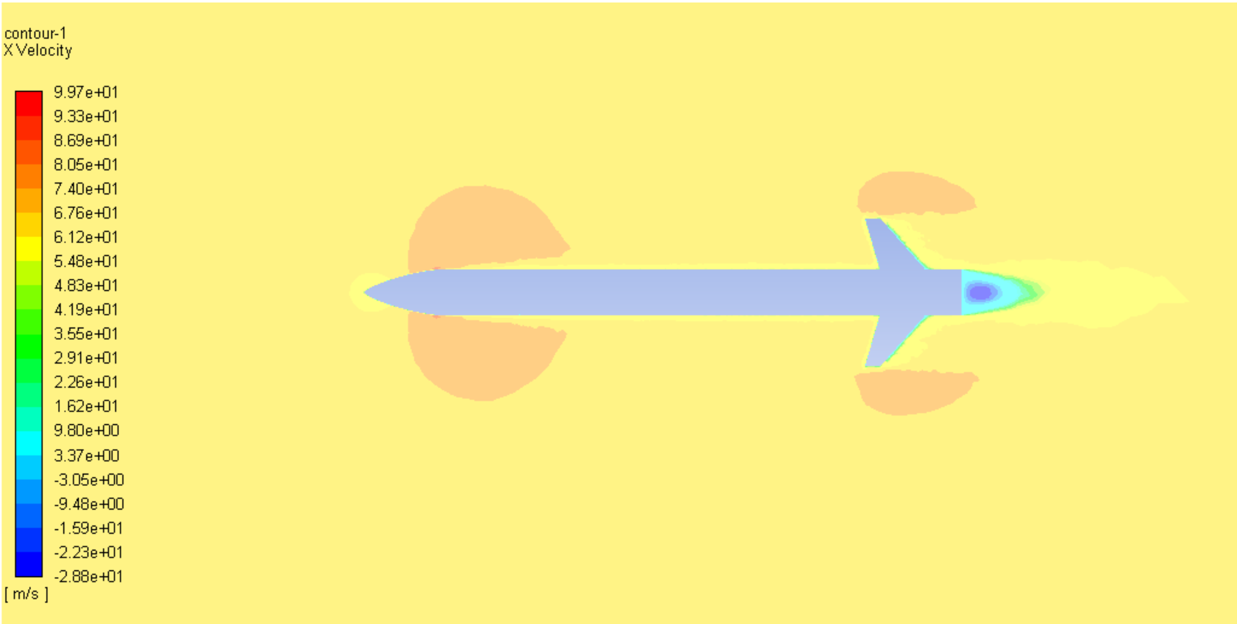
Pressure contours:





Velocity contours:





And with the end of this analysis, all our ANSYS analyzes have been completed.

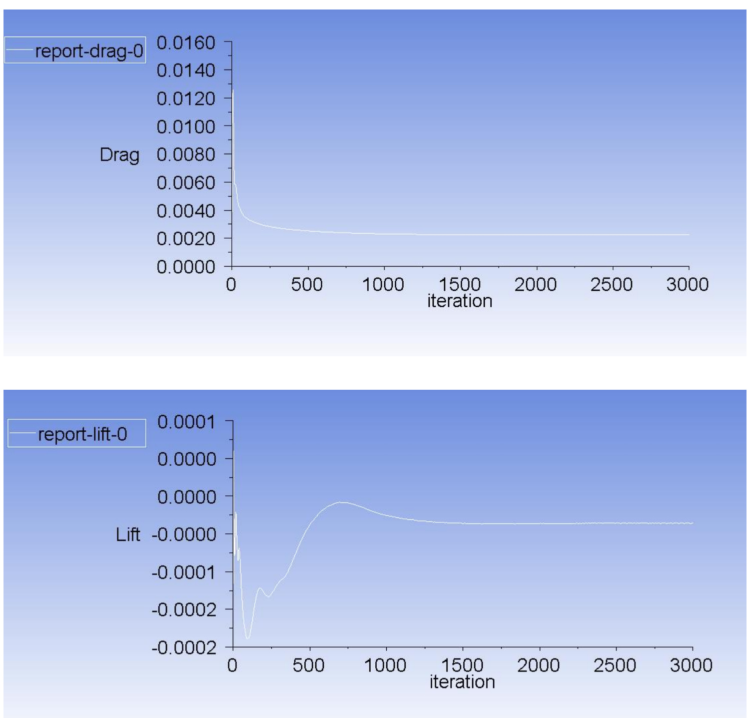
5) Interpretation of Results and Analysis

First of all, it has been deemed appropriate by us to touch on how the interpretation is made.

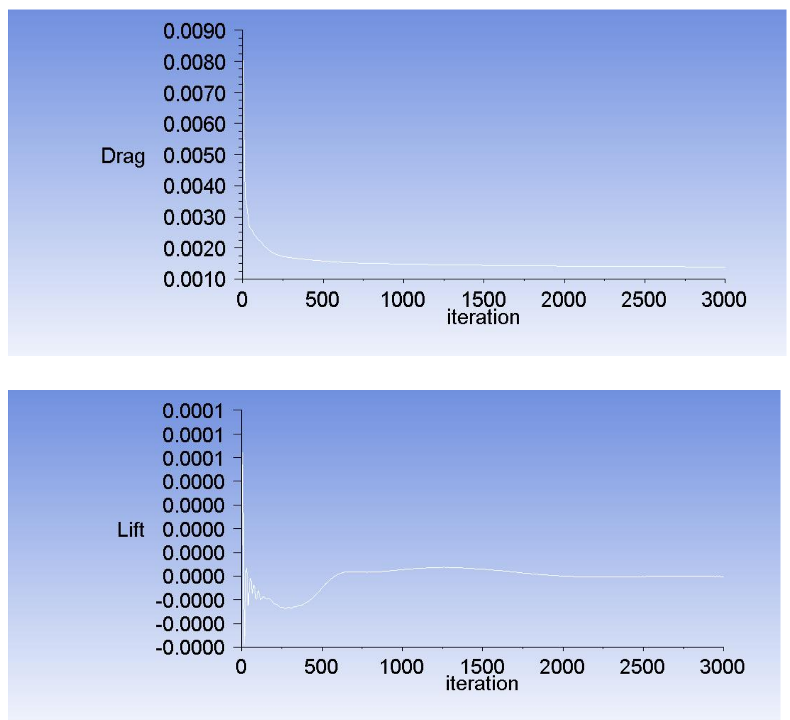
-Drag And Lift

Since the fluctuations of the lift and drag graphs are related to the mesh, the values in which the drag and lift values become stable in these graphs are the basic value that is important for us. In our ANSYS analysis; Since our rocket fins were designed to be rectangular and inserted perpendicular to the flow in the analysis, we expected the drag and lift values of all our rockets to be 0, and the analysis results came in accordance with these expectations.

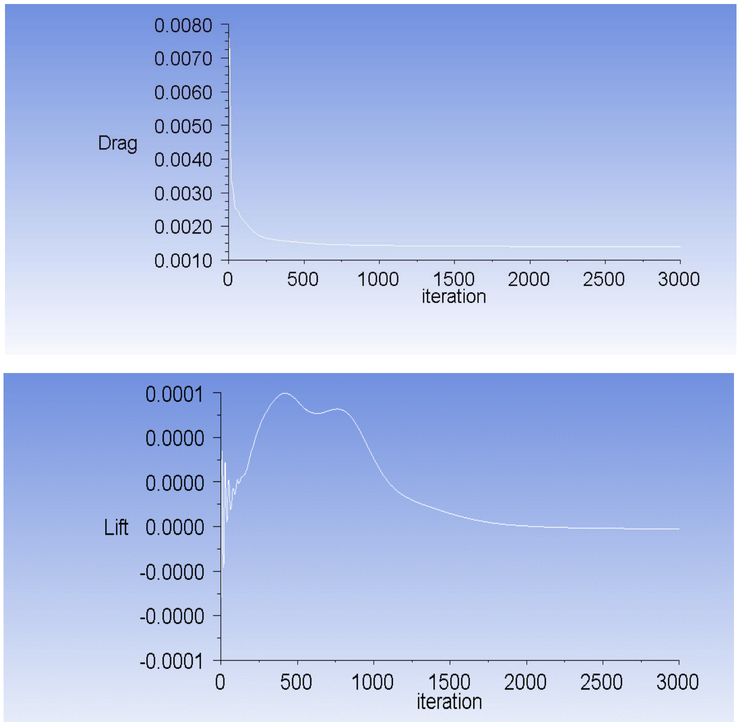
All of our drag and lift values are below so that you can compare and see them more easily. given in order:



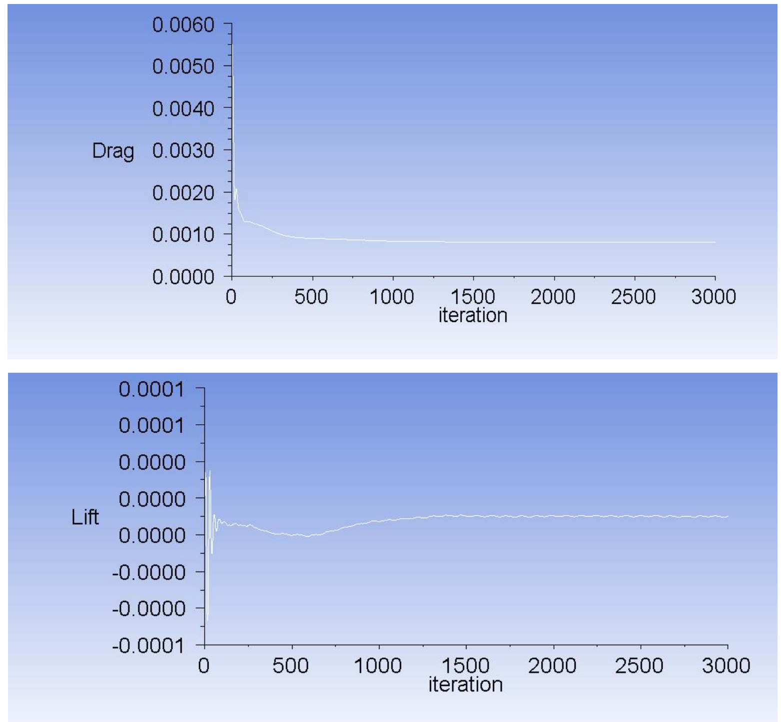
(Reference Rocket)



(Rocket 1-C)



(Rocket 1-C (Rotated 45 Degrees)



(Reference Rocket (With Inverted Fins)))

-Pressure and Velocity Contours

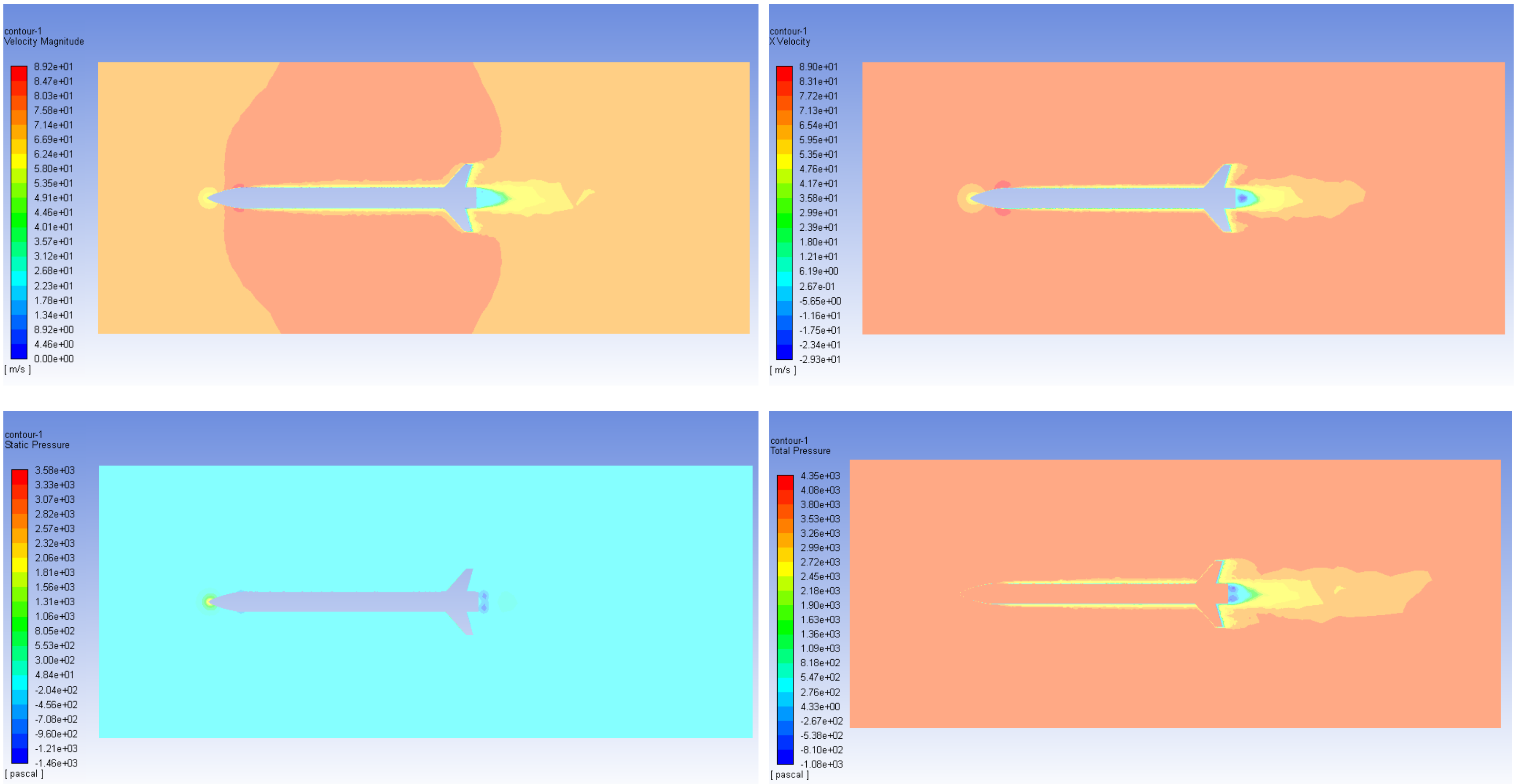
While examining the pressure and velocity contours, we need to look at two critical points as the aerodynamics section, and the first critical point is the nose cone. Looking at the analysis results, you can see that all rockets have certain shock bursts in their nose cones. However, the magnitudes of these shocks gave different results in each analysis. The fact that these shocks are large will mean that the material of the nose cone is made of materials that are more resistant to the pressure and temperature that will occur, which is reflected as additional material damage to our rocket, and therefore designs that are subject to large shocks should be avoided as much as possible.

When we look carefully, we can easily say that our reference rocket was less shocked than other rockets, and 1-C rockets were also exposed to a shocking shock. However, as a result of the analysis of the reverse finned reference rocket, the amount of shock in the nose cones is larger than the other rockets. Therefore, this design should not be preferred.

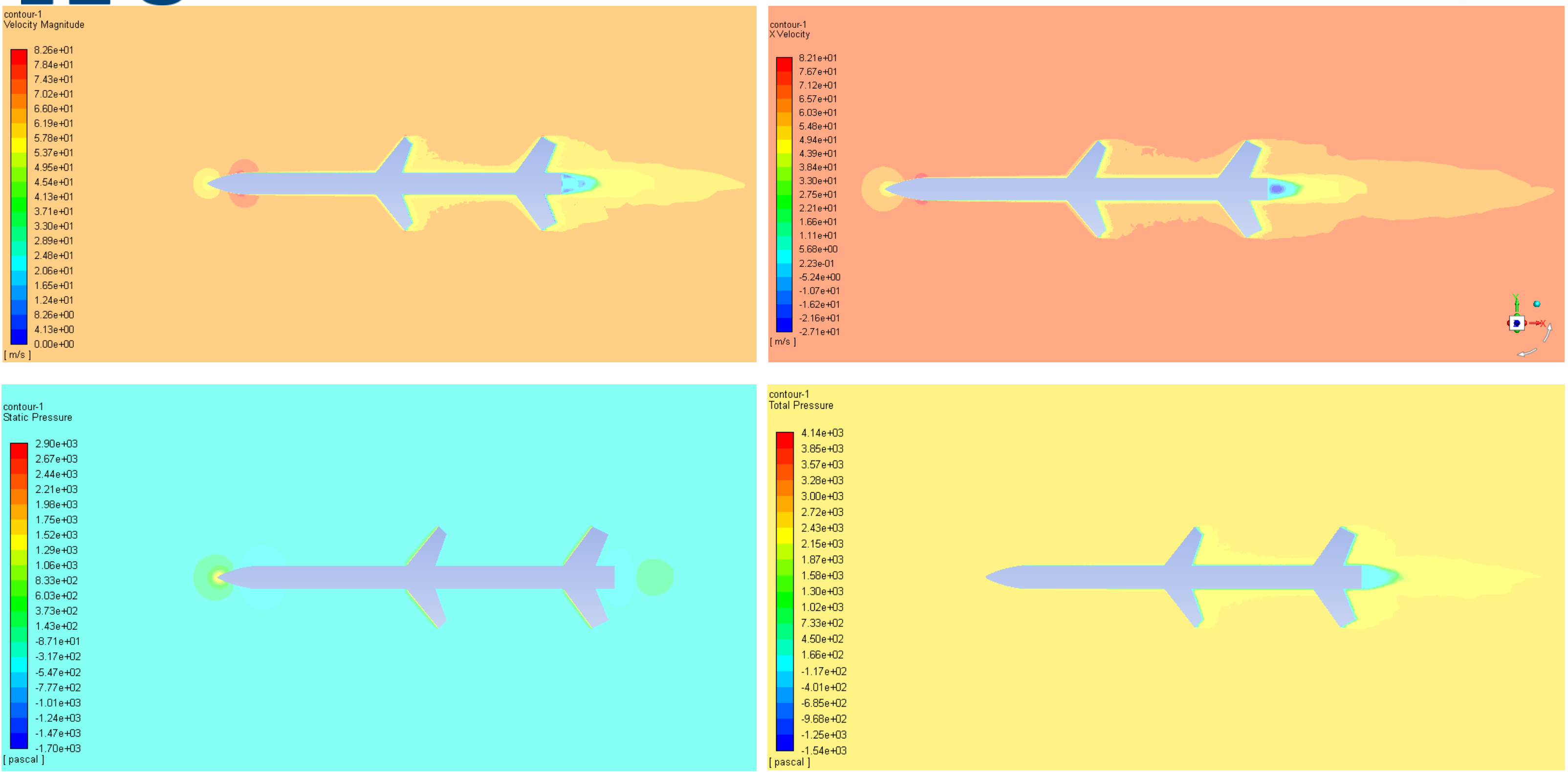
Our second critical point is the fins. The part we will compare is the static pressure contour part. As a rocket team, we want the static pressure value to be at a minimum on the fin. Because the magnitude of this pressure value is due to the pressure applied to the fin.

It shows whether the rocket can exhibit a stable flight. Considering this information, when we examine our rocket analysis, it is not difficult to say that our reference rocket gives the best results. Similarly, 1-C rockets showed acceptable results, while our reverse finned reference rocket showed a very poor result.

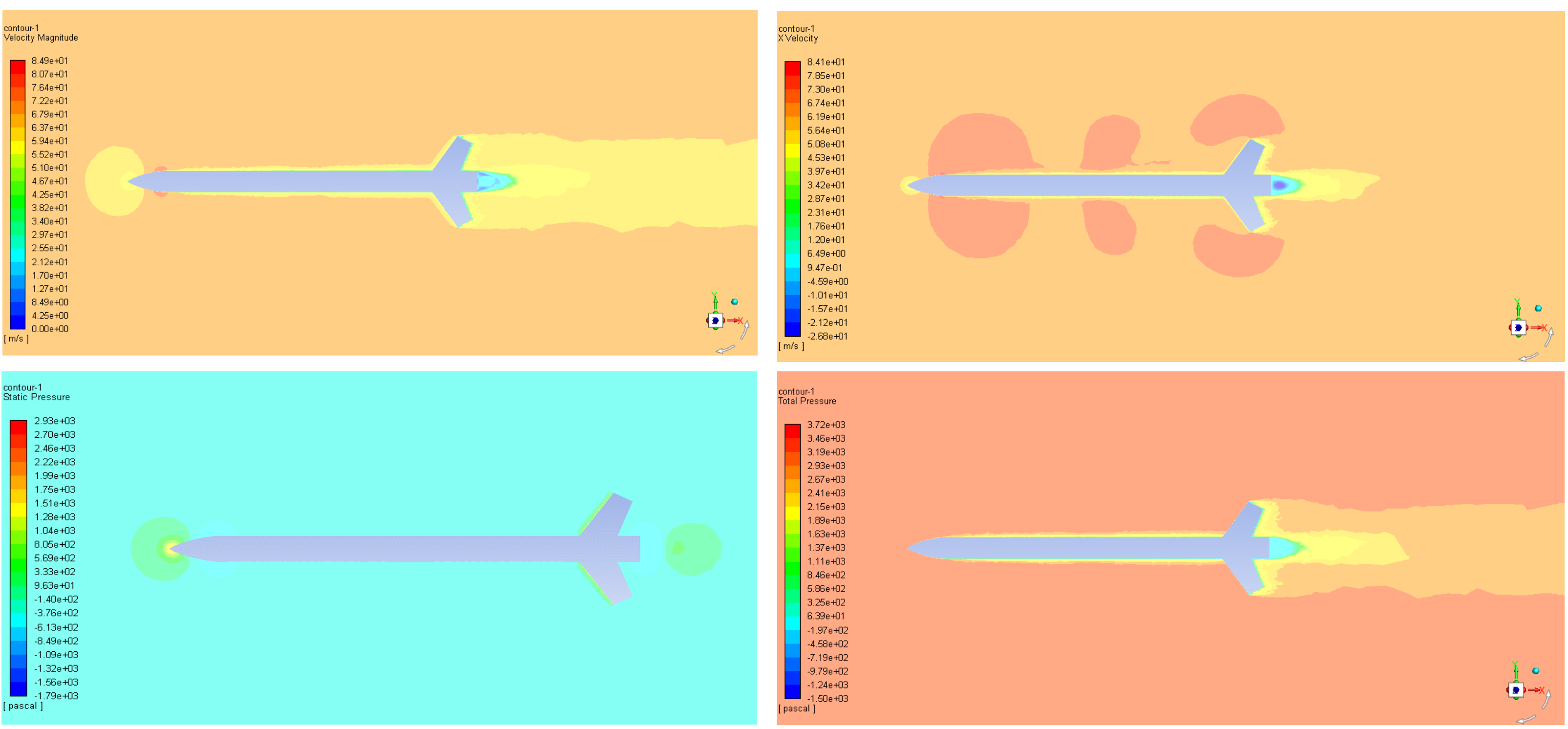
Below, we have given these contours in order to be able to compare them more easily:



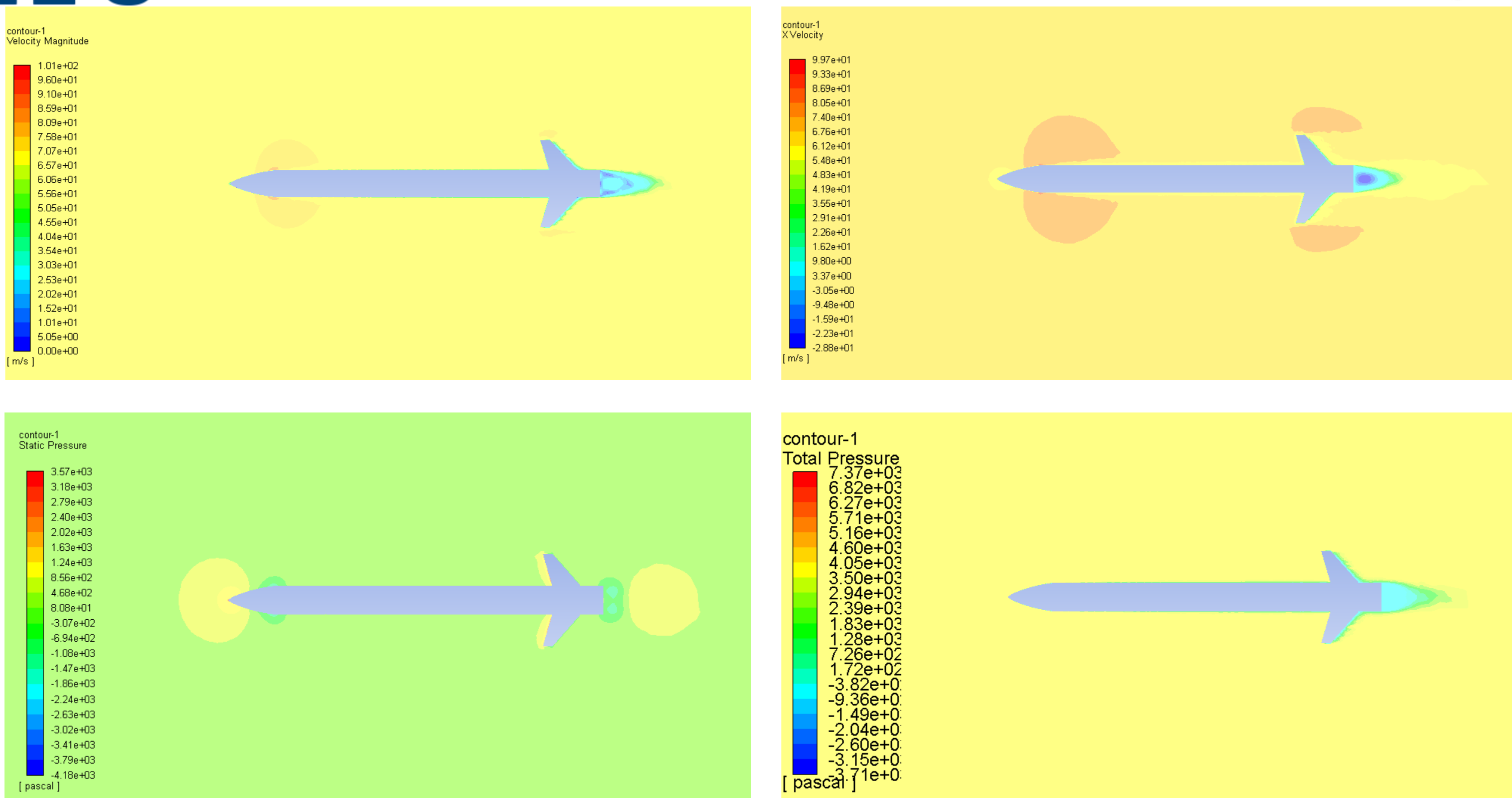
(Reference Rocket)



(Rocket 1-C)



(Rocket 1-C (Rotated 45 Degrees))



(Reference Rocket (Inverted Wing))

As a result, when we look at; Our reference rocket is a successful rocket. Our inverted finned reference rocket has been a clear example of the worst rocket types that can be designed, and our main intention in designing and analyzing this rocket was to prove, with concrete evidence, why this rocket should not be preferred. When we look at our Multistage 1-C rockets, we see rockets that can be built and fly as we expected from our Openrocket analysis. However, since the shock values on these rockets are higher than our reference rocket, they must be made of materials that are more resistant to these shocks and have relatively high heat resistance. This will be reflected to us as an additional cost. In addition, although we could not present it to you in these analyzes, in a multistage rocket that performs an angled flight, the front fins will inevitably reduce the lift on the rear winglets, which will cause various optional changes such as playing with the size of the rear winglets. So our rocket will become a bigger and more costly rocket.

As PARS Rocket Group, we are not planning a multistage rocket study for now, but our results of these multistage rocket analysis can be reused and further detailed by the group if necessary.

And as a result of all these design, analysis and examinations, it is sufficient to make the following summary:

Attachment of additional fins to a rocket; It is an unnecessary action unless there are additional tasks such as a multistage rocket flight or steering the rocket. Because the additional fins to be installed require us to enlarge the rocket and make it from materials that are more resistant to new shocks that may occur. And a bigger, more durable rocket means we have to spend more. Apart from these high costs, the increasing rocket weight will cause us to experience additional altitude loss, and balancing this loss requires the design of a multi-engine multistage rocket.

Considering these conditions, it would be an unnecessary action for us to attach an additional fin to our rockets that we will plan as PARS Rocket Group.

Department: Aerodynamic
Research, Analysis, Report: Halit Yusuf Genç
Direction: Umut Engin, Zeynep Gökçe