# Hermes - Autonomous Water Surface Electric Vehicle

Final Project Report

*Submitted by*

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*in fulfilment of requirements for the award of the dual degree of*

**Bachelor of Technology in Mechanical Engineering**

and

**Master of Technology in Robotics**

**INDIAN INSTITUTE OF TECHNOLOGY MADRAS**

*Under the guidance of*

Dr Prabhu Rajagopal

# Certificate

This is to certify that the project titled **Hermes - Autonomous Water Surface Electric Vehicle**, submitted by **S Tarun Prasad (ME17B114)** to the Indian Institute of Technology, Madras, for the award of the degree of **Bachelor of Technology in Mechanical Engineering** and **Master of Technology in Robotics**, is a bona fide record of the research work done by him under our supervision. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

**Name of the Guide: Dr Prabhu Rajagopal**

**Signature:**

**Name of the Student: S Tarun Prasad**

**Signature:**

# Acknowledgements

I would like to thank my DDP guide Professor Prabhu Rajagopal for providing me with the necessary guidance, access to resources and support for carrying out this project. I would like to thank Professor Tiju Thomas and Parth Mehta for their association with this project. I would like to thank the professors of the different courses I took in the institute who provided me with the necessary tools to be able to carry out this project. I would like to thank Samsung - IITM Pravartak for providing me with a scholarship to support my expenses during the time of this project. Lastly I would like to thank Indian Institute of Technology Madras for providing a great learning experience.

# Abstract

In this report we discuss the implementation of an Autonomous Water Surface Electric Vehicle powered by Hydrogen. We discuss the need for the development of such an autonomous device which utilises clean energy and its utility in the transportation ecosystem. We discuss the overall objectives of the project and how the roles of the project are defined. We also discuss the different stages involved in the project. The power system is discussed in detail in the next section. Initially an in-situ $H_2$ generation reactor coupled with a fuel cell was being implemented and it was later pivoted to an electrically charged LiPo battery. The reasons for the same are also discussed. The processes for selecting the design parameters of the vehicle is discussed. The simulation framework for estimating the resistance on the vehicle and the safety of the vehicle under its loading condition is discussed. The navigation control system is discussed with details on how the sensor apparatus, computational unit and navigation is structured. Fabrication methodology is discussed along with the testing options in the upcoming section. The overall design parameters of the vehicle based on the results of the simulations is discussed and the overall CAD is presented along with component choices for the vehicle. The reasons for modification in design is discussed and the modified CAD is presented. This is followed by a write-up on the manufacturing results and a detailed explanation on the testing results. Future work in the project is presented at the end.

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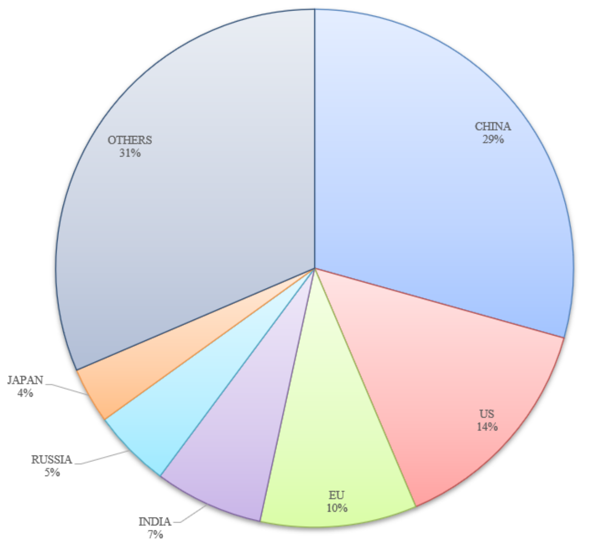
# 1 Abbreviations

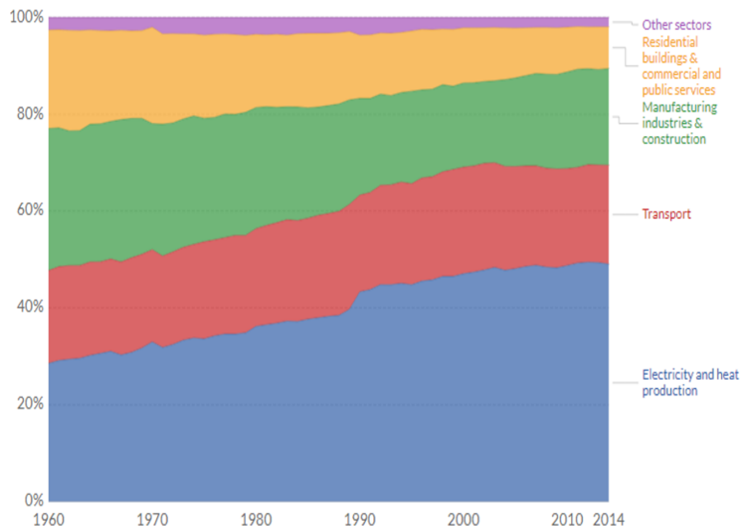
- IITM - *Indian Institute of Technology Madras*
- GDP - *Gross Domestic Product*
- IWT - *Inland Water Transport*
- LiPo - *Lithium Polymer*
- $H_2$ - *Hydrogen*
- ASV - *Autonomous Surface Vehicle*
- GPS - *Global Positioning System*
- ARCI - *International Advanced Research Centre for Powder Metallurgy and New Materials*
- DC - *Direct Current*
- IMU - *Inertial Measurement Unit*
- ESC - *Electronic Speed Control*
- RRT - *Directed Rapidly Exploring Random Trees*
- CNDE - *Centre for Nondestructive Evaluation*
- PLA - *Polylactic Acid*
- CAD - *Computer Aided Design*
- Whr - *Watt-hour*
- KW - *Kilo-Watt*
- KMPH - *Kilometers per Hour*
- CNC - *Computer Numeric Control*

# 2 Introduction

India's transportation sector is large and diverse and contributes about 4% cent to the nation's GDP [1], with surface transport (including roads and rail) having the biggest share. However, with ever-increasing population and ageing infrastructure, the existing infrastructure is struggling to cope, especially against strict environmental pollution and greenhouse emission norms. India is the 4$^{\text{th}}$ largest producer of greenhouse gases (Figure 1a, [2]), and the transportation sector contributes about 14% of it (Figure 1b, [3]). Hence for the betterment of economy and environmental growth, India is in dire need of an alternative clean energy transportation solution.




(a) Countrywise $CO_2$ Emission Share [2]




(b) Sectorwise Greenhouse Gas Emissions [3]

Figure 1: Greenhouse Gas Emissions

Navigable waterways can be a fuel-efficient, environment-friendly and cost-effective mode of transport. Inland water transport has a huge potential to supplement the overburdened rail and roadways. India has a long and under-utilised inland waterway; there is about 14,500 km of navigable waterways throughout the country. Even though India has long inland water channels, only about 55 million tons (<1%) of cargo is being transported annually through Inland Water Transport (IWT).

Water transport vessels are still dependent on fossil fuels and have inherent environmental impacts. Exhaust from such ships is a significant source of air pollution. A ship lets out around 50 times more sulfur than a truck per metric tonne of cargo carried [4]. The vessels running on fossil fuel-based engines also pose the hazard of an oil spill, which may have a chronic effect on aquatic life. Diesel engines, common prime movers in such vessels, are noisy and may disturb the lives (both aquatic and human) around the region of operation.

To make proper utilisation of inland waterways, in a sustainable and eco-friendly manner, a better solution is required. Two methods were explored in this project for powering the vehicle, one the conventional electrically powered version using Lithium Polymer (LiPo) Battery and the other method is explained as follows. A potential source of clean energy can be Hydrogen ($H_2$ ) Fuel cells. But the fact that pressurized $H_2$ gas is to be carried onboard makes it hazardous as well as expensive. To make Hydrogen fuel cell as a viable, safe and economical source of energy, a technology which utilises water to generate $H_2$ gas on demand is essential. Professor Tiju Thomas and his students worked on developing the prototype of this technology ([5],[6] and [7]), in association with this project. This is a very safe, economical and environmentally friendly solution.

Another issue which with inland water transport is safety and monitoring of water traffic and aquatic life. Owing to a vast and distributed inland water system in India, this is not an easy task. But autonomous smart water vehicles can prove to be a viable solution. It is expected that autonomous vehicles can improve safety, increase efficiency, and relieve humans from unsafe and repetitive tasks. The autonomous surface vehicles (ASV) can help in reducing accidents and will also save money by minimising the crew cost and by using the best route for navigation. The most fundamental benefit of automating the vehicle would be the reduction in payload of the human driver and the necessary structures required to facilitate the human driver. This by far reduces the magnitude of power required on the power generation system as work is done to scale the output of the same. This novel eco-friendly $H_2$ technology coupled with the autonomous surface water vehicles, such as passenger boats, goods carriers and water scooters, can be of high utility.

## 2.1 Objectives

This project aims to develop an emission-free solution for mobility in inland waterways. This project seeks to develop 'Hermes' a clean energy powered Autonomous Surface Vehicle (ASV) as an eco-friendly Inland Waterway navigation solution. The capabilities of the proposed ASV are as follows:

1. Can be used as an alternate mode of transportation in inland waterways.
2. The vehicle will use clean energy based propulsion [5] which would produce zero emissions.

3. Onboard intelligence and GPS based navigation in water channels.

Initially the power system explored in this project was an in-situ Hydrogen Generation reactor coupled wih a Hydrogen Fuel Cell which was being developed in association with Professor Tiju Thomas and Parth Mehta (ME20S300). Due to some technical issues and timeline contingencies the power system was pivoted to an electrically charged Lithium Polymer (LiPo) Battery.

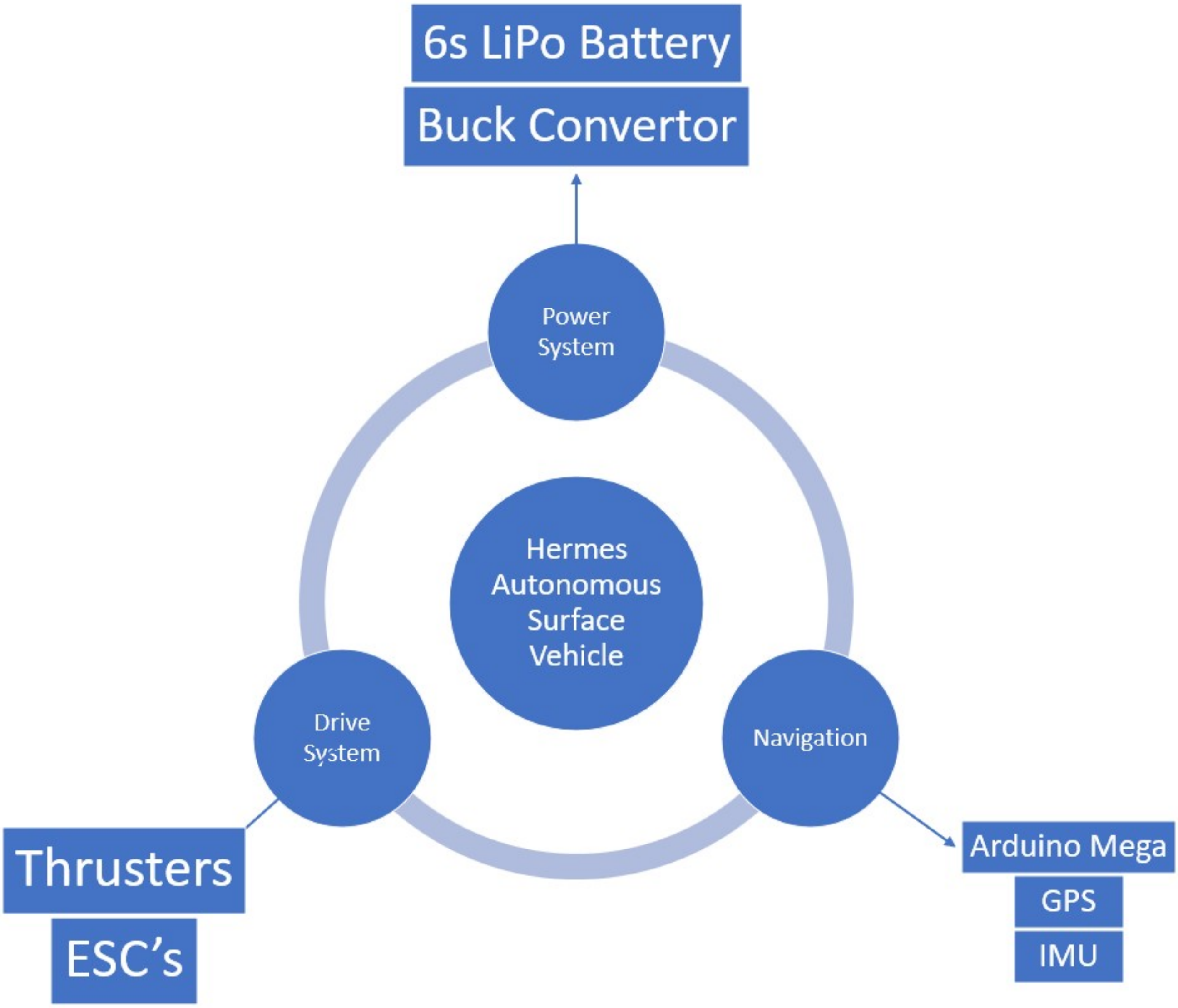



Figure 2: Schematic of the Vehicle's Subsystems

I was responsible for the overall design, fabrication, control and integration of the vehicle. The design of the vehicle involved evaluating the different vehicle capability goals. Based on these goals different design parameters, component choices were made by evaluating the different options available in the market. The design was validated by simulating it for different use case scenarios. The fabrication of the device involved identifying the ideal processes for manufacturing the vehicle structure while optimising between the cost, precision and accessibility of the different processes. Ideal choices were made for the processes and vendors were selected and orders were given out. The control system involved identifying the necessary navigation requirements and setting up the initial framework. The integration process involved putting together the different subsystems of the vehicle. This involved integration of the control of the drive system by the navigation system, integration of the power system with the rest of the vehicle, interacting with the ESC's to control the thrusters, etc. The vehicle was tested in the Wave Pool in the Naval Architecture Department in the Institute and was validated for the effective functioning of the different subsystems. The power system and the hull structure effectiveness was validated. The overall goal of the project was to take the vehicle to Technology Readiness Level.

This report is organised as follows:

- Methods
  - Power System
  - Design
  - Simulations
  - Navigation
  - Fabrication
  - Testing
- Results
- Future Work

# 3 Methods

## 3.1 Power System

The goal of the project is to develop a process which generates energy while producing zero-emissions and being eco-friendly. As discussed earlier the vehicle was first being developed to be powered by a $H_2$ based system. This will be explained in the upcoming subsection and will be followed by a discussion on how a battery based system was used to replace it.

### 3.1.1 In-situ $H_2$ Reactor coupled with $H_2$ Fuel Cell

$H_2$ power is an important clean energy avenue but the processes involved in harnessing it need to be crafted keeping in mind the safety and the ecological footprint of the same. The technology presented in ([5],[6] and [7]) offers a very effective way of achieving the same. The process is initiated by sucking water from the water body and then converting this water into hydrogen by using the $H_2$ generation reactor being developed by Parth Mehta under the guidance of Professor Tiju Thomas. The generated $H_2$ will be converted to electricity using hydrogen fuel cells and this electricity will be stored in a battery. Along with power from hydrogen the vehicle is also supported by battery power in a hybrid manner. The battery used in the vehicle will be fully charged at the beginning of the vehicle's journey. It will be charged by the hydrogen fuel cell as the battery power gets drained by the vehicle's operation. By providing a hybrid source of power with the use of a pre-charged battery, we effectively reduce the energy load on the hydrogen apparatus as the technology gets scaled to larger units. The below figure 3 explains the working of the power generation technology.


Figure 3: Flowchart Explaining the generation of Electricity

Parth and I approached Hybrid Systems, a vendor from Chennai for fabricating a 1 KW $H_2$ fuel cell for the vehicle and received a detailed proposal towards the same. We also approached International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI) from IIT Madras Research with a request to test out their fuel cells with our $H_2$ generation reactor and received consent for the same. However there was a major roadblock in the $H_2$ generation reaction related to pumping powdered Aluminium to the reactor. As this couldn't be sorted in time, an alternative choice had to be made for the vehicle with the foresight of being able to interact with the $H_2$ reactor and fuel cell later on once it gets fully developed.

### 3.1.2 Electric Power System with LiPo battery

The next best alternative was to power it with an electrically charged battery as anyways a battery is required to store energy from the fuel cell eventually when the proposed $H_2$ technology is integrated with the vehicle. This serves as a clean energy alternative at the same time. A Lithium Polymer Based Battery System was preferred due to its high specific energy density to reduce the overall mass of the vehicle. An Inbuilt Battery Management System was preferred to automatically take care of the voltage distribution between the different cells in the vehicle. DC-DC Buck converters were used in the vehicle as different devices such as the micro controller, sensors and thrusters operate at different voltages.

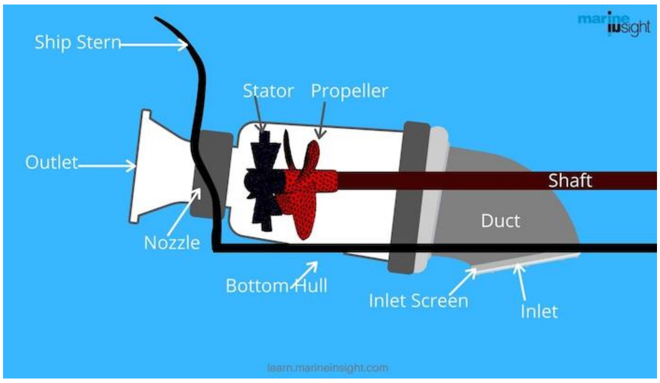
## 3.2 Design

The chassis of the vehicle is supposed to house the hydrogen generation apparatus, battery unit, actuators, water suction unit and the payload of the vehicle. The various design parameters such as thickness of the material, dimensions of the vehicle, etc need to be determined taking into account factors such as:

- Hydrostatic Resistance
- Weight of the vehicle
- Positioning of the Actuators
- Space for Housing Components and Payload
- Stability of the vehicle

To effectively house all the components the initial proposed design process was to have two major components: the upper deck and lower deck. Considering the cost of the quotations received from vendors for fabricating two separate decks while also considering the reduced utlity of the upper deck and important design choice had to be made. The payload on the vehicle needs to be determined taking the hydrostatic resistance that the payload would contribute to by necessitating more contact area of the vehicle with water. The thickness of the hull components needs to be sufficent for taking the payload and the factor of safety for the same needs to be verified with stress simulations. The idea is to have the upper deck house the payload tray while the lower deck houses the other components. The choice of material for the hull needs to be made factoring in buoyancy, weight, ease of fabrication and hydrostatic resistance. For the choice of actuators, there are two main options: water-jet pump and thrusters. Although the water-jet pump is more suitable for the scale of the vehicle it is more complex in design and implementation. However, electric thrusters offer a more simple and viable option. Thrusters have to be positioned considering the pitch moment its action would exert on the vehicle. They also have to positioned with sufficient lateral offset for efficient differential steering of the vehicle. The thrusters have to be coupled in an efficient way. The coupling mechanism needs to be light weight and strong at the same time. The mode of coupling needs to be leak proof as water should not enter the lower hull through the methods used for coupling.

(a) Thrusters




(b) Waterjet

Figure 4: Choice of Actuation

## 3.3 Simulations

To arrrive at an ideal design choice, simulations need to be performed to estimate: Hydrostatic resistance on the vehicle for given payload condition and the Hull's safety for given thickness and payload condition. Ansys Fluent is an ideal choice to estimate the hydrostatic resistance as we can effectively generate a mesh of the hull in the environment and define various operational parameters. By estimating the resistance on the vehicle under maximum operating condition we can also estimate the maximum power requirement of the vehicle. The floating point of the vehicle needs to be estimated for the given payload to effectively define the water surface level with respect to the hull in the simulation environment. Around this level a multiphase environment of water and air has to be setup to effectively compute the drag on the vehicle. Boundary velocity conditions have to be defined by setting Inlet and Outlet Control surfaces on the bounding environment. The mesh has to be setup with a higher relative density around the hull for effective resistance estimation. Autodesk Fusion 360 offers tools to effectively perform stress simulations on the vehicle. We can therefore estimate the effective safety of the hull for different payload conditions and for different hull thicknesses. By varying between these parameters we can arrive at optimum values for thickness of the hull.

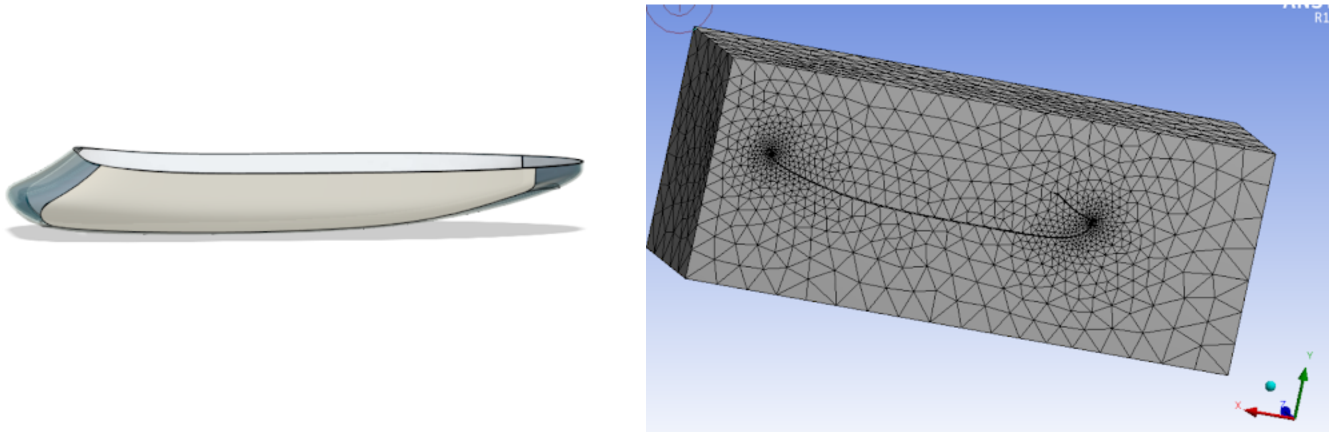


Figure 5: Proposed Simulation Framework

### 3.4 Navigation


Figure 6: Schematic Diagram of Sensors, Actuators and Computation Framework

The goal of the navigation subsystem is to successfully guide the autonomous surface vehicle from the starting point to the destination. A grid map of the environment around the vehicle is generated. When in open environments satellite images will be used to mark out land boundaries and other non-navigable terrain as obstacles in the grid map. It is equipped with GPS sensor and Inertial Measurement Unit (IMU) sensor for data on the vehicle's location and orientations respectively. The sensor processing and computation of the vehicle's navigation is performed onboard on an Arduino Mega Micro-controller. The navigation is structured by providing manual way points on the grid map based on the human heuristic and a trajectory is to be synthesized between them. The initial approach to be taken for this is to use pure pursuit between current location to next way point. If basic navigation is completed using GPS and IMU, obstacle avoidance is to be implemented with proximity sensors using simple Rapidly Exploring Random Tree (RRT) [8].

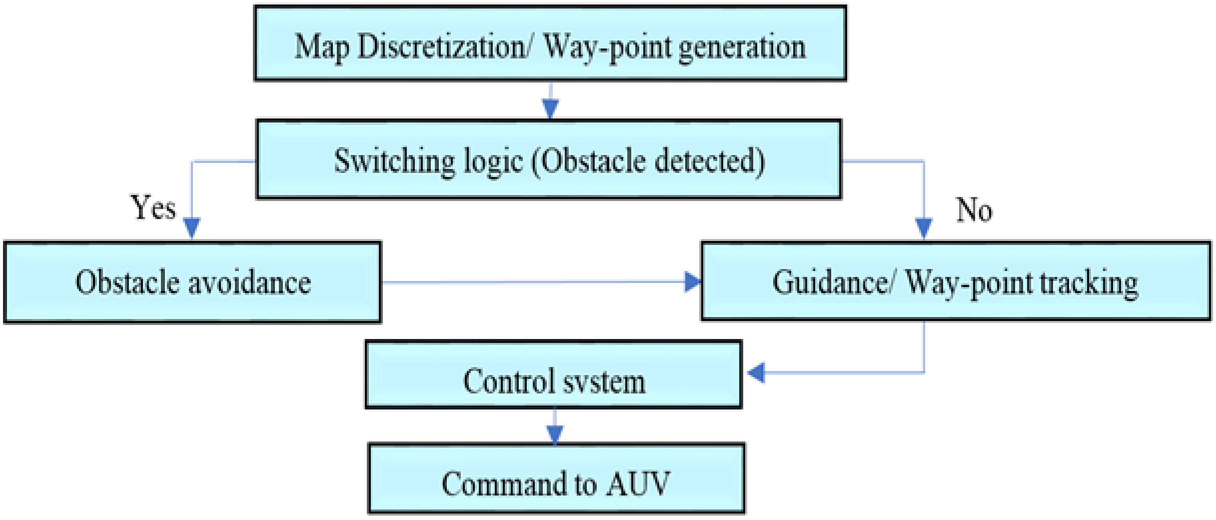



Figure 7: Navigation Decision Tree

## 3.5 Fabrication

The overall fabrication of the vehicle can be divided into three parts:

- Hull
- Thruster Coupling
- Electronics

For the hull manufacturing vendors need to be identified based on the process. As the most suitable options all involve composites, vendors specialised in composite layup and mould making are an ideal choice. Fabheads Automation, an Indian Institute of Technology Madras alumnus company who specialise in both of these along with composite 3D Printing are an automatic choice. Central Fabrication Facility in the Central Workshop in our campus is also a choice as they bring with them a rich experience of fiberglass hull making for the Naval Architecture Department. Estimated costs and promised time of delivery were important factors in choosing between the two as this is both a budget critical and time critical project. Both offer similar costs but the expected time of delivery is shorter with Fabheads Automation. For the thruster coupler manufacturing, the most ideal processes are 3D printing, Laser Cutting, CNC Bending and CNC Milling. 3D printing can be performed at the Centre for Non-Destructive Evaluation (CNDE) Lab using PLA filaments sourced online. For Laser Cutting and CNC Machining, Dhanalaksmi Engineering from Ekkatuthangal are a good choice. Alfab Engineers, Guindy offer CNC Bending Services. Electronics can be built in-house using a General Circuit Board (GCB) procured from Modi Electronics, Ritchie Street.

## 3.6 Testing

Figure 8: Wave Pool, Department of Naval Architecture, IIT Madras

An ideal place is necessary for testing the hull draft, flotation, hull traversal speed, battery and thruster functioning along with navigation. The IIT Madras Swimming Pool is an option but it gets crowded with users. The IIT Madras Lake is a little risky with active currents and aquatic life. The Wavepool in the Naval Architecture Department is an ideal choice as it is a controlled environment with safety precautions and life jackets. The electronics circuitry was tested in the Lab environment in CNDE, IIT Madras and the assembly also was performed there. All necessary equipments for electronics such as a multimeter, soldering kit, breadboards, wires, tap, etc were procured to make the testing process hassle-free.

# 4 Results

By performing various simulations and optimising for the device weight and payload we have arrived at vehicle dimensions of: Length: 2200 mm, Width: 670 mm and Height: 565 mm. The vehicle is designed to carry a payload of up to 60 Kgs as this has a power requirement which is serviceable by the power system. By gradually increasing weight and validating factor of safety for the payload we have arrived at a hull thickness of 8 mm. Fiberglass offers an ideal material choice considering its strength, ease of manufacturing and flotation properties. The initial design plan was to use an upper deck and a lower deck which are to be made from fiberglass layup process. They are designed to have interlocking profiles which are to be bonded together with marine hull adhesives. The thrusters have been positioned at an effective distance so as to provide zero or minimal moment about the center of gravity. Maximum possible lateral offset has been maintained between the thrusters for the given vehicle width so as to provide maximum differential steering torque. The below figure 9 shows the design arrived at as a result of this process.

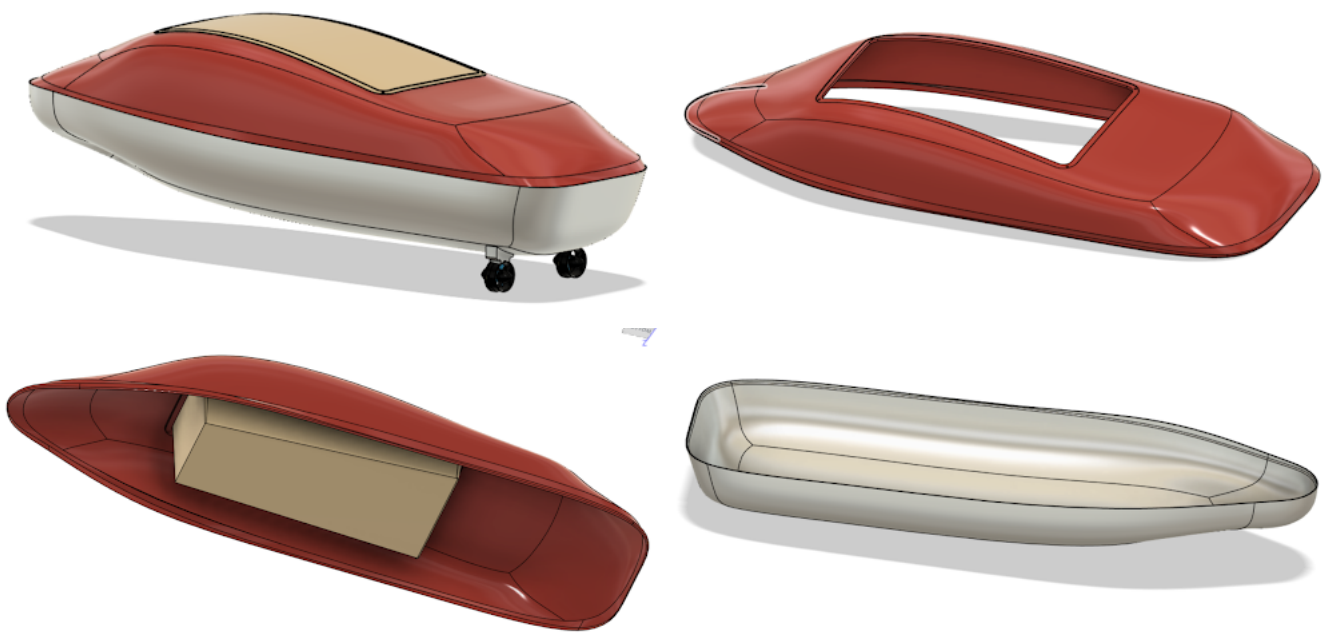


Figure 9: Snapshot of Initial CAD of the vehicle

For the resistance simulation, the mesh of the environment has been generated with higher density of meshing around the hull control surface by using a bounding box. The output drag force on one half of the device converged to 200 N and for the entire vehicle at an operational velocity of 2.5 m/s. This implies the full vehicle is estimated to have a drag of 1 KW at maximum loading condition and a resistance of 400 N. The static load simulation performed on the lower deck and yielded a maximum deflection of 1 mm and a hull thickness of 8 mm is sufficiently safe for the loading condition.

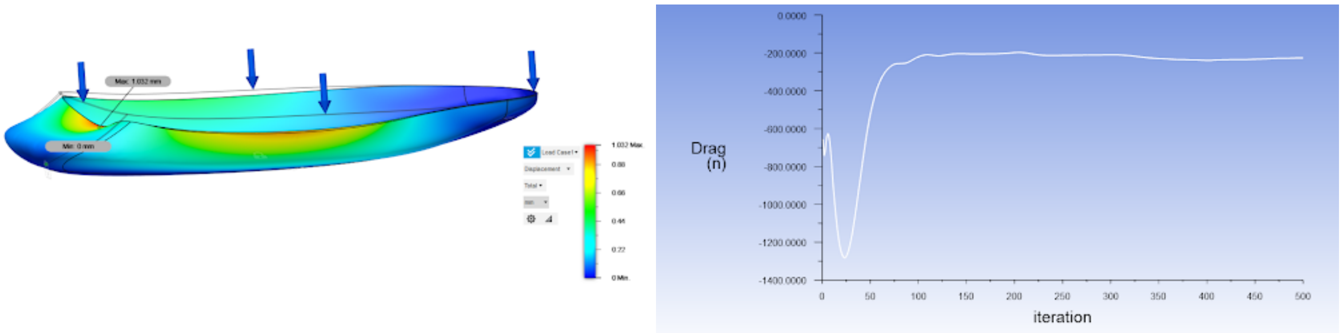
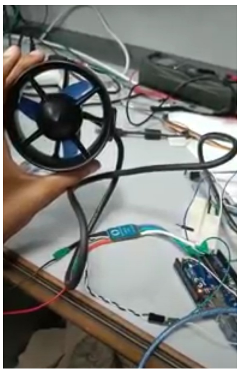



Figure 10: Simulation Results

Blue Robotics T200 Thrusters are an ideal choice for actuating the vehicle because of its reliability, parameters and features. It can provide a maximum thrust of 6.5 kg per thruster and ideally 6 of the same would be required to run the vehicle effectively. 2 of those thrusters were procured initially and their working was tested at low load conditions. After this 2 more were procured as running the vehicle at full power is not under the current timeline's goals. A battery system consisting of 4 24V 250 Whr Lithium-ion Batteries from Robu in parallel configuration will serve as the power system for the device as the device has a maximum power requirement of only 1 KW. But only 1 of it has been procured for the time being as first basic functionality has to be verified.



(a) Photograph of Blue Robotics T200 Thruster


(b) LiPo Battery

Figure 11: Components Procured for the Vehicle

For the integration of the Hydrogen Power System with the vehicle at a later point of time the following things had to be taken care of. The dimensions of the vehicle had to incorporate the positioning of the battery, computational system, and water suction unit and that is the main reason for the large hull size. A water suction unit needs to be integrated with the Hydrogen Power System. This would involve a water pump and an outlet to the water body below. This suction unit has to be made leak proof considering the electronics housed within the vehicle. For this two openings were made on the lower deck of the hull which were sealed for the time being to test the vehicle at its current state. They were sealed with 3D printed covers, Araldite and M-seal Adhesive.

Figure 12: Snapshot of Water Suction Unit Openings

For the coupling of the thrusters to the vehicle the official CAD provided by Blue Robotics was made use of. Each thruster has 4 M3 threaded holes on a horizontal plane. To couple this with the lower deck, the coupler needs to incorporate a horizontal plane at its base and the lower deck's shape at its top. As the base of the lower deck is a complex contour it can't be made through conventional metal machining and hence 3D printing is the most suitable process for the coupler. However it will not have sufficient strength to transmit the thruster force and moment if it is made of PLA. Thus a laser cut and bent aluminium plate was added at the base with extrusions to the side using 6 fasteners along 2 axes of the 3D printed part to reinforce the strength of the coupling.

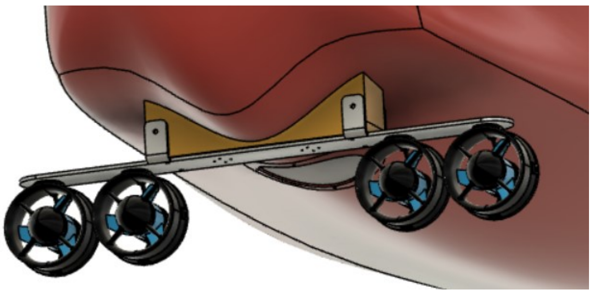


Figure 13: Snapshot of Thruster Coupling

A work request was sent out to Fabheads for the manufacturing of the lower deck and upper deck and a huge quote costing 2.5 Lakh Indian Rupees was received for the same. This was well out of budget for the project and thus redesigning had to be done. As the lower deck had no functional utility a decision was made to do away with it and replace it with an acrylic covering if needed for water proofing. Also the thickness of the hull was reduced to 5 mm from 8 mm to reduce on the material cost . Stress integrity simulation was performed for the loading on the reduced thickness hull and it was still had a reasonable factor of safety. A work request was sent out to Fabheads for the modified lower deck. With this the cost was brought down to 80,000 Indian Rupees. The new modified CAD along with the thruster coupling can be seen below.

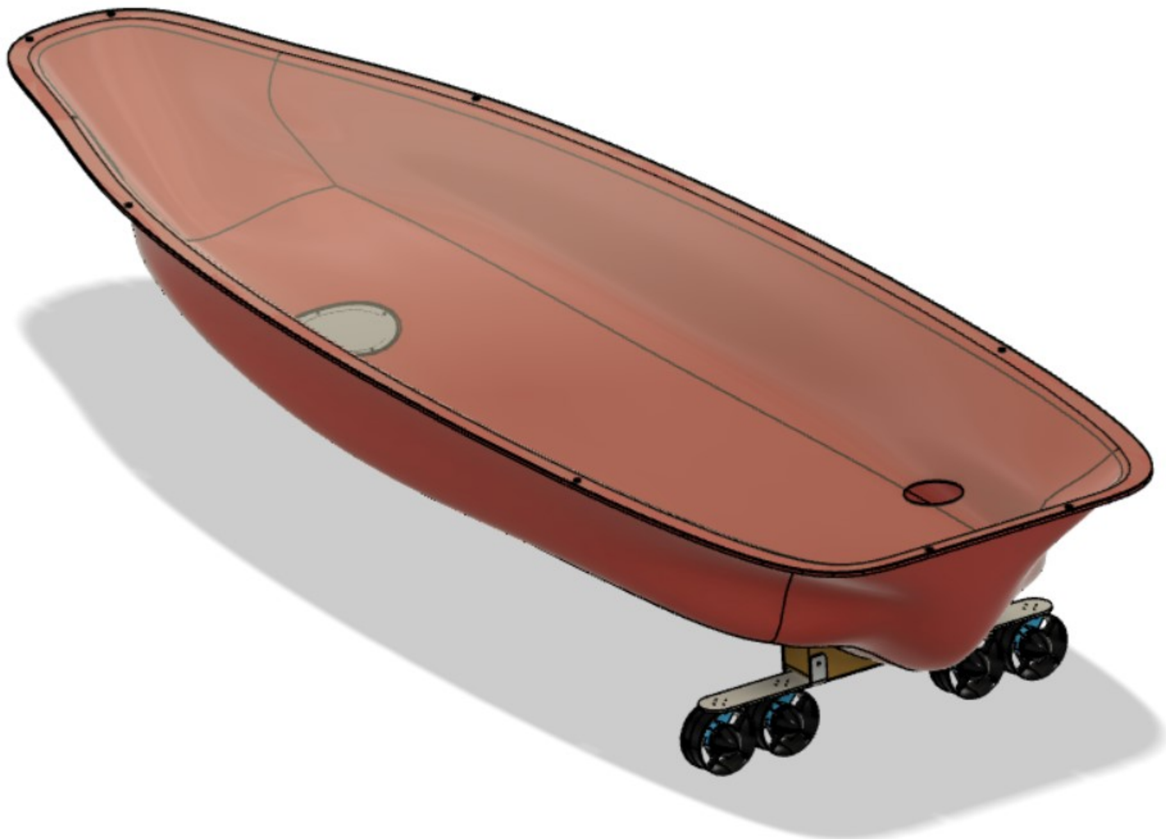


Figure 14: Snapshot of Modified CAD

The manufacturing process of the hull went on for 2 months. It was initially supposed to be completed within 1 month. But there was failure in the first mould made by Fabheads for the layup process. They had to redo the mould and thus it got significantly delayed. This ate up a significant amount of the testing time. For the thruster coupling the 3D printed mount was printed at CNDE along with the 3D printed covers for the suction unit. For the aluminium reinforcement, raw material was procured from JNS Metals, Ekkatuthangal. Laser Cutting and CNC Bending for the same was performed at Dhanalakshmi Engineering Ekkatuthangal and Alfab Engineers, Guindy respectively. The drawings sent out to the different vendors are attached below.

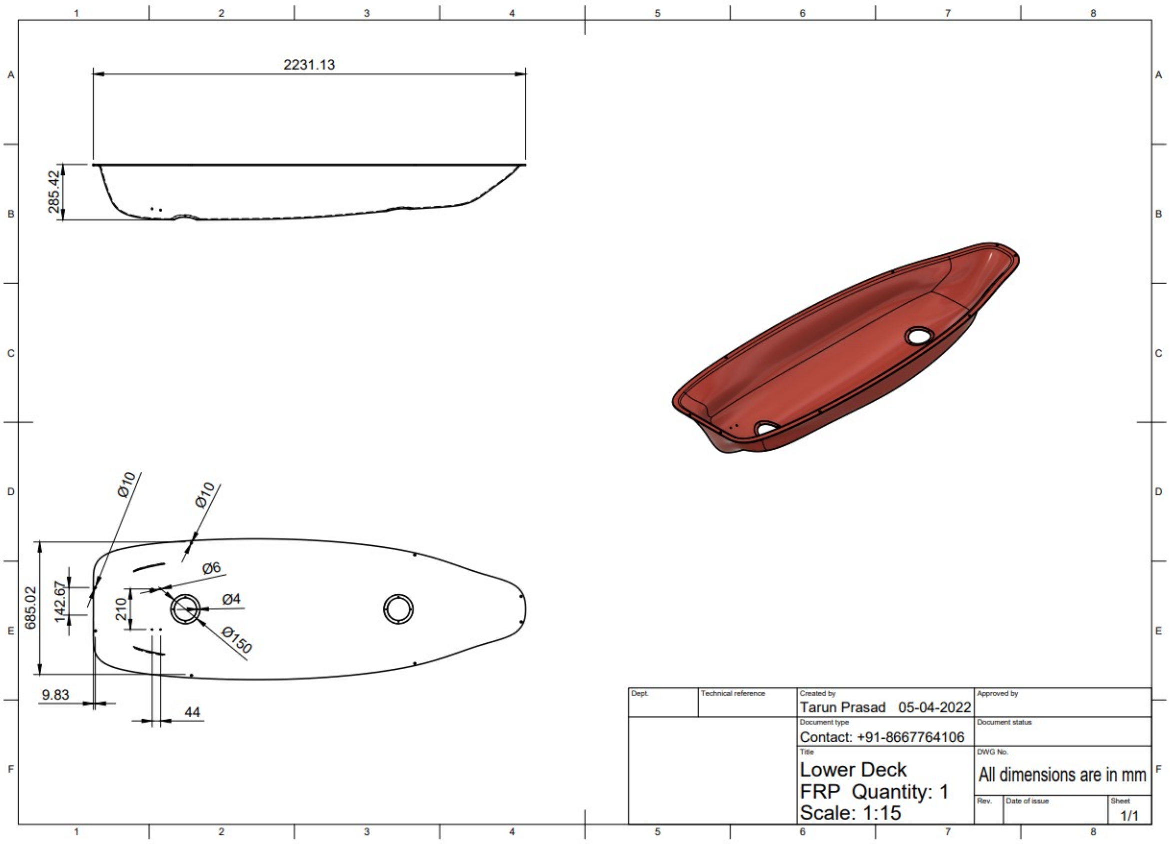



Figure 15: Lower Deck Drawing

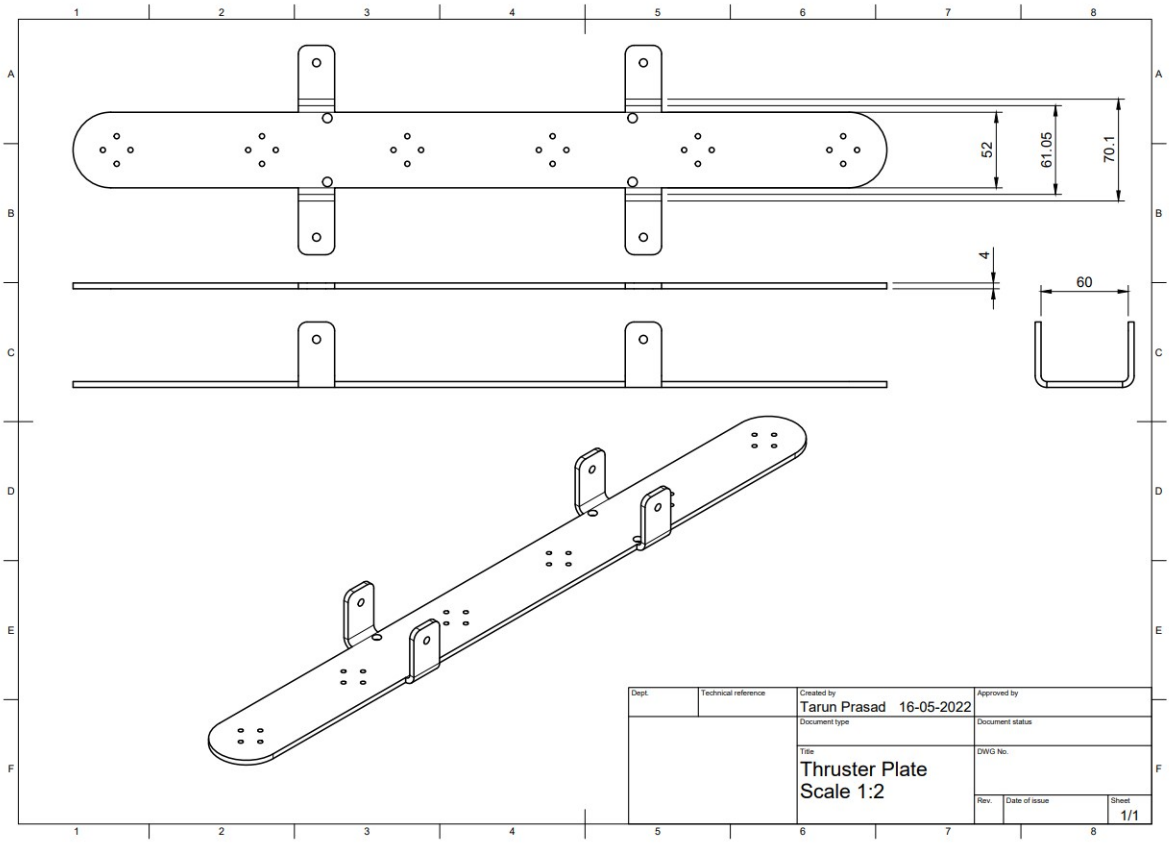



Figure 16: Thruster Plate Drawing

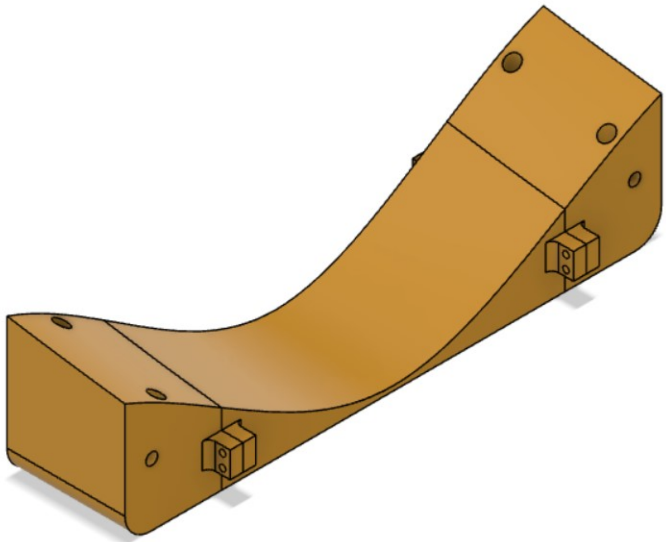


Figure 17: 3D Printed Thruster Coupler

Figure 18: Photograph of Manufactured Hull

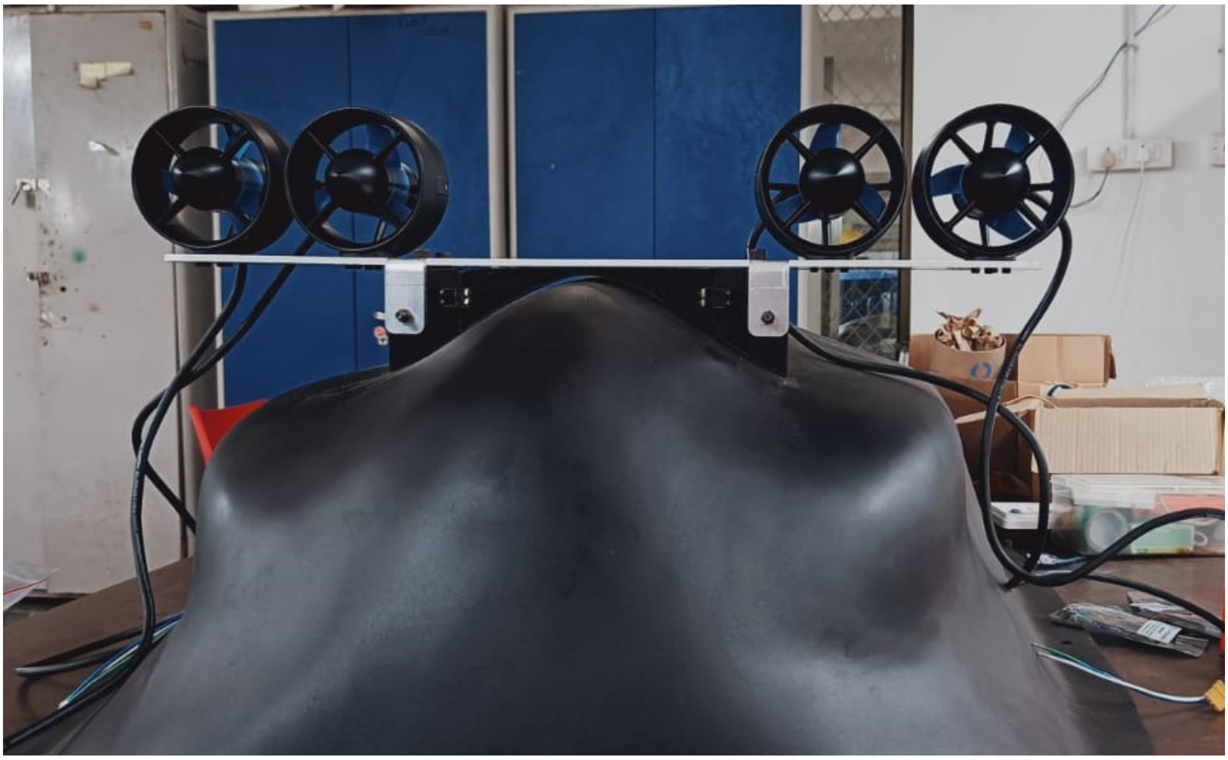


Figure 19: Photograph of Thruster Coupling Assembly

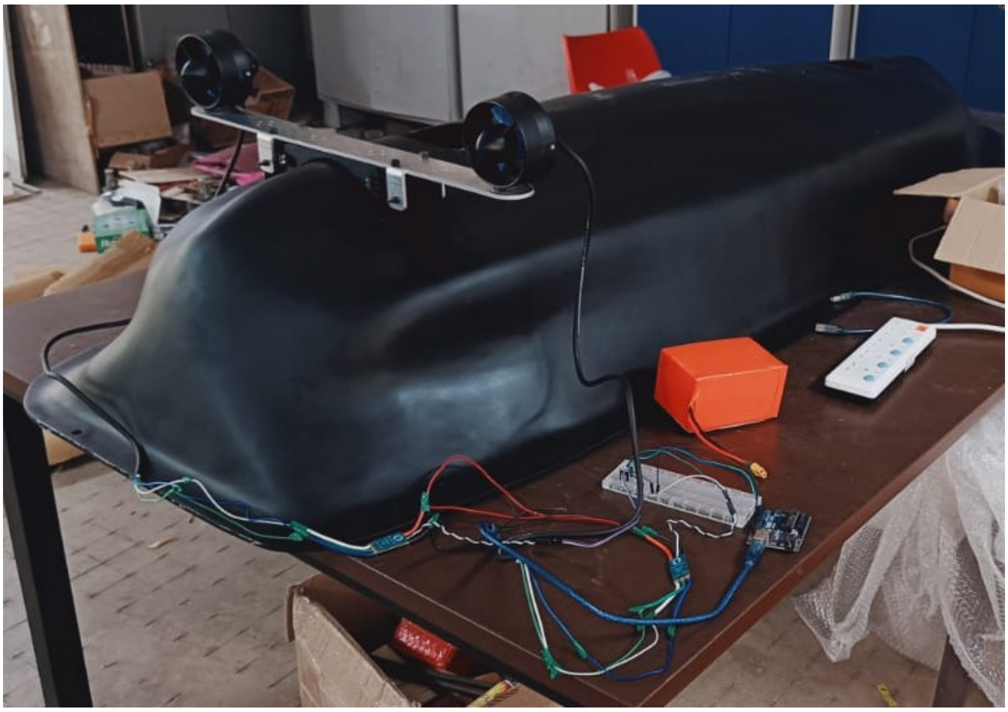


Figure 20: Photograph of Electronics Testing

Figure 21: Photograph of Setting up the Vehicle for Wavepool Testing

Figure 22: Photograph of Wavepool Testing

Figure 18 is the output of the final lower deck hull after layup process. It was later painted with black paint on the bottom and grey paint on the inside. Figure 19 shows how the thruster assembly was mounted onto the lower deck hull. The propeller types where changed to clockwise and counter-clockwise between each successive one. This was done to ensure that no net moment is exerted on the vehicle due to the respective spinning of each thruster. The aluminium reinforcement makes the whole structure sturdy. The coupling to the thrusters was quite rigid and stable. Figure 20 shows the testing of the electronics setup for running the thrusters at different speeds. Two voltage lines were created for powering the thrusters and other electronics. The thrusters were directly powered at 20V. The micro-controller and sensors require a 5 V supply and this powered using DC step down buck converter which was set to 5V from the battery's supply. The thrusters were tested for differential turning commands for the orientation modification of the boat in water. All the sensors were integrated to the Arduino and they were functioning well.

The vehicle was tested in the wave pool in the Naval Architecture Department. Figures 21 and 22 depict the same. Its structural integrity was as expected in the simulations. The water draft level was well within the expected design level. The yellow rope shown in 22 was a safety anchor rope attached to the hull in case any mishap happens and not for any other purpose. The vehicle was able to perform any pre-encoded trajectory in the Arduino. The differential turning of the vehicle performed as expected. One major issue was that GPS wasn't functioning in the Naval Architecture premises due to the closed environment of the testing facility. The only available option for the same was the IITM Lake which requires a lot of precautions. Also there was a huge time constraint due to the impending project deadline and already there was a huge delay in manufacturing from a vendor's side. Thus basic navigation was alone tested for the vehicle in the wave pool premises. The covers used to seal the suction openings performed efficiently. The traversal speed of the vehicle could reach roughly 5 KMPH as expected with the reduced battery count.

# 5 Future Work

The first major step of action would be make it testing ready in the IITM Lake and obtain the necessary permissions. Safety measures have to be taken for the same and GPS functioning should be effectively tested there. Simple way-point testing needs to be performed using the GPS-IMU combo. After this proximity sensors have to be integrated to the vehicle at stategic points. This needs to be extensively tested for efficient obstacle mapping. After this RRT-based obstacle navigation algorithms can be tested out by mapping the environment as a grid. This will take the vehicle to a reasonable level of autonomous capability. After this if the Hydrogen module is ready from the side of Professor Tiju Thomas, the vehicle can be modified to incorporate the same. This would involve building a water suction and storage unit along with the integration of a $H_2$ fuel cell. After this is taken to Technology Readiness Level, extensive documentation of the vehicle needs to be prepared to enable mass scale users to understand how to operate the vehicle. After this commercialisation avenues can be looked into for the project. This work will be carried on by Neha Arora and Lokesh who are MS students

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