TEAM

antariksh

INSIGHT-1

Technical Report:
Airframe Subsystem

Trade off studies between craft paper and PVC tube for body tube :

- The lower cost but comparable strength of craft paper when taken in consideration with PVC was a major factor for selecting craft paper .
- The weight of the body tube would be reduced by greater extent if craft paper is chosen.
- Fiberglass is a better **radiolucent**. This property would help the avionics of the rocket for easier transmission of data.
- The finishing of body tube made by craft paper can be done manually and its procurement is also very easy.

Trade of studies between balsa wood and plywood for fins :-

Plywood has been selected as the material (over balsa wood) for the fins after taking the following points into the consideration.

- Insight-1 will use a motor which will generate G impulse and balsa wood is used mainly used up to the D impulse.
- Plywood is much cheaper than the balsa wood.
- It has higher modulus of elasticity and very good in dealing with compressive strength.
- Plywood can also resist the heat generated during the flight where as balsa wood is inflammable (as it would be near to the motor mount).
- Procurement is easy and the machining can be done with simple tools.

Trade of studies between plywood and balsa wood for bulk head:-

- Plywood is been selected for bulkheads also as it is low in cost and easily available in the market.
- It can absorb the impulse generated during the ejaculation of the parachute and could be attached to the body tube with the help of nuts and bolts
- Extra padding of foam could be easily done to absorb the vibration during the flight.

Trade of studies between PLA and ABS for nose cone :-

- The Ultimate Tensile Strength of PLA is much better than ABS.
- Despite durability the printability of PLA is much higher which reduces the cost.
- The Melting point of PLA is higher than ABS, a property highly important for nose cone.
- Both have good impact resistance while PLA being cheaper than ABS.
- The machining costs for ABS is Rs 15/gram vs. just Rs 10/gram for PLA
- The choice was made keeping in mind the requirements of the project and not overdoing the selection as it might increase costs and difficulty in handling. Component Procurement is simple due to increased ease of getting access to 3D printers and companies that offer their services.

ADHESIVES

Yellow Wood Glue (Paper-Paper, Wood-Paper, And Wood-Wood Joints)

Yellow glue is best for joints that are exposed to more heat ,like centering rings to motor tubes, which are in close contact to very warm motor casings. Yellow glue grabs faster, is thicker, and if used on joints like tube couplers or installing motor mounts inside the main rocket body tube, are prone to "grabbing" or "locking up" halfway through the process. Yellow wood glue shrinks a lot more during drying, and will "pull in" the body tube walls as it dries when used to glue motor mounts inside rocket body tubes, making the tube "pucker in" at the location of the centering rings. Best use is double-glue joints to attach fins:
Apply a thin layer of glue to the fin root edge and the tube where the fin will go and allow to dry, or nearly dry. Apply a second thin layer, then carefully align the fin to the body tube and press them together for about 20-30 seconds, the glue will rapidly "lock up" and permanently join the two parts

Yellow glue is actually best for attaching fins, it gives the speed of CA attachment and the greater than the strength of "regular joints" made with yellow wood glue - because the tube will rip or the fin will break before the glue joint lets go.

White Glue -Why not??

White glue- best for paper/paper joints like tube couplers, motor mount centering rings inside the main body tube of the rocket,

- shrinkage is less - therefore won't "pull in" the body tube outer wall as the glue dries, unlike yellow glue.
- Less heat resistant- therefore for joints in closer contact with heat sources, like the motor tube to centering ring joints, despite being paper/paper joints , should use yellow glue,
- Yellow glue-more heat resistant and the shrinkage doesn't matter on the motor tube of the mount.
- White glue softens substantially when heated
- Yellow glues dries faster than white glue

Urethane Glue (Gorilla Glue) Plastic-Plastic, Plastic-Cardboard, Balsa-Paper Gorilla Glue is a moisture curing polyurethane. Evidence of that can be seen in the foaming that develops as the adhesive adsorbs water and cures. At the interface between wood fibers and glue, a chemical reaction occurs which causes the wood fibers to bond more tightly to the adhesive than they do, indeed, to each other. Properly assembled, a bond of this type is stronger than the wood itself.

- Specialty glue that's good for locking nose weight into nosecones, since it foams up and dries hard.
- Doesn't require evaporation of solvent (like water in white/wood glues, similar to epoxy in that it's a chemical reaction that cures it and it works well in situations with poor ventilation, like inside nosecones.
- Foams as it cures, so as a construction adhesive, it's not very useful, since there's little/no control over it's shape or appearance after application.

- Cures by the absorption of moisture from the air, so adding a drop or two of water is all that's needed to help it cure and lock nose weight in place.

Epoxy

Epoxy cures at a given rate by a chemical reaction that forms polymers, the chemicals will remain liquid regardless of absorption or being spread extremely thinly during assembly by tight- fitting parts, which can rapidly soak up the moisture in thin layers of white, and especially wood glue, causing the glue to 'lock up' the parts before they can be fully assembled.

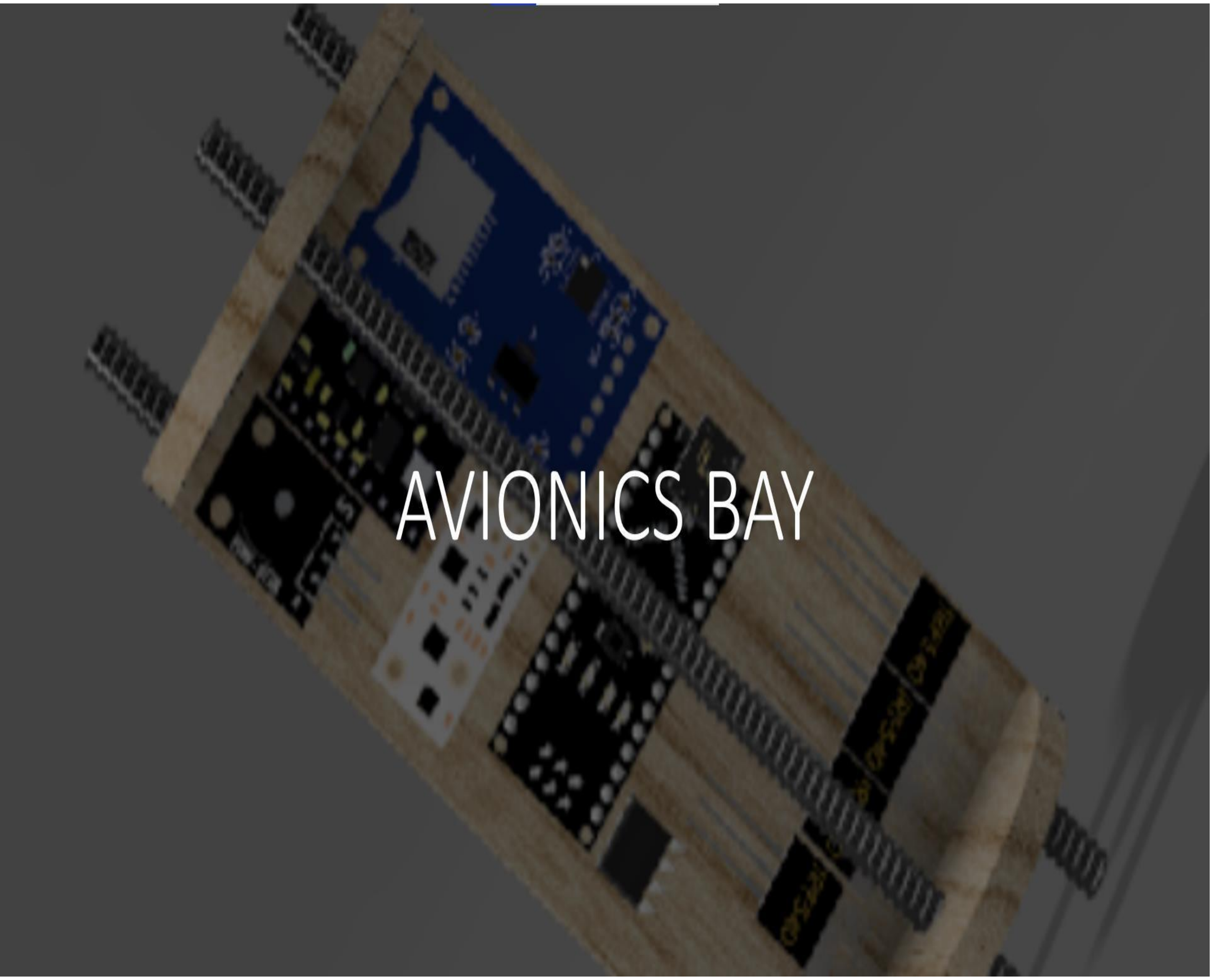
It can be used for any other joint, and especially useful for joining dissimilar materials (plastic and wood/paper) so long as it can grip the plastic.

Measuring and mixing required, and limited pot life leads to a lot of waste, unlike other glues, and the chemical nature of it requires nitrile gloves to protect skin from exposure, and over time it can lead to sensitization even from the vapors of it.

Cyanoacrylate (CA) Super Glue – Why not??

- It's too weak in the shear plane (fins pop off the tube on landing if they hit the ground hard)
- CA gets brittle over time.
- CA also soaks into balsa and seals off the pores, hardening the balsa at the same time. This makes it useful for hardening balsa parts.
- It dries so quickly, that repositioning the materials being glued, once super glue has been applied, is usually impossible.

Uses: Covering of shock cord


AVIONICS BAY

Components

The following lists give the details of the components that are to be used in the successful functioning of the Avionics bay.

Components of the Avionics section

Components	Quantity	Dimensions(mm)
Altimeter-BMP388	1	21.6*16.6
IMU-MPU6500	1	15*25
Arduino Nano	1	45*18
MOSFET	4	(H)9.15*(L)10.4
Op-amp-LM318	1	8 pin IC
9V Battery	2	48*25*15
SD Card module	1	41*24
Buzzer 150dB	1	8.5(H)*12(D)
Nichrome wire	1	(L)100*(T)0.3211

Components of the Airframesection

Components	Quantity	Dimensions(mm)
Sled board	1	6*11
Bulkheads	2	D(6)
Threaded Rods	3	M4
Screws	TBD	M3
L-Brackett	TBD	10*10*3

Requirements and Specifications

Meetings with the Avionics subsystem members were conducted, and the required specifications and placement were discussed and enlisted.

R&S of Avionics

1. Recovery and Rocket avionics separated
2. Components accessible by Nano
3. Distances between the components

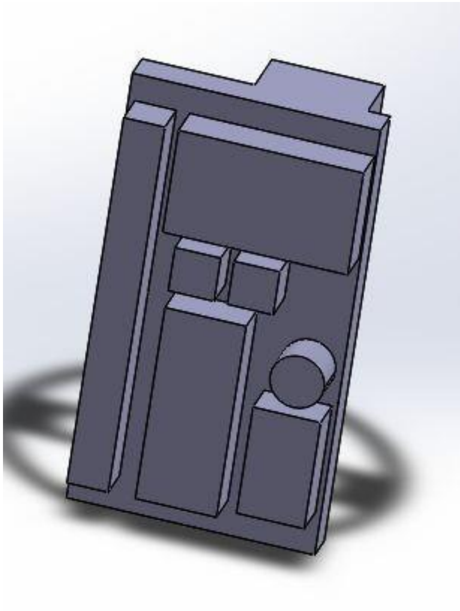
R&S of Airframe

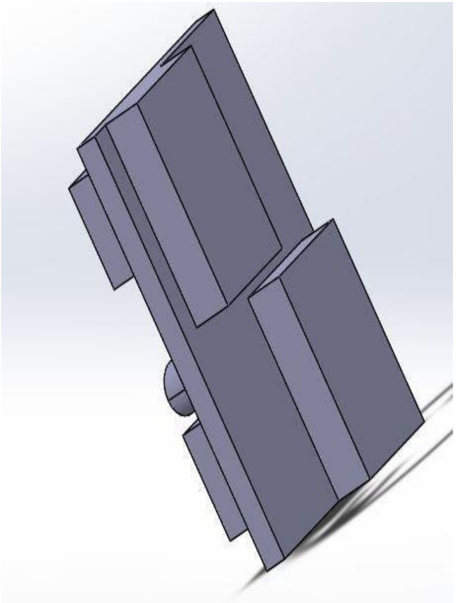
1. Lightweight
2. Low diameter
3. Structural Stability
4. Avoid damage to the components
5. Using the area wisely

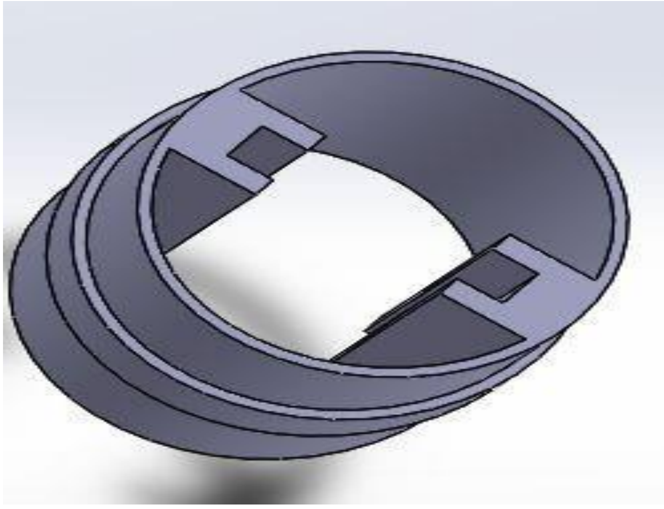
From the above lists of components and the requirements, designs for the avionics bay were done in iterations making the bay functionally and structurally efficient.

Iteration 1

Several designs were discussed in the first iteration, among which the above design is one.







Advantages

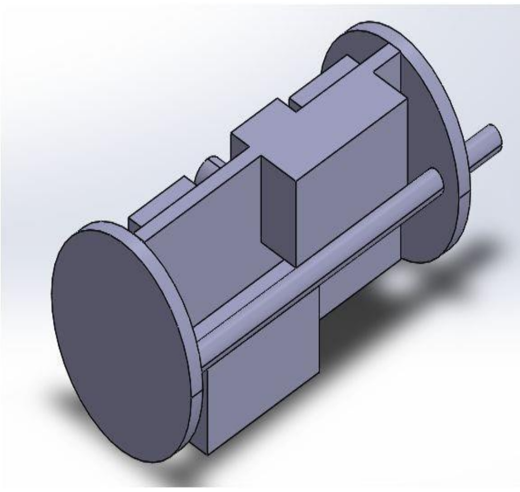
1. Good Placement of Components
2. Secure positioning of the sled board

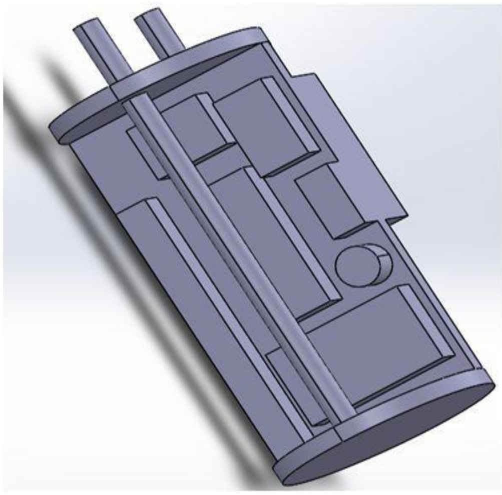
Disadvantages

1. Side ridges machining difficulty
2. Inability to transfer loads efficiently
3. Reduces modularity

Iteration 2

With greater problems to be tackled in the previous designs, a further better way to transfer the loads by using threaded rods was designed. The design is structurally better and keeps the components of the avionics bay safe.





Advantages

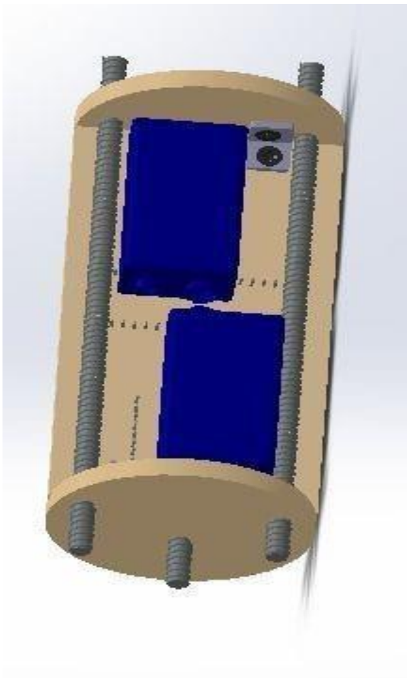
1. Load transferring capability
2. Increased Modularity

Disadvantages

1. The batteries extruded from the sled board
2. Threaded rods far away from the sled board

Iteration 3

Since the threaded rods hampered the placement of the batteries and there rised a requirement of increasing the dimension, the next design with the addition of one more threaded rod totaling to 3 M4 rods, canceled out the disadvantage of the placement of the batteries and the threaded rods away from the sled board. With the addition of L- brackets, a firmer fixing of the bulkheads with the sled board was done.



Advantages

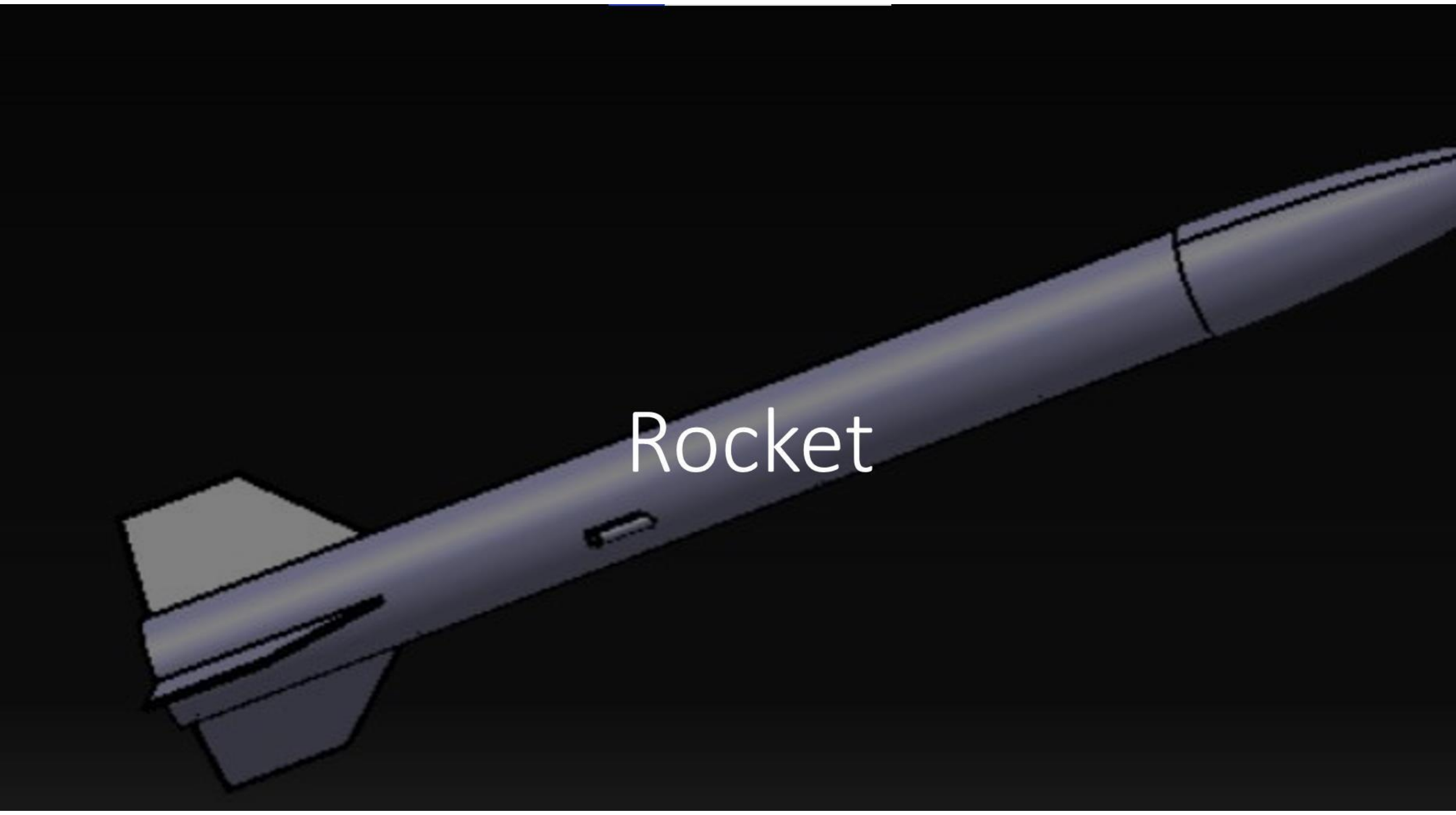
1. Load transferring capability increased
2. Increased Modularity
3. Batteries and other components comfortably settled
4. Threaded rods near the sled board

Avionics Bay Mass

With the last iteration of the design, the mass of the Avionics bay has been calculated below, in order to ensure its proportion in the proposed mass of the Insight-1 rocket.

Components	Qty	Weight per Component(g)	Total Weight (g)
Arduino Nano	1	7	7
Altimeter BMP388	1	0.561	0.561
IMU MPU 6500	1	5	5
MOSFET IRF540	4	9	36
OpAmp LM318	1	1	1
Batteries 9V	2	45	90
SD card module	1	4	4
Buzzer 150dB	1	1	1
Sled board	1	20	20
Threaded Rods(DIA 4mm LENGTH 15cm) Al-6063	3	5.1	15.3
Bulkheads	2	9.95	19.9
U-Bolts			20
		TOTAL WEIGHT	**219.761**
Contingency			10%
		FINAL WEIGHT	**241.7371**

INSIGHT-1



NOSE CONE

3D printing for the development of nose cone can be a good and effective choice as it gets increased reusability and durability. The choices for the material to be used for printing the nose cone have narrowed down to ABS (Acrylonitrile butadiene styrene) and PLA (Polylactic Acid). The comparison for the two has been drawn out below:

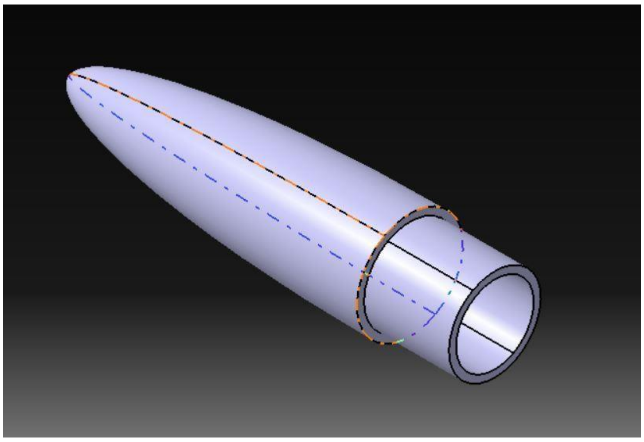
Table 1: Comparison between ABS and PLA

Parameters	ABS	PLA
Type	Thermoplastic	Thermoplastic
Density(g/cm^3)	1.05	1.24
Durability (out of 10)	8	4
Ultimate Strength (MPa)	40	65
Printability (out of 10)	8	9
Impact Resistance	✓	✓
Maximum Service Temperature (^{o}C)	98	52
Cost (Rs/kg)	1215	989

From the table following conclusions can be deduced:

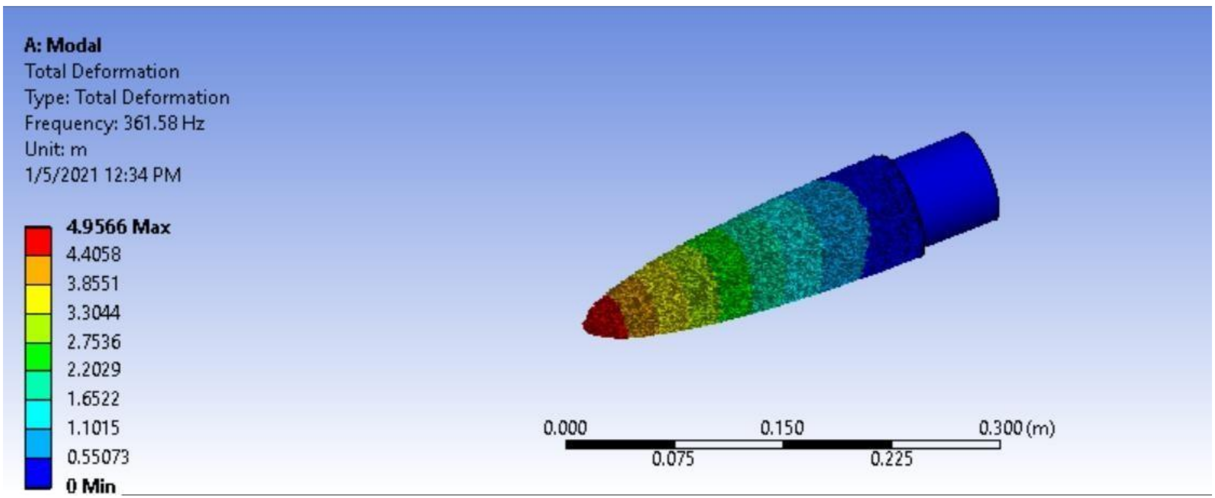
1. The Ultimate Tensile Strength of PLA is much better than ABS.
2. Despite durability the printability of PLA is much higher which reduces the cost.
3. The Melting point of PLA is higher than ABS, a property highly important for nose cone.
4. Both have good impact resistance while PLA being cheaper than ABS.
5. The machining costs for ABS is Rs 15/gram vs. just Rs 10/gram for PLA.

Design



Outer Radius	37.5mm
Inner Radius	32.471mm & 27.471mm
Mass	0.253kg
Material	PLA

Modal Analysis



Static Structural

Model (A4) > Static Structural (A5) > Solution (A6) > Results

Object Name	*Total Deformation*	*Equivalent Stress*
State	Solved	
Scope		
Scoping Method	Geometry Selection	
Geometry	All Bodies	
Position		Top/Bottom
Definition		
Type	Total Deformation	Equivalent (von-Mises) Stress
By	Time	
Display Time	Last	
Calculate Time History	Yes	
Identifier		
Suppressed	No	
Results		
Minimum	0. mm	1.3376e-008 MPa
Maximum	1.3571e-002 mm	0.59734 MPa
Average	6.7059e-003 mm	0.18433 MPa
Minimum Occurs On	Nose cone	
Maximum Occurs On	Nose cone	
Information		
Time	1. s	
Load Step	1	
Substep	1	
Iteration Number	1	
Integration Point Results		
Display Option		Averaged
Average Across Bodies		No

BODYTUBE

Body Tube is required in the rocket to hold the components together and it also ensures the safety of it's internal components from the changing exterior atmospheric conditions, wherever required. It also maintains the structural integrity of the rocket. Nose cones, Fins, etc all are attached to the body tube. These reasons are enough to understand the importance of the body tube's strength for any mission to be as planned. Meanwhile, consideration of its material's density also plays an important role since it is the largest component of any rocket. The weight of the rocket is mostly based on the weight of the rocket's body tube.

The team come up with three materials based on the mission constraints i.e.

- KRAFT PAPER
- BLUE TUBE 2.0
- PVC

SELECTION OF THE MATERIAL

The material selection is based on several constraints i.e.

- Strength
- Strength/Weight Ratio
- Availability
- Cost
- Ease of Manufacturing
- The material is itself a paper, so the weight is understood to be less. The strength of the body tube made with this a question thatthe team had doubts. But the references took by the subsystem regarding it showed that the estimated required strength can be achieved

when we use several layers of it. The cost of purchase and availability was also very much what we had planned. The manufacturing can also be done in-house, if required

Based on the above discussions we decided **Kraft Paper** to be the material for the Body tube.

PARAMETERS	CARDBOARD	PVC	CPVC
Density (g/cc)	0.68	1.41	1.52
Tensile Strength(Psi)	200	7500	8200
Thermal conductivity(W/mC)	0.06	0.16	0.17
Price	cheapest	cheap	costly

Properties

- Density- 0.2g/cc
- Poisson's ratio- 0.3
- Young's modulus- 2500 MPa

Making

Materials Required

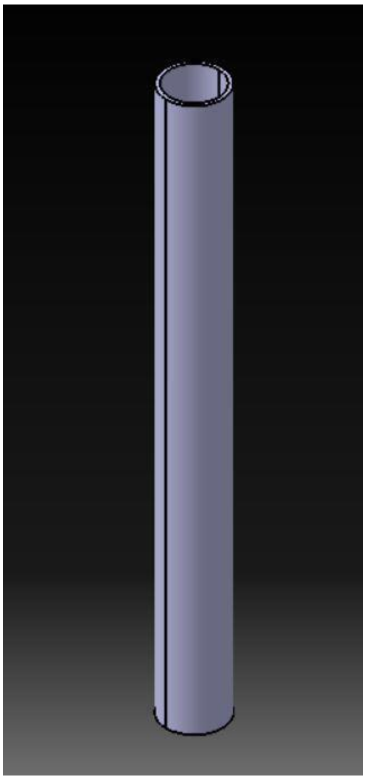
- Kraft Paper roll
- Wood glue (Titebond)
- PVC mandrel
- Masking tapes
- 220 grit sandpaper

Process

1. Cut strips of Kraft Paper that are appropriately sized for wrapping around the form. Too narrow, and your spirals will be really close together resulting in a shorter finished tube. Too wide, and you won't be able to wrap it very easily.
2. Wrap the first strip around the form in a spiral fashion, without overlapping any of the seams. Use a small piece of masking tape to fasten the Kraft paper to the form at both ends.
3. Glue the papers: Mix one-part water to four-part glue. Make sure to apply it throughout the strip without any puddles.
4. Make sure there is no overlapping of the seams of the paper. Once done make sure there is no bubble in the wrapping of the paper before the glue dries.
5. After the layers are done, roll the tube back and forth, to put pressure and create better bonding.
6. Trim the ends of the body tube. Use any kind of guide and give an equal trim using a cutter.
7. Let the tubes dry by placing them in standing position and later sand the tube until a smooth and required finishing is obtained.

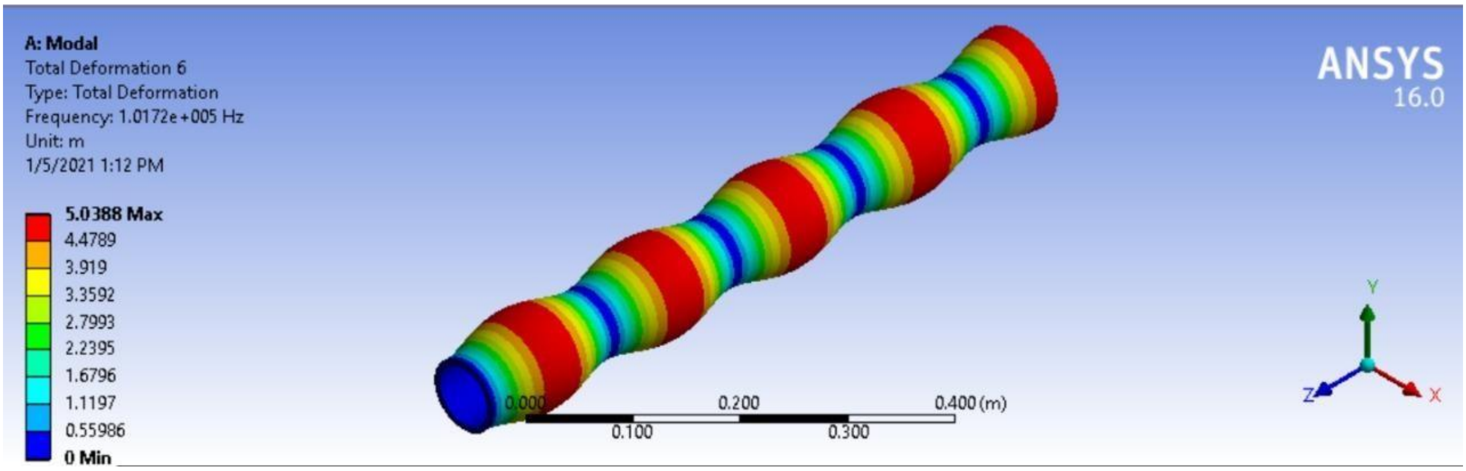
Four to Five layers of Kraft paper wrapping is given, in order to ensure a strong and durable body tube.

Design



Outer Radius	37.5mm
Inner Radius	32.5mm
Height	730mm
Mass	0.161kg
Material	Kraft Paper

Modal Analysis



Static Structural

Model (A4) > Static Structural (A5) > Solution (A6) > Results

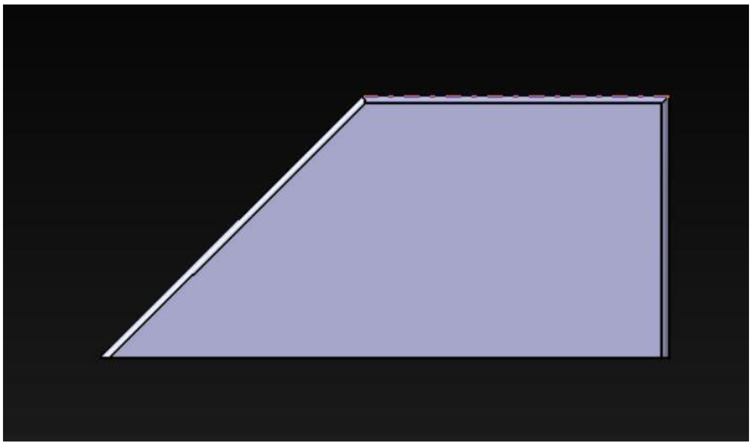
Object Name	*Total Deformation*	*Equivalent Stress*
State	Solved	
Scope		
Scoping Method	Geometry Selection	
Geometry	All Bodies	
Position		Top/Bottom
Definition		
Type	Total Deformation	Equivalent (von-Mises) Stress
By	Time	
Display Time	Last	
Calculate Time History	Yes	
Identifier		
Suppressed	No	
Results		
Minimum	0. mm	7.0957e-012 MPa
Maximum	6.2603e-003 mm	0.19669 MPa
Average	4.1697e-003 mm	7.9212e-002 MPa
Minimum Occurs On	Part1	
Maximum Occurs On	Part1	
Information		
Time	1. s	
Load Step	1	

FINS

Plywood has been selected as the material (over balsa wood) for the fins after taking the following points into the consideration.

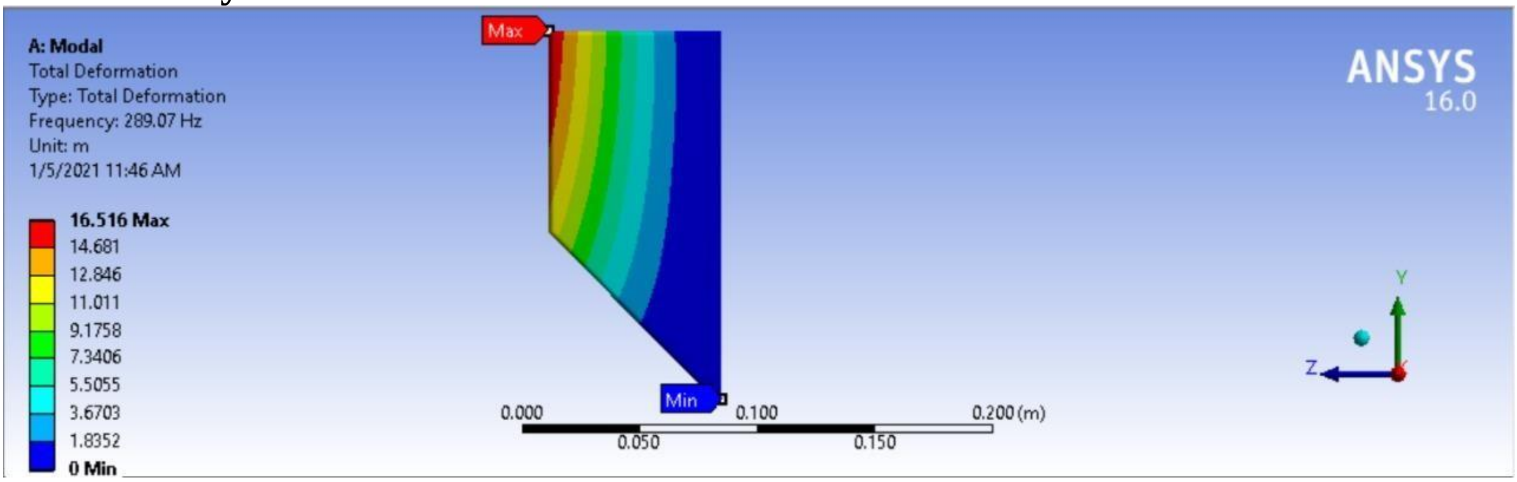
- Insight-1 will use a motor which will generate G impulse and balsa wood is used mainly used up to the D impulse.
- Plywood is much cheaper than the balsa wood.
- It has higher modulus of elasticity and very good in dealing with compressive strength.
- Plywood can also resist the heat generated during the flight whereas balsa wood is inflammable (as it would be near to the motor mount).
- Procurement is easy and the machining can be done with simple tools.

Design



Upper edge Length	83.176mm
Lower edge Length	155.162mm
Height	71.5 mm
Mass	0.036kg each
Material	Plywood

Modal Analysis



Static Structural

TABLE 12
Model (A4) > Static Structural (A5) > Solution (A6) > Results

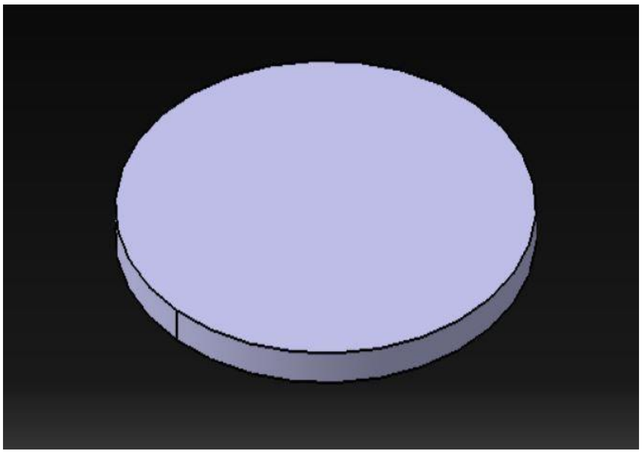
Object Name	*Total Deformation*	*Equivalent Stress*
State	Solved	
Scope		
Scoping Method	Geometry Selection	
Geometry	All Bodies	
Position		Top/Bottom
Definition		
Type	Total Deformation	Equivalent (von-Mises) Stress
By	Time	
Display Time	Last	
Calculate Time History	Yes	
Identifier		
Suppressed	No	
Results		
Minimum	0. mm	2.3792e-003 MPa
Maximum	1.4424e-002 mm	3.8027 MPa
Average	6.6069e-003 mm	0.63061 MPa
Minimum Occurs On	fin	
Maximum Occurs On	fin	
Information		
Time	1. s	
Load Step	1	
Substep	1	
Iteration Number	1	
Integration Point Results		
Display Option		Averaged
Average Across Bodies		No

BULKHEAD and CENTRING RINGS

Plywood is been selected for bulkheads also as it is low in cost and easily available in the market. It can absorb the impulse generated during the ejaculation of the parachute and could be attached to the body tube with the help of nuts and bolts.

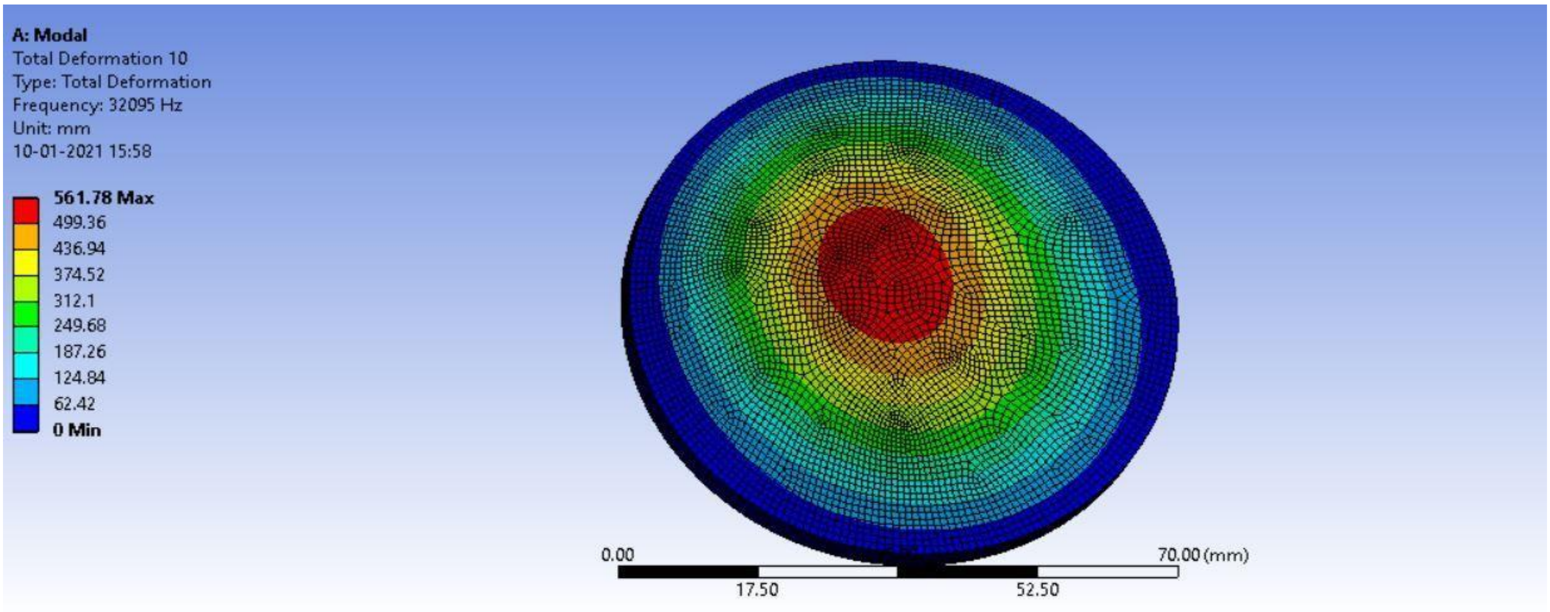
Extra padding of foam could be easily done to absorb the vibration during the flight.

Design



Radius	35mm
Thickness	5mm
Mass	0.012kg each
Material	Plywood

Modal Analysis

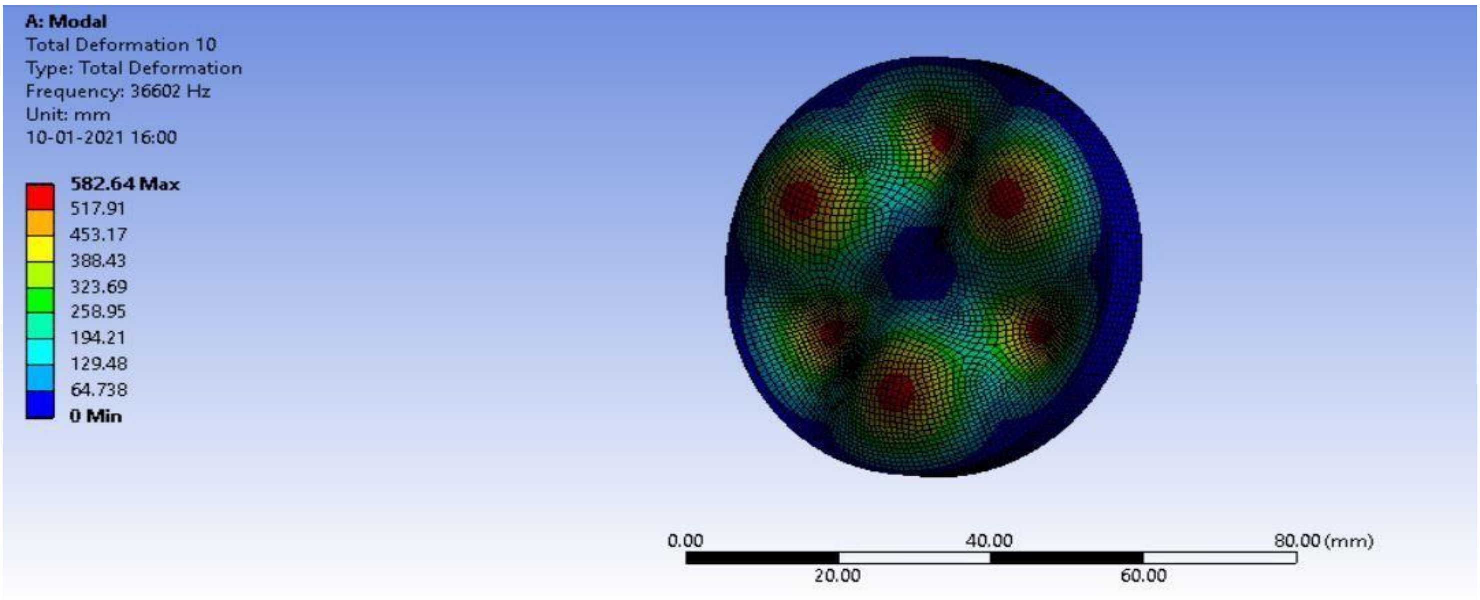


Static Structural

Model (A4) > Static Structural (A5) > Solution (A6) > Results

Object Name	*Total Deformation*	*Equivalent Stress*
State	Solved	
Scope		
Scoping Method	Geometry Selection	
Geometry	All Bodies	
Definition		
Type	Total Deformation	Equivalent (von-Mises) Stress
By	Time	
Display Time	Last	
Calculate Time History	Yes	
Identifier		
Suppressed	No	
Results		
Minimum	0. mm	3.1788e-002 MPa
Maximum	3.2925e-002 mm	3.3219 MPa
Average	1.1587e-002 mm	1.0578 MPa
Minimum Occurs On	PartBody	
Maximum Occurs On	PartBody	
Information		
Time	1. s	
Load Step	1	
Substep	1	
Iteration Number	1	
Integration Point Results		
Display Option		Averaged
Average Across Bodies		No

Bulkhead (Nosecone) Modal Analysis

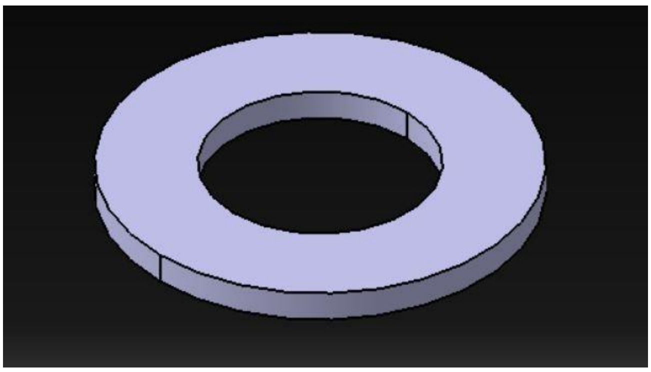


Static Structural

Model (A4) > Static Structural (A5) > Solution (A6) > Results

Object Name	*Total Deformation*	*Equivalent Stress*
State	Solved	
Scope		
Scoping Method	Geometry Selection	
Geometry	All Bodies	
Definition		
Type	Total Deformation	Equivalent (von-Mises) Stress
By	Time	
Display Time	Last	
Calculate Time History	Yes	
Identifier		
Suppressed	No	
Results		
Minimum	0. mm	3.7899e-002 MPa
Maximum	1.7093e-002 mm	2.5445 MPa
Average	6.1915e-003 mm	0.76203 MPa
Minimum Occurs On	BULK HEAD NOSE CONE	
Maximum Occurs On	BULK HEAD NOSE CONE	
Information		
Time	1. s	
Load Step	1	
Substep	1	
Iteration Number	1	
Integration Point Results		
Display Option		Averaged
Average Across Bodies		No

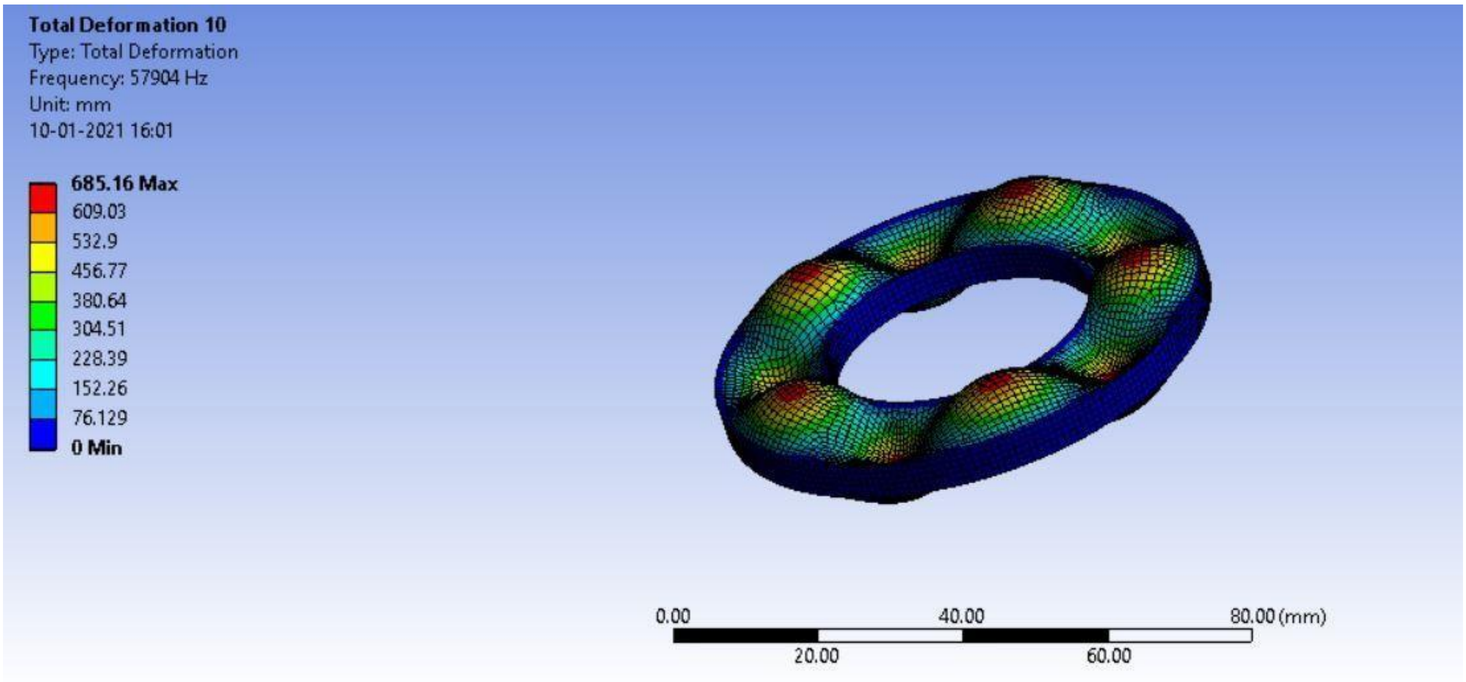
Design



Inner Radius	19mm
Outer Radius	35mm
Thickness	5mm

Mass	0.009kg each
Material	Plywood

Modal Analysis



Static Structural

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Object Name	*Total Deformation*	*Equivalent Stress*
State	Solved	
Scope		
Scoping Method	Geometry Selection	
Geometry	All Bodies	
Definition		
Type	Total Deformation	Equivalent (von-Mises) Stress
By	Time	
Display Time	Last	
Calculate Time History	Yes	
Identifier		
Suppressed	No	
Results		
Minimum	0. mm	3.1607e-002 MPa
Maximum	7.0577e-004 mm	1.0739 MPa
Average	4.3724e-004 mm	0.24363 MPa
Minimum Occurs On	PartBody	
Maximum Occurs On	PartBody	
Information		
Time	1. s	
Load Step	1	
Substep	1	
Iteration Number	1	
Integration Point Results		
Display Option		Averaged
Average Across Bodies		No

LAUNCH PAD

The launch pad is designed to launch a rocket vertically. Launch Pad physically supports the vehicle and it is a service structure with umbilical's. It consists of circular plywood pod with hinges, three supportive PVC legs with PVC caps, one plywood plate attached with utensil pod , PVC 4-way cross coupler, PVC 45° Elbow couplers, PVC TEE coupler, Steel Rod of 1/4" Diameter and fasteners. The design is made in the way to provide launch in 360° with equivalent supporting structure.

The design specifications and considerations are as follows:

- **Circular plywood pod with hinges (*1)** : This was chosen due to higher strength in compression.
  - Outer diameter = 300mm
  - Thickness = 10mm
  - Thickness of hinge(*3) = 10 mm (with orientation of 120° each)
  - Slots(10mm) provides the accommodation for the hinges ,on which the legs are attached

- **PVC legs with caps (*3) :** The legs provides the strength to the pad and exerted load distributes equally along the legs.
  - Diameter = 1 inch
  - Length = 13 inch
  - 10 mm holes were drilled on the pipe to fix the fasteners.

- **Plywood plate attached with utensil pod (*1) :** This was chosen to provide flame deflection structure to prevent the intense heat of the rocket exhaust from damaging the vehicle or pad structures.
  - Outer diameter = 350mm
  - Thickness = 10mm
  - Dimensions of the slots = 5*6.35mm and 10*50mm
  - M10&M4 holes were drilled on the plate to fix the fasteners.

- **1" PVC 4-way cross couple :** It is used to join the pipes to obtain the required design.
  - Dimensions (L*W*H) = 0.98 x 5 x 15.98 inches.
  - Quantity = 01

- **1" PVC TEE coupler :** It is used to join the pipes to obtain the required design.
  - Dimensions (L*W*H) = 3.69 x 2.66 x 1.63 inches.
  - Quantity = 01

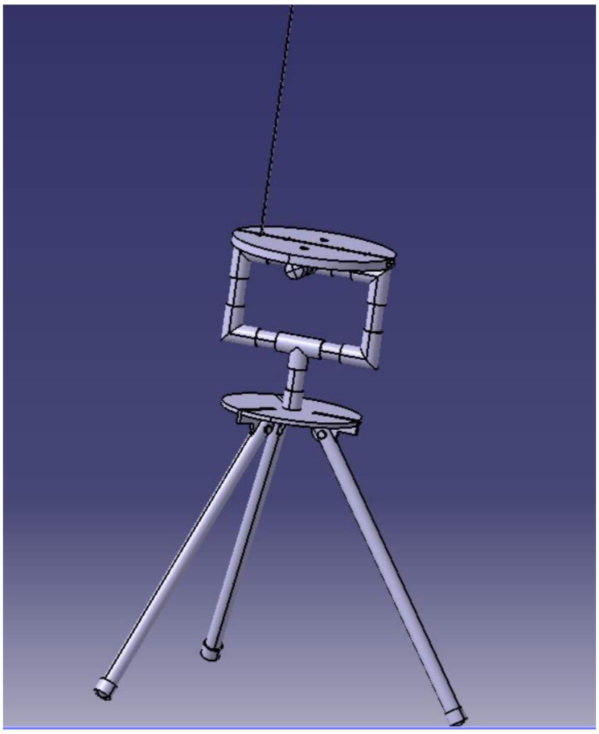
- **1" PVC coupler :** It is used to join the pipes to obtain the required design.
  - Dimensions (L*W*H) = 2.38 x 1.69 x 1.69 inches
  - Quantity = 01

- **PVC 45° Elbow couplers :** It is used to join the pipes to obtain the required design.
  - Diameter = 1 inch.
  - Quantity = 04

- **1" PVC pipes :** Pipes of different length were required to obtain the desired design.
  - Diameter = 1 inch.
  - Total length = 50 inch.

- **Steel Rod :** It provide guidance to rockets as they leave the launch pad, before they are moving fast enough for the fins to guide the rocket. Since the size of our motor is G , we chosen the diameter of the rod as 1/4"**.**
  - Diameter = ¼ inch.
  - Length = 1m

- **FASTENERS :**
  - M10 hexagonal headed bolt and Nut (*3) were used to attach the leg to hinges.
  - M10screws (*3) were used to fix the plywood plate to pipe at top assembly.
  - M4 screws (*2) were used to fix the launching rod to plywood plate at top**.**



Launching Pad assembly

Analysis

- The Catia model of launch pad saved in .stp format is opened in Ansys workbench 18.1..
- Then in workbench library we have assign the required material as per the design.
- After that we have performed meshing in workbench. After meshing is done, the file is saved in. inp format so that it can be opened in APDL.
- In APDL we gave the required ply orientation.
- After that we gave fixed support to the leg and on the surface of the top plate we gave pressure load of 138N.
- Then we solved the problem in APDL to get the maximum total displacement.
- The results are noted below:

Static structural analysis with 138 compressive load was done and the maximum deformation was **0.00041296mm**