Underwater Data Collection Using an Autonomous Float-Back Sub

Inspiring Excellence

Department of Computer Science and Engineering

Submitted by

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Declaration

We, hereby declare that this thesis is based on robotics application we have implemented. Materials of work from research conducted by others are mentioned in references.

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Abstract

The more water bodies are monitored, the more efficient that watershed management system is. However, it is not always possible to manually collect water quality data to monitor water bodies. Students all over the world also needs water quality data for research purpose. Remotely operated vehicle also known as ROV and autonomous underwater vehicle also known as AUV are are often used by offshore industries to do different task underwater. Additionally they are also used to collect underwater data. Moreover there are other tethered solutions to collect data from water bodies. However, using a tethered data collection device has some limitations, specially when working with more depth.

In this research a new innovative water data logging device and subsea survey device has been developed that can go deeper than current ROV/AUV systems and collect data. Initially we developed a module on which a number of sensors are embedded to collect entire parametric data. The size of the device makes it extremely portable. There is a suspended weight attached to the device. Deployed from the water surface, it will reach the water bed while collecting various data from the integrated sensors and once it reaches the bottom (or a certain depth), the weight is detached and the main body floats back to the surface and as soon as it reaches the surface it will offload all its data including GPS coordinates to the cloud data center. The user can see its exact location with an app in his/her smartphone and can retrieve the device easily. In this way, the device can be dropped multiple times in multiple locations easily.

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Chapter 1 : Introduction

1.1 Background Study

The ecosystem dynamics are generally non-linear, and these changes can occur abruptly due to both human and natural causes. Therefore, a mechanism is needed to provide continuous monitoring capable of detecting changes in critical environmental indicators and transmitting warning signals. Given the ever-increasing demand for water due to the growing population, it is critical to have a reliable, long-term and accurate real-time or near-real-time monitoring of water quality if effective management of water resources is to be realized.

We live in the era of ocean [1, 2]. Fish ethology, a discipline that studies the movement and behavioral activities of wild and cultivated fish under natural conditions, has indicated incredible prospects in the field of aquaculture, fisheries and other marine studies and applications[3-8]. Conventional studies focus primarily on observations in situ performed intermittently by marine biologists, which is time consuming and dependent on the skillset of the human operators[3-8]. Moreover, this ways are very costly and are mostly unaffordable for researchers in underdeveloped countries. Underwater visionary and data collection devices either tethered, shore based, conducted by remotely operated vehicles (ROVs) or autonomous underwater vehicles (AUVs) have expanded throughout the last couple of decades[9-16]. Journalist Starre Vartan writes at Mother Nature Network said that human knows more about Mars surface than the sea floor [17]. Understanding the ocean floor is a monumental task and might be the hardest task researcher are doing right now. Panoramic

Videography is another field of underwater exploration. Previously multiple cameras were used to capture this type of videos [18]. We believe that it's high time more students should also get involved in this research. This is the only way this field can be explored faster. So, developing improved underwater imaging and quality monitoring device is needed.

1.2 Motivation

The authors of this paper built the first autonomous underwater vehicle (AUV) named BRACU Duburi in Bangladesh to attend any international competition. Team Duburi attended SAUVC 2018 and stood 7th position despite being their first time. The AUV they build was completely from the scratch and no aftermarket underwater was used as underwater components are costly and was not affordable for them. This motivated the authors to build an underwater exploration device than can be easily affordable by students, researcher and hobbyist. This can make underwater exploration and data collection much cheaper and easier for students all over the world.

CanSat is considered as a fundamental teaching tool for introduction to satellite technology. CanSats are launched using a small hydraulic rocket and on reaching few hundred meters of height it deploys parachute to land back. On it's way the CanSat logs data from it's environment. Inspired by the popular CanSat [19] concept, we built a device that can submerge in water on it's own weight. On reaching target dept it releases an extra weight attached to it and floats back. On it's way the device logs underwater sensor data. The device is named CanSub as it is 'can' shaped and can perform data collection task like underwater subs.

1.3 Problem Statement

Different approaches over the years had been taken to log underwater water parameters for water resource management and research. But most of them are manual, time consuming and costly methods. Therefore, these approaches are limited by coverage due to the high cost of implementation and also prone to errors due to human error in recording or quality degradation during sample collection. Remote sensor monitoring systems are promoted as more sustainable and cost effective methods for long-term monitoring of water quality. Unfortunately the cost of implementing remote water quality monitoring system is still high and are not affordable by small groups of researcher. And such system are hard to deploy in remote places where wired or wireless system are not possible to setup. Moreover such system requires a level of technical skill which also adds to the cost of personnel training to manage these instruments.

Since small groups of researchers and students are experiencing trouble in implementing system for underwater data collection and analysis, there is a rising concern on how to develop a system to makes data acquisition easier, effective and most importantly affordable. The main focus of this research is to build an effective system to acquire underwater data that can be easily build by students or researcher with low cost. Moreover the system needs to be on wireless sensor network (WSN) based on Delay Tolerant Network (DTN) architecture. The WSN and DTN are shown in section 1.6. The system is made using inexpensive IoT compatible microcontroller, low cost energy-saving power management and some water parameter monitoring sensors.

This monitoring system is designed to collect water quality data such as pH, water turbidity and temperature. This data is autonomously conveyed through a wireless network from the remote location where the device is deployed to a cloud database where the data can ubiquitously be accessed and visualized.

1.4 Objectives of Study

The main objective of this research is to built a wireless sensor network that is portable, low cost, easily deployable to monitor water data through these objectives:

- To determine how to implement a system to low water quality parameter at different depth of water bodies.
- To implement wireless sensor networks (WSN) built on DTN architecture and build a low cost water monitoring system.
- To examine how effectively the system can log data at different dept of water.

1.5 Significance of Study

The research is focused on developing a system capable of monitoring water quality easily at different depth of water while the system is also capable of integrating other sensors depending on the requirement to measure other parameters of water.

1.6 Key Concepts

Delay Tolerant Networking (DTN) is and end-to-end network designed to supply interoperable communication between networks that are setup to transmit information in unstable and stressed environments. In such environments, the network experiences intermittent property, high bit error rates that degrade traditional communication, and frequent and long lasting disruptions. So as to modify communication between the DTN nodes, its design is meant to use the Bundle Protocol (BP) that sits on the application layer within the open system interconnection (OSI) networking framework (RFC5050). Due to intermittent property between the nodes, there's never a continuous connection with the server.So to keep up a reliable transmission of data, DTN is meant to run based on “store-and-forward” approach creating it additional disruption tolerant as compared to the traditional web protocol (TCP/IP).

WSN is a technological development that is made up of embedded systems, wireless networks and sensor technology.

Chapter 2 : Literature Review

In this section, background of ROV, AUV and underwater data logger device are given along with the process of data acquisition and maneuver mechanism.

2.1 ROV

Besides dedicated data logging devices ROVs and AUVs are used by students to collect water quality data. ROV are unoccupied and highly maneuverable system that are used for underwater exploration. ROV stands for remotely operated vehicle. For small ROV, usually the vehicles are tethered driven and a person drives these vehicle. The person remains in a comfortable place while the ROV is driven in hazardous environment or deep in the see where drivers cannot reach. The ROV system contains an underwater vehicle which is connected to the control platform and the operator in the surface by a cable. The vehicle has cameras in it. Live video for maneuvering and other observations are passed to the control stations and are viewed in screen, tv or other medias [20]. The use of ROV have increase rapidly over the past few decades because of it easy of underwater exploration [9-16]. However, it is still costly and not so affordable for independent researchers and small organizations.

Figure: 2.1a BlueROV2, an ROV by Blue Robotics [21]

In figure.2.1a the picture is BlueROV2. This ROV was developed by Blue Robotics, a startup founded on May 2014. This ROV has 6 thrusters and of vector configuration. It can tether live videos and can reach at a depth of upto 300 meters.

The advantages and disadvantages of ROV system are given below in general view. The advantages are:

- No time limit as power can be supplied all time
- Can cover larger area like divers
- Can closely examine sea bed
- Can be easily deployed in small space
- Some models have gripper attached to it to collect samples

The disadvantages are:

- Limit of depth range because of cable
- Needs an operator to drive the vehicle
- Equipments are very expensive and not widely available
- Difficult to maneuver in areas of strong current

Table 2.1a: Summary of ROV categories

Class	Capability	Power(hp)
Low cost small ROV/ mini or micro ROV	Observation(<100 meters)	<5
Small ROV (Electric)	Observation (<300 meters)	<10
Medium (Electro/ Hydraulic)	Light/ Medium Heavy Work (<2,000 meters)	<100
High Capacity Electric	Observation/Light Work (<3,000 meters)	<20
High Capacity (Electro/ Hydraulic)	Heavy work/Large Payload (<3,000 meters)	<300
Ultra-Deep (Electric)	Observation/Data Collection (>3,000 meters)	<25
Ultra-Deep (Electro/Hydraulic)	Heavy Work/Large Payload (>3,000 meters)	<120

2.2 AUV

An autonomous underwater vehicle (AUV) is a robotics device that is driven underwater by a propulsion system, controlled and piloted by and onboard computer and are maneuverable in three dimension [22]. An AUV might look like a ROV but it has onboard system to sense environment and maneuver by itself autonomously. Thus it can follow pre-programmed movements in most environments[22]. Many universities nowadays are doing research on AUV, where their task is to design more efficient and cheaper AUV than the existing ones. Multiple vehicle survey increases productivity and can ensure better data sampling [23].

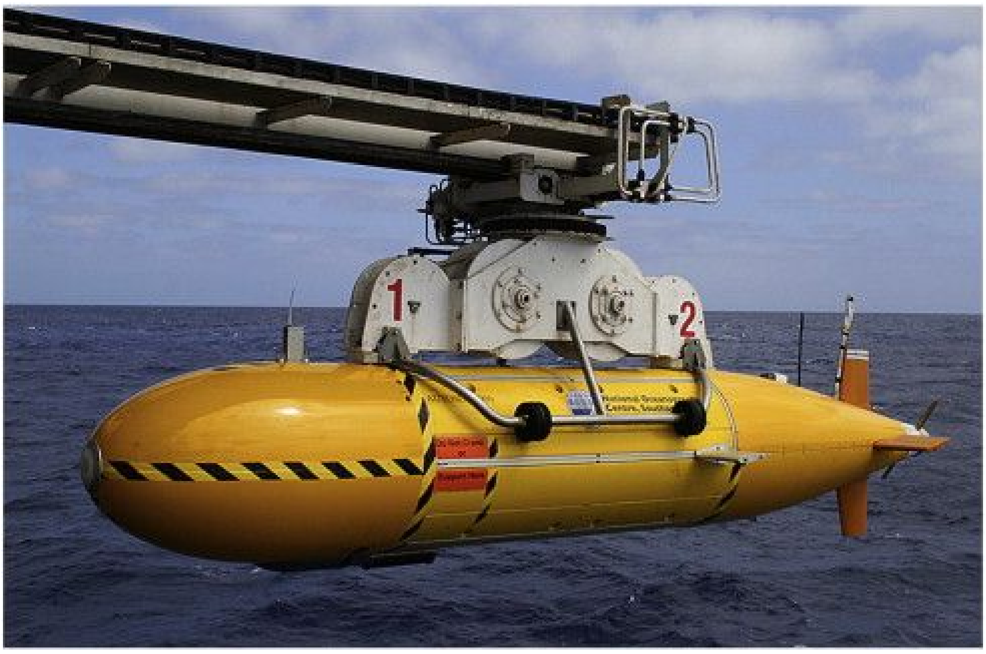


Figure: 2.2a The UK Natural Environment Council (NERC) Autosub6000 AUV [24]

In figure.2.1b the AUV is Autosub6000 by The UK Natural Environment Council (NERC) which has a depth-rated to 6000m. It can be equipped with multiple payloads for marine geoscience research and includes high-resolution multibeam echosounder, sub-bottom profiler, sidescan scanner, camera system. It also have Conductivity, Temperature, Depth (CTD) and electrochemical redox (Eh) sensors. This 5.5m long AUV weights 180 kg and is capable of precise navigation with terrain following and sophisticated collision avoidance system.

The advantages and disadvantages of AUV are given below. The advantages are:

- Highly stable and agile.
- Excellent navigational algorithms for providing accurate target location.
- It has low deployment costs as it does not require bulky and complex support equipment.
- High reliability and improved data quality.
- It reduces operational errors and high costs associated in employing a human operator.
- It follows rough terrain easily with the optimal positioning of sensors.

The disadvantages are:

- Needs good programming.
- Needs an operator to set mission
- Needs external sensor to perceive environment
- Needs a lot of skill to design and program

Table 2.2a: UAVs Classification according to the US Department of Defense (DoD)

Size	Max Gross Takeoff weight (MGTB)(lbs)	Normal Operating Altitude (ft)	Airspeed (knots)
Small	0-20	<1,200 AGL*	<100
Medium	21-55	<3,500	<250
Large	<1320	<18,000 MSL**	<250
Larger	>1320	<18,000 MSL	>250
Largest	>1320	>18,000	>250

*AGL = Above Ground Level

**MSL = Mean Sea Level

2.3 Underwater Data Logger

Underwater data loggers are electronic devices that are used to record data from underwater and use these data for analysis. It has built in sensors or external sensor to record different parameters of water quality. Bartram and Balance (1996) pointed out that there are primary water quality parameters such as temperature, turbidity, conductivity and pH that are better measured in situ so as to record the conditions at the time the water sample was taken [25].

Figure: 2.3a SDL500, underwater data logger by NexSens Technology [26]

Figure 2.3a is an underwater data logger by NexSens Technology. It is model SDL500. It is a rugged, self powered remote data logging system for deploying environmental sensors in stream, river, wetlands, coastal waters and other water bodies.

Chapter 3 : System Design

3.1 Overview

In this chapter, background of CanSub is given along with the process of data acquisition. CanSub is a 'can' shaped portable, easy to use and modular device that can be used for data acquisition of bothe sweet water and marine water. It is portable because the size of the device is much smaller than any traditional ROVs or AUVs while it's capable of acquisitioning underwater data like ROVs or AUVs. It is extremely easy to use as it take almost no time to start and user just drops the device in any water body. The device, submerges by itself and on reach target dept it float backs. The target dept can also be set easily in the device. After floatback the device automatically connects to wifi which can be tethered using a modern Android or IOS phones or even a router. As it has a built in GPS the device pings it's geo location with certain interval of time. The user can retrieve the device from that location. Moreover the device is modular because it has its own firmware which supports a large number of underwater sensor which can be attached and detached anytime to collected any data required for the user. It has a camera mount at the top to add any underwater camera or ordinary cameras with underwater housing.

Figure: 3.1a 3D model of CanSub

Figure 3.1a is the 3D model of Cansub. The device contains three main parts, Camera Mount, Watertight Enclosure, Circuits and Release Mechanism.

3.2 Hardware

Inspired by the popular cansat model, the CanSub is designed in a 'can' shaped enclosure with a camera mount at the top, circuits inside the enclosure and a release mechanism at the bottom. A 3d model of the mechanical design was implemented in ***Autodesk Fusion360***. All of these are discussed below:

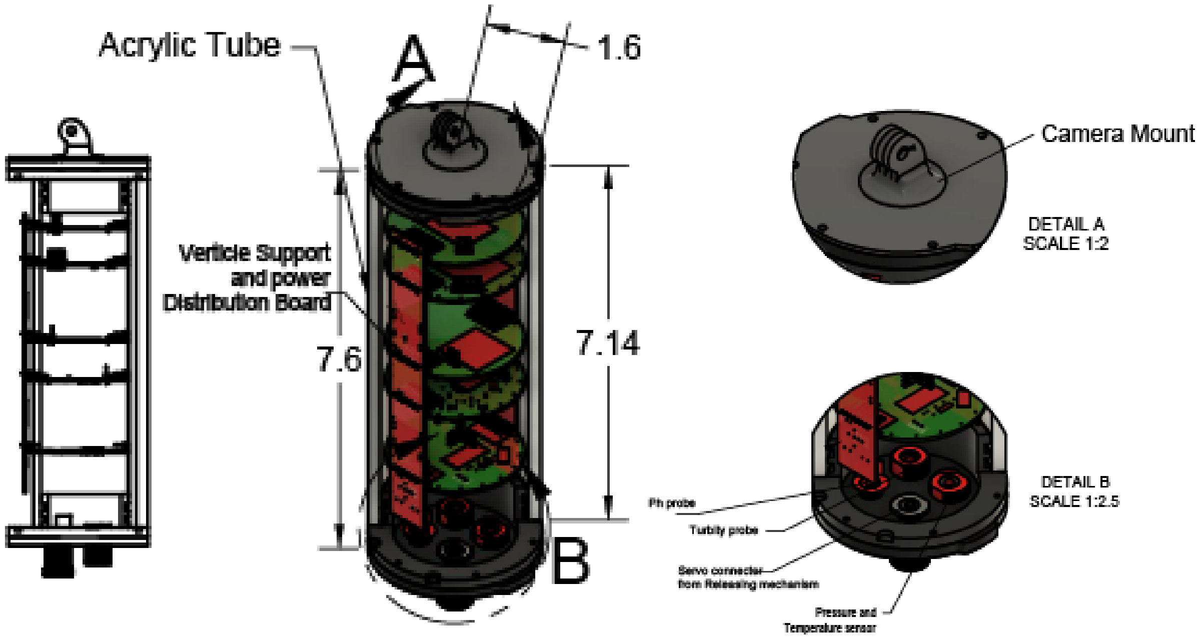


Figure: 3.2a measurement diagram of CanSub

3.2.1 Watertight Enclosure

The watertight enclosure is the chamber that holds the circuits inside. It is watertight to keep the circuits waterproof. It is made up of several parts :

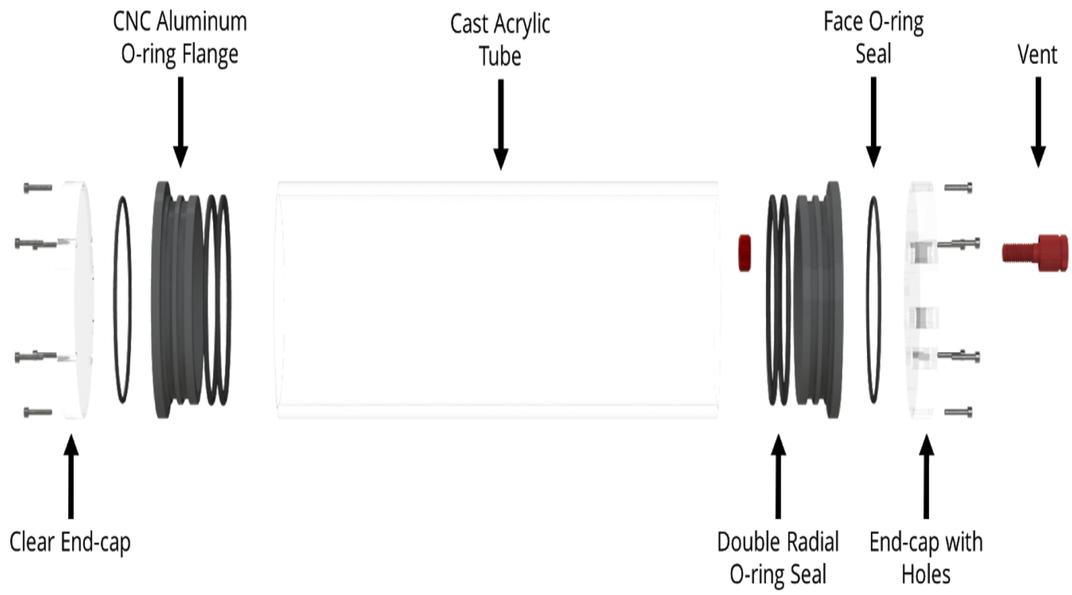


Figure: 3.2.1a 3” by 8” watertight enclosure

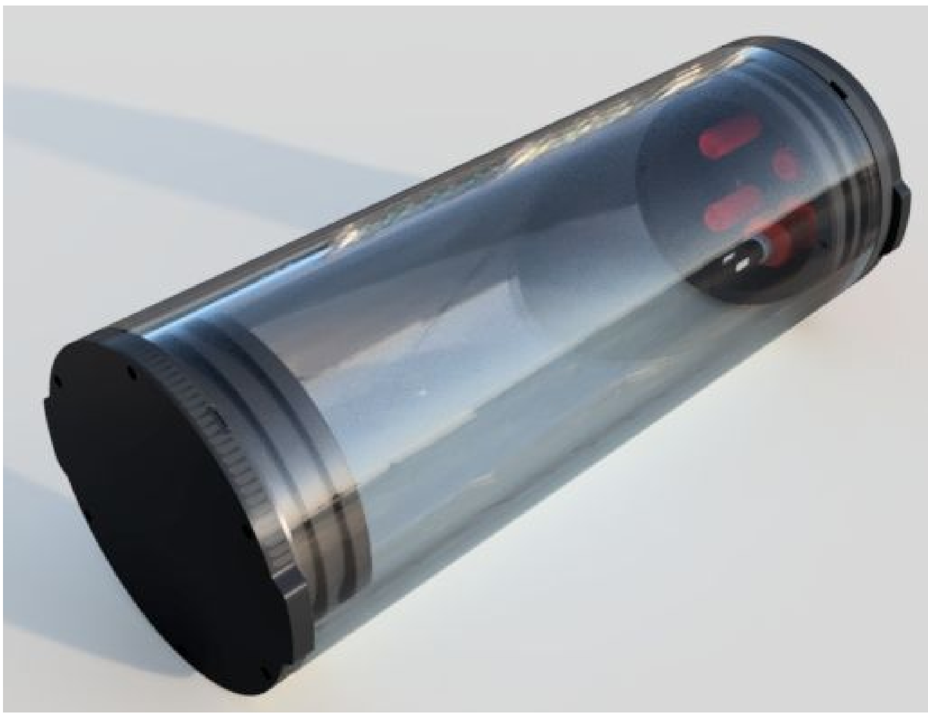


Figure: 3.2.1b watertight enclosure with all parts attached

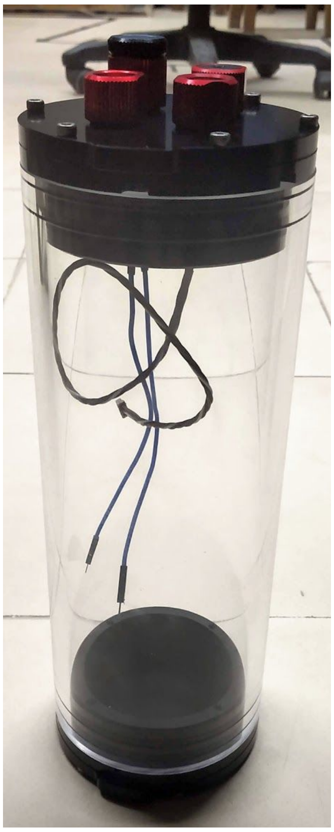


Figure: 3.2.1c Assembled Watertight Enclosure

Figure: 3.2.1a is the labelled picture of different parts of the enclosure. Figure: 3.2.1b is the 3D model of the enclosure.And figure: 3.2.1c is assembled version in lab.

3.2.2 Camera Mount

The camera mount is attached to the top of the main body. CanSub uses a 360 camera to capture 360 video data for underwater exploration.

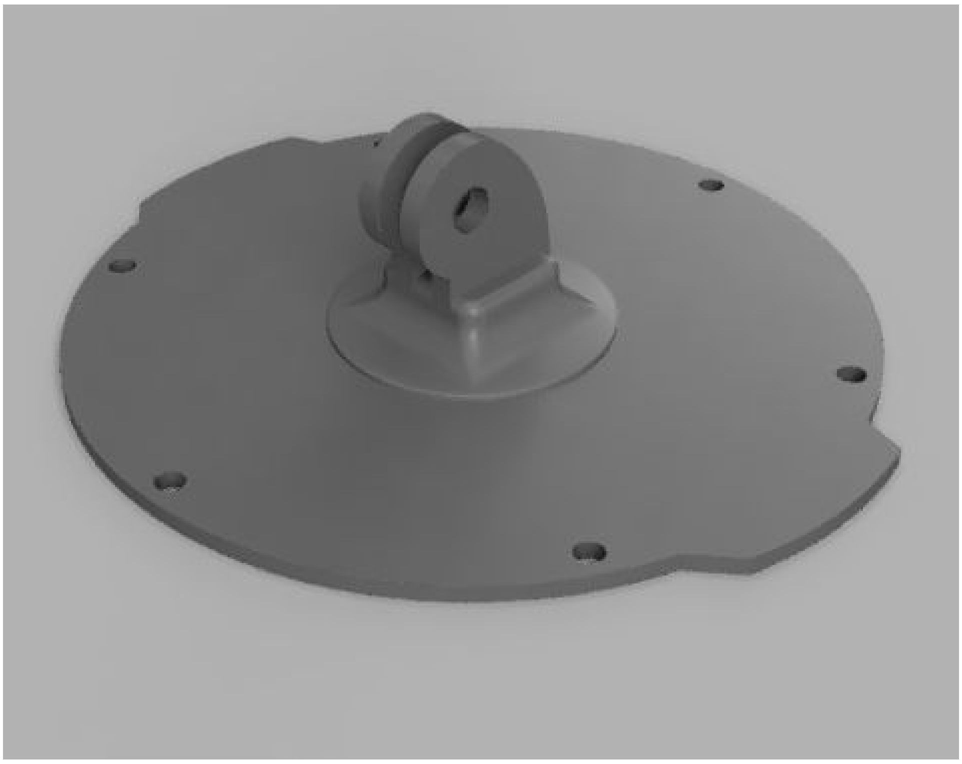
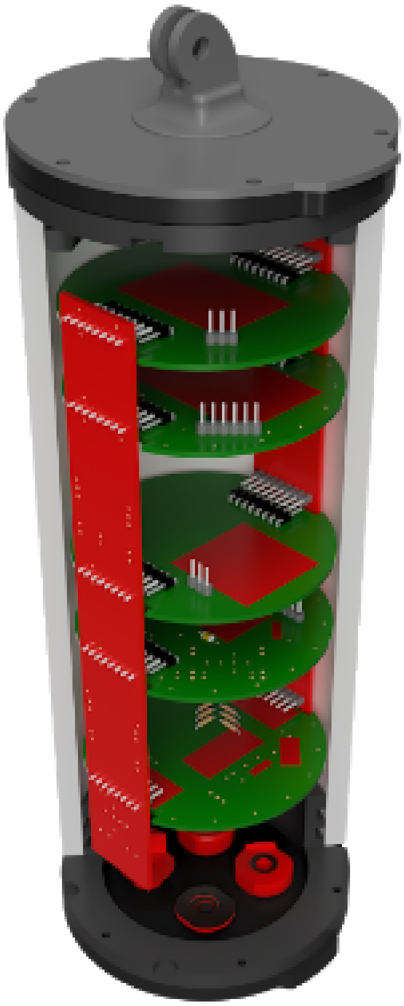


Figure: 3.2.2a 3D model of the Custom Camera Mount

Figure 3.2.2a is the 3D model of the standard action camera mount with a customized base. This camera mount can be easily attached to the body of the CanSub and any action cam can be attached to collect video samples.

3.2.3 Circuitry

The circuits of CanSub are stacked into five layers with two vertical circuits holding them consisting power and communication buses.



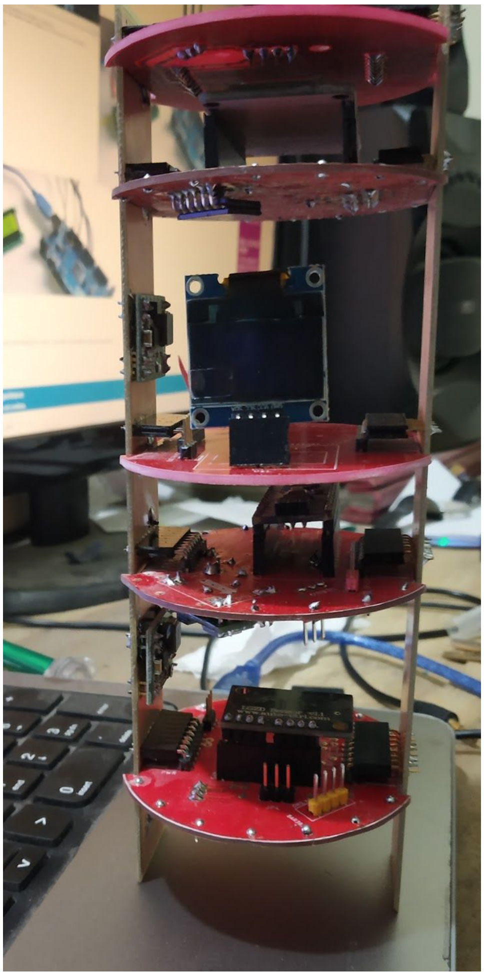


Figure: 3.2.3a Circuit Stack (from left to right: 3D Model and Actual Outcome)

Figure 3.2.3a shows the Circuit Stack (from left to right: 3D Model and Actual Outcome). Five PCBs are stacked between two vertical PCBs to make the who system fit in the enclosure.

a. The first layer holds the GPS system to log the geo location of the sample collection site.
b. Second layer of PCB holds the ESP32, the main control unit, which is also equipped with wifi to send data to the server. However it also holds the sd card module to store data while submerging for later pushing the data to the server.
c. The third stack contains the PCB that holds a OLED display to show the status of the device.
d. Fourth stack of the PCB is to control the servo of the release mechanism.
e. Lastly, fifth stack of the PCB holds the connections for the sensors used for water quality monitoring.

However, there are two more vertical circuits that holds the stack while providing communication and power busses between each stack of the PCBs.

PCB Design Considerations

One of the primary design consideration was reducing signal attenuation from analogue sensors as much as possible. This is significantly challenging considering the fact that both digital and analog circuitry was sharing the same PCBs. Several routing technique was followed to minimize signal distortions.

A. **Additional ground -** a dedicated ground plane was used on the double layered PCBs to ensure minimum impedance from ground reference[27].
B. **Via Shielding -** Comprises of a line of closely placed through holes, forming a pseudo faraday cage, providing barrier to electromagnetic wave propagation of slab modes in the substrate. This improves isolation between analog traces which would otherwise be coupled by electromagnetic fields[28,29].

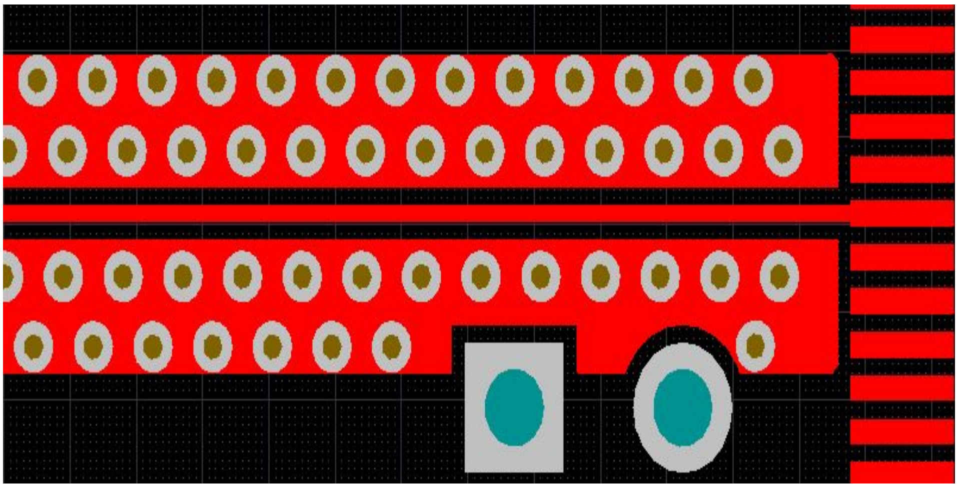


Figure: 3.2.3b: Via Shielding [30]

3.2.4 Electronics

The entire electrical system was designed using Autodesk Eagle Cad and printed on single and double layer PCBs which made the device assembly easy and plug-n-play. So the circuit system is also modular and can be easily debugged, replaced or swapped in case of errors. The electronics system consists of ESP32, a dual-core system with two Harvard Architecture ***Xtensa LX6 CPUs*** [31], highly-integrated with in-built antenna switches, RF balun, power amplifier, low-noise receive amplifier, filters, and power management modules. An SD card module to store data while not connected to the internet. Ublox NEO-6m GPS Module V2 is used for accurate geo location tagging. Additionally an OLED display is included for visual feedback and debugging. An arduino Nano based on ATmega328P is used to control the release mechanism. Powered from a single 1000mAh 2S Li-Po battery, 5V and 3.3V step down module is used to control the input voltage of different electronics device. Lastly, pH, turbidity, pressure and temperature sensor is used in this device.

a. MCU (Micro Control Unit):

The electric control unit is the main brain of the entire system which include ESP32. It is connected to every other stack for controlling. Moreover this it is also used to push data to server via wifi.

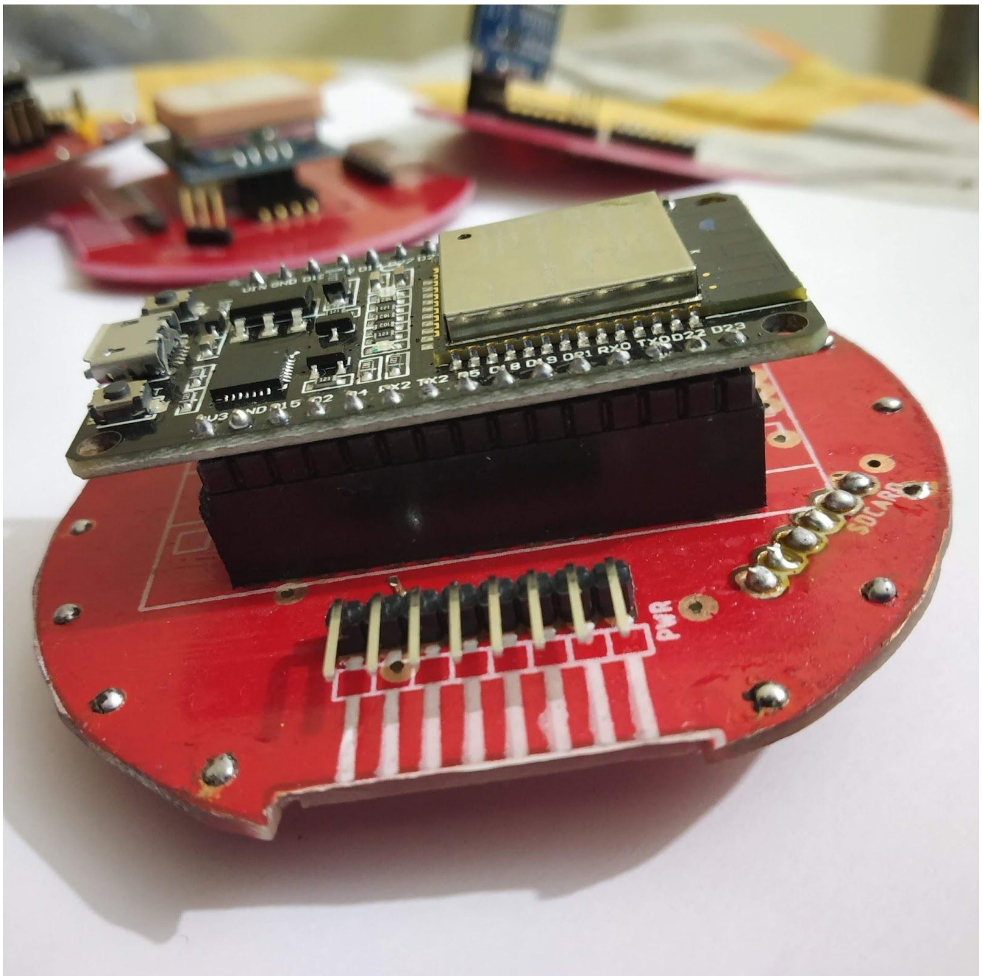


Figure: 3.2.4a MCU (Micro Control Unit)

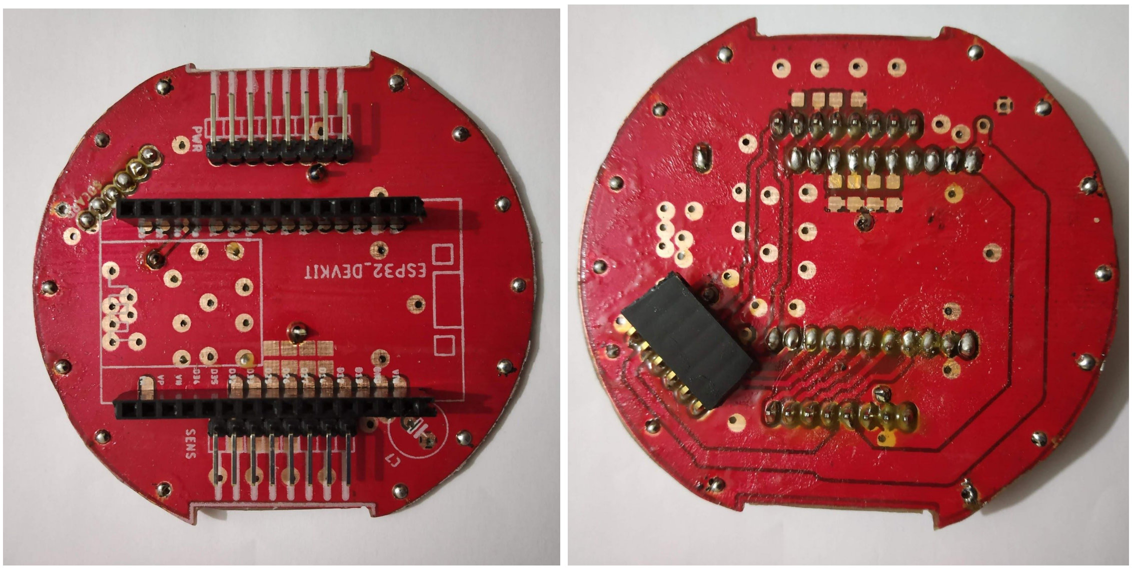


Figure: 3.2.4b MCU PCB Top and Bottom View

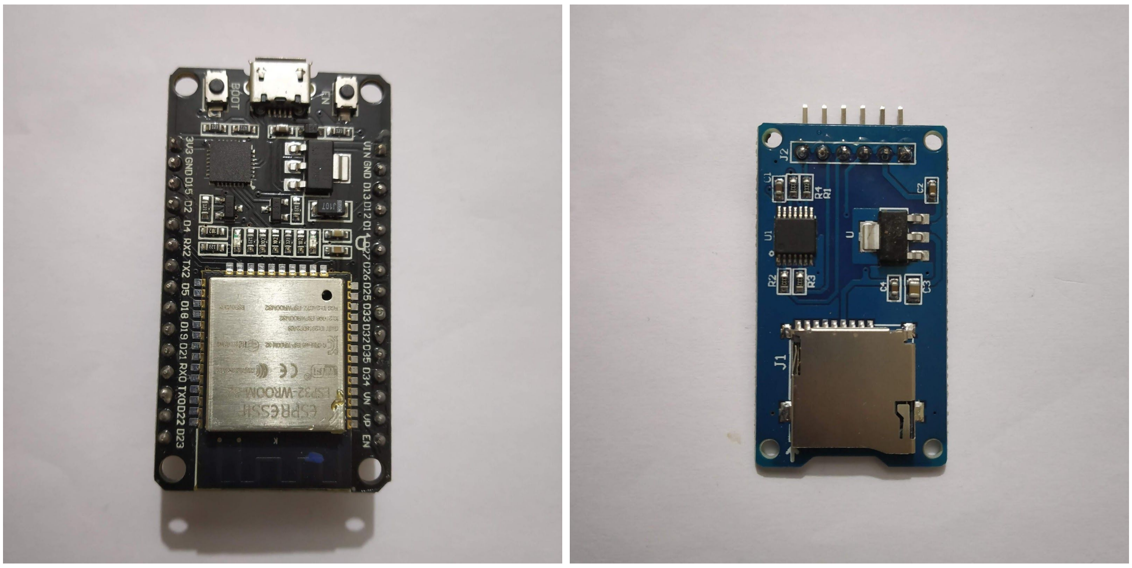


Figure: 3.2.4c ESP32 and SD Card Module

a. Sensors and modules:

GPS - The Ublox NEO-6M gps engine on this board is of high precision binary output. It has also high sensitivity for indoor applications. The antenna is connected to module through ufl cable which allow for flexibility in mounting the gps. The Ublox gps module has serial TTL output, it has four pins:TX, RX, VCC and GND.

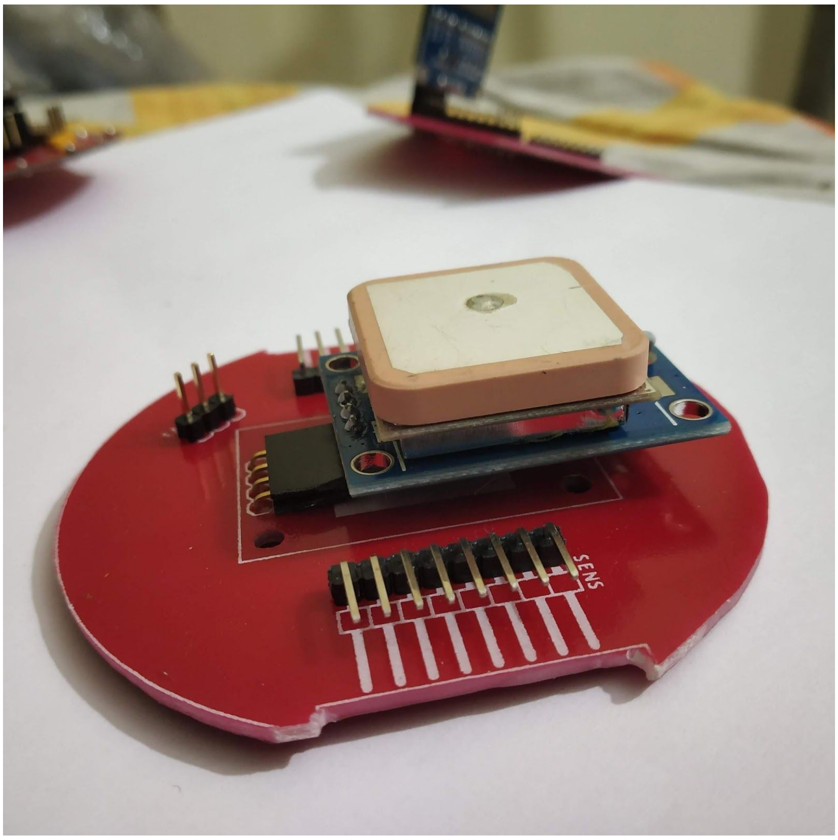


Figure: 3.2.4d GPS sub-system

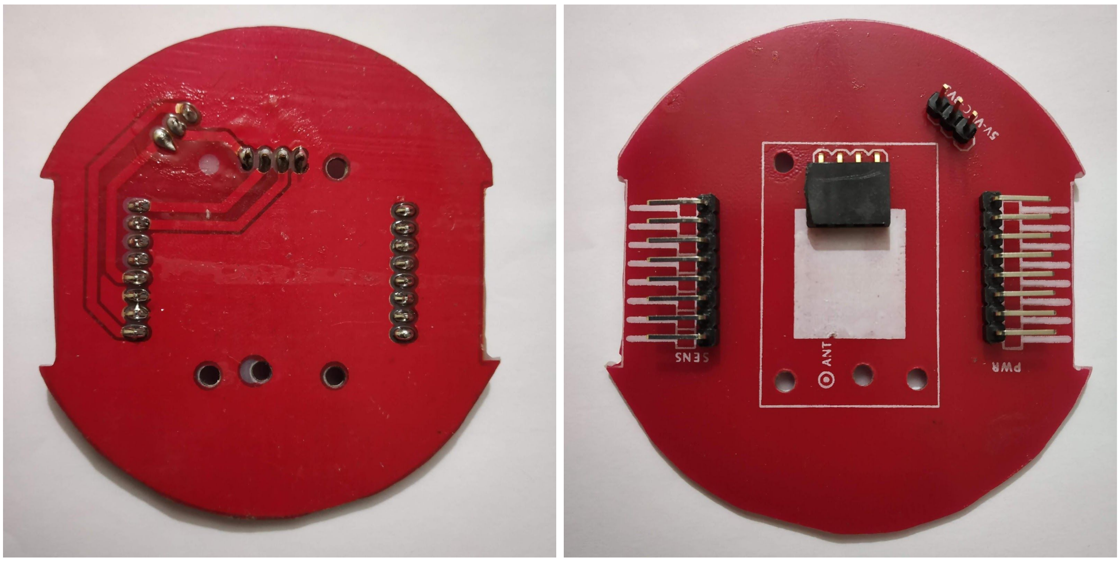


Figure: 3.2.4e Top and Bottom view of PCB for

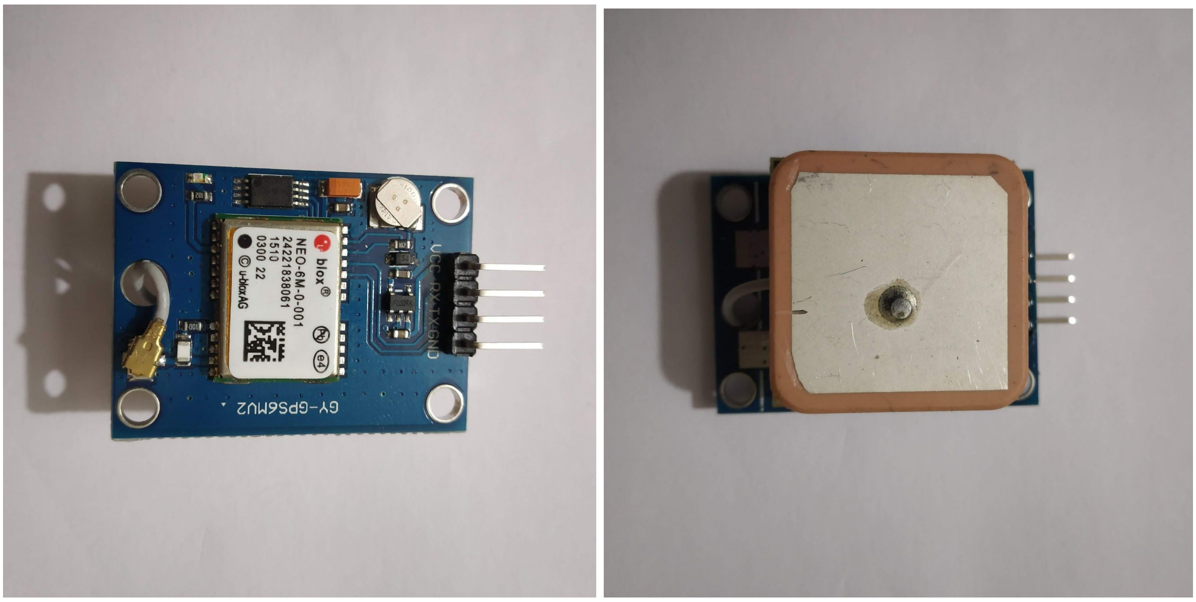


Figure: 3.2.4f Ublox NEO-6m GPS Module

pH - It is the acidic or alkaline properties of a liquid. There are multiple sensor probes available for pH detection with high resolution. Industry grade (continuous submersion) analogue pH kit is used in the proposed system.

Figure: 3.2.4g Analog ph Sensor kit

Turbidity - Turbidity sensor detects turbidity by measuring the in-water light scattering rate. Many robust solution for turbidity measurement exists in market. A general purpose turbidity sensor is used in the system after waterproofing using silicon and epoxy glue. This sensor also produces analogue voltage with respect to the turbidity of the water.

Figure: 3.2.4h Turbidity Sensor

Pressure(Depth) and Temperature - An open-source, high-pressure, high-resolution pressure sensor, sealed from the water from ***BlueRobotics*** was used. With 0.2 mbar resolution, it has an depth measurement resolution of 2mm in the water column. The sensor is the Measurement Specialties MS5837-30BA, which can measure up to 30 bar (300m/1000ft depth) and communicates over I2C. This sensor includes a temperature sensor accurate to ±1°C, with data also accessible through I2C.

Figure: 3.2.4i Bar30 Pressure Sensor

3.2.5 Release Mechanism

The release mechanism consists an underwater servo motor controlling 3d printed Parabolic Dispenser Throw Switch. A suspended weight is hooked into the lever and locked. The servo control unit (atmega328p) drives the servo either in locking or unlocking position depending on its constraints.

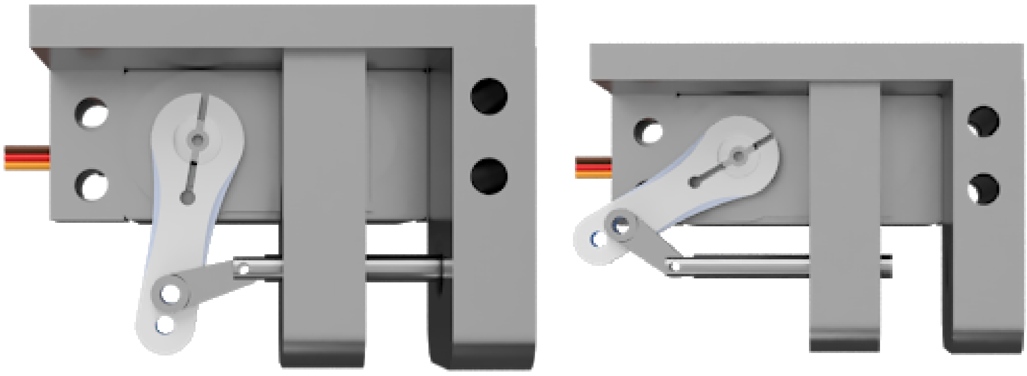


Figure: 3.2.5a Servo Switch (CAD model)

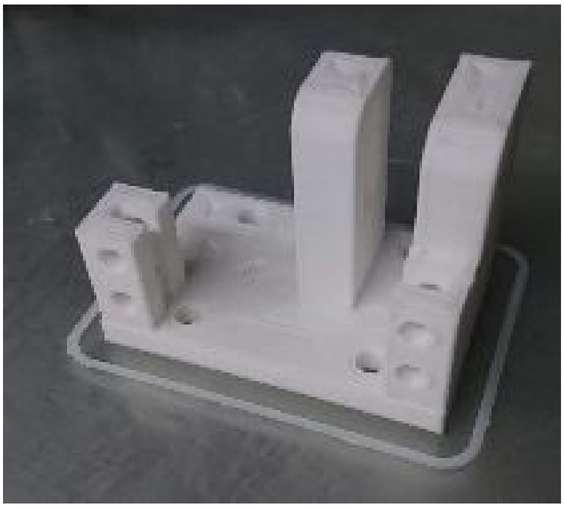


Figure 3.2.5b 3D printed model of Servo Release Mechanism.

3.3 Software

In order to provide the computer functionality that enables the operation of the system, Arduino software IDE was used for developing the firmware. This firmware provides the ability to customize the necessary functions of the monitoring system. The firmware was designed to conserve energy by scheduling data collection, switching the communication module between a sleep and wakeup mode, disabling unused interface ports on the ESP32, turning off the LED lights and automating data conveyance from the remote location to a cloud database.

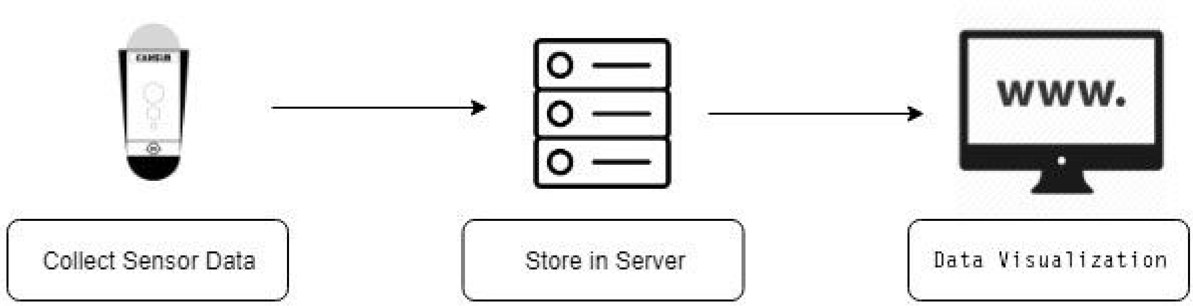


Figure 3.3a Data Flow Diagram.

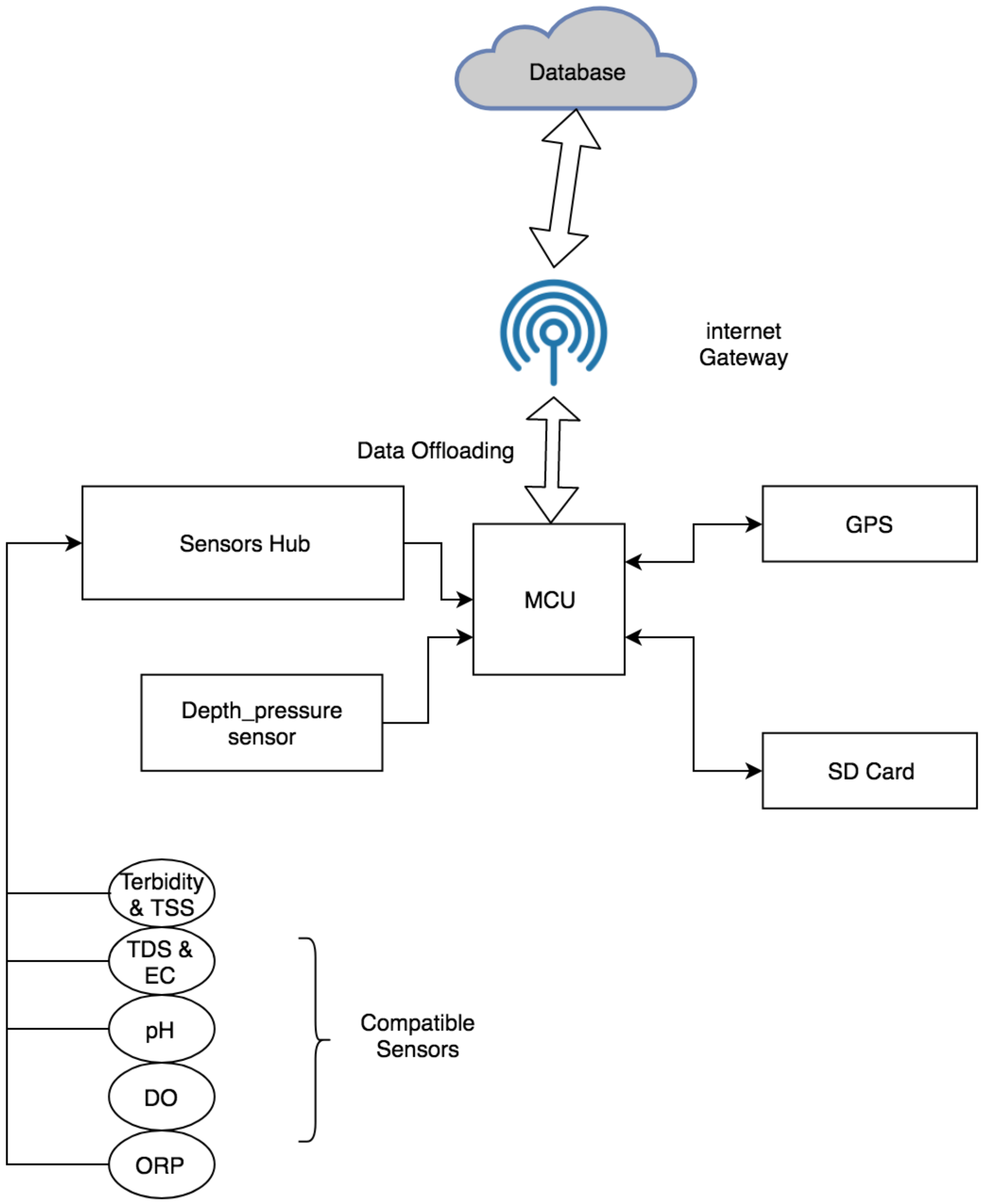


Figure 3.3b System Flowchart

3.3.1 Sensor Data Collection:

The CanSub MCU needs to collect data from several sensor and the store them to the SD Card for pushing to the server as soon it is connected to the network.

a. pH : The pH sensor needs to be calibrated for the first time to reduce error.

```
{
      analogSampleTimepoint = millis();
      //read the analog value and store into the buffer
      analogBuffer[analogBufferIndex] = analogRead(PHSensorPin);
      analogBufferIndex++;
      if(analogBufferIndex == SCOUNT)
          analogBufferIndex = 0;
}
```

VOLTAGE (mV)	pH value	VOLTAGE (mV)	pH value
414.12	0.00	-414.12	14.00
354.96	1.00	-354.96	13.00
295.80	2.00	-295.80	12.00
236.64	3.00	-236.64	11.00
177.48	4.00	-177.48	10.00
118.32	5.00	-118.32	9.00
59.16	6.00	-59.16	8.00
0.00	7.00	0.00	7.00

Figure 3.3.1a: pH vs Voltage chart

b. Turbidity : The analogue turbidity sensor detects water quality by measuring level of turbidity. It is able to detect suspended particles in water by measuring the light transmittance and scattering rate which changes with the amount of total suspended solids (TSS) in water. As the TSS increases, the liquid turbidity level increases.

```
{
    // read the input on analog pin 0:
  int sensorValue = analogRead(A0);
  // Convert the analog reading (which goes from 0 - 1023) to a voltage (0 - 5V):
  float voltage = sensorValue * (5.0 / 1024.0);
  Serial.println(voltage); // print out the value you read:
}
```

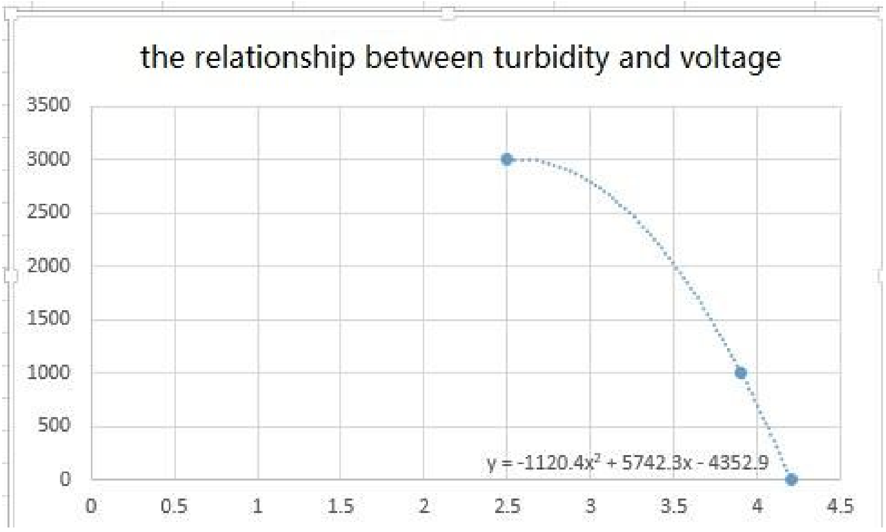


Figure 3.3.1b: Turbidity Sensor value mapping chart

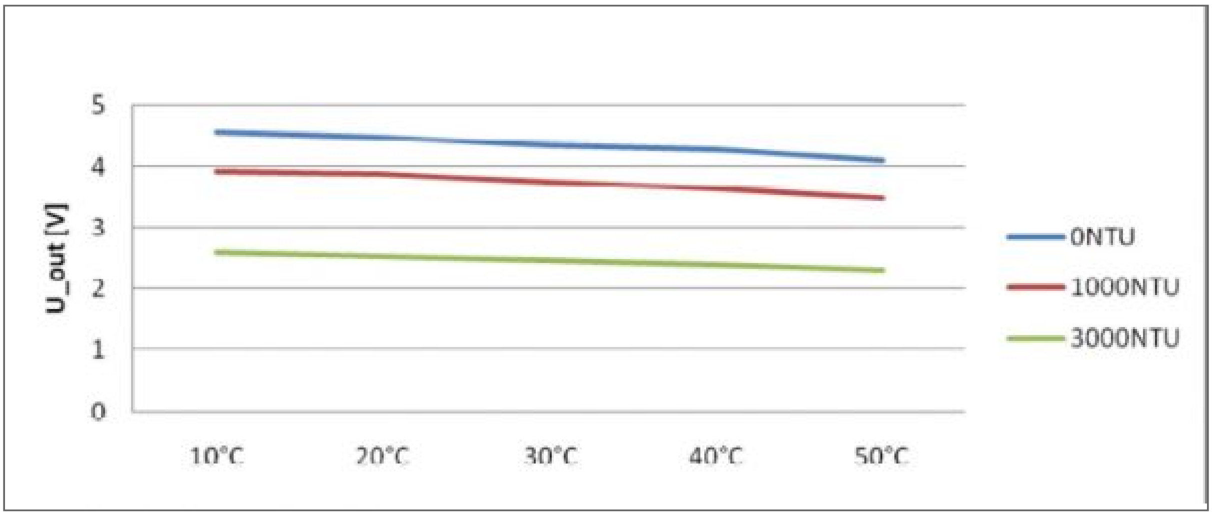


Figure 3.3.1c: characteristic curve Voltage vs Temperature

c. Bar 30 Pressure and Temperature Sensor: The sensor is the Measurement Specialties MS5837-30BA, which can measure up to 30 bar (300m/1000ft depth) and communicates over I2C. MS5837 Library is used to pull the data for this sensor.

```
import ms5837
import time

sensor = ms5837.MS5837_30BA() # Default I2C bus is 1 (Raspberry Pi 3)

# We must initialize the sensor before reading it
if not sensor.init():
        print "Sensor could not be initialized"
        exit(1)

# Print readings
while True:
        if sensor.read():
                print("P: %0.1f mbar  %0.3f psi\tT: %0.2f C  %0.2f F") % (
                sensor.pressure(), # Default is mbar (no arguments)
                sensor.pressure(ms5837.UNITS_psi), # Request psi
                sensor.temperature(), # Default is degrees C (no arguments)
                sensor.temperature(ms5837.UNITS_Farenheit)) # Request Farenheit
        else:
                print "Sensor read failed!"
                exit(1)
```

d. Localization: Using a GPS module we calculate the latitude and longitude with a 5 meter error margin which is experimented in open environment with preloaded map. Tiny GPS c library is used here.

```
{
  while(gpsSerial.available()){ // check for gps data
    if(gps.encode( gpsSerial.read())){
      gps.f_get_position(&lat,&lon); // get latitude and longitude
      Serial.print("Position: ");
      Serial.print("Latitude:");
      Serial.print(lat,6);
      Serial.print(";");
      Serial.print("Longitude:");
      Serial.println(lon,6);
      Serial.print(lat);
      Serial.print(" ");
   }
  }
```

```
  String latitude = String(lat,6);
  String longitude = String(lon,6);
  Serial.println(latitude+";"+longitude);
}
```

3.3.2 Connectivity:

The ESP32 has a build in wifi to connect to the internet. An ad hoc network was designed based on a static routing model to enable connection between the data acquisition node and the data mule.

All the requirement for the DTN architecture is addressed in the built in IoT infrastructure of the ESP32. The BP sits on the transmission control protocol (TCP) and provides the ability to autonomously transfer data from the data acquisition node to the data mule. The DTN architecture was also setup in the data collection center to enable an automated data transfer from the data mule to the data collection center.

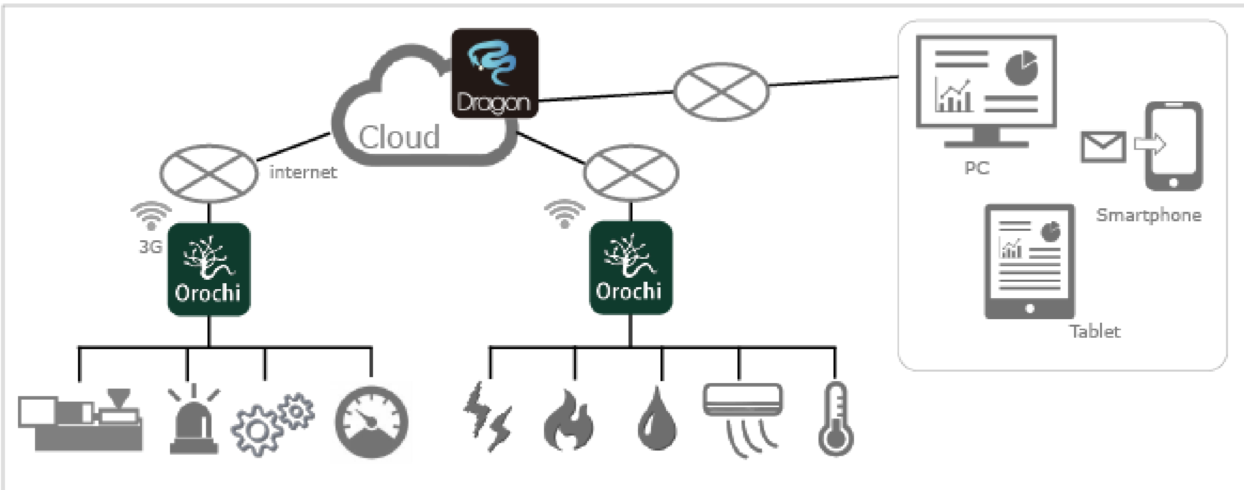


Figure 3.3.2a: Typical Iot system [32]

3.3.3 Server :

Data bundles from the data acquisition nodes are transferred wirelessly using the IoT protocols from the remote location to a data center where the data is autonomously 34 verified for authentication and then uploaded to the MongoLab cloud database. The data is ubiquitously accessible to the public through the Internet using different platforms.

Chapter 4 : RESULT AND DISCUSSION

This chapter presents a detailed description of the system design, how to implement the remote water quality monitoring system and how effective the system can be for monitoring water quality. Additionally, it examines the findings of the study and describes how it conforms to related research studies.

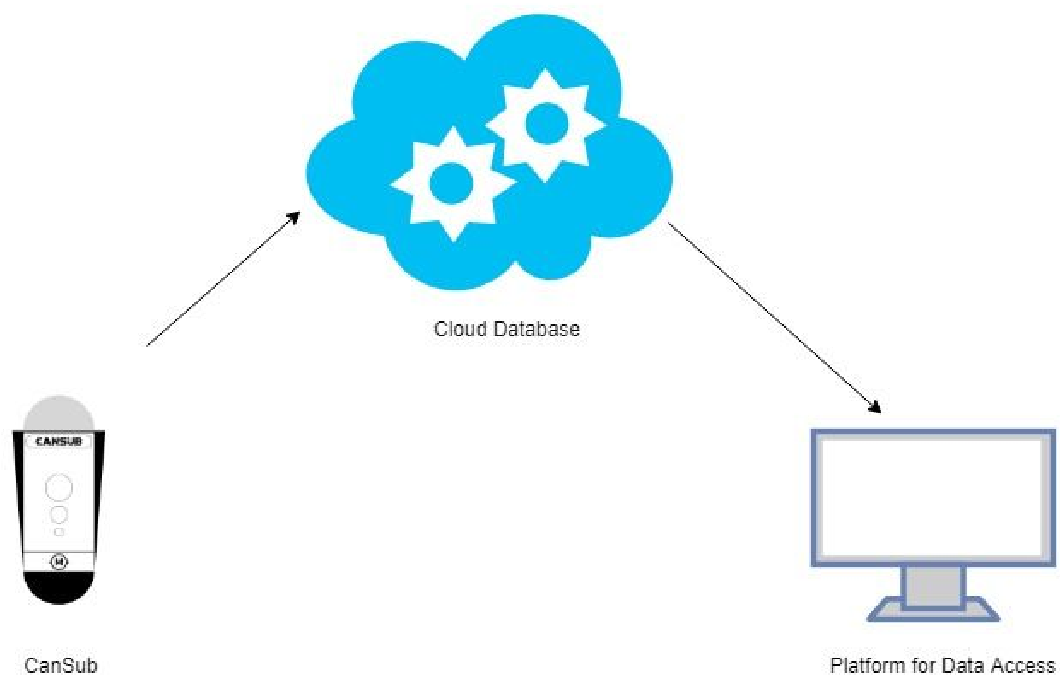


Figure 4a System design

The CanSub's built in IoT system provides the functionality to push data to the server after taking reading. DTN End-point is the data collection and processing center where the data is validated for authentication before being uploaded to database. Cloud database provides the ability for ubiquitous access of water quality data over the Internet from different platforms.

4.1 System Implementation

In order to achieve the goals of this study, the system was designed, built and tested in several locations. The experiment workflow is as follows.

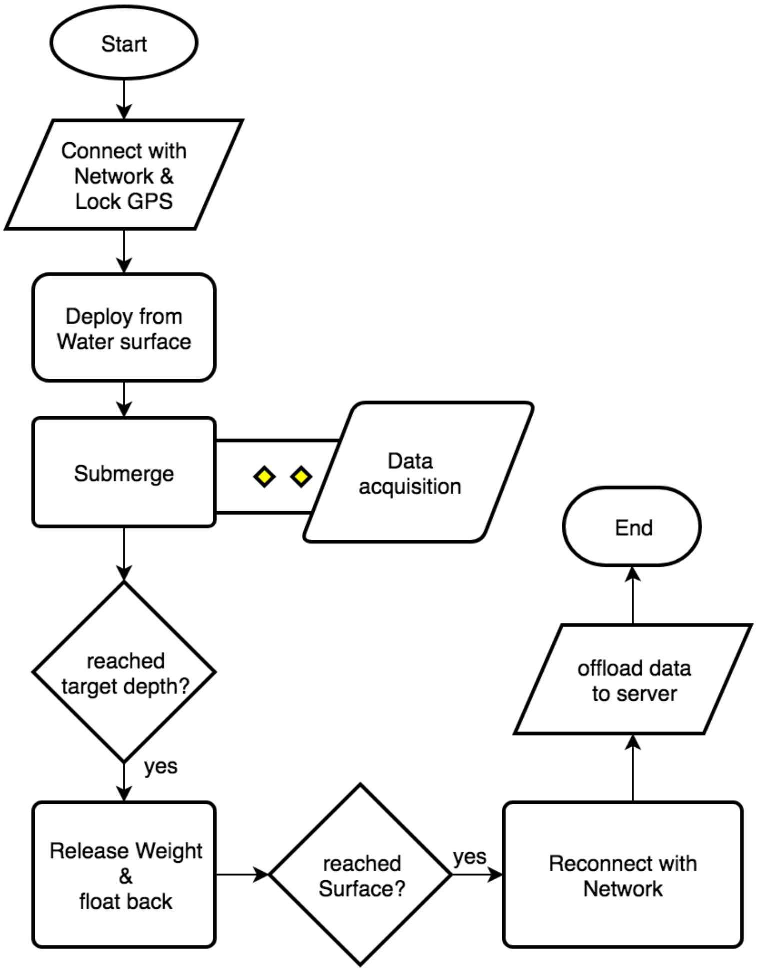


Figure 4.1a Process Flowchart

4.1.1 Experimental Setup

For the demonstration purpose, this experiment was conducted in a water tank considering the fact that the controlled environment would provide us safety to retrieve and debug the system easily in case of failure. A nylon rope was attached to the module for easy retrieval.

Figure 4.1.1a Test Setup

4.1.2 Data Acquisition and Logging

After the CanSub takes readings, the data is buffered to an SD memory card. The text in the file is categorized in columns showing the date and time of data acquisition, location where the monitoring system is deployed, temperature, pH and EC values.

4.1.3 Data Transfer

The sensor nodes and the data mule communicate through an Ad hoc wireless sensor network. The WiFi receiver on the sensor nodes are configured to switch off till the device reaches water surface and wake up when reaches the surface to discover and establish a connection to the data mule. This is for the sensor node to conserve energy.

4.1.4 Data Visualization

As all the data are stored in the cloud they are visible as table format to the users with access credentials.

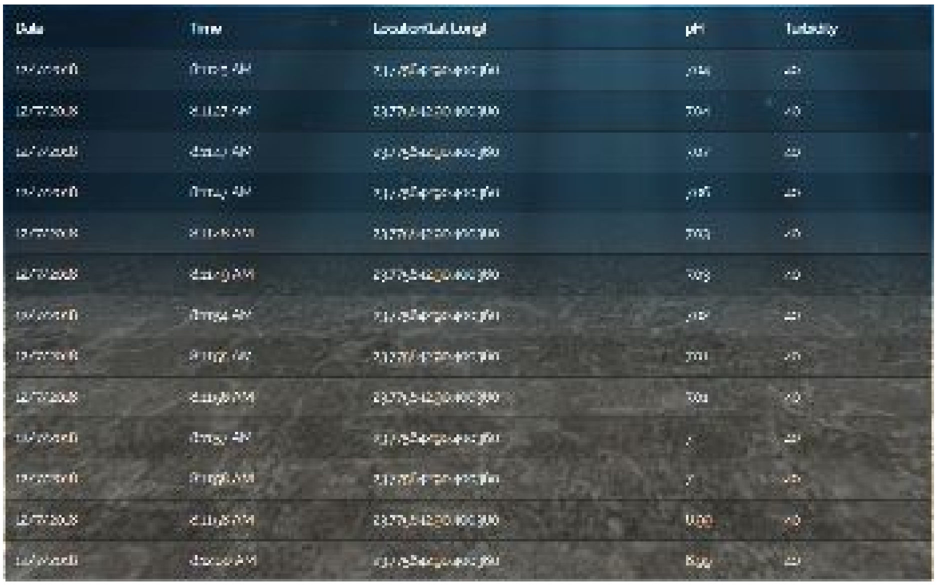


Figure 4.1.43a Data Visualization table (Snapshot of our online dashboard)

Chapter 5 : Conclusion and Future Development Scopes

The cost of water quality monitoring and marine research can be reduced by using portable and diy devices which can be easily developed by students themself.

In this research a low cost and affordable device is built which can be used by students, researchers or even hobbyists to explore underwater. With this device, underwater data can be easily collected and stored for further analysis. Rather than using all the sensor, only temperature, turbidity and pH sensor were used to demonstrate that the device can successfully collect data from underwater at different layers efficiently. The device developed in this research is focused mainly to make it portable and easy to use by students and researchers of even non technical background. It is a small can shaped device where all the circuits are inside an enclosed chamber while the different sensors are outside it. The device build in this research can also be equipped with a Samsung 360 Camera at the top to record underwater panoramic video for subsea or clearwater condition.

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