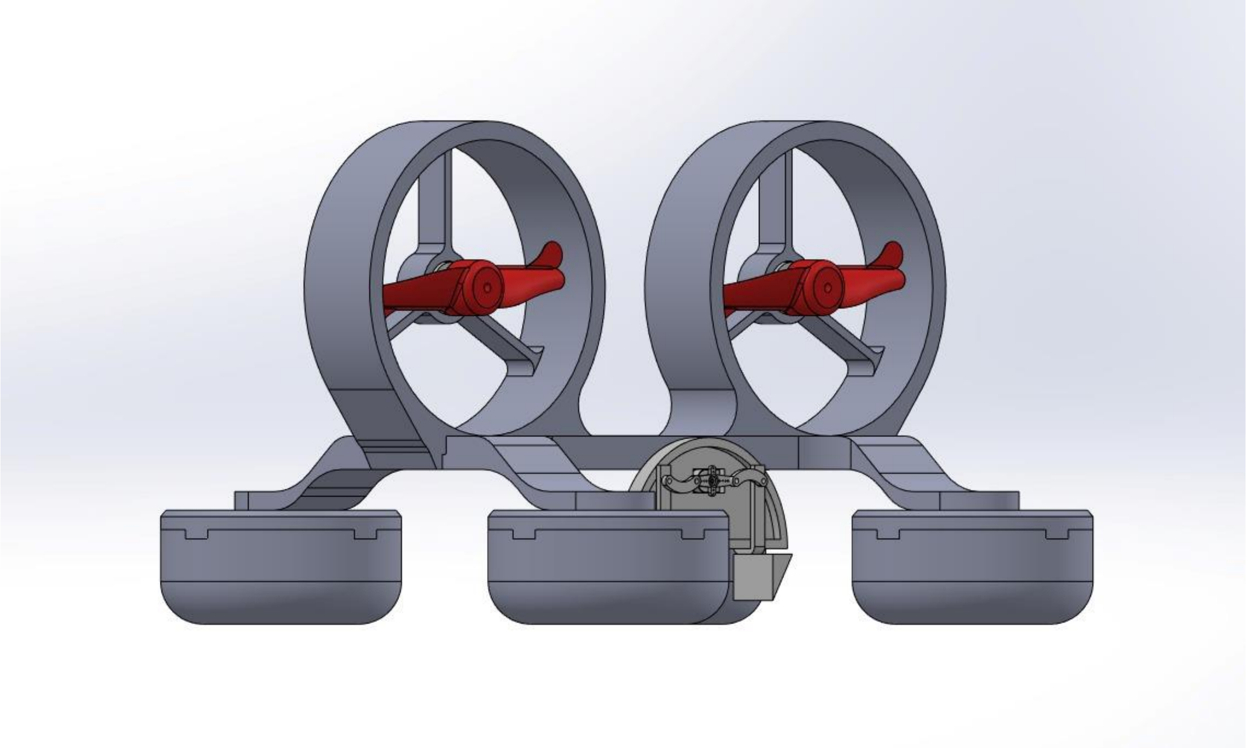


ASME IAM3D 2023

Hovercraft Resupply Vehicle Design Competition

Design Report

ASME EFx India Bengaluru 2023

ASME NSUT STUDENT SECTION

Netaji Subhas University of Technology, Sector 3, Dwarka, Delhi 110078
India

Declaration

We, the undersigned members of Team ASME NSUT, hereby declare that the engineering design report submitted by us is entirely original and has been prepared by our team. We have not copied any part of this report from any other source without proper attribution.

Furthermore, we confirm that we have adhered to all the rules and guidelines outlined in the competition rules. We have not used any prohibited materials or techniques in our design, and we have conducted ourselves in accordance with the ethical standards expected of us.

We understand that any violation of these rules may result in disqualification from the competition, and we accept full responsibility for this report's content and the design it describes.

Team Members

Raghav Krishan Garg (Captain)
Keshav Dahiya
Pranav Mehrotra
Prashant
Deepanshu Naggar
Ishaan Nagpal
Devansh Rastogi

Acknowledgement

We would like to share our sincere gratitude to all those who helped us in the completion of this project. While working on this project, we faced several challenges, but their help and support at every step of this journey guided us in giving shape to our ideas.

We would like to thank our faculty advisor, Dr. Vivek Kumar, for his continuous help and guidance throughout the project. His oversight allowed our team to learn and understand even the smallest aspects of the project, which significantly contributed to its success.

CONTENT

1. Introduction

This engineering design report presents the analysis and design of an innovative hovercraft, created for the ASME 2023 IAM3D® Hovercraft Resupply Vehicle Design Competition. The primary goal of this project was to develop a hovercraft using additive manufacturing, which could transport a payload through a ground course and deliver it to its destination.

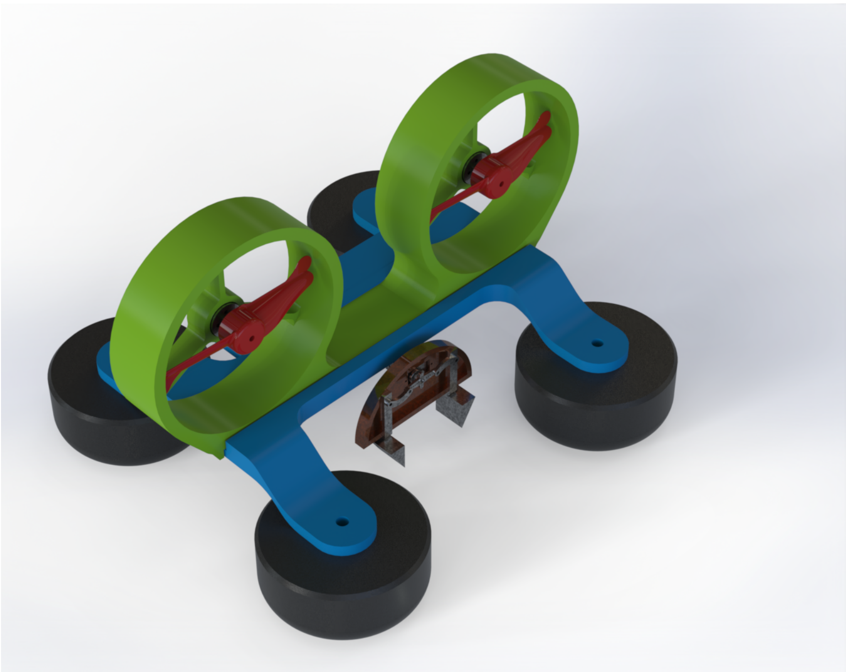
The aim of this project was to create a prototype of an unmanned emergency resupply hovercraft that can traverse many mediums to deliver lifesaving aid to those in need during natural disasters, search and rescue operations, defence and other use cases.

To achieve this objective, we took a fresh approach and utilized an iterative design process. Each aspect of the design was carefully considered and refined to create an efficient, high-performance hovercraft. The prototype was manufactured using Polyethylene terephthalate glycol (PETG) and polyacitic acid (PLA) with the Fused Deposition Method of additive manufacturing.

A F7 flight controller along with T-Motor Velox V2 V45A 3-6S speed controller has been used to control 6(4 upward thrust + 2 propellers) T-Motor VELOX V2 motors to navigate the hovercraft's flight through the obstacle course.

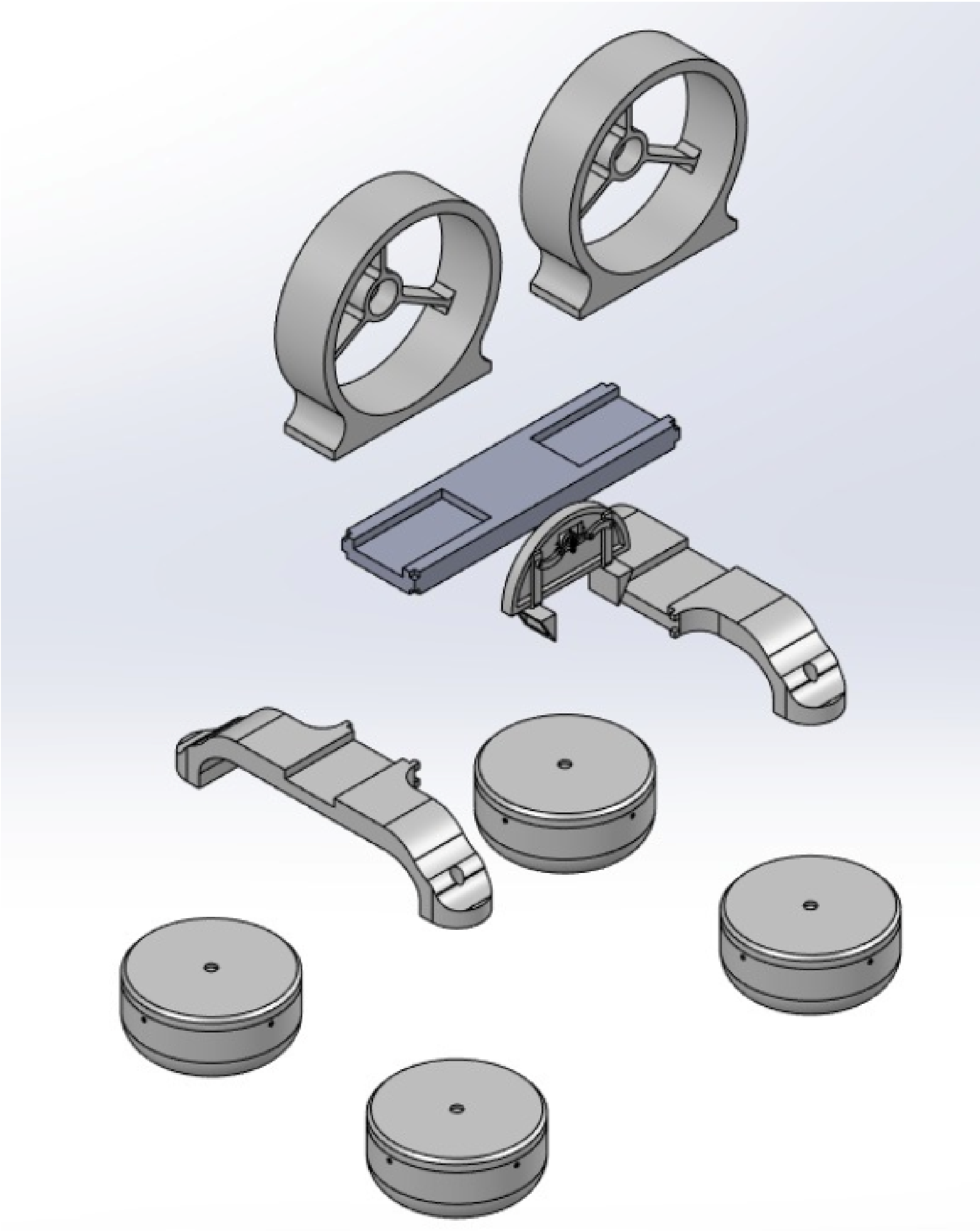
Our hovercraft features a precise pick-and-drop mechanism, operated by a single servo motor. This innovative mechanism allows for accurate and efficient loading and unloading of the payload. Through extensive prototyping and testing, we were able to refine our design to create a stable, agile, and highly effective hovercraft capable of meeting the challenge objectives.

Figure 1: Render of Hovercraft



2. Exploded CAD Assembly Drawing

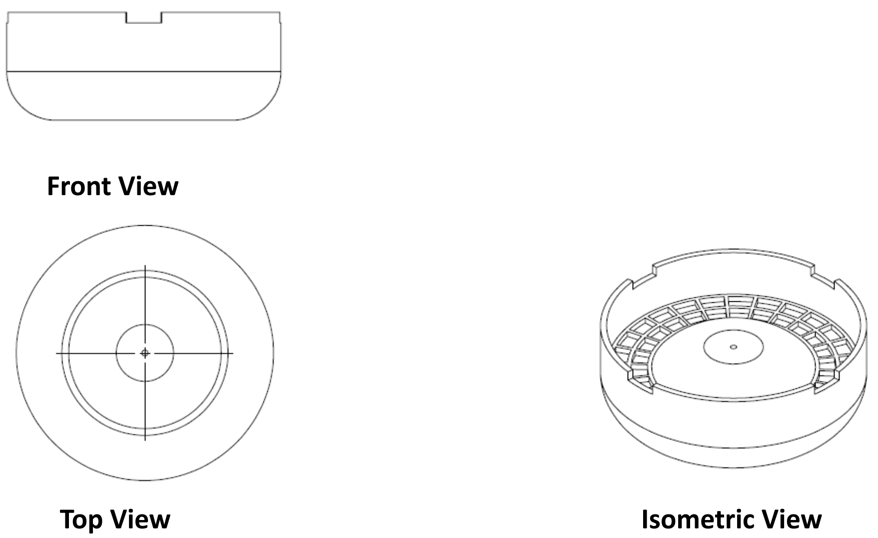
Figure 2: Exploded CAD Assembly Drawing(without electronics components)



3. Drawings of Individual Parts

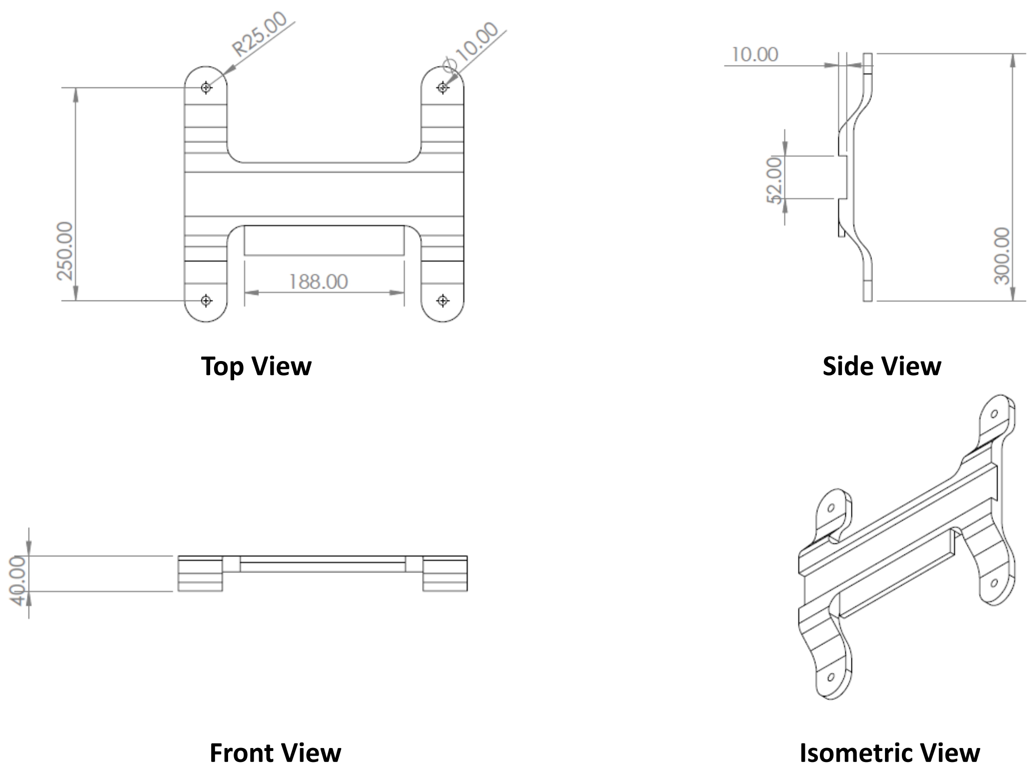
3.1 Cushions

Figure 3: Engineering drawing for Cushions



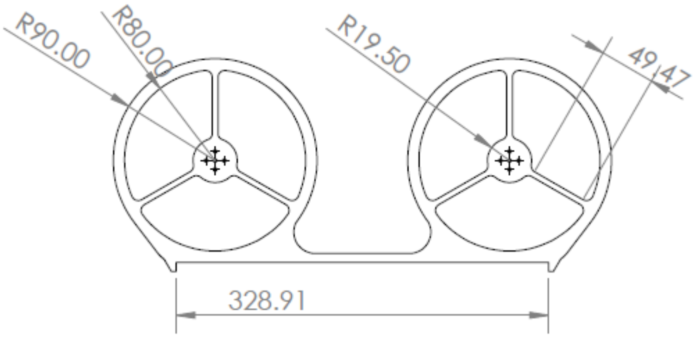
3.2 Chassis Base

Figure 4: Engineering drawing for Chassis Base

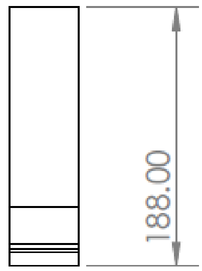


3.3 Maneuvering Propellor Chassis

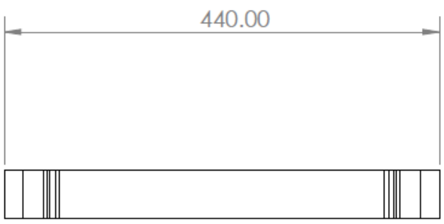
Figure 5: Engineering drawing for Maneuvering Propellor chassis



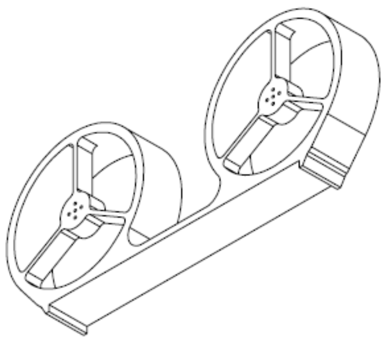
Front View



Side View



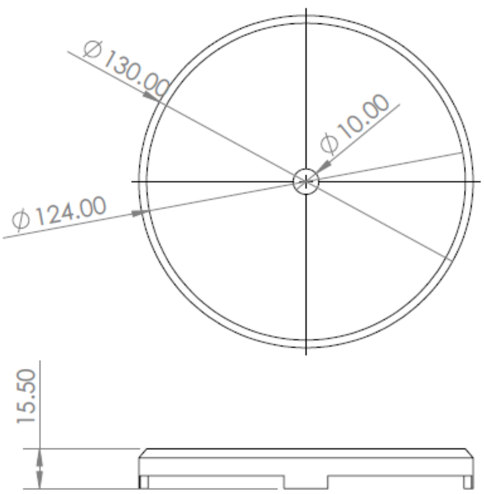
Top View

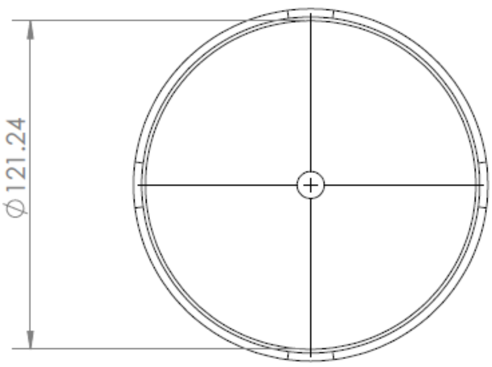


Isometric View

3.4 Cushion Lid

Figure 6: Engineering drawing for cushion lid





4. Selection of Filament

The choice of filament is critical in 3D printing because it greatly affects the quality and functionality of the printed object; it dictates the final characteristics of the prints.[1]
We shortlisted PLA, ABS and PETG as our materials of choice for our hovercraft. The structure should keep the electronics inside safe in the event of a crash or impact by any external source

Table 1: Comparison between PLA, ABS and PETG

	PLA	**ABS**	**PETG**
	Polyacitic Acid	Acrylonitrile Butadiene Styrene	Polyethylene terephthalate glycol
Printing	Easy to print	Easy to print	Easy to print
Durability	High Tensile strength	High	High
Density	1.24g/cm3	1.15g/cm3	1.27g/cm3
Fatigue Resistance	Low	Low	High
Bed Temperature	45-60°C	95-110°C	75-90°C
Shrink %age	0.2%	0.6%	0.3%
Water Resistivity	No	No	Yes
Cost of Printing	Low	Low	High
Heat Deflection Temperature	52-49°C	84°C	70°C
Fumes	No Fumes	Harmful Fumes produced	No fumes produced

Keeping in mind all the above properties, we narrowed down our material of choice to PETG for the hovercraft cushions and propellers because of its superior toughness, impact resistance, and printing convenience, despite its higher cost compared to PLA and ABS. The main frame of the hovercraft was printed in PLA, as it was subjected to less loading.

Table 2 : List of parts and corresponding materials along with their quantities

Part	Material	Quantity
Chassis Base	PLA	1
Propellers	PETG	6
Cushions	PETG	4
Maneuvering Propellor Chassis	PLA	1

[1] https://all3dp.com/2/pla-vs-abs-vs-petg-differences-compared/

5. Methods of 3D Printing

The choice of material/filament takes us to the next step, the method of 3D printing. [2]

Table 3: Comparison between FDM, SLS and SLA methods of 3D printing

	Fused Deposition Method	**Selective Laser Sintering**	**Stereolithography Apparatus**
	FDM	**SLS**	**SLA**
Method	Thermosetting filament is heated and extruded layer by layer to get the desired part	Uses a laser to harden and bond powdered nylon to form the part	High powered laser is used to harden resin present in a container
Advantages	Quick printing time Flexibility in material choice Create small and detailed parts Create parts with decent strength	Easy to handle Stands in wear and tear conditions Reduce the risk of part damage Takes comparatively less time to print	Can handle even the tightest dimensional tolerance Print surfaces are smooth Oldest technology used Good tensile strength
Disadvantages	Poor surface finish Moderate glass transition temp	Low volume production Poor strength Rough surface finish Limited material options	High printing time Very low glass transition temp
Cost of Printing	Low	High	High
Availability	High	Medium	Medium

Keeping in mind the prior experience and familiarity of the team with the 3D printing technology and evaluating the viable option in terms of cost-effectiveness and time constraint. The fused Deposition Method of 3D printing was chosen due to its ease of availability, easy implementation and low cost.

6. Design Methodology

Being a new section and participating in the competition for the first time, we got an opportunity to approach the problem from a fresh perspective.

We went to the drawing board to design the hovercraft from scratch that aligns with our objectives.

We used an iterative approach for our design, i.e., creating an initial design, testing and evaluating it, making modifications and improvements, and repeating the process until the desired performance, functionality, and quality are achieved. This approach allowed us to identify and address design flaws and optimize the design for specific requirements.

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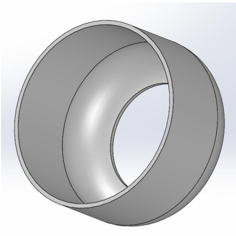
[2] www.futurelearn.com/info/courses/getting-started-with-digital-manufacturing/0/steps/184102

6.1 The objectives for the design

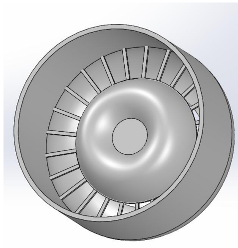
1. Design the cushion to regulate the airflow to keep the hovercraft at an optimal level from the surface.
2. Design the pick and drop mechanism for the hovercraft
3. Carry the payload to the destination.
4. Maximum use of additive manufacturing technology.

7. Design Iterations

7.1 Motor Mount

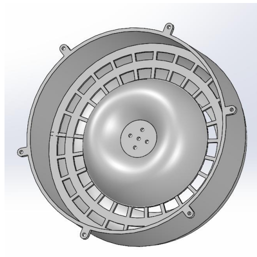


Iteration 1



Iteration 2

Iteration 3



Iteration 4

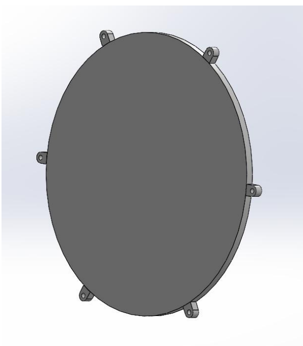
Iteration 1: Initially we started with a cup type structure for the motor casing.

Iteration 2: Core structure was created keeping in mind the size and position of the motor, along with this space was provided for air passage.

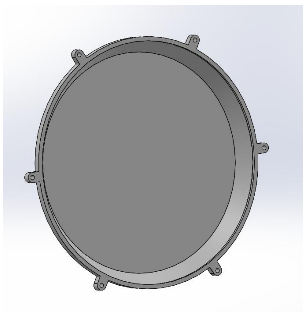
Iteration 3: The core construction has mounting holes for the motor, and the air column has been further improved to increase airflow.

Iteration 4: On the exterior surface extrudes were added to attach the cover plate after placement of the motor.

7.2 Lid



Iteration 1

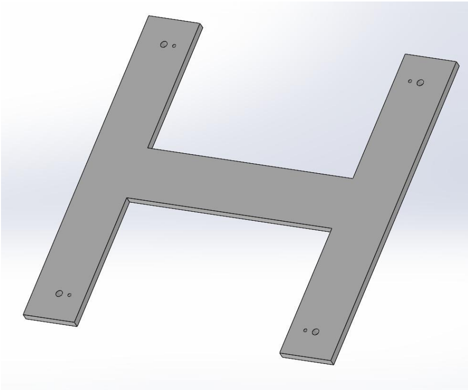


Iteration 2

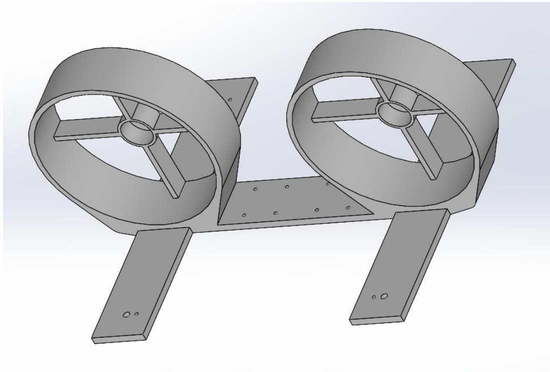
Iteration 1: Initially, we used a straightforward extrusion structure for the cover plate with protruding holes along the surface to attach the cushion.

Iteration 2: The design was further improved to provide a better position on the cushion.

7.3 Base



Iteration 1



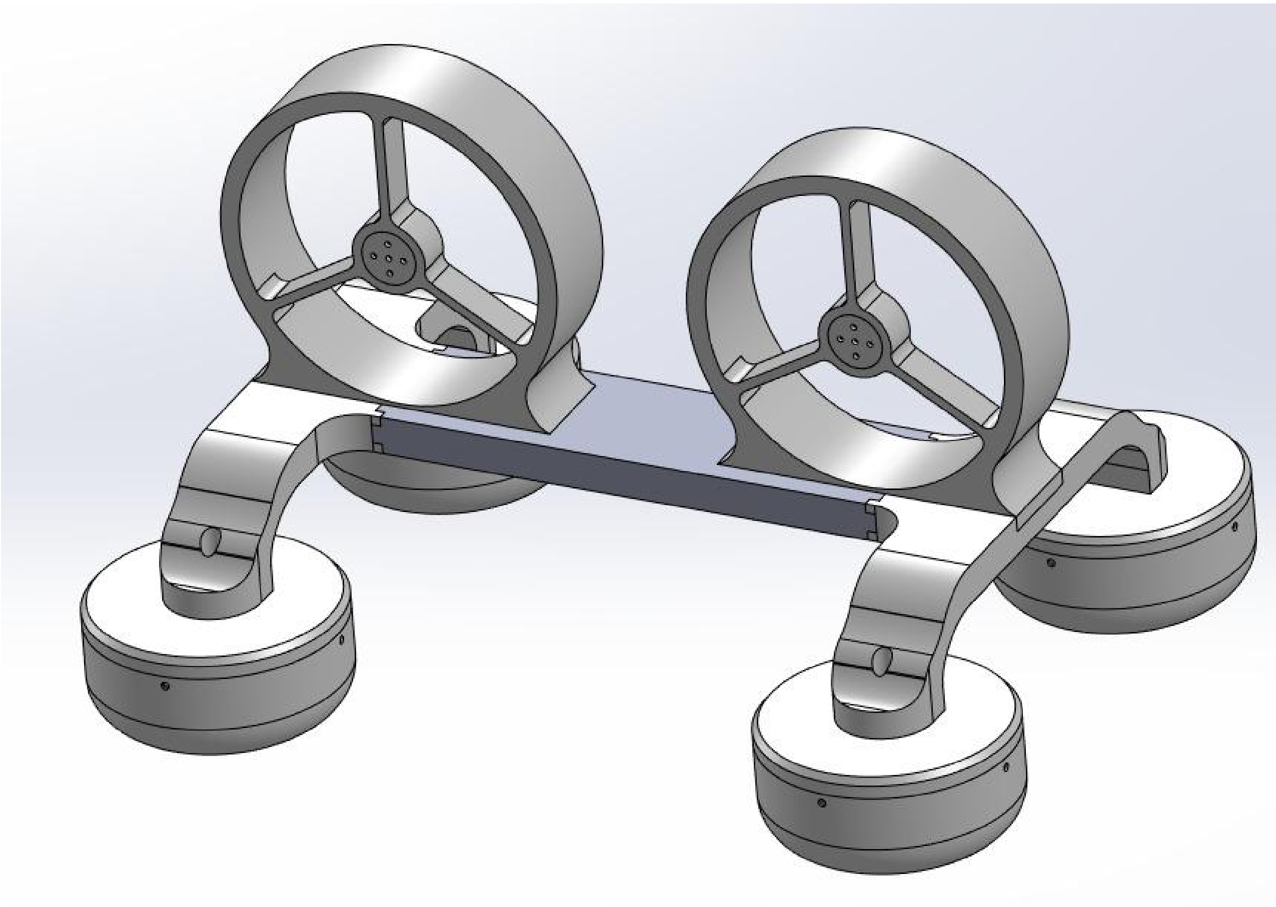
Iteration 2

Iteration 1: For the base plate we started with a simple structure with mounting positions at each end of the 'H' structure for four motors.

Iteration 2: Manoeuvring propeller frames were designed and placed for the position of two motors on the top of the base plate.

As a result of our iterative design approach this is our final design

Figure 7: Final Hovercraft Design



8. Design for manufacture and assembly (DFMA)

We used the design for manufacture and assembly approach to identify and eliminate the waste and efficiencies from our design. [3]

Hovercraft is designed to minimise the number of parts, thus reducing its assembly operations

a) Battery support integrated into the mainframe
b) Manoeuvring propeller frame integrated into the mainframe.

and for minimum re-orientation of parts during assembly.

a) All cushions can be mounted into any of the positions.

8.1 Minimise the use of flexible components

Due to the risk of degraded quality with continuous loading and the potential for added vibrations affecting hovercraft handling, flexible components have been avoided. This approach aims to ensure the hovercraft's optimal performance and minimise potential issues caused by flexible parts. By this, the hovercraft can maintain stability and improve its longevity.

8.2 Ease of disassembly

Only four threaded fasteners and four nuts need to be removed to remove each cushion

The battery can be easily removed by lifting the top base.

8.3 Design for ease of fabrication

All the parts have been designed keeping in mind the advantages and limitations of additive manufacturing, described in the next section.

8.4 Design for modularity

The chassis has been designed to be modular.

[3] www.plm.automation.siemens.com/global/en/our-story/glossary/design-for-manufacturing-and-assembly-dfma/53982

9. Design for additive manufacturing (DFAM)

Design for additive manufacturing (DfAM or DFAM) is design for manufacturability as applied to additive manufacturing (AM).[4] It is a general type of design methods or tools whereby functional performance and/or other key product life-cycle considerations such as manufacturability, reliability, and cost can be optimized subjected to the capabilities of additive manufacturing technologies[5]

9.1 Supports

The printing process utilized breakaway support structures instead of soluble ones to create the overhangs. The straightforward design allowed for easy mechanical removal of the breakaway supports without causing any harm to the printed object. Also, to reduce the no. of supports, fillets were provided in the overhangs.

9.2 Wall thickness / Perimeter

To enhance the durability and resistance to stress concentration caused by fasteners, the 3D printed parts were designed with a shell thickness of 3 walls (1.2mm, nozzle diameter = 0.4mm), and a thickness of 3 walls(1.2mm) for top and bottom layers. The increased wall thickness provided the parts with the ability to withstand higher loads.

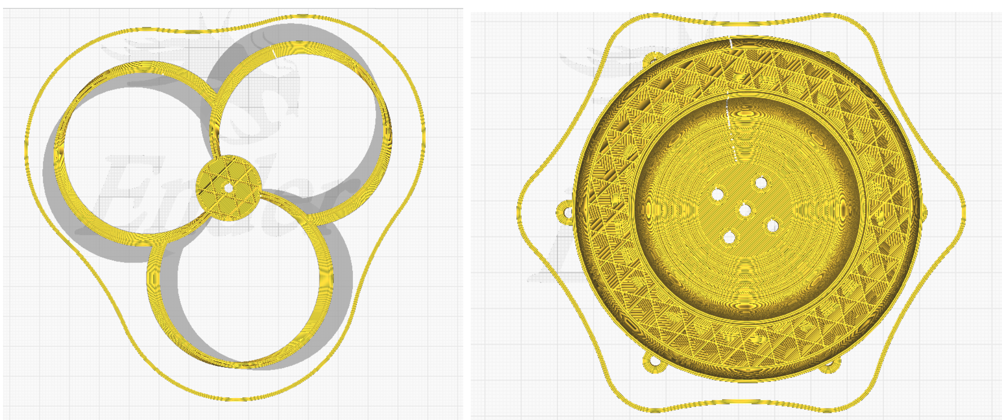
9.3 Infill percentage

To strike a balance between print time, brittleness, and weight, all the hovercraft parts were printed with a *20% infill percentage*. With this percentage deemed suitable, we proceeded to bolster the strength of the parts by increasing the number of walls to an optimal level.

9.4 Infill pattern

All parts were printed using the cubic infill pattern, which imparts excellent strength in both the vertical and horizontal directions.

Figure 8: Infill Pattern of the designs in CURA Slicer



[4] https://en.wikipedia.org/wiki/Design_for_additive_manufacturing
[5] https://all3dp.com/2/3d-printing-wall-thickness-tutorial/

9.5 Layer height / Quality

A layer height of 0.2mm was selected as the optimal choice for printing the parts. This decision was based on the fact that increasing the layer height would improve adhesion, while decreasing it would enhance detail at the cost of longer print times.

9.6 Printed Parts Specifications

The following tables shows the specifications of the printed parts for the hovercraft

Table 4: ***Estimated Time taken to print the parts***

Part	Quantity	Infill %age	Quality	Weight	Total Time taken
Chassis Base	1	20	0.2mm	157g	**8 hr 12 min**
Maneuvering Propeller Chassis	1	20	0.2mm	220g	**23 hr**
Propellor	6	20	0.2mm	6*7g	6***60 minutes**
Cushions	4	20	0.2mm	4*59g	4***9 hr 23 min**

Figure 9: Sliced models in CURA Slicer

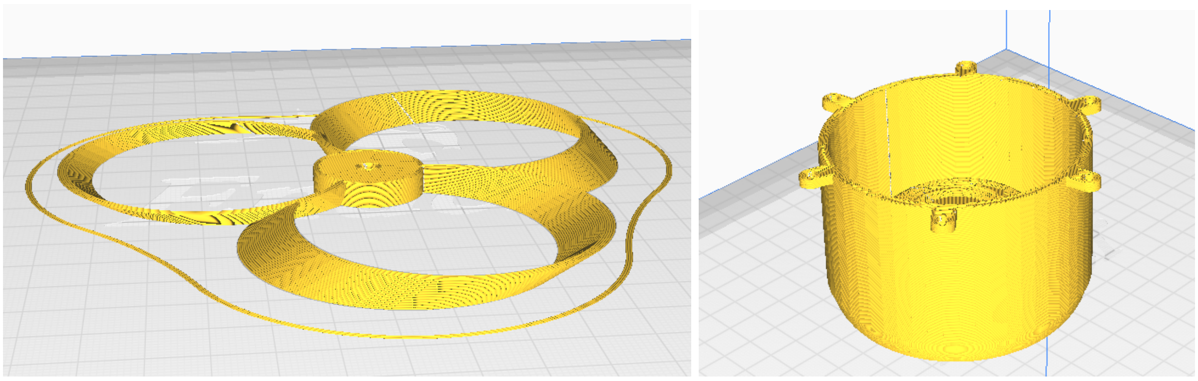
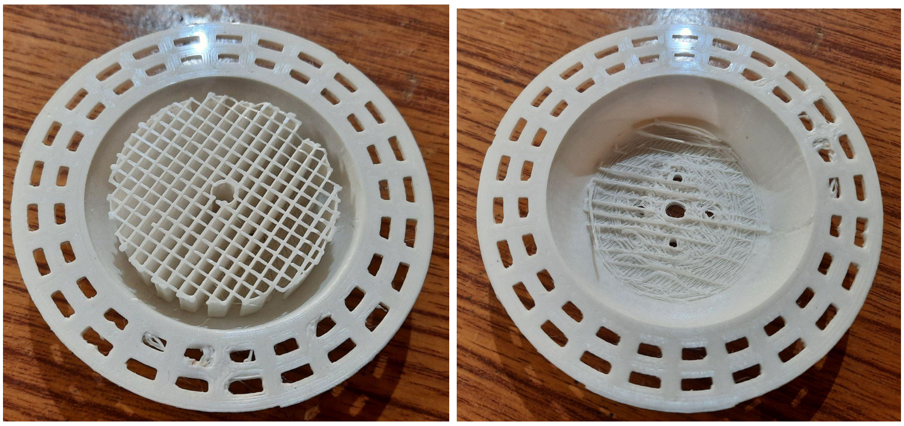


Figure 10: Cushion mount with and without supports



10. Bills of Material

The following table contains the items along with their model, quantity(Qty.), price and source from where it is procured. [6]

Table 5: Cost of the Hovercraft Project

S.No	Item	Model	Qty.	Price	Source
1.	Motor	T-Motor VELOX V2	6	INR 9,600	drkStore.in
2.	Battery	Bonka 14.8V 1000mAh	1	INR 3,136	Electronics Components.in
3.	Flight Controller	T-Motor F7 HD	1	INR 6,400	drkStore.in
4.	Speed Controller	T-Motor Velox V2 V45A 3-6S	1	INR 5,000	drkStore.in
5.	Transmitter	Flysky FS-i6X 2.4GHz 6CH 2A RC	1	INR 5,400	Robu.in
6.	Receiver	FS-iA10B 2.4GHz 10CH Receiver	1		
7.	PLA filament	NUMAKERS PLA+ 3D Printer Filament	1	INR 980	amazon.in
8.	PETG filament	SUNLU PETG 3DPrinter Filament	1	INR 1,700	amazon.in
9.	3D Printing	-	-	-	University
10.	Soldering Kit	-	-	-	University
11.	Wires	-	-	-	University
			Total Cost	**INR 32,216**	

[6] The prices indicated in the table are actuals for which the item(s) is/are procured.

11. Part Specifications

11.1 Speed Controller: T-Motor Velox V2 V45A 3-6S BLHeli_32 4-in-1 ESC[7]

- Current: 45A
- Peak Current: 55A (10s)
- BEC: 10V/2A
- Lipo: 3-6S
- Weight: 21g
- Size 44.6x41x7mm
- Mounting Hole: 30.5×30.5mm, M3
- ESC Firmware: Tmotor_32Bit

11.2 Flight Controller: T-Motor F7 HD Flight Controller[8]

- Main Control Chip: STM32F722RET6
- Gyroscope: MPU-6000
- RAM: on board 16Mb
- Input voltage: 12V-25.2V (3-6S) BEC: 5V/2A(Receiver), 10V/2A(VTX)
- Dimension:37MM*37MM Mounting distance: 30.5mm*30.5MM
- Weight:8.4g
- Firmware:TMOTORF7(BETAFLIGHT)

11.3 Motors: V2 V2306.5 2550KV Motor[9]

- Motor Dimension: 28.6*30.45mm
- Lead: 20#AWG 150mm
- Internal Resistance: 47mΩ
- Configuration: 12N14P
- Rated Voltage (Lipo): 4-5S
- Peak Current (60s): 33A
- Shaft Diameter: 4mm
- Idle Current(10V): 1.72A
- Max.Power (the 60s): 490W
- Weight (Excl. Cable): 30g

11.4 Transmitter and Receiver:

Flysky FS-i6X 2.4GHz 6CH AFHDS 2A RC Transmitter With FS-iA10B 2.4GHz 10CH Receiver[10]

- Transmitter: FS-i6X (6 Channels); Receiver: FS-iA10B (10 Channels)
- RF Range: 2.408-2.475 GHz
- RF Power : < 20 dBm
- RF Channel: 135
- Bandwidth: 500 kHz
- Total Weight: 392 gm
- Power: 6V DC 1.5A

[7] https://www.drkstore.in/t-motor-velox-v2-v45a-3-6s-blheli_32-4-in-1-esc/
[8] https://www.drkstore.in/t-motor-f7-hd-flight-controller/
[9] https://www.drkstore.in/t-motor-velox-veloce-v2306-5-v2-motor-1950kv-2550kv/
[10] https://robu.in/product/flysky-fs-i6x-2-4ghz-10ch-afhds-2a-rc-transmitter-with-fs-ia10b-2-4ghz-10ch-receiver/

11.5 Battery: Bonka 14.8V 1000mAh 95C 4S Ultra Light U2 Series Lipo Battery[11]

- Model: BONKA 1000/95C-4S
- Max. Continuous Discharge : 95C
- Balance Plug: JST-XH
- Discharge Plug: XT 60
- Max Burst Discharge: 190C
- Dimensions : 7 x 3.5 x 2.5 cm (LxWxH)
- Weight : 135gm

11.6 3D Printer: Creality Ender 3 v2[12]

- Machine size: 475 470 620mm
- Print size: 220 X 220 X 250mm
- Molding technology:FDM
- Product weight: 7.8kg
- Package weight: 9.6kg
- Hotbed temperature: ≤100°
- Layer thickness: 0.1-0.4mm
- Print precision: ±0.1mm
- Filament: PLA/TPU/PETG
- Filament diameter:1.75mm

11.7 PLA Filament: NUMAKERS PLA+ 3D Printer Filament[13]

- Diameter: 1.75mm
- Diameter tolerance of +/- 0.03 mm
- Melt flow index (g/10min) 2(190°C/2.16kg)

12. Softwares Used

Table 6: Softwares used for project

S. No.	Software	Purpose
1	SOLIDWORKS ® 2022	Designing, Simulations
2	Ansys	Simulations
3	UltiMaker CURA 5.2.2	3D Printing, Slicing
4	Google Docs (docs.google.com)	Documentation
5	Betaflight	Flight Control Software

[11] https://www.electronicscomp.com/bonka-14.8v-1000mah-95c-4s-ultra-light-u2-series-lipo-battery
[12] https://www.creality.com/products/ender-3-v2-3d-printer-csco
[13] https://india.numakers.com/collections/pla-plus

13. Electric Components

Electronics component used:

- Brushless Motors
- Flight Controller
- Electronic Speed Controller
- Lithium Polymer Battery
- FSi6 transmitter
- FS-Ai6 Receiver

13.1 Motors

We have opted for high-quality Brushless DC motors to achieve the optimal balance between stability, speed, and power consumption. Through thorough research on BLDC motors, our team determined that motors with a KV rating ranging from 2000 to 2800 were the most suitable for the dimensions of the hovercraft. Therefore we purposefully chose T-Motor VELOX VELOCE V2306.5 V2 Motor 2550KV for our hovercraft.

13.2 Flight controller

- The F7 HD Flight Controller has been employed by us due to its speedy processing rate of 216Mhz and integrated PDB support, which streamlines wiring. Additionally, the F7 processor boasts superscalar pipeline and DSP capabilities.
- F7 boards offer the ability to incorporate more UARTs(universal asynchronous receiver-transmitter), all with built-in signal inversion capability. Moreover, the F7 processor can handle 32KHz without the need for overclocking. It is compatible with Betaflight and Cleanflight and enables Black Box logging.

13.3 Electronic Speed Controllers (ESCs)

- Our choice for an electronic speed controller is a 45A 4in1 model that can sufficiently provide power to the motors.
- This specific ESC was selected because it features the latest generation BLHeli_32 firmware and is compatible with the newest DSHOT1200 protocol. Additionally, it can handle a burst current of up to 55A for 10 seconds.
- Utilizing a 32 bit architecture, this ESC can operate at remarkable speeds, leading to improved performance, faster signal inputs, and reduced latency when compared to older 8bit ESCs. Furthermore, the ESC is low profile and compact in size, resulting in weight savings and simplified builds.

13.4 Battery

- Most attention was paid in selecting the batteries for our build. as we have to trade off between the flight time and battery weight.

- Despite having lower density than Li-ion batteries, LiPo batteries offer a high current discharge rate that is capable of meeting the high current requirements of BLDC motors.
- Choosing a higher capacity battery can extend the flight time, but this comes at the cost of added weight. Therefore, it was crucial to select an optimal battery capacity that could improve flight time without making the hovercraft too bulky and heavy.
- After careful consideration, a 4S 1000mAh battery was determined to provide the maximum flight time while maintaining a decent thrust-to-weight ratio. However, beyond this capacity range, flight time begins to decrease despite the increase in capacity due to the added weight.

13.5 Radio Transmitter

- Our setup includes a FlySky FS-i6S 2.4GHz transmitter, which boasts 10 channels and utilizes the dependable Automatic Frequency Hopping Digital System (AFHDS) spread spectrum technology.
- The transmitter features digital trims, a backlit LED screen, and user-friendly programming. Additionally, it is equipped with a 3-position switch for switching between flight modes.

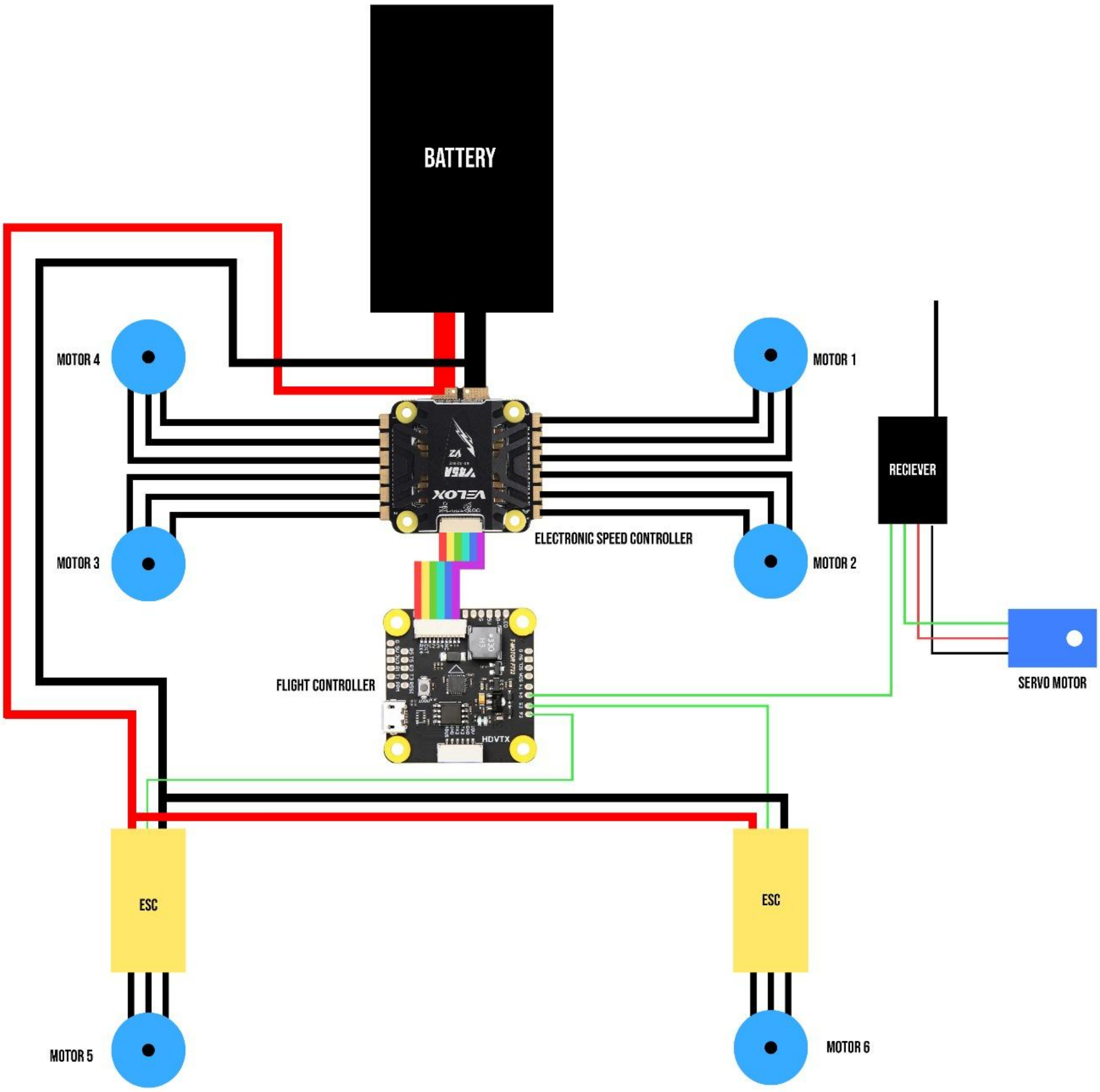
13.6 Radio Receiver

- We have incorporated a 10-channel radio receiver that utilizes the highly dependable AFHDS 2A (Automatic Frequency Hopping Digital System) protocol, and can generate a standard PPM output.
- Furthermore, the receiver provides i-BUS support for up to 10 channels and operates within a Radio Frequency range of 2.408-2.475GHz. Its compact size of only 12 x 15 mm and weight of 1.0g ensures that it does not take up too much space in our hovercraft.
- After careful analysis, we have concluded that this is the most suitable receiver for our hovercraft. It is more than capable of supporting the vehicle's equipment.

Figure 11: Electronic Components

14. Circuit Diagram

Figure 12: Electronics Circuit Diagram of Hovercraft

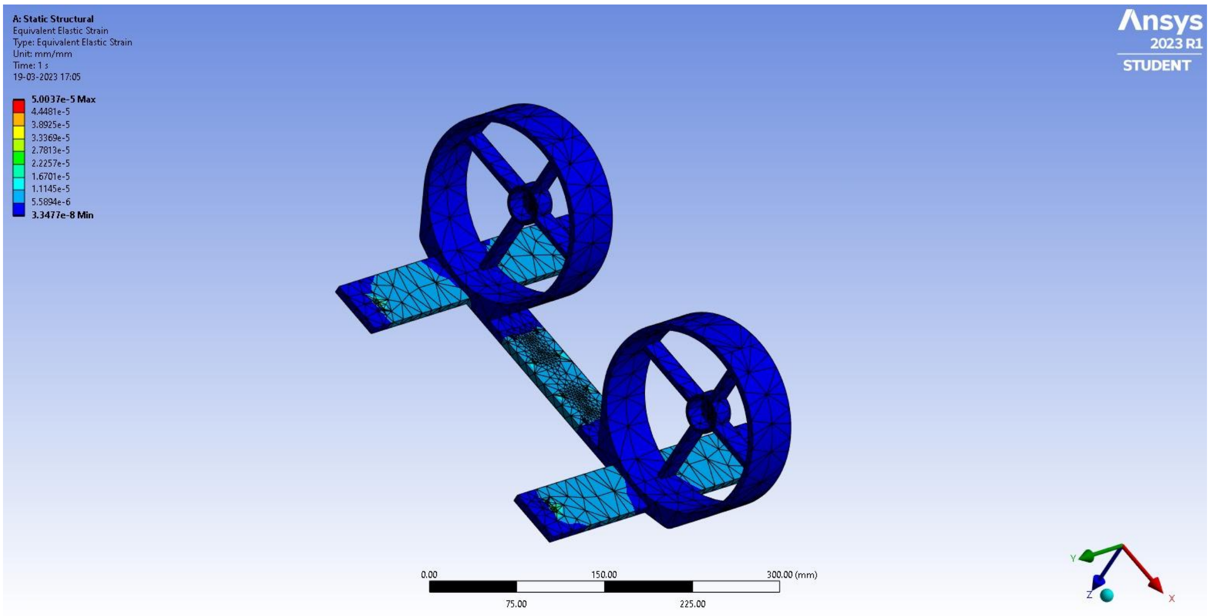


15. Simulations

15.1 Chassis

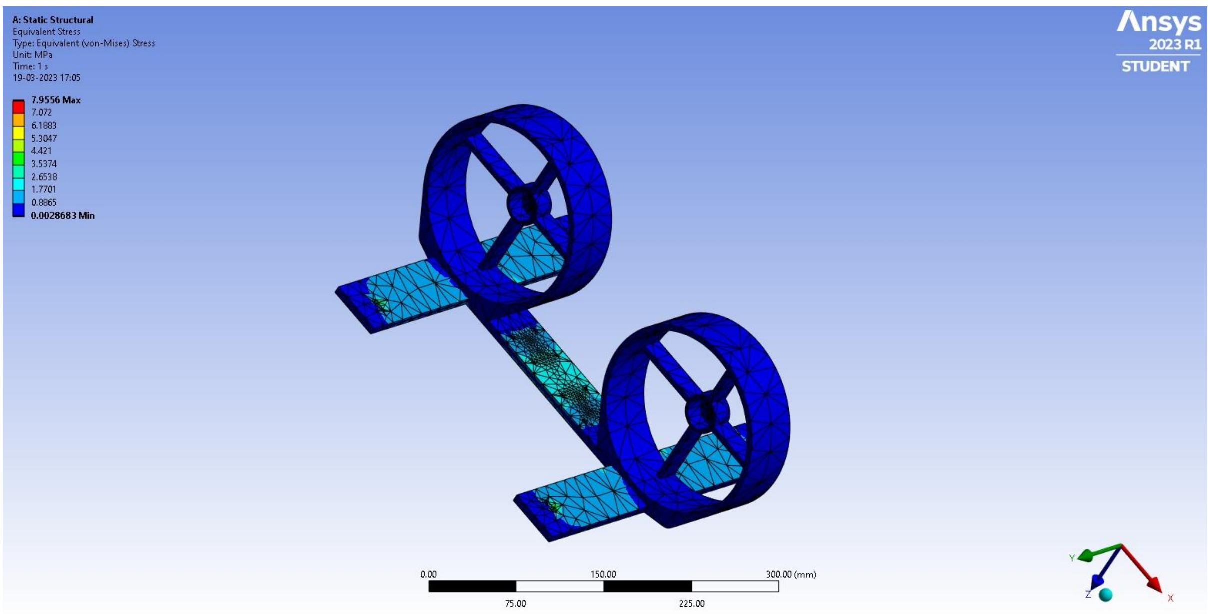
15.1.1 Equivalent Elastic Strain

Figure 13: Test: Equivalent Elastic Strain



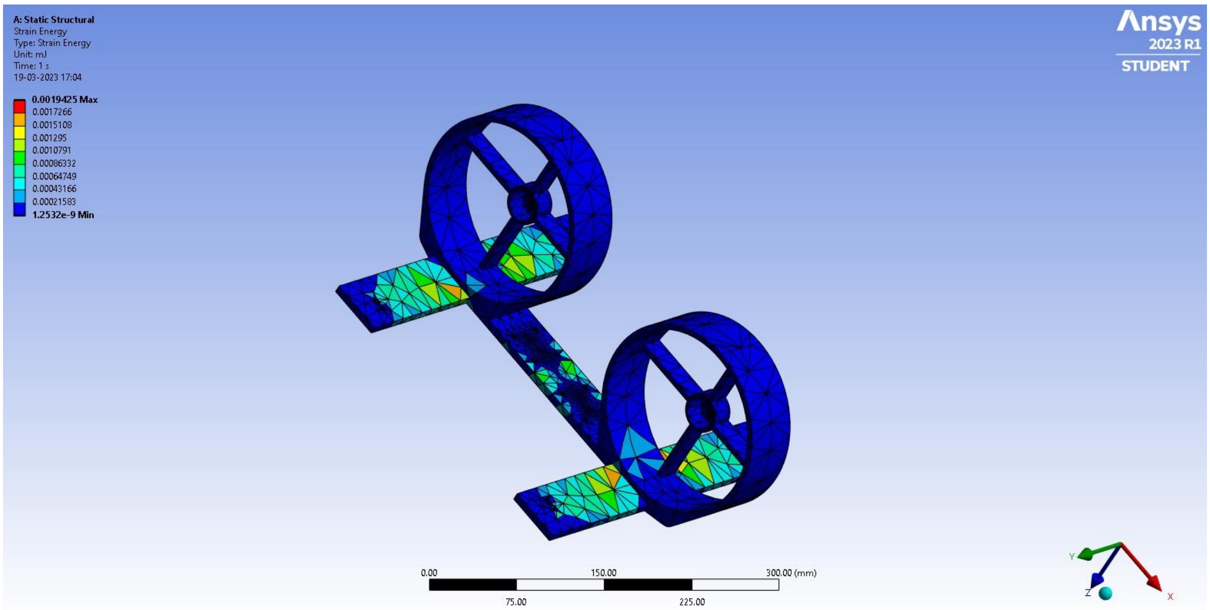
15.1.2 Equivalent Stress

Figure 14: Test: Equivalent Stress



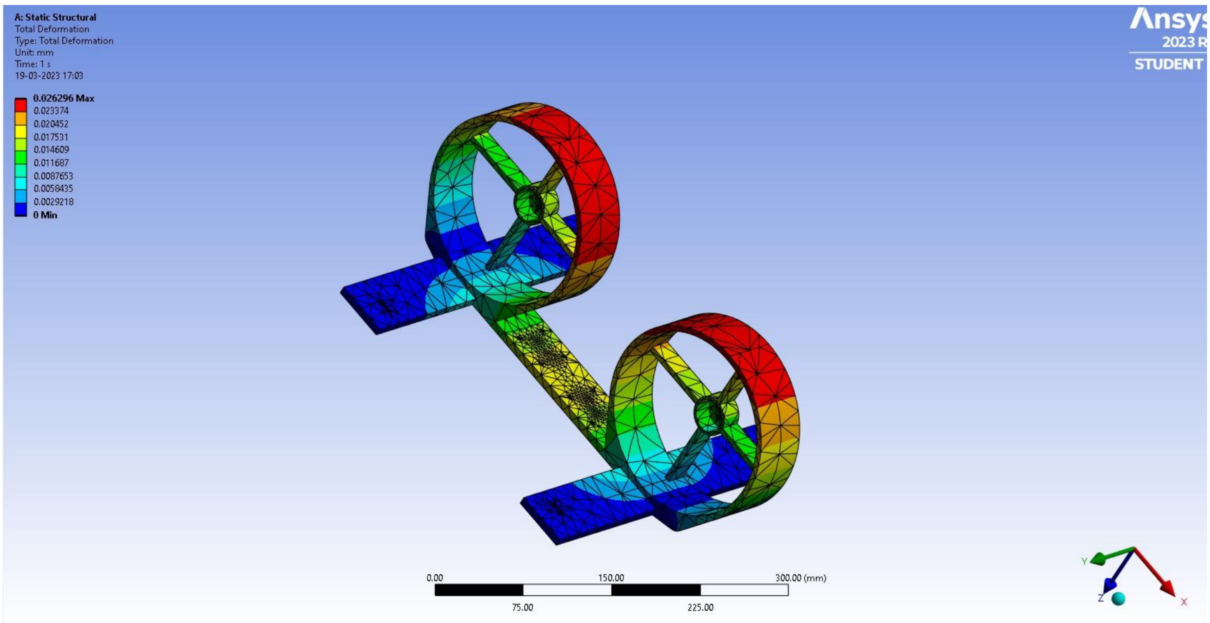
15.1.3 Strain Energy

Figure 15: Test: Strain Energy



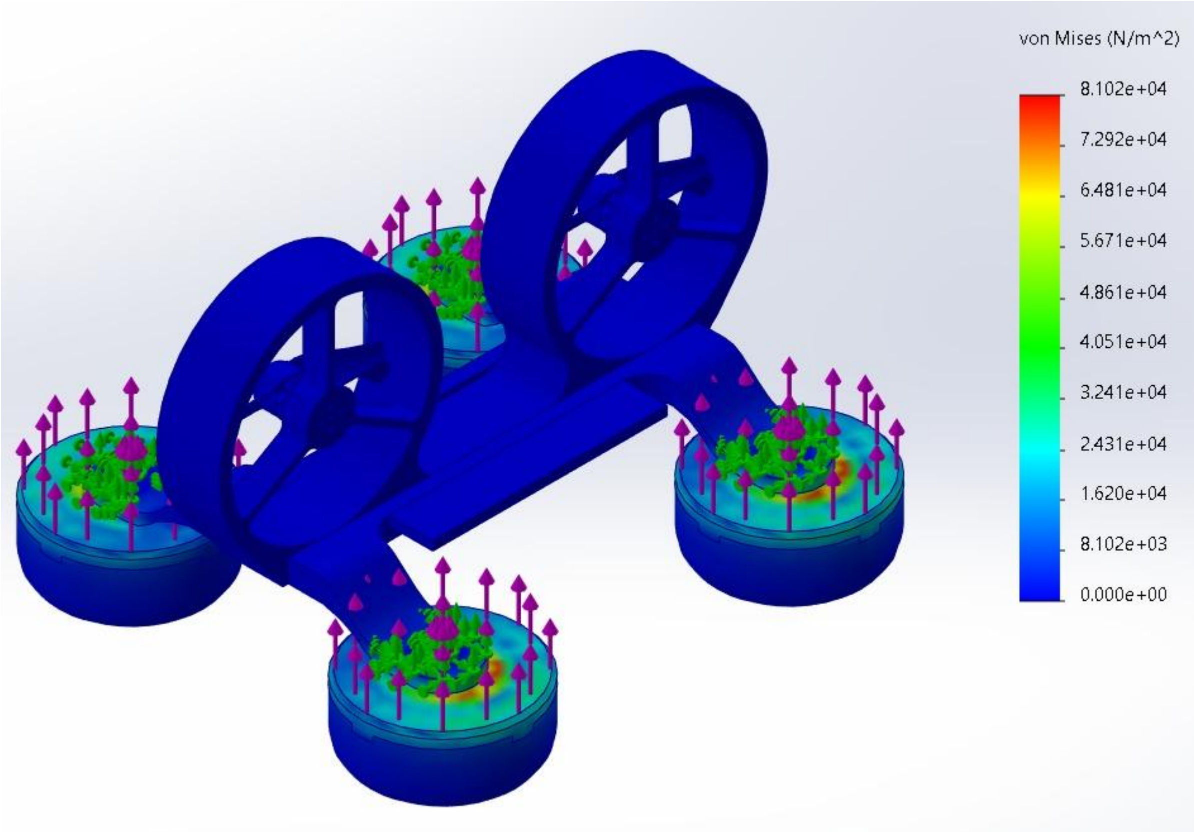
15.1.4 Total Deformation

Figure 16: Test: Total Deformation



15.2 Final Assembly

Figure 17: Test: Static Nodal Stress



Conclusion

Our solution for ASME IAM3D 2023's Hovercraft Resupply Vehicle Design Competition employed an iterative design process to create an efficient hovercraft that makes use of 3D printed parts wherever possible. The team prioritized weight reduction and focused on minimizing the use of non-3D printed elements. By doing so, we were able to create a hovercraft that is optimized for resupply operations. The resulting design includes numerous 3D printed parts, demonstrating the versatility and durability of 3D printing technology. Overall, the team's use of an iterative design process and focus on 3D printing highlights the potential for additive manufacturing to revolutionize the manufacturing industry.

ASME

SETTING THE STANDARD

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