Design of an Underwater Vehicle

Summer Internship
at
Centre for Indian Knowledge Systems (CIKS), IIT Guwahati

Under the supervision of

Prof. Uday Shanker Dixit
Professor,
Department of Mechanical Engineering,
IIT Guwahati

Presented by

Triluk Sharma | ME
Abhilekh Hazarika | ME
Jarna Devi | ME
Pusparani Moirangthem | ME
Astha Mohan | ME
Kritik Gurung | ECE

NERIST, ITANAGAR

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Introduction

A Remotely Operated Vehicle (ROV) is a versatile underwater tool designed for a variety of tasks. It operates without a human occupant and offers numerous advanced features:

- Operates underwater without a human occupant
- Controlled from the surface via cables or wireless communication
- Equipped with cameras, lights, and sensors
- Operator can manipulate the ROV to avoid obstacles

Objectives

- **Design**: Developing an unmanned underwater drone.
  - Exploration and detection of underwater hostile activities
  - Safe storage for electrical control systems
  - Waterproof compartment for electronics
  - Cost effective

Key Features of the Underwater Drone

- **Intuitive Control**: Drone is controlled using FS-i6S controller and receiver allowing for precise command and navigation.
- **3D Printed Design**: Customizable and efficient body design using additive manufacturing
- **Enhanced Vision**: High-quality video feedback from Raspberry Pi-powered camera
- **Autonomous Capabilities:** Pixhawk flight controller enables stable and autonomous underwater navigation
- **Efficient Propulsion**: Four thrusters with dedicated ESCs for agile and precise movement
- **Real-time Data Transmission:** Live video feed and sensor data transmitted back to the operating device
- **Modular Design:** Easy maintenance, upgrade, and customization for prolonged lifespan and adaptability

Application of Underwater Drones

- **Underwater Exploration:** Marine life, coral reefs, underwater formations
- **Data Recording:** Inspections, environmental monitoring
- **Offshore Oil and Gas Industry:** Inspections, maintenance, repair of underwater infrastructure
- **Hydroelectric and Dam Inspections:** Identify issues: cracks, sediment buildup, structural damage
- **Military and Defence:** Mine countermeasures, surveillance, reconnaissance, salvage, recovery
- **Search and Recovery:** Assist police, fire, and first responders
- **Aquaculture:** Fish monitoring, net inspections, feed monitoring, water quality sampling
- **Infrastructure Inspections:** Sewer pipelines, wastewater pipelines, underwater cables
- **Scientific Exploration and Archaeology**

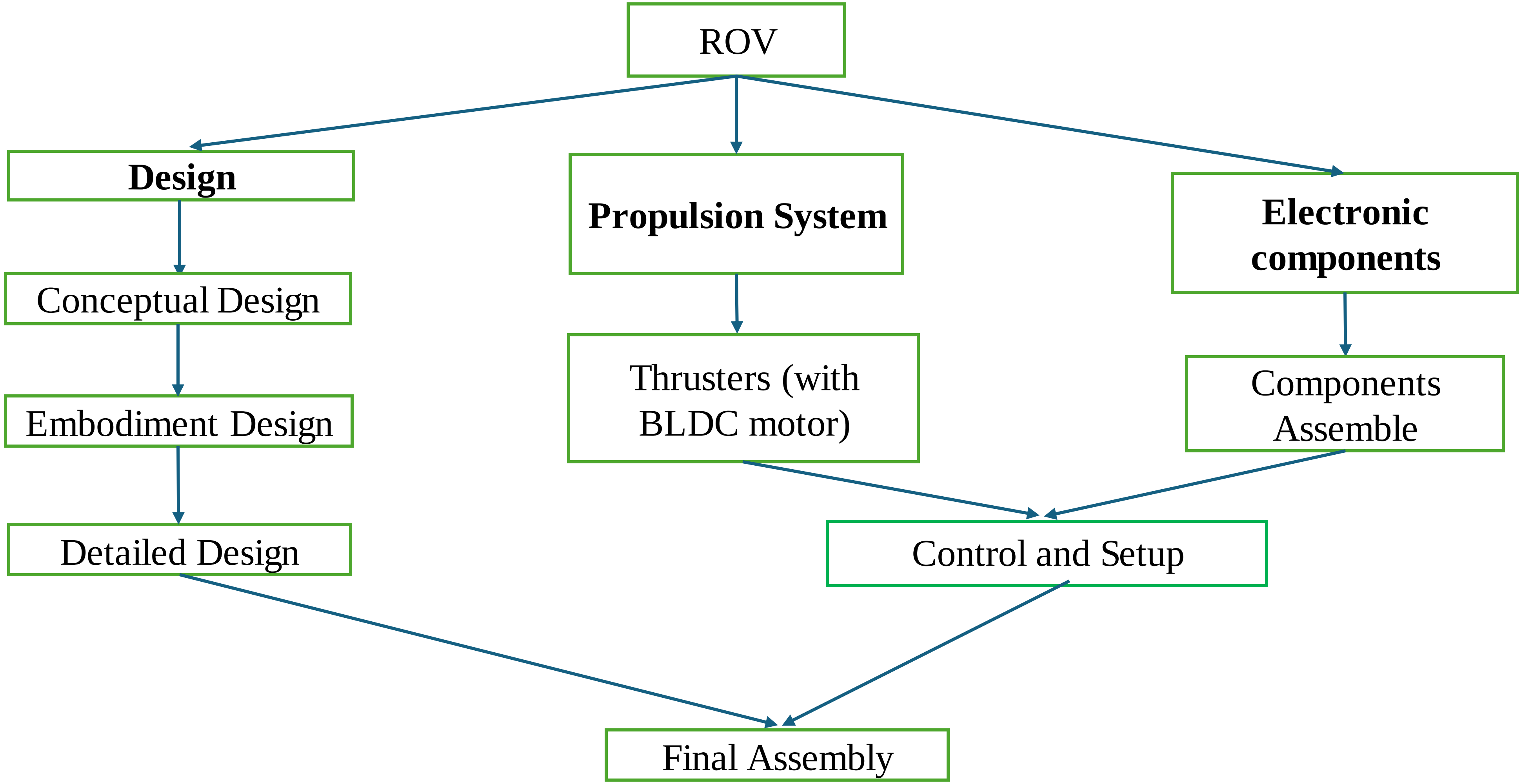
Methodology

- **Design and Development:**
  - Created model in SolidWorks; 3D printed main body.
  - Acrylic tube used to house electronics and ensure waterproofing.
  - Components: Pixhawk, 4 brushless DC motor (BLDC) (Thruster) , 4 Electronic speed controller (ESC), power distribution board, Battery, GPS, Pixhawk power module, buzzer.

- **Control System:**
  - FS-i6S controller and receiver.
  - QGroundControl software for navigation and control.

- **Assembly and Integration:**
  - Assembled 3D printed parts; mounted acrylic tube inside.
  - Integrated electronic components, ensuring no water leakage.

Flow Chart


ROV
Design
Propulsion System
Electronic components
Conceptual Design
Thrusters (with BLDC motor)
Components Assemble
Embodiment Design
Detailed Design
Control and Setup
Final Assembly

DESIGN

Key Features of ROV Design

- **Durability**: Withstand deep water pressure
- **Compatibility**: Integrate seamlessly with chassis and propeller
- **Internal Space**: Compulsory space for electrical control systems
- **Waterproofing**: Effective joining method to prevent water leakage

Phase 1: **Conceptual Design**

The conceptual design phase is a critical step in the development of a drone, where ideas are translated into a feasible design plan.

- **Vessel Shape**: **Cylindrical Shape with Hemispherical Dome**
    - Combines stability and capacity of a cylinder with the aerodynamic and structural advantages of a hemisphere.
    - Results in an efficient and robust vessel.
    - Cylindrical shape ensures uniform load distribution and minimizes collapse risk and water leakage.
    - Excellent maneuverability

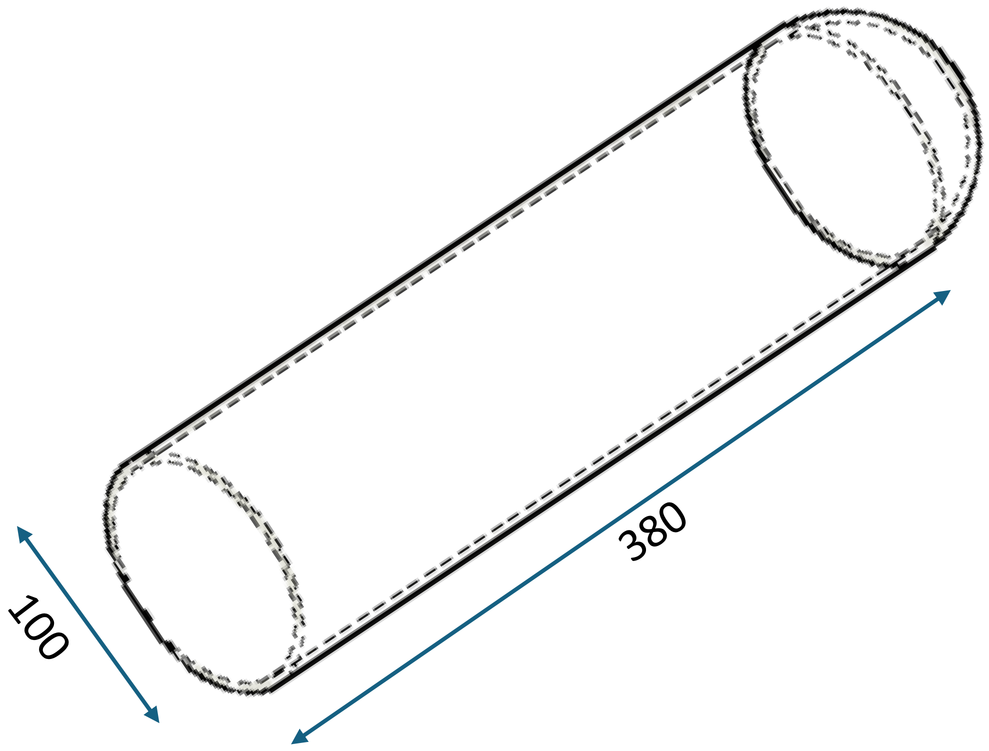


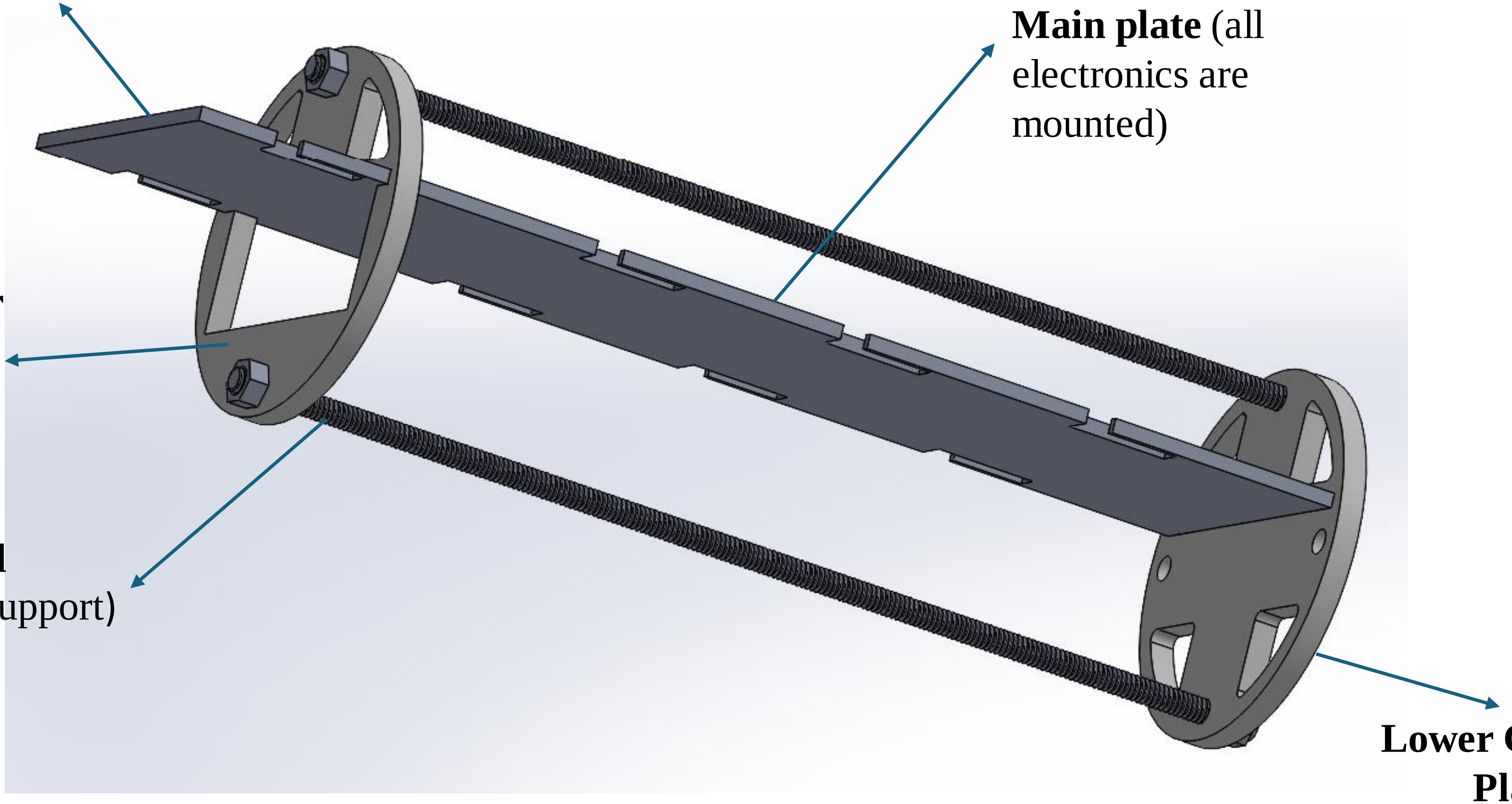
Fig: Conceptual Design of the vessel (All dimensions are in mm)

Phase 2 : **Embodiment Design**

The embodiment design phase consists of two major activities: design configuration and analysis.

- **Design Configuration**
  - Defined shapes and general dimensions of all components
  - Selected preliminary components' materials and manufacturing processes
  - Created 3D CAD models
  - Assigned dimensions to the parts
- **Analysis of the Design**
  - Verified that the proposed solution meets all requirements and specifications
  - Identified elements that need modification or replacement

INNER DESIGN



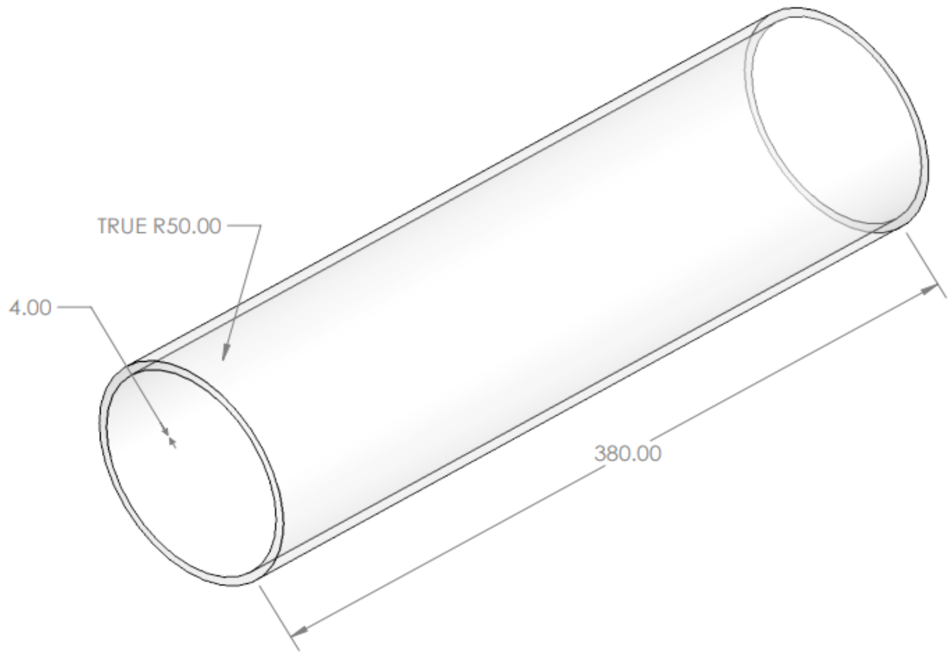


Fig: Acrylic Tube

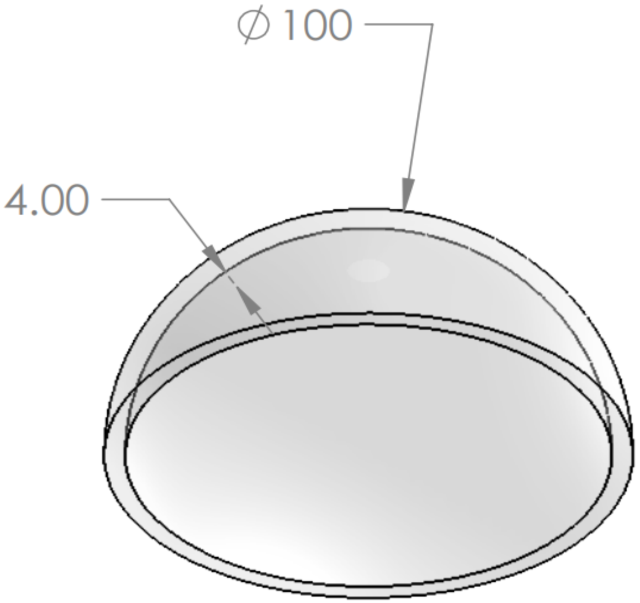
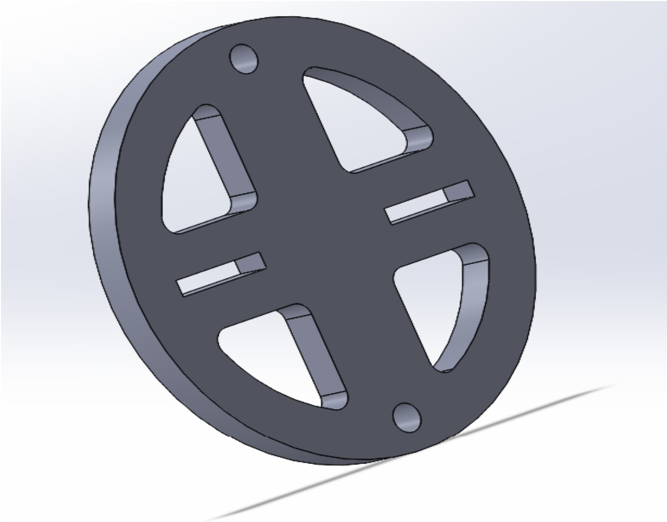


Fig: Hemispherical Dome

All dimensions are in mm



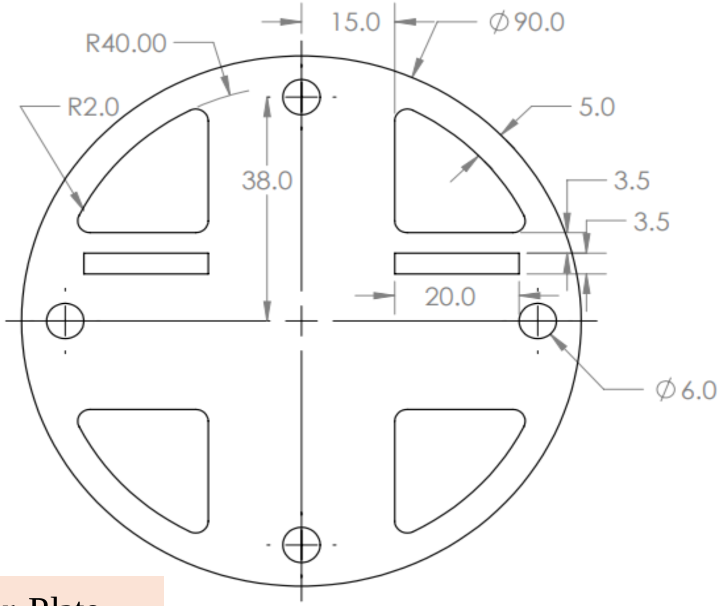
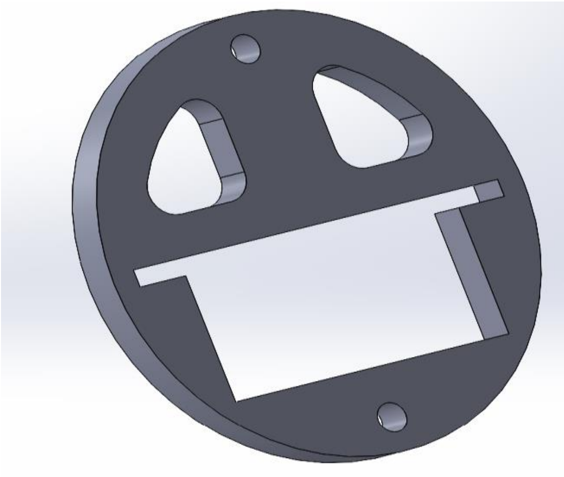


Fig: Lower Circular Plate



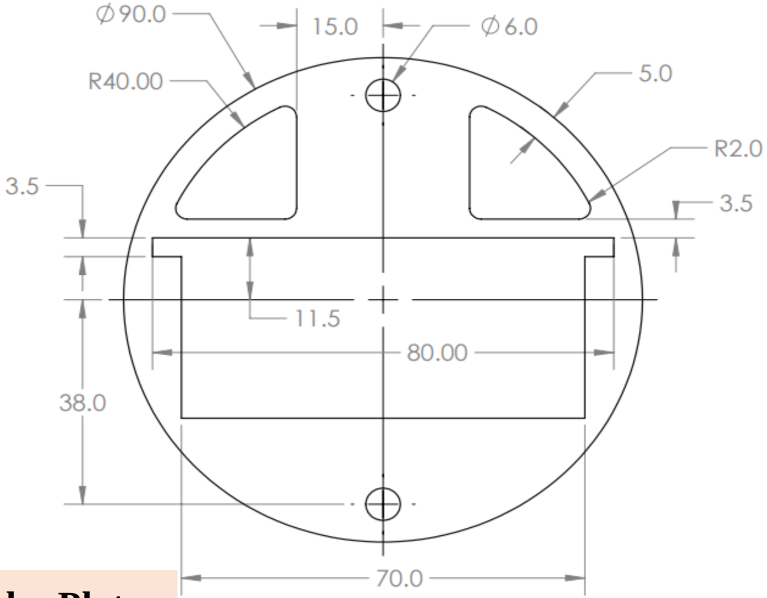
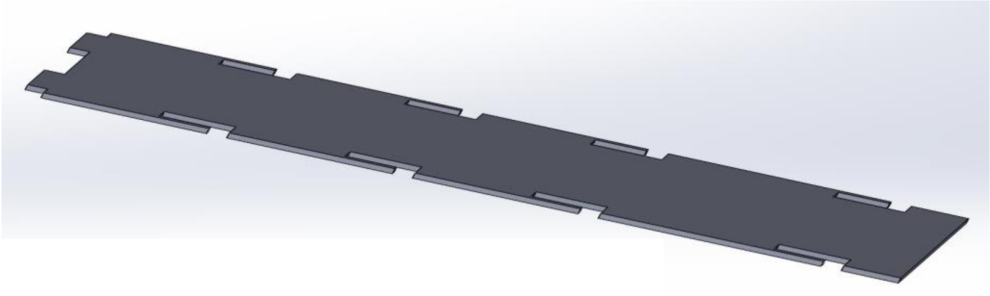


Fig: Upper Circular Plate

All dimensions are in mm



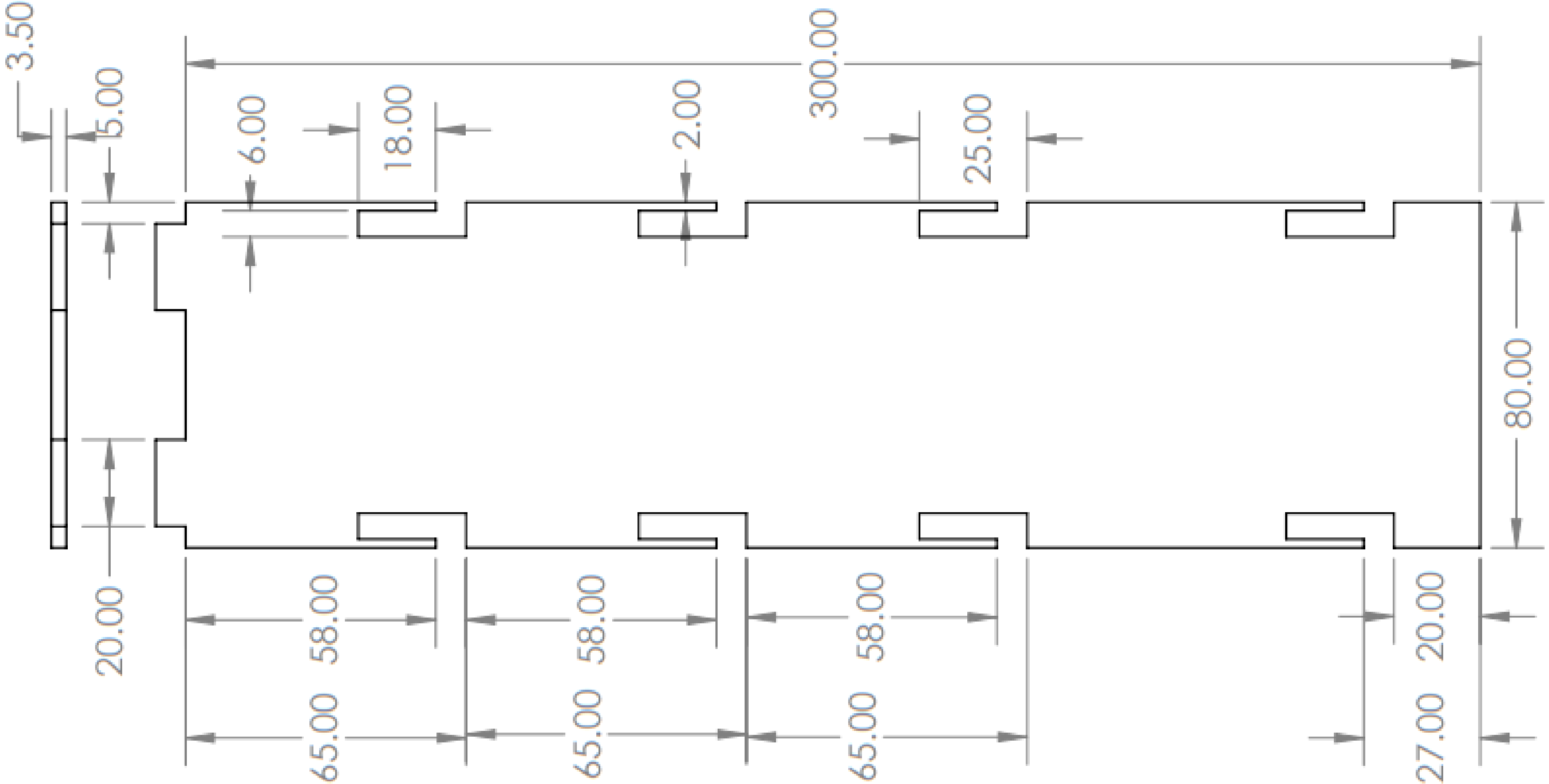


Fig: Main Plate (All dimensions are in mm)

Phase 3 : **Detailed Design**

- ❑ Defined complete specifications for geometry, materials, and tolerances
- ❑ Created detailed, assembly, and general assembly drawings
- ❑ Produced a precise physical description of all parts
- ❑ Generated a general parts list for manufacturing
- ❑ Guided grouping of components into assemblies and full product

CAD MODEL (Solidworks)

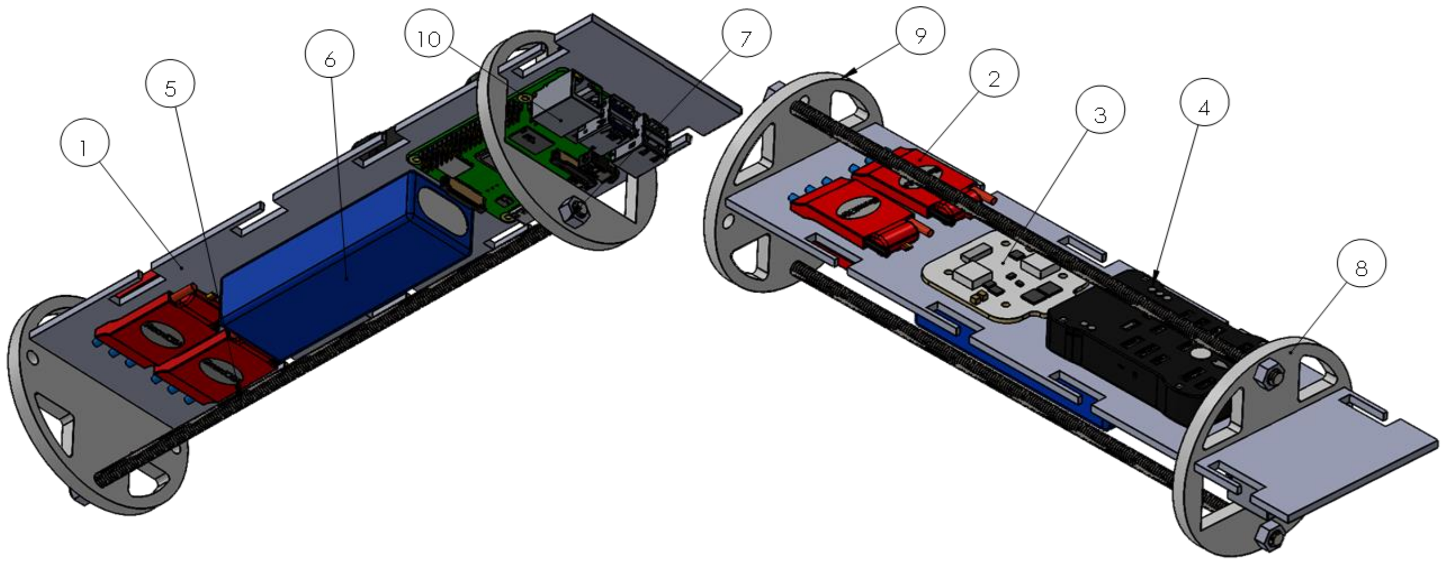


Fig- Inner Frame with Components

ITEM NO.	PART NAME	QTY.
1	Main Plate	1
2	ESC	4
3	Power_Distributation_ Board	1
4	Pixhawk	1
5	Stick	2
6	Battery LiPo	1
7	Nut	4
8	Top Circular Plate	1
9	Bottom Circular Plate	1
10	Raspberry Pi	1

Sources of Electronic Components:

1. https://grabcad.com/library/30a-esc-with-simonk-firmware-1 (ESC) - by Creative Electronics
2. https://grabcad.com/library/pixhawk-2-4-8-v1-flight-controller-1 (Pixhawk 2.4.8) - by Faiyaz Sabik
3. https://grabcad.com/library/matek-12s-pdb-1 (Power Distribution Board) by Misha BOZHKOV
4. https://grabcad.com/library/lipo-battery-4 (LiPo Battery) - by Jorge Alberto Gutierrez Canales
5. https://grabcad.com/library/raspberry-pi-4-model-b-1 (Raspberry Pi) - by Hasanain Shuja

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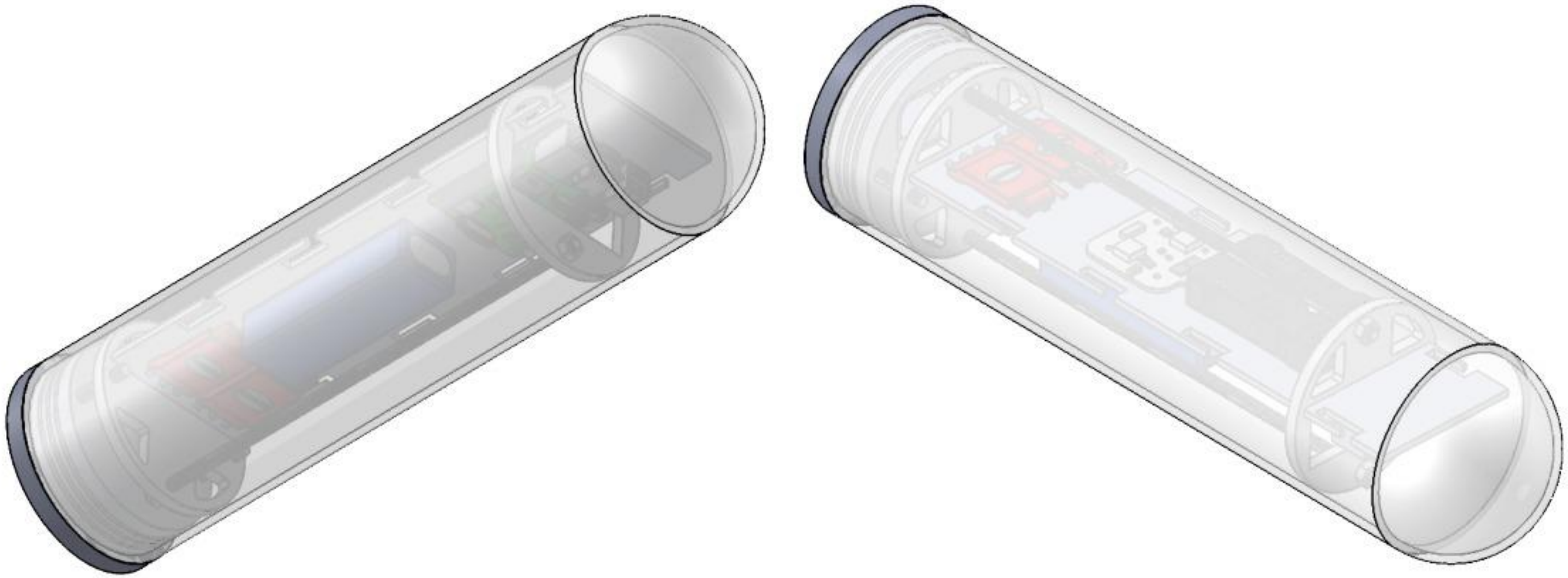
Inner Design Mounted in Acrylic Tube with Hemispherical Dome



Outer Cover of the Underwater Drone

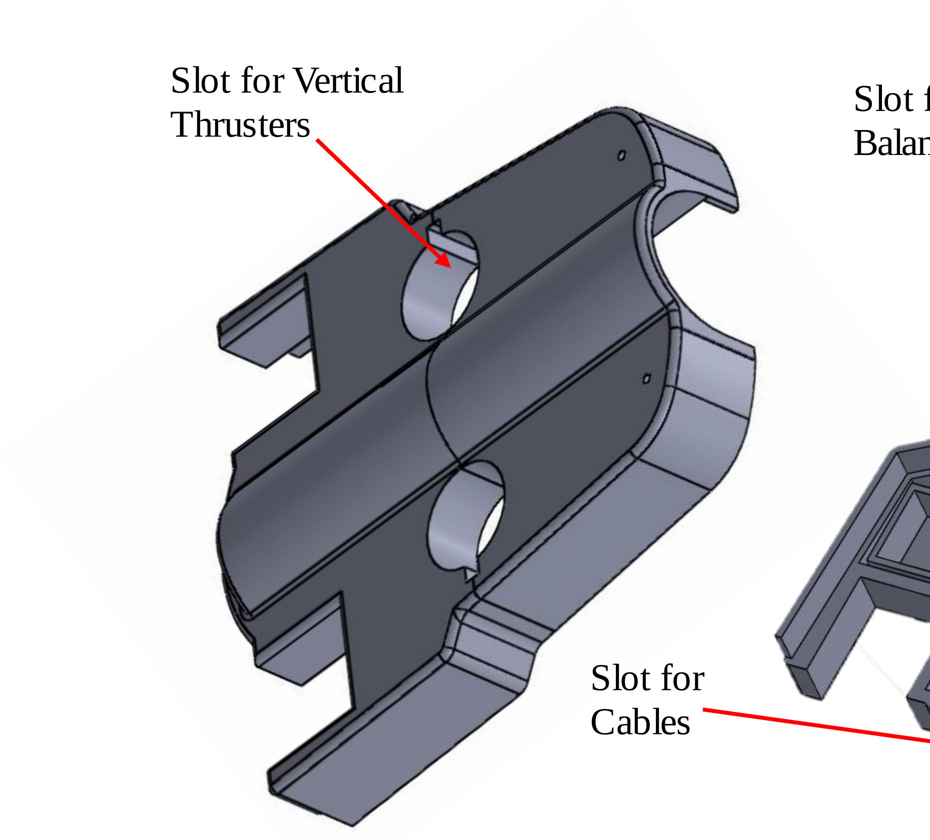


Fig: Upper part of the body

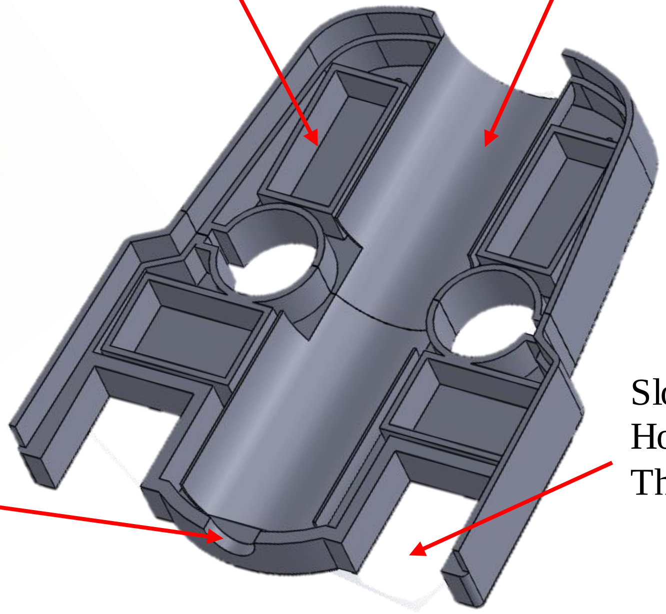
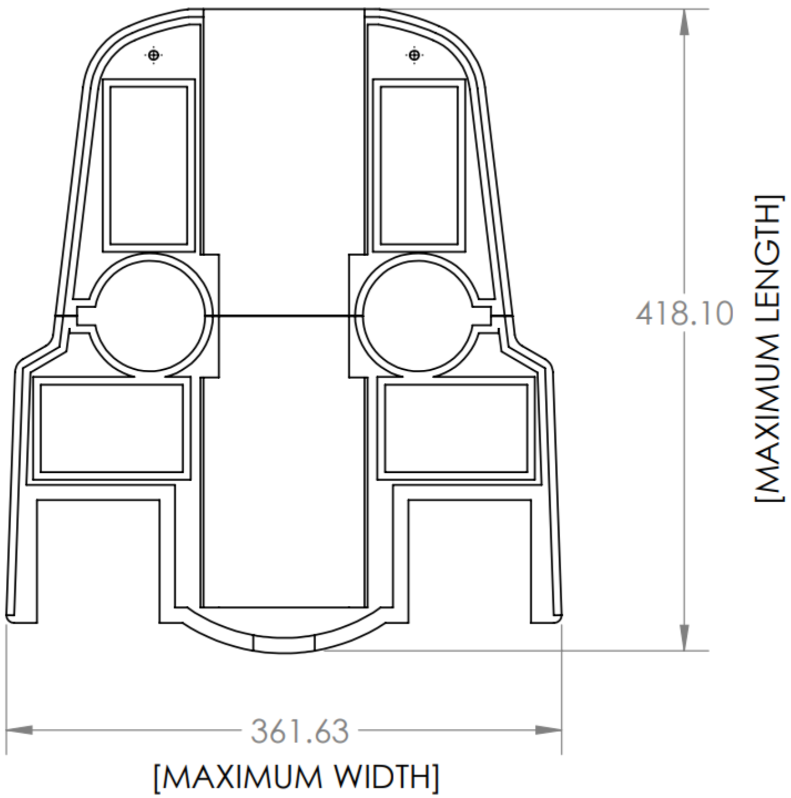


Fig: Lower part of the body



All dimensions are in mm

Laser Cutting Process

Steps:

- Generated the code from the Solidworks design.
- Placed the acrylic sheet on the cutting bed
- Adjusted the laser settings for cutting acrylic
- Started the laser cutting process to shape the parts

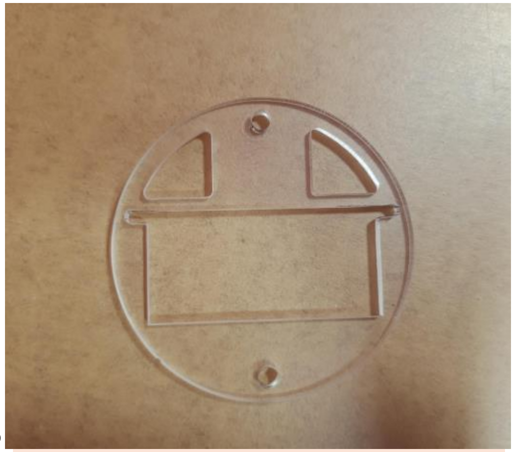


Fig : Top circular plate

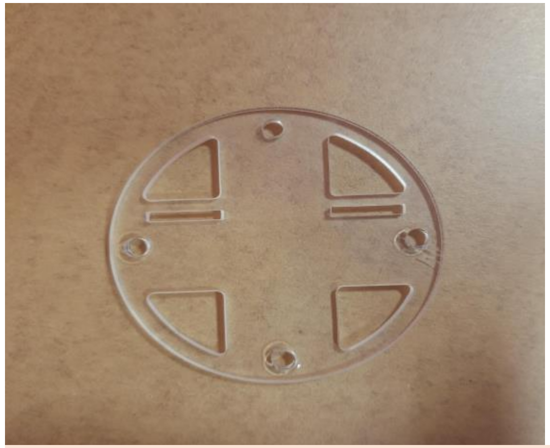


Fig : Bottom circular plate

Advantages:

- Very precise cuts
- Smooth edges, no extra finishing needed
- Saves material, less waste

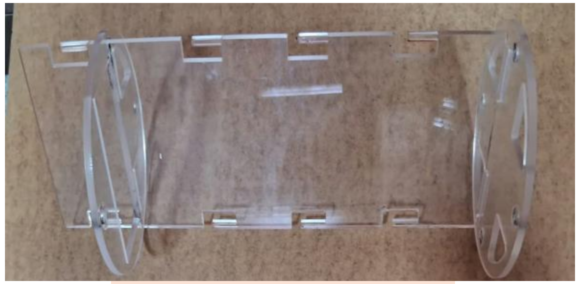


Fig : Assembly

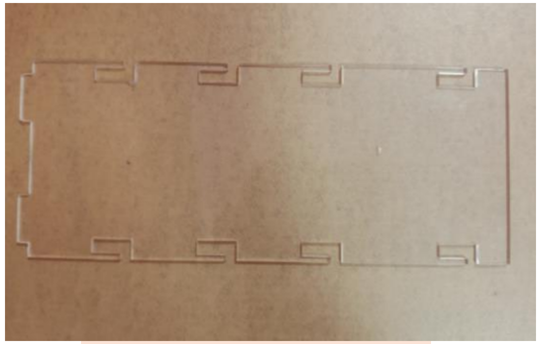


Fig : Main plate

PROPULSION

Propulsion System

A propulsion system refers to the mechanism or components responsible for generating thrust to move a vehicle through a medium, such as air or water. For underwater drone ,propulsion system includes the following components:

- **Motors:** Four BLDC motors for propulsion.
- **Thrusters:** Equipped with four thrusters to provide movement in all directions.
- **ESCs (Electronic Speed Controllers):** Four ESCs to control the speed and direction of each motor.
- **Power Distribution:** Power distribution board to manage power supply to all components.
- **Control:** Integrated with Pixhawk flight controller for precise control. Operated using FS-i6S controller and QGroundControl software for navigation and adjustments

Thruster and Motor

- **BLDC Motors:**
  - Used for efficient and reliable propulsion.
  - Provide high torque and precise control.

- **Thrusters:**
  - Four thrusters enable movement in all directions.
  - Designed to operate underwater, ensuring stability and maneuverability.

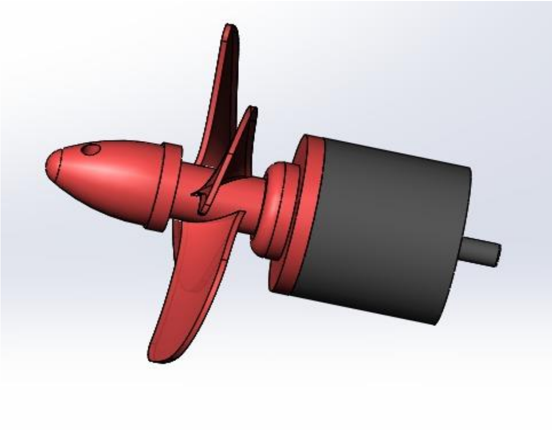


Fig: BLDC motor with propeller

Source: 12-24V Underwater Thruster Brushless Motor 4 Blade Propeller | 3D CAD Model Library | GrabCAD by A. K. Paramasatya
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Fig: Thruster

Specifications of thrusters

- **Description**: Suitable for refitting , remote control ship , nest boat , net boat , remote control submarine, micro underwater robot.

- **Specification**:

  Material: Aluminum Alloy+ Others.
  Voltage: 12-24 (lithium battery 3S-6S)
  Current: 20A
  Power: 30-200W
  Motor: 1000kV (BLDC)

- **Size Chart**:

  Diameter:62mm/2.44inch.
  Length:70mm/2.76inch
  Cable length: 250mm/9.84inch

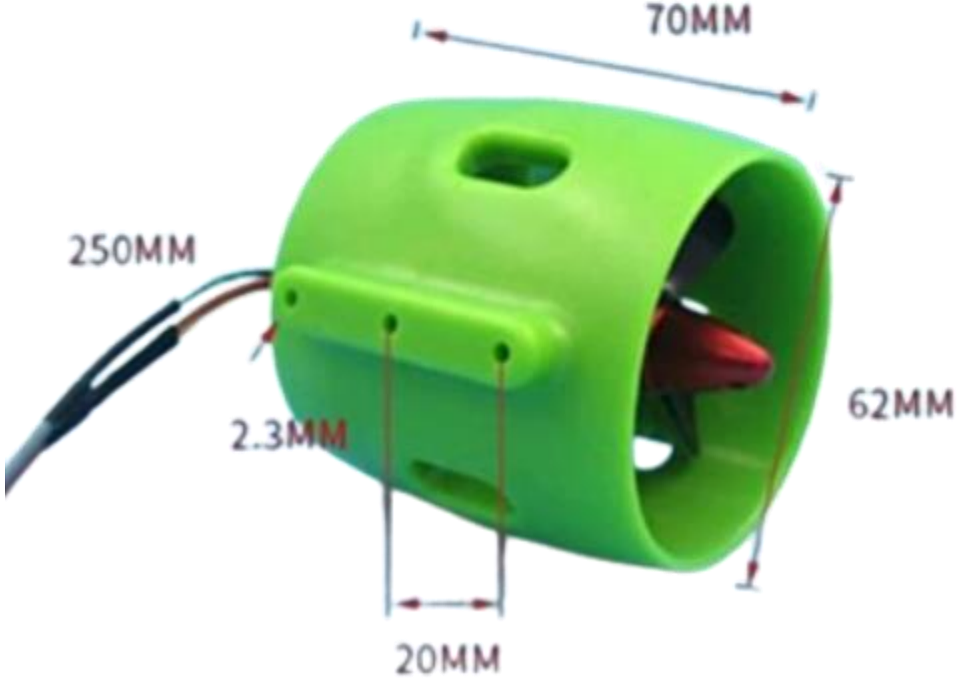


Fig - Thruster

ELECTRONIC COMPONENTS

Electronic Speed Controller(ESC)

- **Function:**
  - Controls the speed and direction of the BLDC motors.
  - Converts signals from the flight controller (Pixhawk) to adjust motor performance.

- **Components:**
  - Includes circuitry for power regulation and motor control.
  - Ensures smooth and responsive motor operation.

- **Integration:**
  - Four ESCs used, one for each motor.
  - Connected to the power distribution board for consistent power supply

Fig: Electronic speed controller

Specifications of ESC

- Model: SIMONK 30A.
- Constant Current: 30A (Max 40A < 10 sec).
- Suitable Batteries: 2-3S LiPo.
- Application: BLDC Motors, Multirotor, Rc Planes etc.
- Cost: Rs. ₹450

LiPo Battery

- ❑ Lithium Polymer (LiPo) battery used as the power source for the drone
- ❑ Integrated with the power distribution board
- ❑ Used to supply power to all components, including motors, ESCs, and the Pixhawk flight controller.

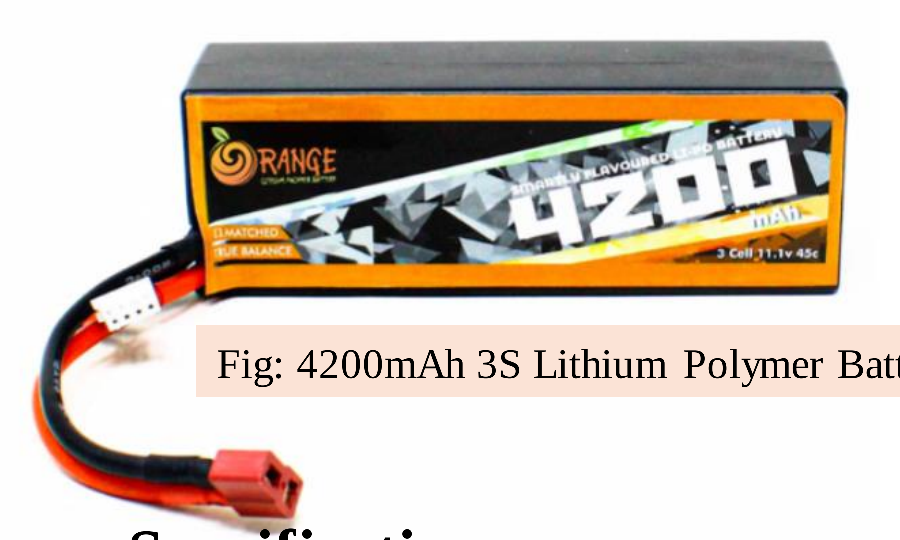


Fig: 4200mAh 3S Lithium Polymer Battery

Specification

- Product: Orange Hard-case Li-Po Battery
- Cell: 3S
- Capacity (mAh): 4200mAh
- Output Voltage (VDC): 11.1V
- Discharge Plug: Female T-connector
- Max. Charge Rate: 45C
- Cost: ₹3699

Pixhawk Flight Controller PX4

- Pixhawk is a versatile and powerful open-source flight controller used for drones and other unmanned vehicles.
- Equipped with advanced sensors for precise navigation and control
- Connects with various components like BLDC motors, ESCs, and sensors.
- Interfaces with control software such as QGroundControl for configuration and monitoring.
- Works seamlessly with remote controllers like the FS-i6S

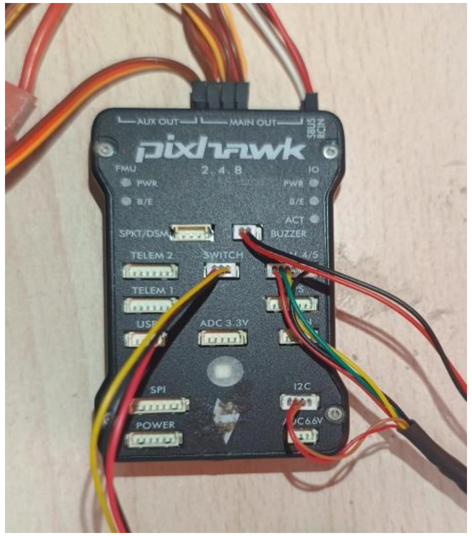


Fig: Pixhawk

Specifications

- Supply Voltage: 7V.
- Processor: 32 Bit Cortex M4 Core
- Firmware: QGroundControl
- Sensors: Gyrometer, Accelerometer, Barometer & Magnetometer
- Micro SD card to record flight data.
- Price: ₹14231

Pixhawk Power Module

- ❑ The Pixhawk Power Module is a critical component that supplies regulated power to the Pixhawk flight controller and monitors battery voltage and current.
- ❑ Provides stable power supply from the LiPo battery to the Pixhawk

Specifications

- Operating Voltage:6~28 VDC
- Max Input Voltage:28 V DC
- Max Current Sensing: 90 A
- Connecting Type: XT-60
- Price: ₹685

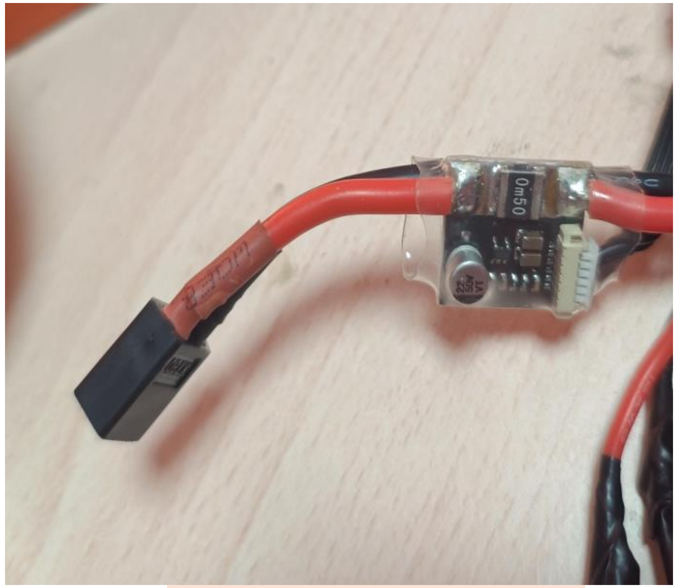


Fig: Power Module

NEO 7M GPS With Compass

The NEO-7M GPS module is a high-performance receiver with an integrated compass for precise location tracking and orientation.

- **GPS:** Connects to the Pixhawk flight controller, providing position data for navigation and mission planning.

- **Compass:** Interfaces with the flight controller to offer heading information, crucial for maintaining the correct orientation

Fig : GPS with Compass

Specifications

- Tracking sensitivity: 161 dBm
- Capture sensitivity : 148 dBm
- cold start time: 38s average
- Warm start time: 35s average
- hot start time: 1s average
- Capture time: 0.1s Average
- Price: ₹1399

FS-i6S Transmitter

- **Function:** Provides user input for navigating and controlling the underwater drone.
- **Features:**
  - 10 channels for comprehensive control.
  - Ergonomic design for comfortable handling.
  - LCD screen for easy monitoring and adjustments.

Fig: Controller

Specifications

- No. of Channel: 10
- Frequency Range: 2.4055 – 2.475GHz
- Band Width: 500KHz
- Band Number: 135
- Transmitting Power: <20dbm
- 2.4G Mode: AFHDS 2A
- Modulation System: GFSK
- Price: ₹5295 (Transmitter + Receiver)

FS-iA10B Receiver

- **Function:** Receives commands from the controller and transmits them to the flight controller (Pixhawk).

- **Features:** Reliable 2.4GHz frequency for strong signal transmission.

Specifications:

- No. of Channel: 10
- Frequency Range: 2.4055 – 2.475GHz
- Band Number: 140
- Receiver Sensitivity: -105dbm
- 2.4G Mode: AFHDS 2A
- Modulation System: GFSK
- Price: ₹5295 (Transmitter + Receiver)

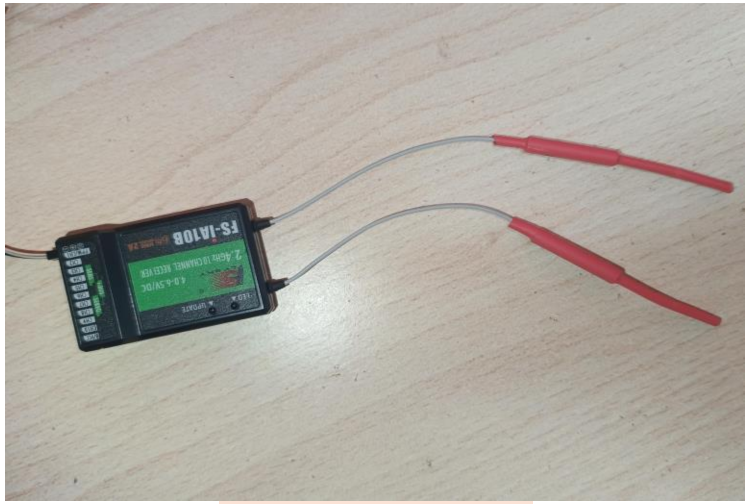
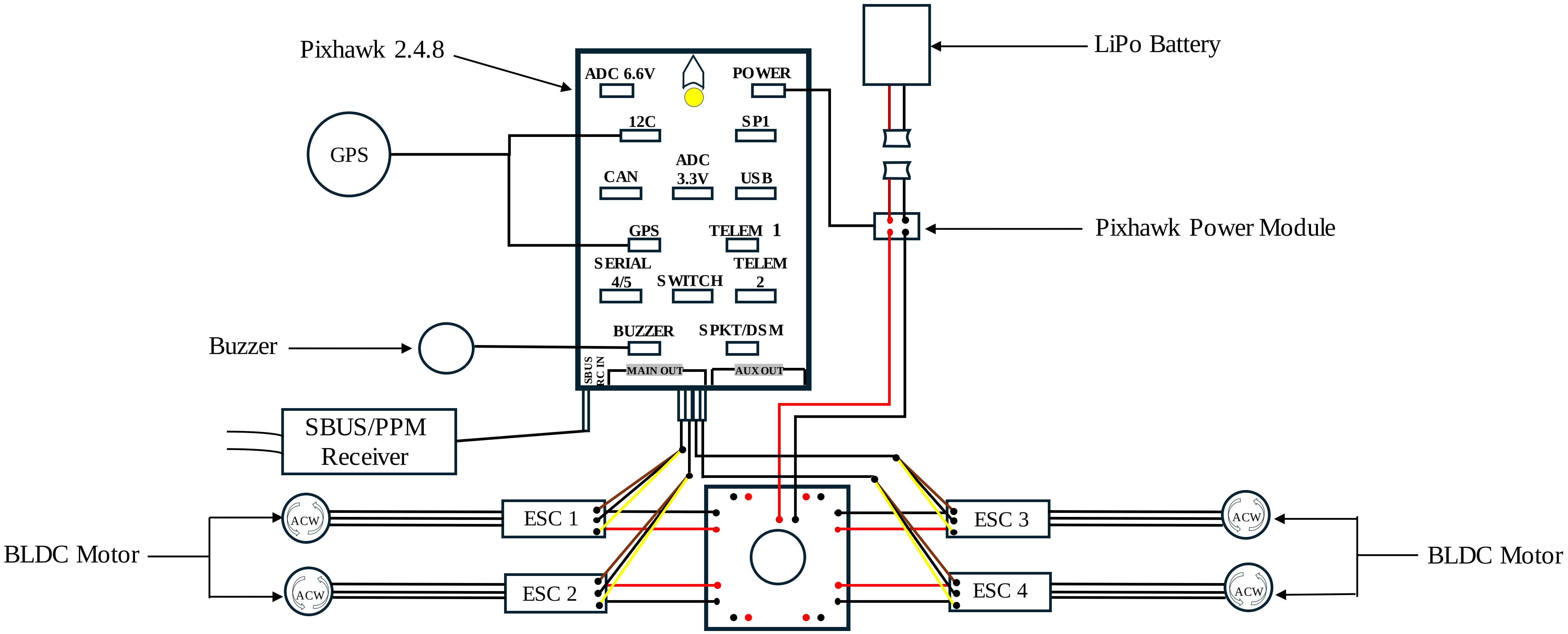


Fig : Receiver

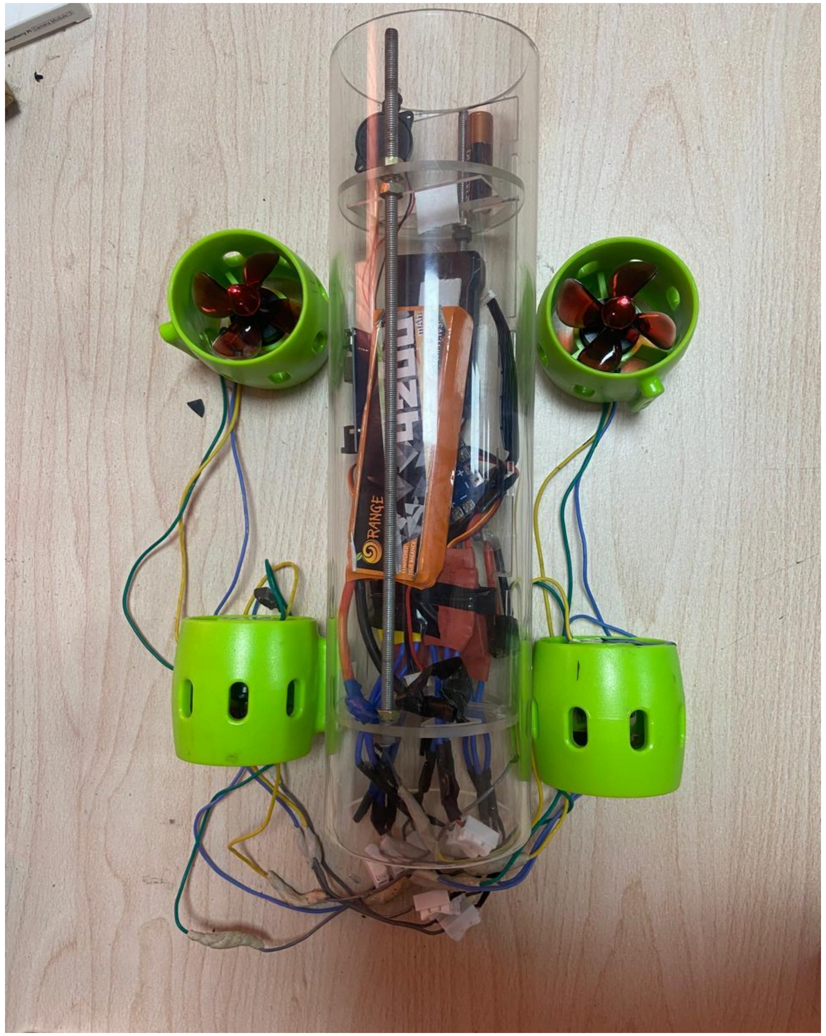
List of the Components

ITEM NO.	PART NAME	QTY.
1	ESC	4
2	Power Distribution Board	1
3	Pixhawk Px4	1
4	Battery LiPo5200	1
5	Pixhawk Power Module	1
6	GPS with Compass	1
7	FS-i65 Transmitter	1
8	FS-iA10B Receiver	1

CIRCUIT DIAGRAM



Assembly of Components



Testing of Electronic Components and Thrusters

Downward Motion

SETUP
&
CONTROL

QGroundControl Overview

Q Ground Control is a popular software for controlling unmanned vehicles like drones, rovers, and submarines. It provides a user-friendly interface for mission planning, control, and monitoring.

- **Key Features:**
  - User-friendly interface
  - Mission planning and control
  - Vehicle Setup
  - Remote video streaming
  - Various autopilot modes
  - Open Source:
    - Allows user contributions
    - Allows to evolve and enhance software to meet specific needs

(Cont. …)

- **Functionality**
  - Interface between operator and vehicle
  - Facilitates safe and efficient operations

- **Compatibility**
  - Comprehensive flight control for MAVLink-enabled drones
  - Suitable for professional users and developers

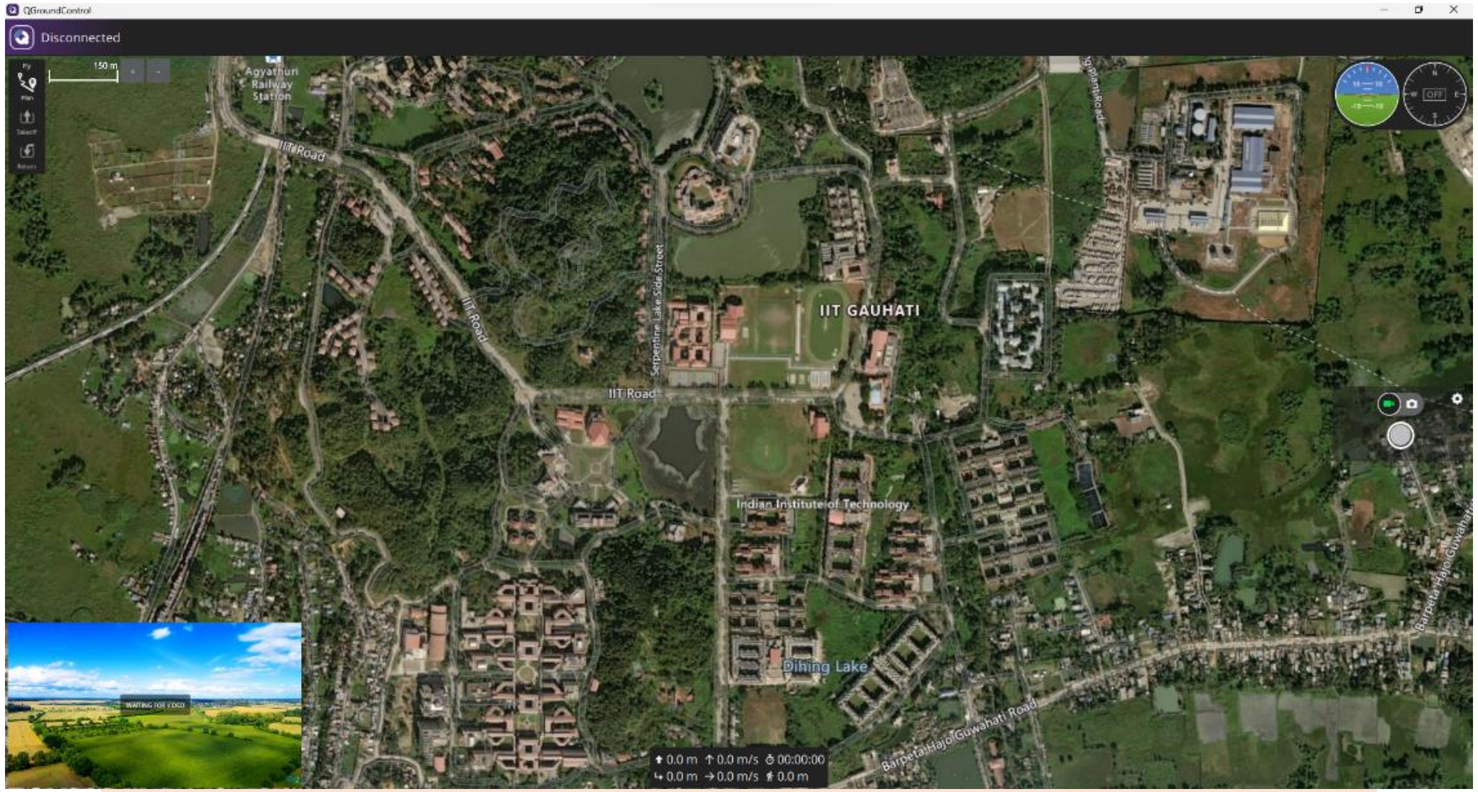


Fig- Home Interface of QGroundControl

(Screenshot from the QGround Control software)

Main Procedures to setup the AUV

1. Connect the Vehicle to QGroundControl
2. Initial Setup
3. Firmware Update (if necessary)
4. Vehicle Configuration
   - ❑ Airframe Setup
5. Sensor Calibration
   - ❑ Accelerometer Calibration
   - ❑ Compass Calibration
   - ❑ Gyroscope Calibration
6. Motor Configuration
7. Frame Configuration

Firmware Setup:

Firmware is the software running on the autopilot hardware of unmanned vehicles, essential for their operation and control.

- **QGroundControl Role**
  - Acts as an interface to manage and control vehicles
  - Supports various autopilot systems like PX4 and ArduPilot
- **Compatibility**
  - Works with different hardware (autopilot boards) and vehicle types (drones, rovers, submarines)
- **Functionality**
  - Allows users to upload firmware to the autopilot board

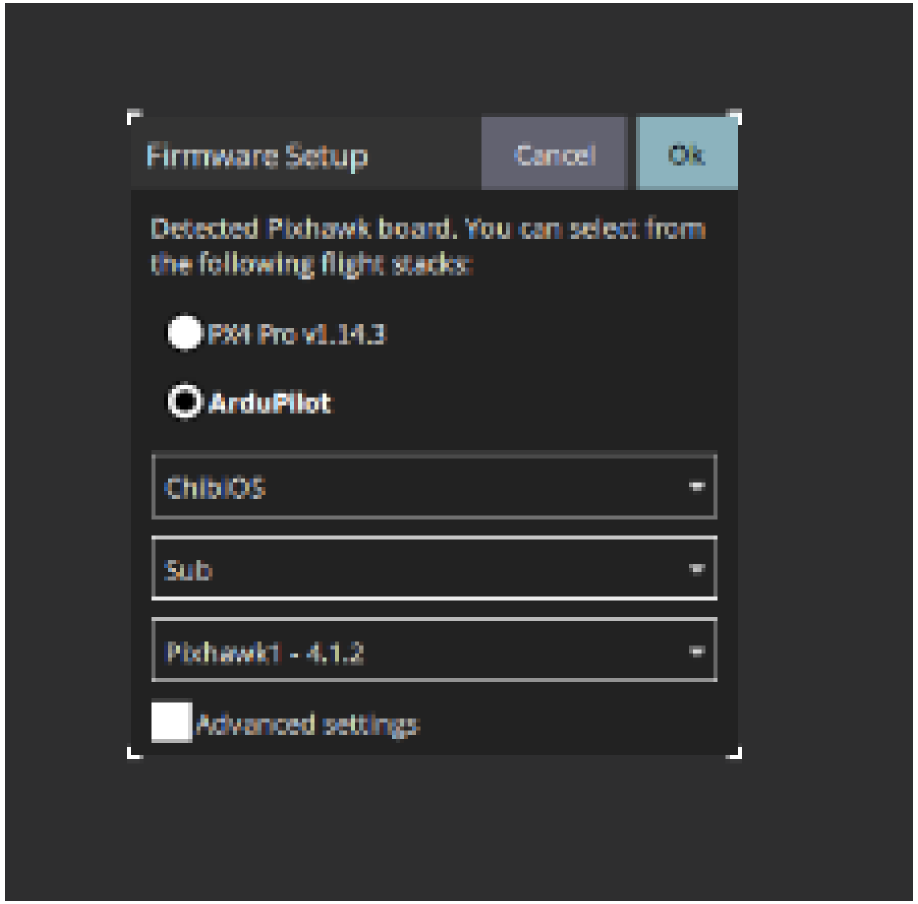


***Fig-** Firmware setup in QGroundControl*

(Screenshot from the QGround Control software)

Sensor Calibration

Sensor calibration is essential for accurate data collection from onboard sensors in drones, rovers, and ROVs.

- ❑ **Compass**
  - ❑ Ensures accurate heading information
  - ❑ Eliminates magnetic interference
- ❑ **Accelerometer**
  - ❑ Corrects measurements of vehicle acceleration and altitude
- ❑ **Gyroscope**
  - ❑ Adjusts for biases
  - ❑ Ensures accurate measurement of angular rates

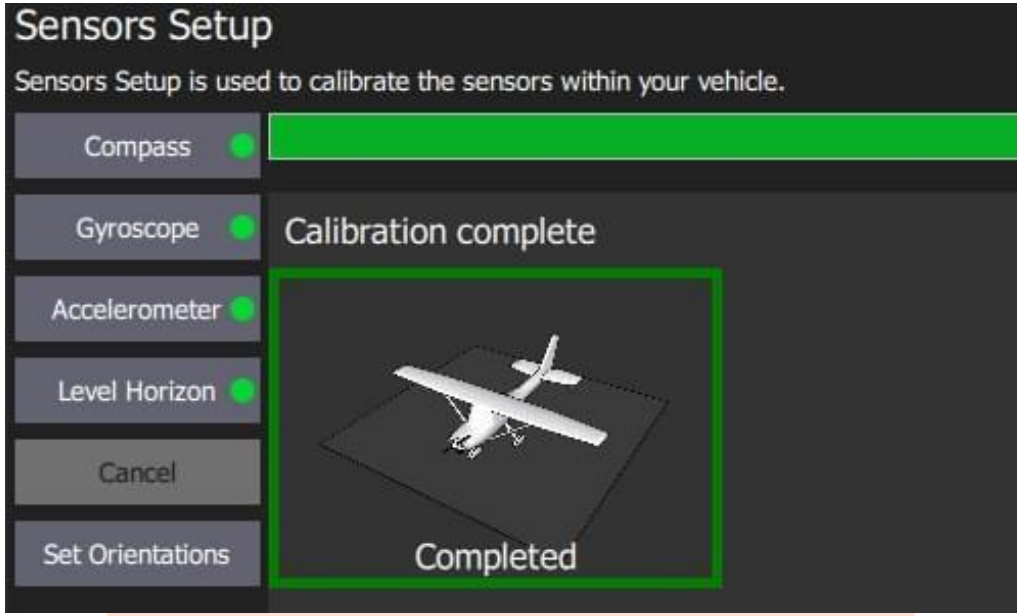


***Fig-** Sensor Calibration in QGroundControl*

(Screenshot from the QGround Control software)

Motor Configuration

Motor configuration involves setting up Electronic Speed Controllers (ESCs) and ensuring proper motor assignment and direction.

- ❑ **Setup**
    - ❑ Configure ESCs
    - ❑ Assign motors correctly
- ❑ **Testing**
    - ❑ Gradually increase throttle for each motor individually
    - ❑ Verify correct motor spins in the correct direction

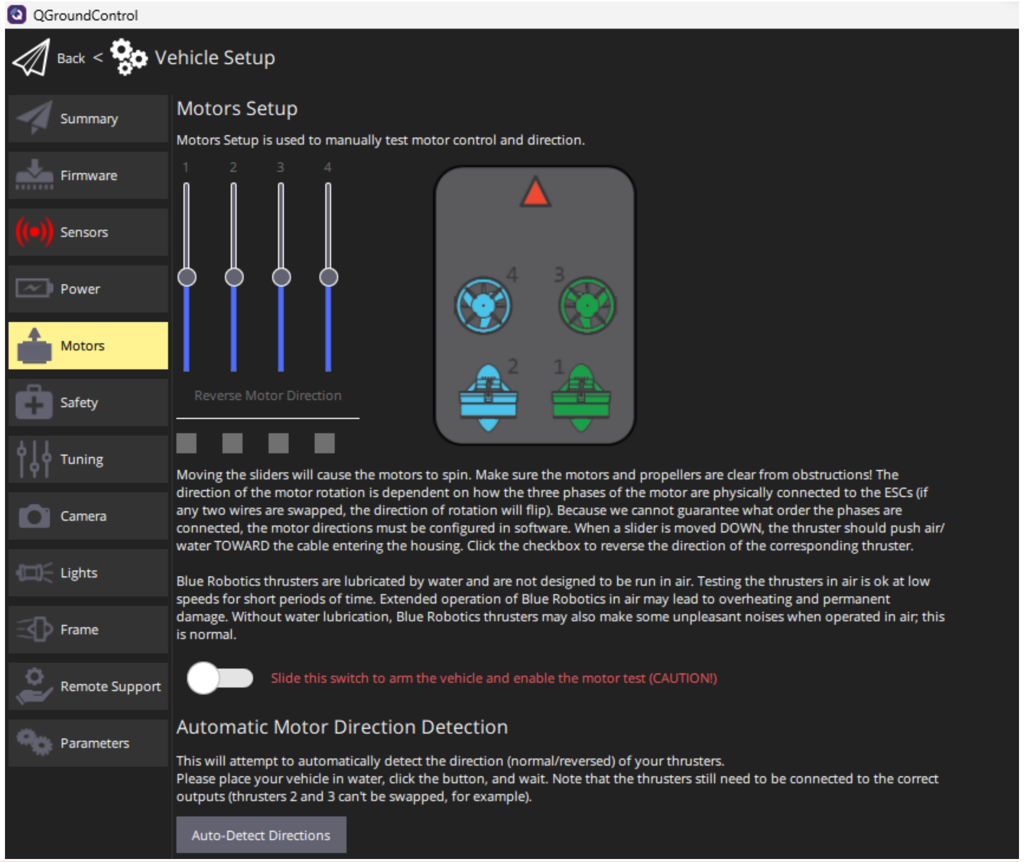


Fig- Motor Configuration in QGroundControl (Interface)

(Screenshot from the QGround Control software)

Frame Configuration

The frame type determines how the flight controller interprets the orientation and arrangement of motors and other components.

- ❑ **Frame Types Supported**
  - ❑ Multirotor
  - ❑ Fixed-wing aircraft
  - ❑ VTOL (Vertical take-off and landing) aircraft
  - ❑ Rovers
- ❑ **Importance of Proper Setup**
  - ❑ Ensures accurate understanding of UAV’s physical layout
  - ❑ Leads to stable and reliable flight performance

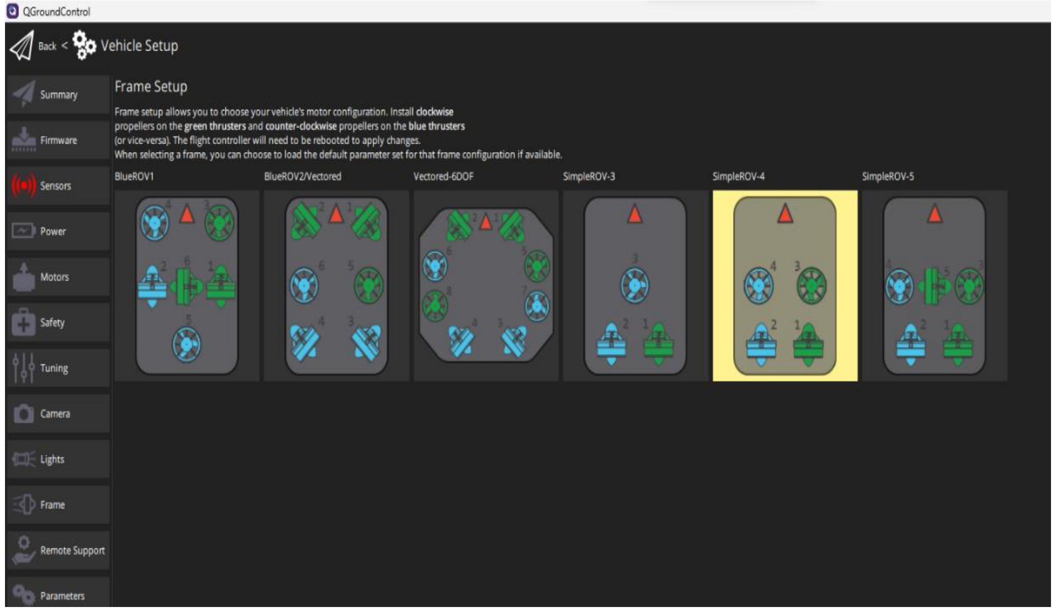
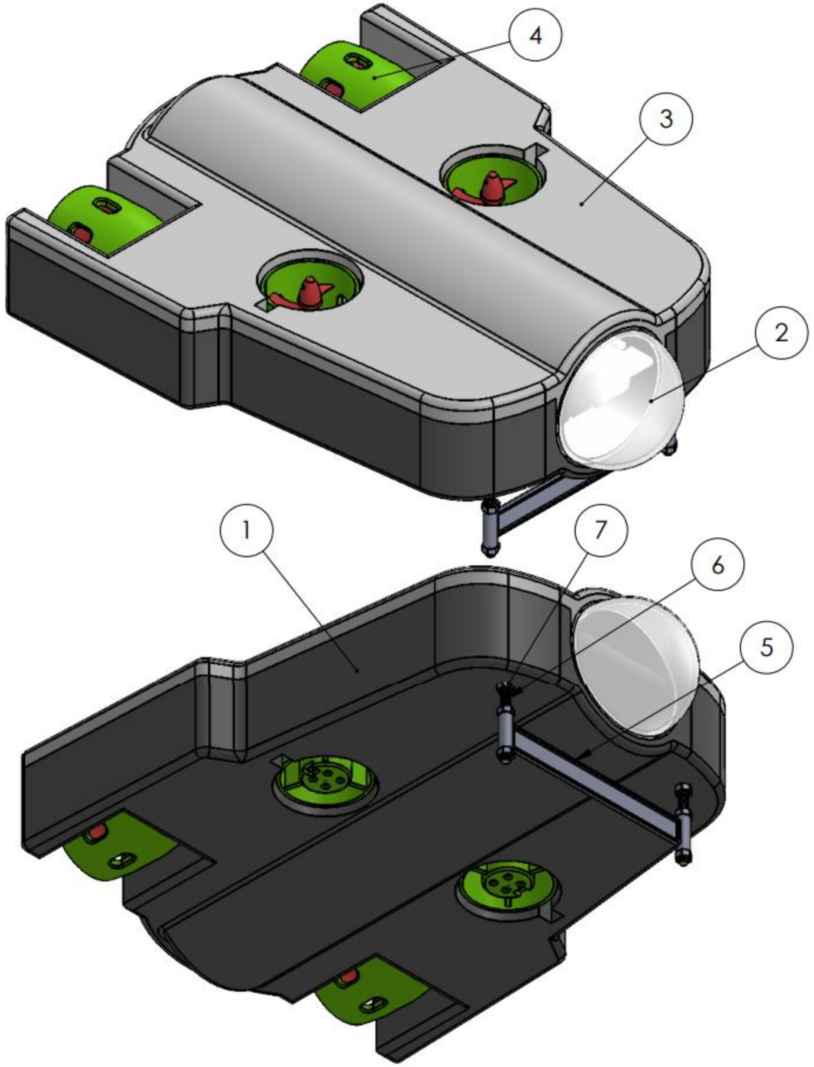


Fig- *Frame Configuration in QGroundControl*

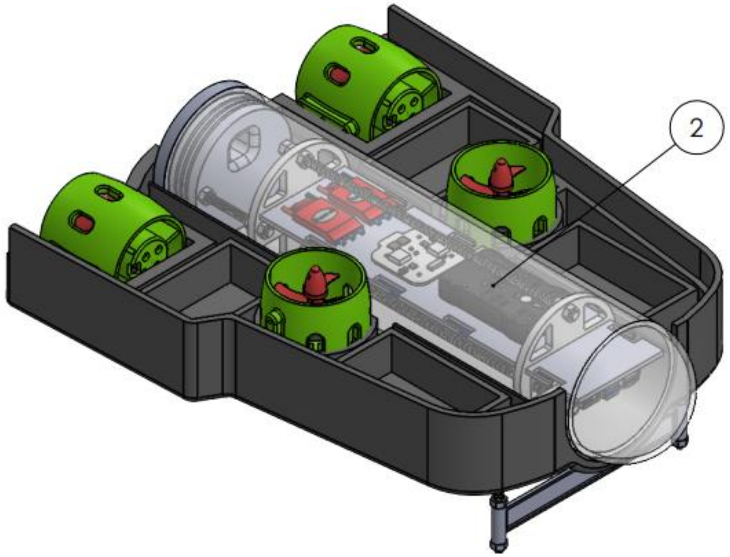
(Screenshot from the QGround Control software)

FINAL ASSEMBLY

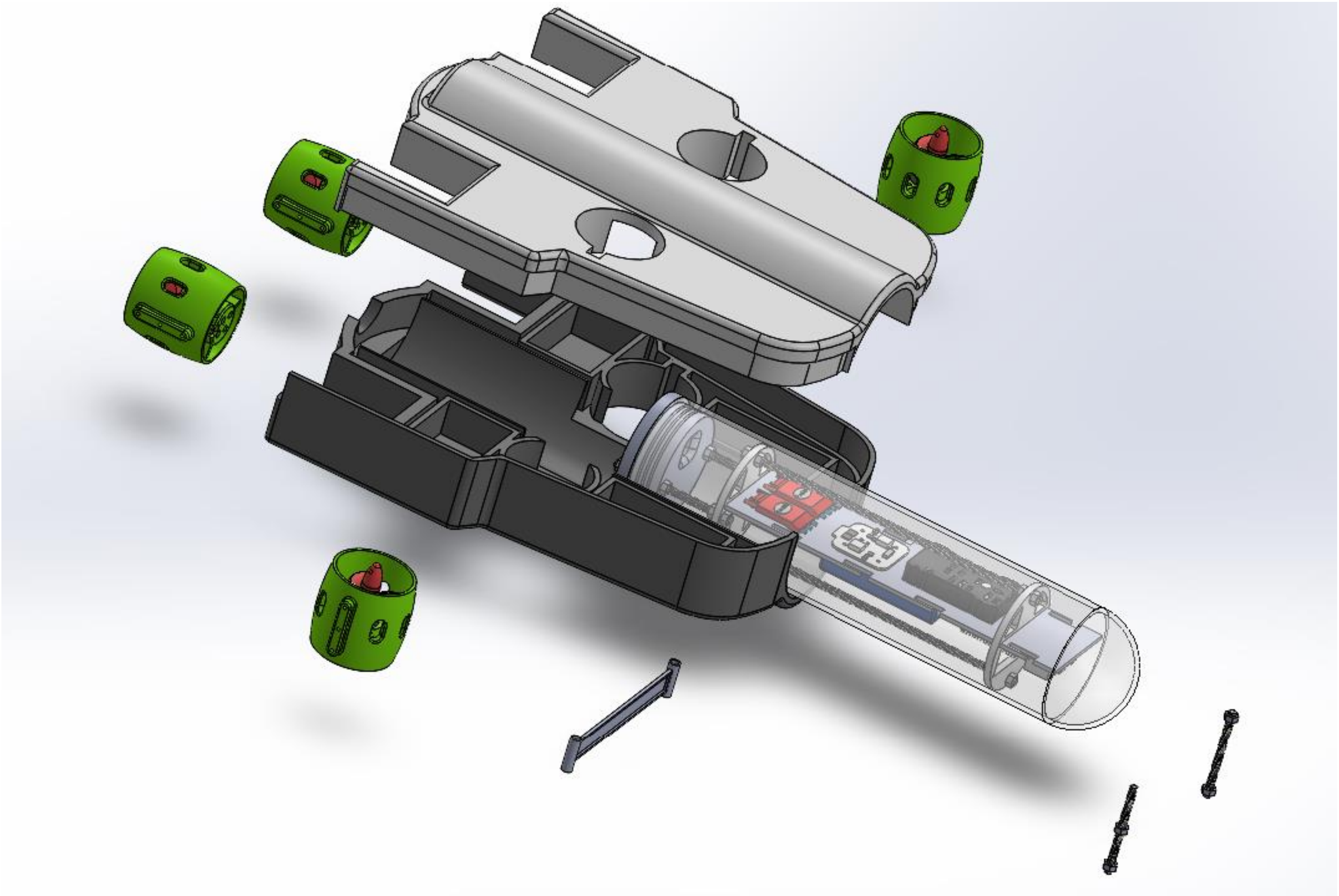
Collapsed View



ITEM NO.	PART NAME	QTY.
1	Lower Cover	1
2	Acrylic_Tube_Inner_Frame	1
3	Upper_Cover	1
4	Underwater Thruster Brushless Motor 4 Blade Propeller	4
5	LED Slot	1
6	Stick LED	2
7	Nut	8



Exploded View



FUTURE SCOPE

Assembly of 3D printed parts

- **Preparation:**
  - Gather all 3D printed parts and ensure they are free of defects
  - Prepare epoxy and O-rings for waterproofing
- **Cover Acrylic Tube:**
  - Assemble 3D printed parts around the acrylic tube
  - Apply epoxy to all joints to eliminate gaps
  - Place O-rings in the cap of the acrylic tube for additional waterproofing
  - Check for accuracy and integrity of the assembly
- **Thruster Installation:**
  - Attach the four thrusters to the designated areas on the 3D printed parts
  - Use nuts and bolts to secure the thrusters in place
  - Apply epoxy around thruster mounts for additional stability and waterproofing

(Cont.…)

- **Electronic Components and Shielding:**
  - Secure battery, Pixhawk, GPS, threaded rods, Raspberry Pi, and power distribution board inside the acrylic tube
  - Apply epoxy to electronic component mounts and connections for waterproofing and stability
- **Dry Run Tests:**
  - Conduct dry run tests to check the integrity of the assembly
  - Verify that all components are securely attached and functional
  - Fine-tune assembly based on test results
- **Final Checks:**
  - Inspect the entire assembly for any remaining gaps or potential leak points
  - Ensure all O-rings and epoxy applications are properly set and sealed

Field Testing

- **Waterproofing:**
  - Verify integrity of waterproof seals
  - Identify potential leakage points
- **Thruster Functionality:**
  - Test thruster performance in water
  - Assess propulsion efficiency and responsiveness
- **Electronics:**
  - Ensure all electronic components are operational underwater
  - Monitor for any malfunctions or performance issues
- **Battery Power Consumption:**
  - Measure battery usage during operation
  - Evaluate battery life and efficiency
- **Navigation:**
  - Test navigation systems for accuracy
  - Ensure smooth and precise manoeuvring

Initial Buoyancy and Stability Test

- **Buoyancy Check:**
  - Submerge the drone in the freshwater pond
  - Observe the initial floating position and depth
  - Adjust weight distribution if the drone is not neutrally buoyant
- **Stability Assessment:**
  - Check for any tilt or imbalance
  - Add objects to compartments available to correct instability
  - Ensure the drone remains level and stable in the water
- **Thruster Functionality:**
  - Activate front thrusters to test upward and downward motion
  - Activate back thrusters to test forward movement
  - Observe any effects of thruster operation on stability
- **Data Collection:**
  - Monitor and record performance using onboard electronics
  - Adjust and repeat tests as necessary to achieve optimal buoyancy and stability

Study on
SENSORS USED FOR WATER QUALITY ASSESSMENT

Objectives

- Explore sensors for water quality assessment.
- Study effects of varying water quality parameter values.
- To know the different applications of different water quality assessment sensors.

pH Sensor

- ❑ **Units**: pH
- ❑ Measures the acidity or alkalinity of water, crucial for aquatic life and usability in various applications.
- ❑ **pH Scale Overview:**
  - Ranges from 0 to 14.
  - 7 is neutral, below 7 is acidic, above 7 is basic.
  - Pure water is neutral at approximately pH 7.0..
  - Safe Drinking Water pH: Ranges from 6.5 to 8.5.

❑ **Connection of the pH Sensor**

- Connect pH sensor to signal board.
- Plug pH interface into microcontroller.
- Verify power indicator LED is on

FIG: pH levels sensors

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.flickr.com%2Fphotos%2Fsparkfun%2F14129002152&psig=AOvVaw3IAcv96FU1rMuLanFmeSuN&ust=1719554762168000&source=images&cd=vfe&opi=89978449&ved=0CBQQjhxqFwoTCICyj_SO-4YDFQAAAAAdAAAAABAE

https://how2electronics.com/diy-iot-water-ph-meter-using-ph-sensor-esp32/

Effects of different ranges of pH levels on aquatic life

- **Low pH (Acidic):**
  - pH below 5.0
  - Fish struggle, experience stress.
  - Trout eggs die at pH 4.8.
  - Carp sensitive below pH 5.0.
  - Some fish survive temporarily at pH 4.5-4.2.
  - pH below 4.0 is lethal.
- **Moderate pH (Optimal):**
  - pH 7.0-8.0
  - Supports fish health, growth, reproduction.
  - Maintains stable aquatic environment.
- **Extreme pH (Alkaline):**
  - pH above 9
  - Fish stressed, potential mortality.
  - pH 10.0 near upper tolerance limit.
  - Alkaline conditions affect toxicity (e.g., NH_3).

Tarzwell, Clarence M. "Water quality criteria for aquatic life." *Trans. Seminar Biological Problems in Water Pollution*. 1956, pp 253-254.

General effects of temperature and depth on pH levels:

- **Temperature:**
  - Fluctuations affect pH sensor accuracy.
  - Higher temperatures may lower pH readings.
  - Sensors often have temperature compensation for accuracy.
- **Depth:**
  - Increased pressure at depth impacts sensor performance.
  - Specialized sensors needed for high pressures.
  - Water chemistry changes at depth influence pH levels; calibration required.

Applications of pH sensors:

- **Water Treatment:**
  - Ensures safe drinking water by maintaining neutral pH levels.
- **Aquatic Life:**
  - Maintains suitable pH for the survival of aquatic organisms.
- **Agriculture:**
  - Optimizes soil and water pH for crop growth.

Tarzwell, Clarence M. "Water quality criteria for aquatic life." *Trans. Seminar Biological Problems in Water Pollution*. 1956, pp 253-254.

Dissolved Oxygen (DO) Sensor:

- **Units**: mg/L or ppm (parts per million)
- Measure oxygen levels in water
- Assess health of aquatic health system and presence of pollutants

- **Connections:**
  - Analog sensors typically have three wires: Ground (GND), Signal, and Power (VCC).
  - The ground wire is connected to the GND pin on the Arduino or controller.
  - The Signal wire is attached to an analog input pin on the Arduino.
  - Finally, the power wire is connected to the 5V pin on the Arduino.

FIG: DO Sensor

https://www.google.com/url?sa=i&url=https%3A%2F%2Fcommons.wikimedia.org%2Fwiki%2FFile%3ADissolved_oxygen_meter.jpg&psig=AOvVaw1jjl9eUOyBmHmALb9WWJRJ&ust=1719555599849000&source=images&cd=vfe&opi=89978449&ved=0CBQQjhxqFwoTCKCovfyR-4YDFQAAAAAdAAAAABAE

(Under common creative license)

https://www.learnrobotics.org/blog/read-analog-sensors-arduino/

Effects of different ranges of DO ranges on aquatic life:

- **High DO Levels (Near Saturation, 8-14 mg/l)**
  - Fish use water breathing primarily.
  - Low energy spent on ventilation.

- **Moderate DO Levels (4-8 mg/l)**
  - Increased ventilation rates.
  - Threshold air breathers start utilizing air.

- **Low DO Levels (2-4 mg/l)**
  - Fish rely on air breathing and ASR.
  - High energy spent on respiration.

- **Very Low DO Levels (<2 mg/l)**
  - Fish heavily use ASR and air breathing.
  - Significant energy expenditure, reduced growth rates.

Kramer, Donald L. "Dissolved oxygen and fish behavior." Environmental biology of fishes 18 (1987): 81-92.

General effects of temperature and depth on DO

- **Temperature:**
  1. Higher temperatures → lower oxygen solubility → lower DO levels.
  2. Colder temperatures → higher oxygen solubility → higher DO levels.
- **Depth:**
  1. Increased depth → reduced light penetration and photosynthesis → lower DO levels.
  2. Deeper layers have more organic decomposition and less surface mixing → further reduced DO levels

Applications:

- **Monitoring and Management**: Regular monitoring of DO levels helps assess water quality and identify potential stressors on aquatic life, guiding management practices.
- **Species Management**: Understanding DO requirements allows for targeted conservation efforts, ensuring suitable habitats for diverse fish populations.
- **Environmental Impact Assessment**: DO data informs regulatory frameworks and environmental impact assessments to protect aquatic ecosystems from pollution and habitat degradation.

Kramer, Donald L. "Dissolved oxygen and fish behavior." Environmental biology of fishes 18 (1987): 81-92.

Turbidity Sensor

- **Units**: NTU
- Measures water clarity
- Detect presence of suspended particles
- Works on the principle of light absorption and scattering by matter (silt, sand, algae, soil residues, clay).
- Turbidity level is proportional to suspended particle quantity.
- High turbidity is more particles, less light penetration.
- **Connections:**
  - The turbidity sensor typically has three pins: **VCC**, **GND**, and the **signal output** pin.
  - Connect the following:
    - **VCC** to **5V** on the Arduino.
    - **GND** to **GND** on the Arduino.
    - The signal output pin to an analog input pin on the Arduino.

FIG: Turbidity Sensor

https://lk-tronics.com/turbidity-liquid-sensor-with-arduino/

The effects of different ranges of turbidity on aquatic life:

- **Low Turbidity (up to 30 NTU)**
  - Minimal impact on aquatic life
  - No adverse effects observed in trout over 5 months

- **Intermediate Turbidity (30 - 100 NTU)**
  - Some fish mortalities and gill damage
  - Spawning severely restricted above 100 NTU

- **High Turbidity (100 NTU and above)**
  - High mortality rates and significant gill damage
  - Disruption of spawning activities and high fish kill rates

Hollis, E.H., Boone, J.G., DeRose, C.R. and Murphy, G.J., 1964. A literature review of the effects of turbidity and siltation on aquatic life. Un-published staff report, Department of Chesapeake Bay Affairs, Annapolis, Maryland, USA, pp 3-9.

General effects of temperature and depth on turbidity:

- **Temperature Effects**:
  - Increased temperatures can lead to greater suspension of particles, raising turbidity levels.
  - Higher temperatures may also reduce water density, promoting mixing and further increasing turbidity.
- **Depth Effects**:
  - Turbidity generally decreases with depth as particles settle, reducing light penetration.
  - In deeper waters, stratification can occur, creating distinct layers with varying turbidity levels.

Applications:

- **Regulatory Compliance**:
  - Setting local turbidity standards for light penetration and ecosystem health.
  - Conducting field tests to monitor and enforce compliance.
- **Environmental Management**:
  - Using lagooning techniques to remove turbidity from wastewater.
  - Collaborating with soil conservation efforts to reduce erosion and turbidity.
- **Ecological Assessment**:
  - Studying turbidity's impact on aquatic ecosystems and species.
  - Evaluating effects on biodiversity and primary productivity for conservation planning.

Hollis, E.H., Boone, J.G., DeRose, C.R. and Murphy, G.J., 1964. A literature review of the effects of turbidity and siltation on aquatic life. Un-published staff report, Department of Chesapeake Bay Affairs, Annapolis, Maryland, USA, pp 3-9.

TDS Sensors

- ❑ **Units:** ppm
- ❑ TDS stands for Total Dissolved Solids
- ❑ It is the measure of all organic and inorganic substances contained within a given sample of water.

Connection of TDS sensors :

- ❑ Connect the **VCC** pin of the TDS sensor to the **5V** pin on the Arduino.
- ❑ Attach the **GND** pin of the TDS sensor to the **GND** on the Arduino.
- ❑ Connect the **analog output** pin of the TDS sensor to one of the analog pins on the Arduino.

FIG: TDS sensors

Source: https://commons.wikimedia.org/wiki/File:Tds-meter.jpg

https://how2electronics.com/tds-sensor-arduino-interfacing-water-quality-monitoring/

Effects of Different Ranges of TDS on Aquatic Life:

- **Low Concentrations (up to 800 ppm):**
  - Generally non-toxic and necessary for aquatic organisms.
  - Contributes to physiological and osmotic balance.
  - Specific ions (e.g., Na2CO3) at around 800 ppm can be unfavourable for certain species like catfish.
- **Moderate Concentrations (800 - 3,000 ppm):**
  - Tolerable by most fish species if the dissolved solids are non-toxic salts of earth metals (Ca, Na, Mg, K).
  - Physiological balance is crucial.
  - Unbalanced solutions may have a direct toxic effect on organisms.
- **High Concentrations (3,000 - 11,000 ppm):**
  - Tolerance varies by species.
  - Some fish can adapt, while others cannot survive.
  - Around 11,000 ppm, only certain species can tolerate these levels indefinitely.
- **Very High Concentrations (11,000 - 28,000 ppm):**
  - Extremely high levels (e.g., 28,000 ppm of chloride) exceed the tolerance of many freshwater fish species.
  - Only highly specialized or adapted species can survive.
  - Examples include fish populations in high-salinity environments like the Quill lakes (16,550 ppm total solids).

Tarzwell, C.M., 1956, April. Water quality criteria for aquatic life. In *Trans. Seminar Biological Problems in Water Pollution,* pp 260-261.

General effect of depth and Temperature upon Total dissolved solids

- **Temperature Influence:**
  - Higher temperatures generally increase the solubility of many salts.
  - This can lead to higher concentrations of dissolved solids in warmer waters.
- **Depth Variation:**
  - Concentrations can vary at different depths due to pressure and temperature gradients.
  - Deeper waters may have different chemical compositions compared to surface waters.

Applications

- **Water Quality Management**: Ensures optimal water conditions for healthy aquatic ecosystems and informs pollution control measures.

- **Aquaculture**: Maintains water conditions to support the health and growth of farmed fish, preventing diseases and enhancing productivity.

- **Environmental Monitoring and Regulation**: Assesses the impact of pollutants on aquatic life, aiding in the setting and enforcement of environmental standards.

Tarzwell, C.M., 1956, April. Water quality criteria for aquatic life. In *Trans. Seminar Biological Problems in Water Pollution*, pp 260-261.

Water temperature Sensor

- **Units:** degree Celsius (°C) or degree Fahrenheit (°F)
- Monitor water temperature for ecosystem health.
- Water temperature regulates physical, chemical, and biological processes in water and air-water interactions.
- Influences the solubility and availability of chemical constituents in water.
- Affects dissolved oxygen concentrations; solubility decreases as temperature increases.

- **Connections:**
  - The DS18B20 sensor (Water temperature sensors) has three pins:
    - **GND**: Connect this pin to the **GND** (ground) pin on the Arduino.
    - **Data**: Connect this pin to **pin 10** on the Arduino.
    - **VCC**: Connect this pin to the **5V** pin on the Arduino.

FIG: Water temperature sensors
https://commons.wikimedia.org/wiki/File:Sensor_DS18B20.jpg
(Under Creative Commons Attribution-Share Alike 4.0 International

https://peppe8o.com/water-temperature-arduino-uno-ds18b20/

Effects of different temperature ranges on aquatic life:

- **Cold Water Species (e.g., trout):**
  - Optimal Range: 52°F to 68°F for growth and survival.
  - Upper Tolerance: Survive up to 83°F briefly, but prolonged exposure above 68°F reduces survival.
  - Spawning: Fluctuations around 60°F disrupt spring spawning.

- **Warm Water Species (e.g., bass):**
  - Spawning Temperature: >60°F in spring.
  - Peak Summer Tolerance: <93°F for health; >96°F critical.
  - Adaptation: Withstand up to 103°F briefly but not prolonged extremes.
  - Impact: Temperature affects metabolism, growth, reproduction, food, and populations.

General Effect of Depth on Temperature:

- As depth increases in water bodies, temperature tends to decrease due to reduced exposure to solar radiation and thermal stratification.

Tarzwell, Clarence Matthew. *Biological problems in water pollution*. US Department of Health, Education, and Welfare, Public Health Service, Division of Water Supply and Pollution Control, 1965, pp 162-163.

Applications

- **Fisheries Management**:
  - Understand temperature preferences and tolerances.
  - Use this knowledge to manage fish populations.
  - Implement conservation measures, including protected habitats with optimal thermal conditions.
- **Aquaculture**:
  - Crucial to optimize growth rates and reproductive success.
  - Maintain water temperatures within species-specific ranges.
  - Ensures health and productivity of aquaculture systems.
- **Environmental Monitoring**:
  - Monitor water temperatures.
  - Assess habitat suitability.
  - Detect climate change impacts on aquatic ecosystems.
  - Inform conservation efforts and regulatory policies.

Tarzwell, Clarence Matthew. *Biological problems in water pollution*. US Department of Health, Education, and Welfare, Public Health Service, Division of Water Supply and Pollution Control, 1965, pp 260-261.

Table Cost involved

SL No.	Components	Price (Rs)	Quantity	Total Price (Rs)
1	**Acrylic tube (450mm)**	**1,520**	**1**	**1,520**
2	**Pixhawk Flight Controller**	**14,231**	**1**	**14,231**
3	**Pixhawk power module**	**685**	**1**	**685**
4	**Neo 7M GPS with compass**	**1,399**	**1**	**1,399**
5	**2A RC Transmitter with Receiver**	**5,295**	**1**	**5,295**
6	**Electronic speed controller(ESC)**	**450**	**4**	**1,800**
7	**LiPo Battery (4200mAh 45C 3S)**	**2,569**	**1**	**2,569**
8	**Epoxy Resin**	**599**	**1**	**599**
9	**Underwater Propeller Motor**	**2,519**	**4**	**10,076**
				Total = 38,174