Design and Development of a Remotely Operated Underwater Vehicle

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Contents

Introduction

1. While designing an ROV following parameters are taken into consideration -
    - Shape
    - Orientation
    - Thruster Positions
    - Buoyancy, center of buoyancy, weight and center of gravity, etc.
2. For deciding the specifications of the electronics, following parameters are calculated -
    - Drag Force
    - Maximum Velocity
    - Pressure Distribution

Literature Review

We referenced various papers related to waterproofing, volume estimation, calculation of parameters, image processing, etc.

Waterproofing

By industry standards, 8 types of waterproofing exists. We decided to move ahead with IPX7 standard which describes waterproofing as *“Protection against the effects of immersion in water at 1 m depth for 30 minutes.”*

We finalized on IPX7 because it satisfies our initial operational targets. Various levels of waterproofing can be done on our model:

- Outer lid
- Inner lid
- Electronics

We will further explain the processes and final methods we are going to adopt for these.

For outer lid:
Available methods:

- Glass fiber with epoxy resin,
- using ARPD with Polyethylene in 1:1 or 2:3 ratio

Constraints to be kept in mind:

- Water absorption should be <2% wt/wt
- Relative elongation at break should be no less than 100%

We have to also include other parameters like availability, economic as well as technical feasibility while deciding the best fit solution.

For inner lid:
The inner lid needs to be opened and closed constantly for checking on electronics as well as for other purposes. This means we can't apply glue or resin to that part. Other physical methods like lids are explored for this purpose.

For Electronics: The electronics can be waterproofed by using
i) materials like LifeProof™
ii) applying epoxy glue, silicone coating, etc.
While both materials are equally suitable, LifeProof™ requires Vacuum Deposition for application on any surface. In contrast, Epoxy glue/silicone coating can be applied by simply using a brush.

Waterproofing at these 3 levels will make our system safe from all possible scenarios of our system getting damaged by water.

Volume Estimation

As the physical model differed from the proposed one, we need to estimate its volume for Buoyancy and drag calculations. Three methods were proposed for estimating volume:

- **Archimedes Principle**- Dipping the ROV in water and calculating the volume of displaced water
- **Machine Learning models**- Using Laser scanning
- **Physically calculating the parameters and using CAD tools to estimate volume**

Underwater Image Processing

In underwater situations, clarity of images is degraded by light absorption and scattering. This causes one color to dominate the image. The images we are interested on can suffer the following problems: limited range visibility, low contrast, non-uniform lighting, blurring, bright artifacts, color diminished (bluish appearance) and noise.

The image processing can be addressed from two different points of view:

- as an image restoration technique or
- as an image enhancement method.

The image restoration aims to recover a degraded image using a model of the degradation and of the original image formation; Image enhancement uses qualitative subjective criteria to produce a more visually pleasing image and they do not rely on any physical model for the image formation.

In order to improve the perception of underwater images, we proposed an approach based on color contrast and image fusion techniques.

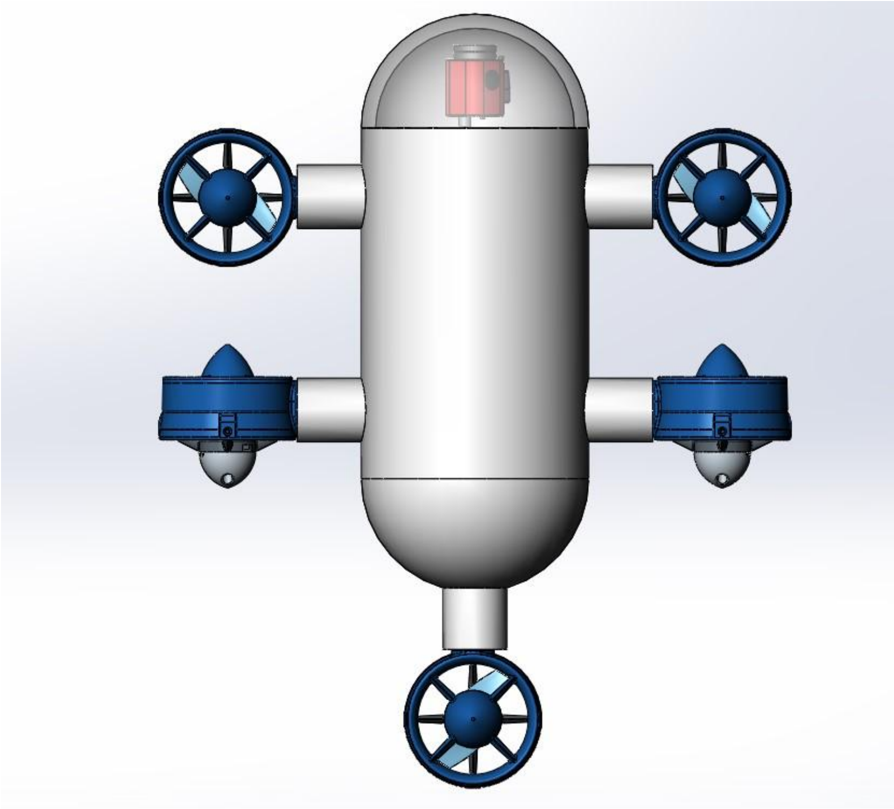
Objectives

- Inspecting and testing the working condition of the existing ROV Model
- Making changes in the CAD model based on the actual dimensions and calculating physical parameters to perform flow simulation on the existing model
- Optimising the position, orientation and validating the specifications of the thrusters
- Testing the waterproofing of the existing model and devising new methods to improve it
- Checking feasibility of different hull designs as per our requirements
- Implementing and testing the underwater image processing methods

Observations

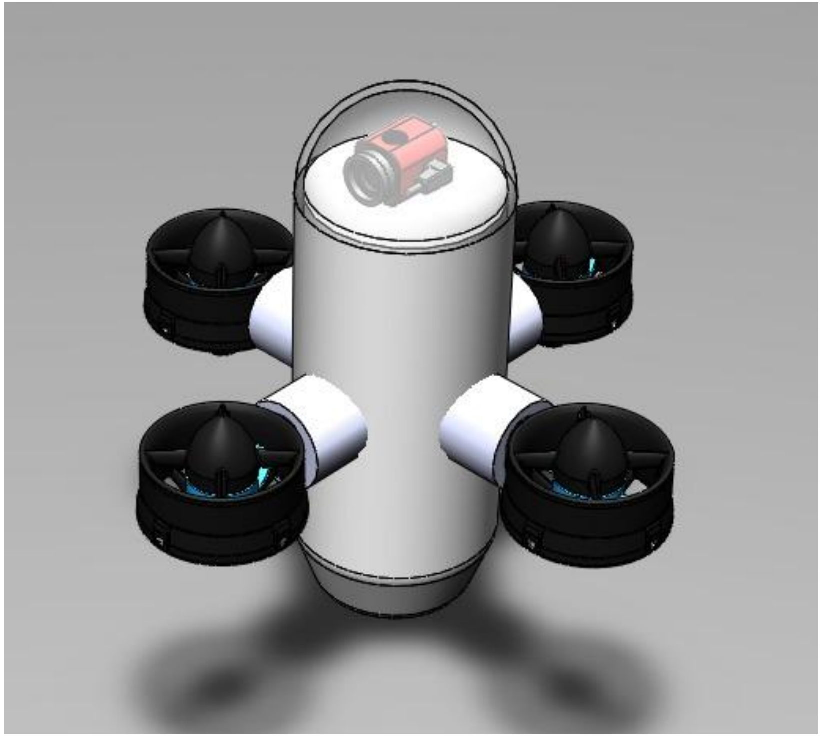
- Weight of the ROV (without LiPo) = 3.00 kg = 3000 gm
- Weight of the ROV (with LiPo) = 4.163 kg = 4163 gm
- Volume Estimation with SolidWorks, V = 4950.022 cc
- Expected Density, ρ = 0.844 gm/cc
    - Since overall density of the ROV < 1 gm/cc (density of water), dead weights are required.
    - Expected weight of dead weights, m = 4950.022 - 4163 = 780 gm
- Error :
    - $\Delta\rho = 0.0201 \Rightarrow \rho = 0.844$ gm/cc $\pm\ 0.0201$

CAD Design

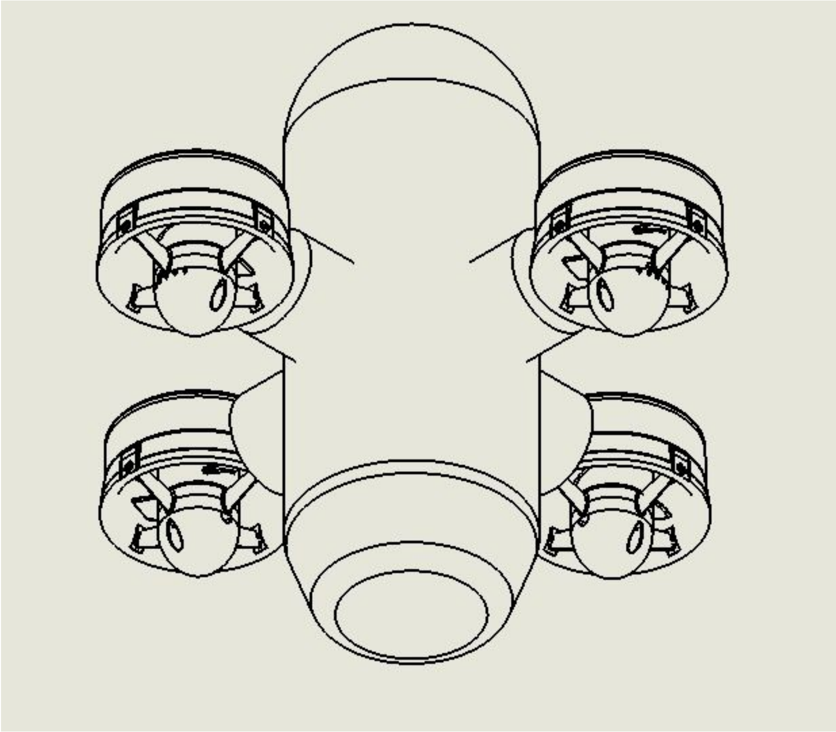


This model was initially proposed but found infeasible during analysis.

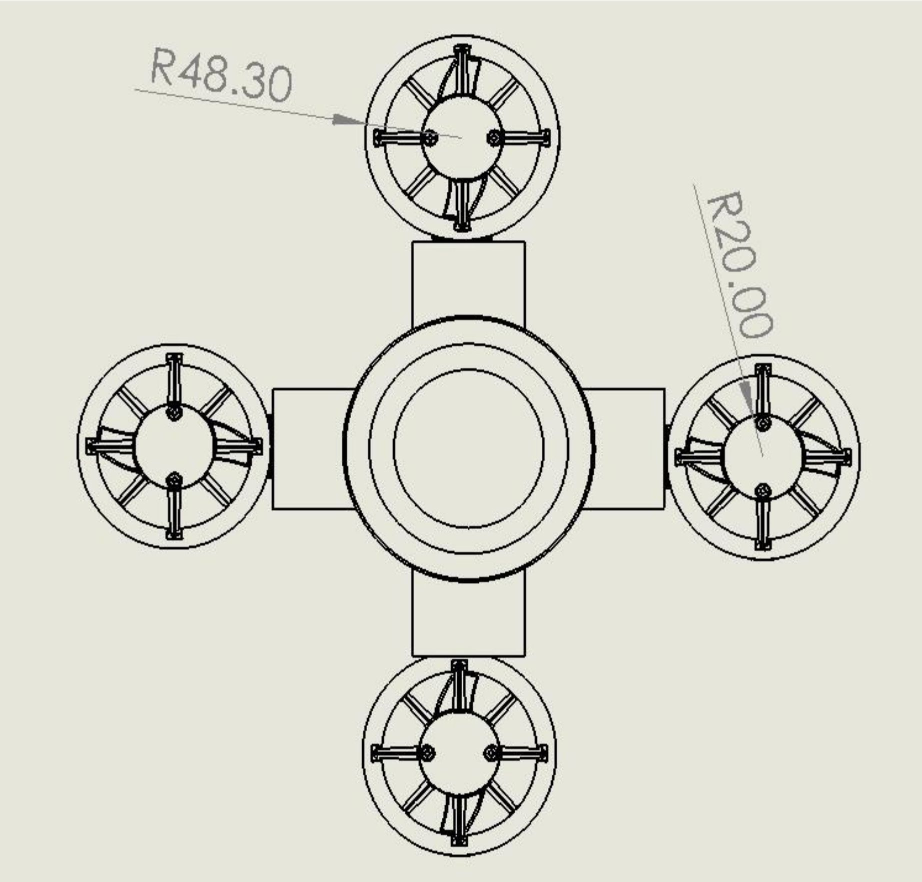
CAD Design

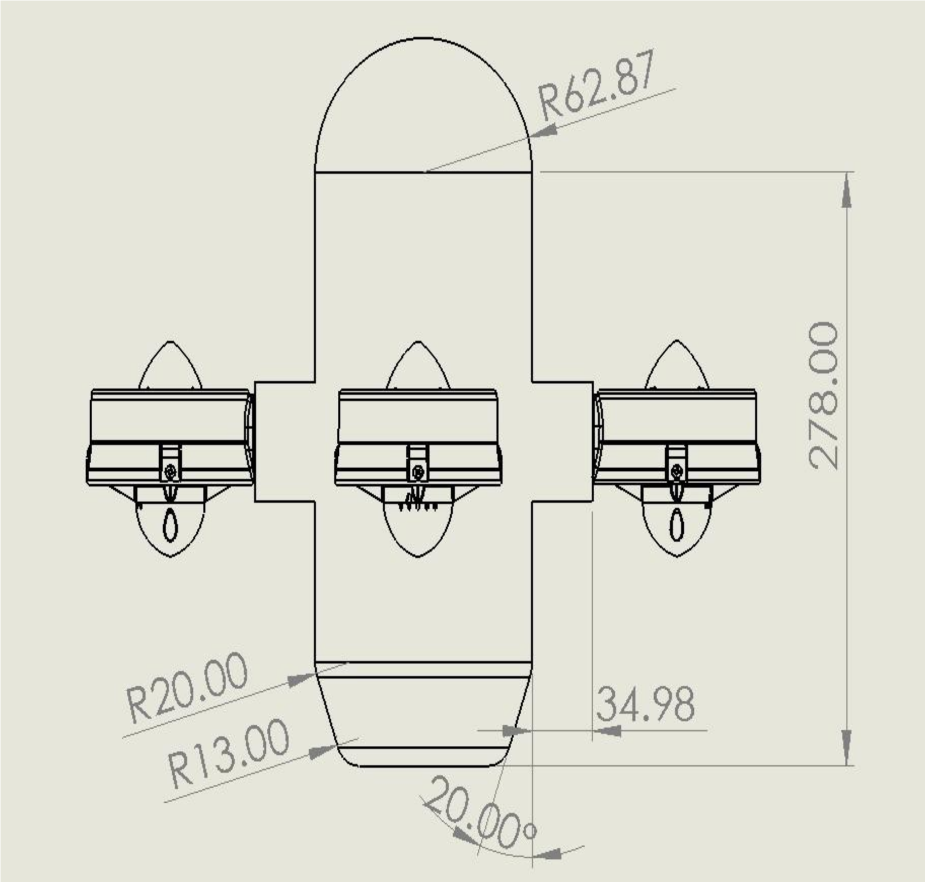


Final Design

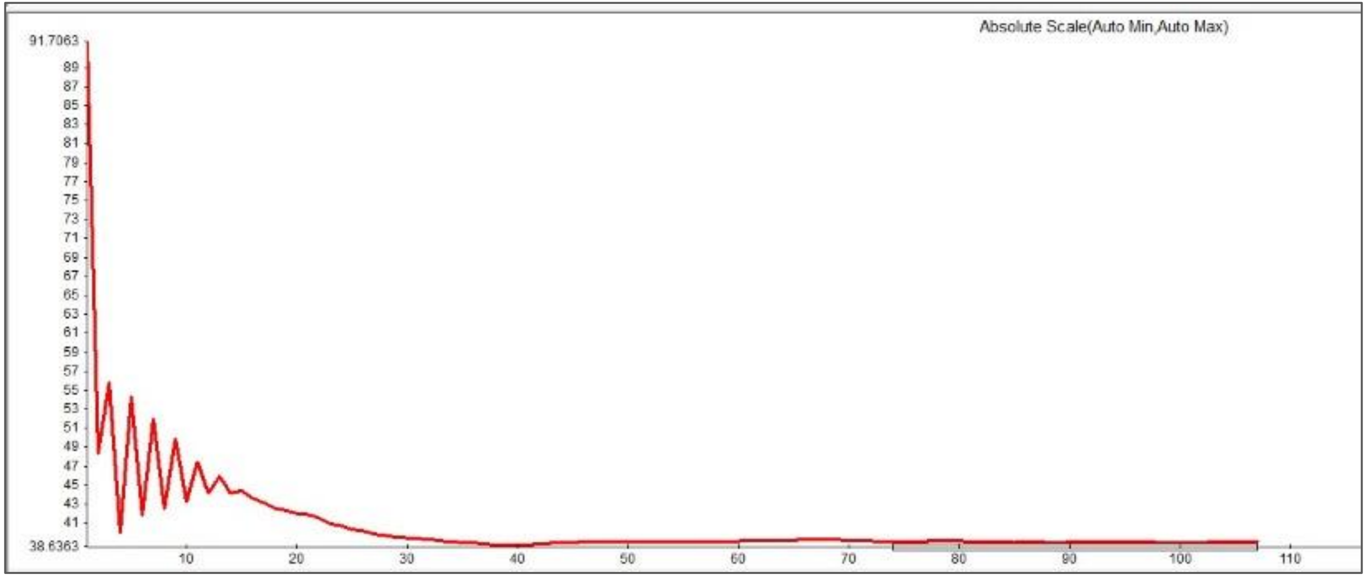


Isometric View


R48.30
R20.00

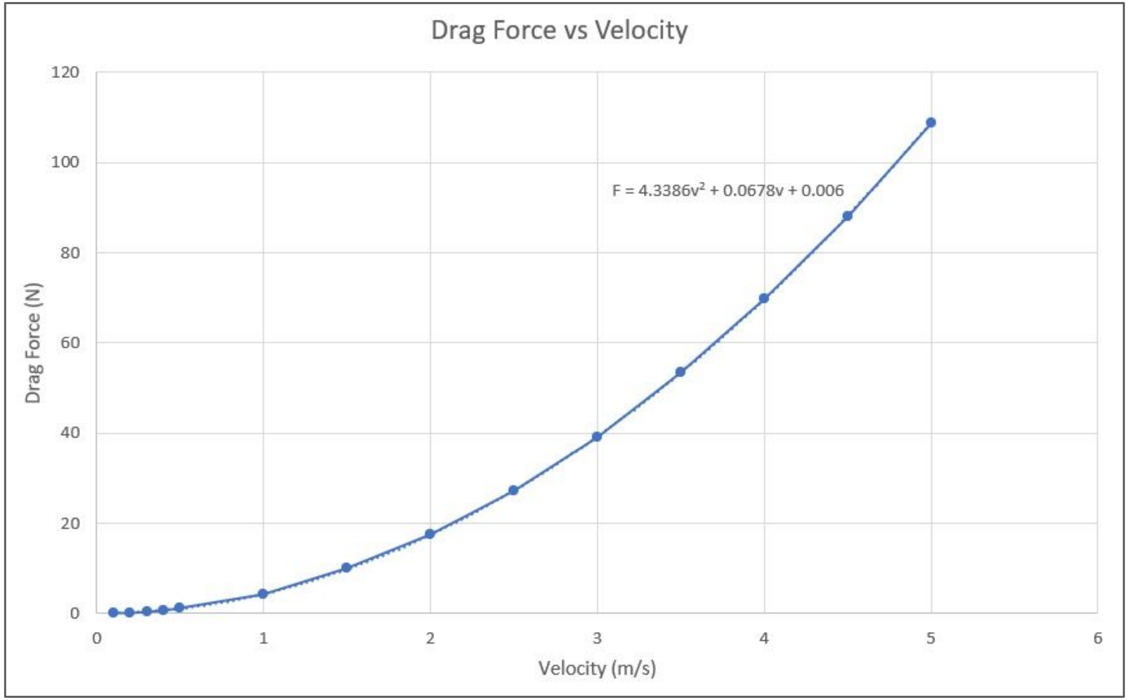

R62.87
278.00
R20.00
R13.00
34.98
20.00°

Drag Force



For Velocity = 3 m/s

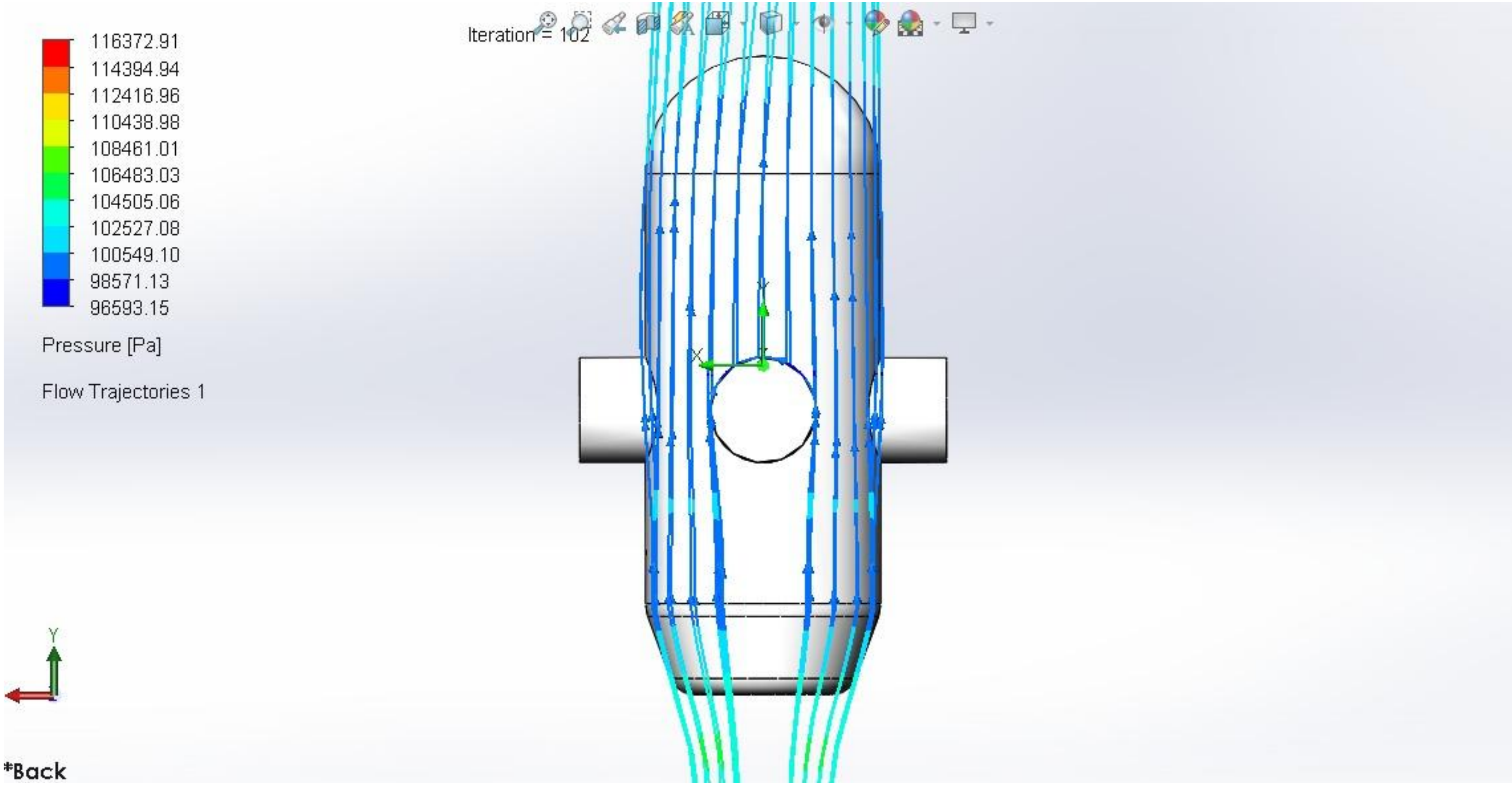
Variation of Drag force with Velocity

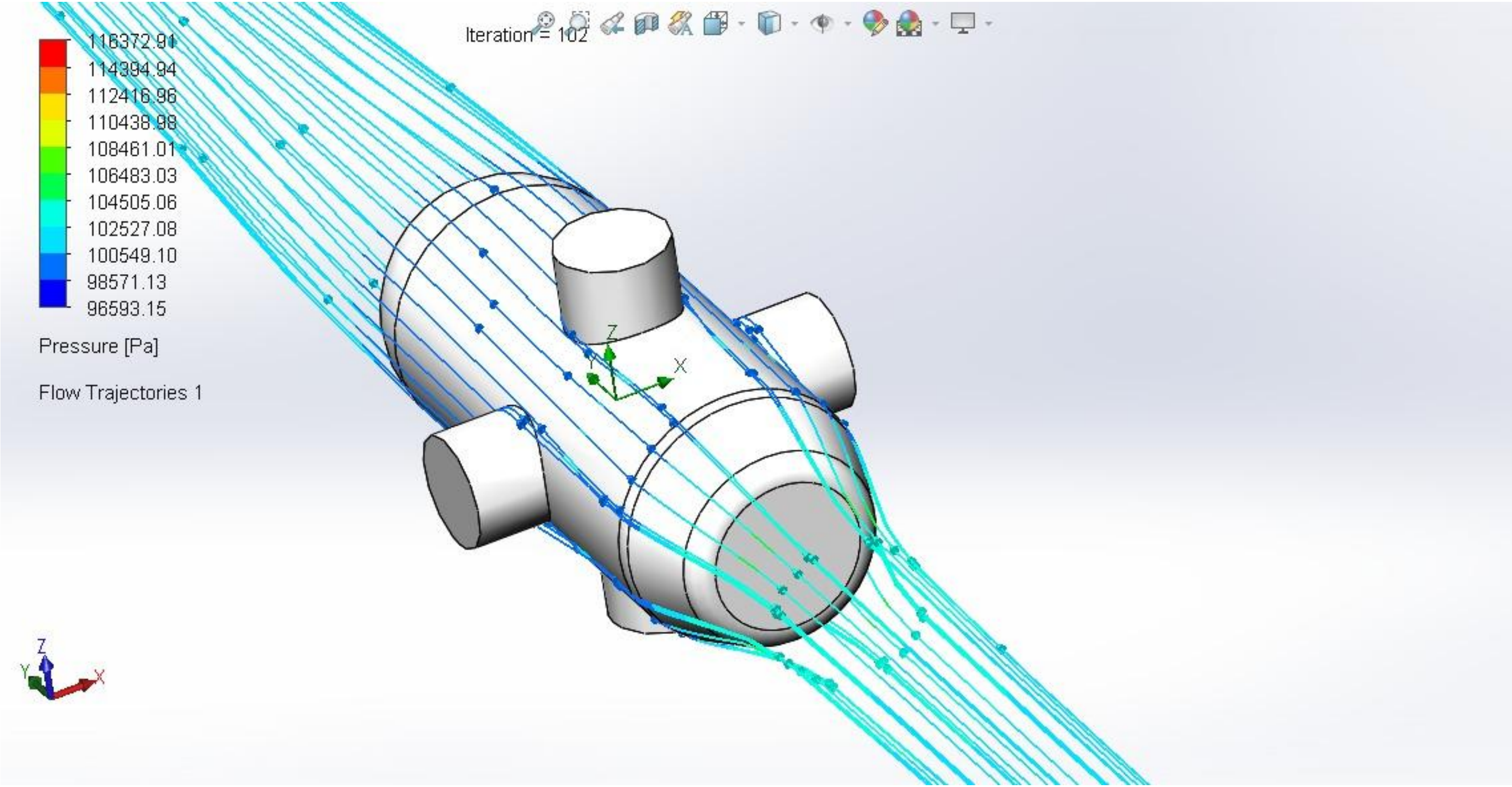


Velocity	Force
0.1	0.047
0.2	0.182
0.3	0.403
0.4	0.718
0.5	1.1181
1	4.412
1.5	9.977
2	17.564
2.5	27.259
3	39.023
3.5	53.54
4	69.717
4.5	88.099
5	108.853

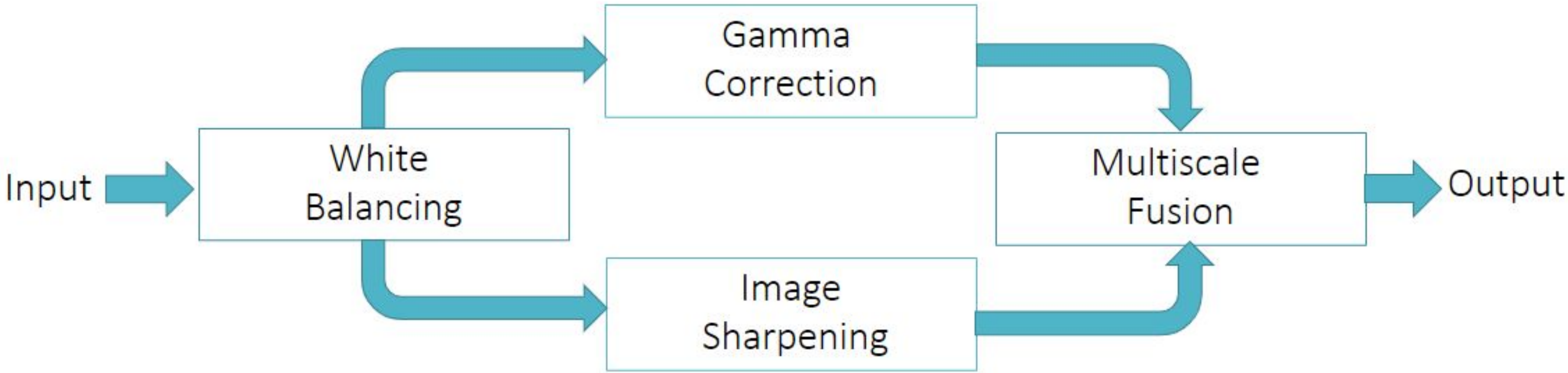
These values were calculated using Solidworks and fitted in a polynomial curve using MS Excel

Pressure Distribution





Iteration = 102
116372.91
114394.94
112416.96
110438.98
108461.01
106483.03
104505.06
102527.08
100549.10
98571.13
96593.15
Pressure [Pa]
Flow Trajectories 1
Z
Y
X


Input
White Balancing
Gamma Correction
Image Sharpening
Multiscale Fusion
Output

White Balancing - It aims at removing the color cast induced by underwater light scattering.

Gamma Correction - to correct the global contrast. It increases the difference between darker/lighter regions at the cost of a loss of details in the under/ over exposed regions.

Image Sharpening - We blend a blurred (Gaussian Filtered) version of the image with the image to sharpen it.

Image Fusion – We use final weights alongside the original image and join them into single final image.

The Weights

Using a weight graph in the fusion process can highlight the pixels with high weight value in the result. For the selection of weight image, the Laplacian contrast, saliency, and saturation features of the image are calculated.

Laplacian Contrast Weight

Saliency Weight

Saturation Weight

Results & Conclusions

Waterproofing

- **Glass+Epoxy Resin** was chosen by analysing the parameters.
- Gasket was chosen as the best fit for this lid. Elastomers are the best suited materials for waterproofing gaskets.
  Silicone Rubber gasket was chosen because of low creep values and less compression with change in temperature.
- **Silicone coating** was chosen for waterproofing the electronics.

Volume Estimation

- Archimedes principle discarded because of waterproofing issue with the model
- Machine Learning models were too complex to employ in our case
- The physical calculations were made using thread, meter scale with a least cound of 1mm & weighing scale with LC 0.1 kg. The volume was estimated using **Solidworks**

Drag force v/s velocity:

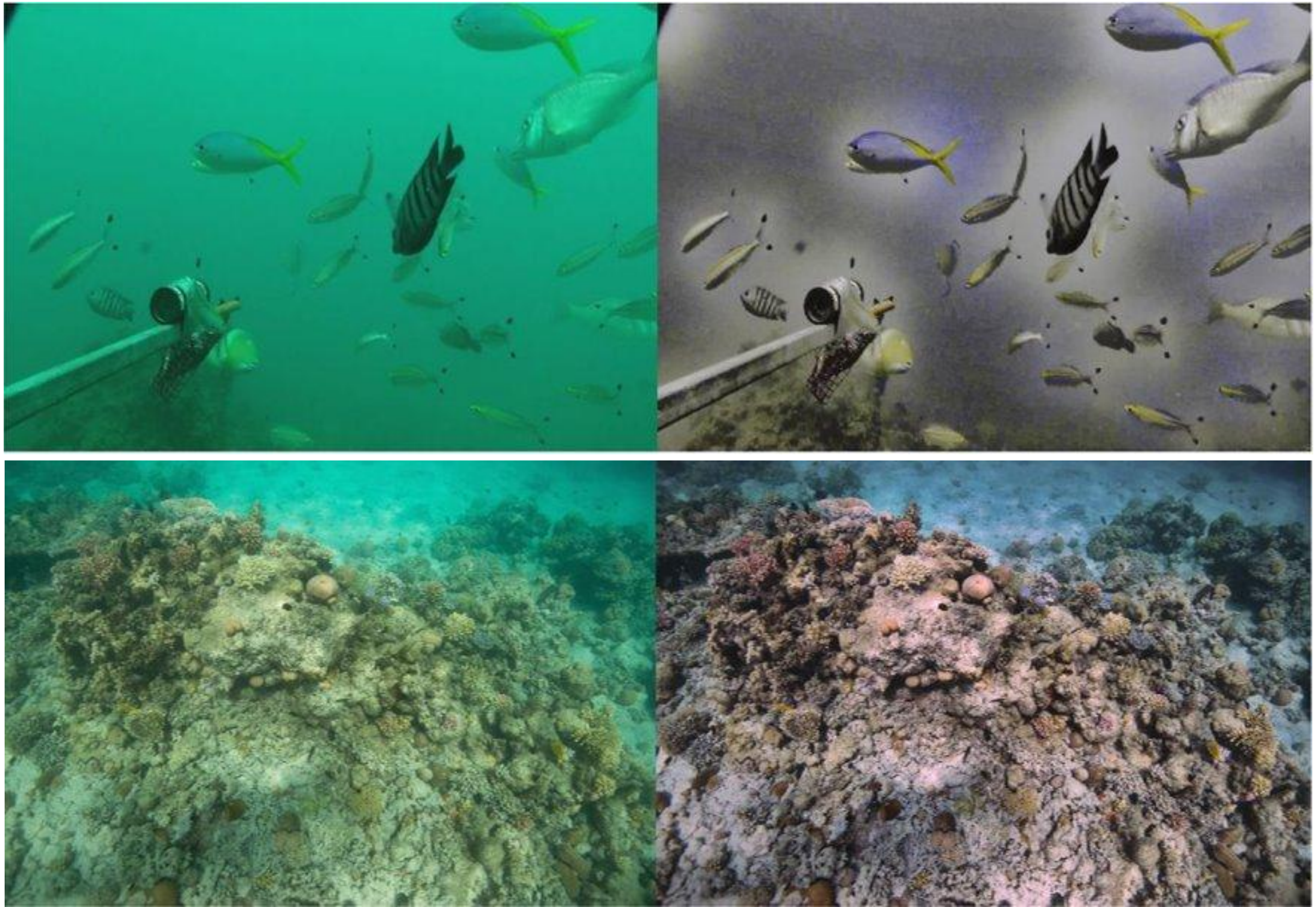
The values were fitted in a polynomial curve and the formula was found to be

$$F = 4.3386v^2 + 0.0578v + 0.006$$

$$V_{max\ (upward)} = 4.65\ m/s$$

$$V_{max\ (downward)} = 4.08\ m/s$$

Original Images Output images



Future Plans

1. Following components to be attached to the ROV and make it workable -
    a. Arduino Mega or UNO R3
    b. Lithium-ion Battery (14.8V, 15.6Ah)
    c. Pixhawk Autopilot
    d. GPS Module
    e. Low-Light HD USB Camera
    f. Controller

2. Waterproofing -
    a. Epoxy Resin for Electronics inside the hull
    b. Fiberglass Sheets or Epoxy resin for thrusters and upper lid and dome
    c. Double layer waterproofing if space is available
    d. Silicone Rubber gasket for the inner lid