ECE 4336 - Team 12
Autonomous Boat Monitor
Owner's Manual

Team Members: Michael Stinson, Daniel Lamonte, Chimaobi Omeh, Ikponmwosa Evbayiro, and Fredy Orellana

Date: 4/26/24

Table of Contents

1 Features

The autonomous boat monitor is intended to enhance water pollution monitoring through autonomous water quality data collection. The features of the autonomous boat monitor are:

- 3D Printed Design
- Fully autonomous system
- Object avoidance
- Air Propulsion System (Environmentally friendly)
- System able to navigate under fair to light rain weather conditions
- Line of sight remote control ability to override autonomous system when necessary
- Adjustable water quality data depth collection
- Able to take temperature, pH, total dissolved solids, and turbidity water quality measurements
- Post mission processing data tool to analyze obtain data and identify regions of interest

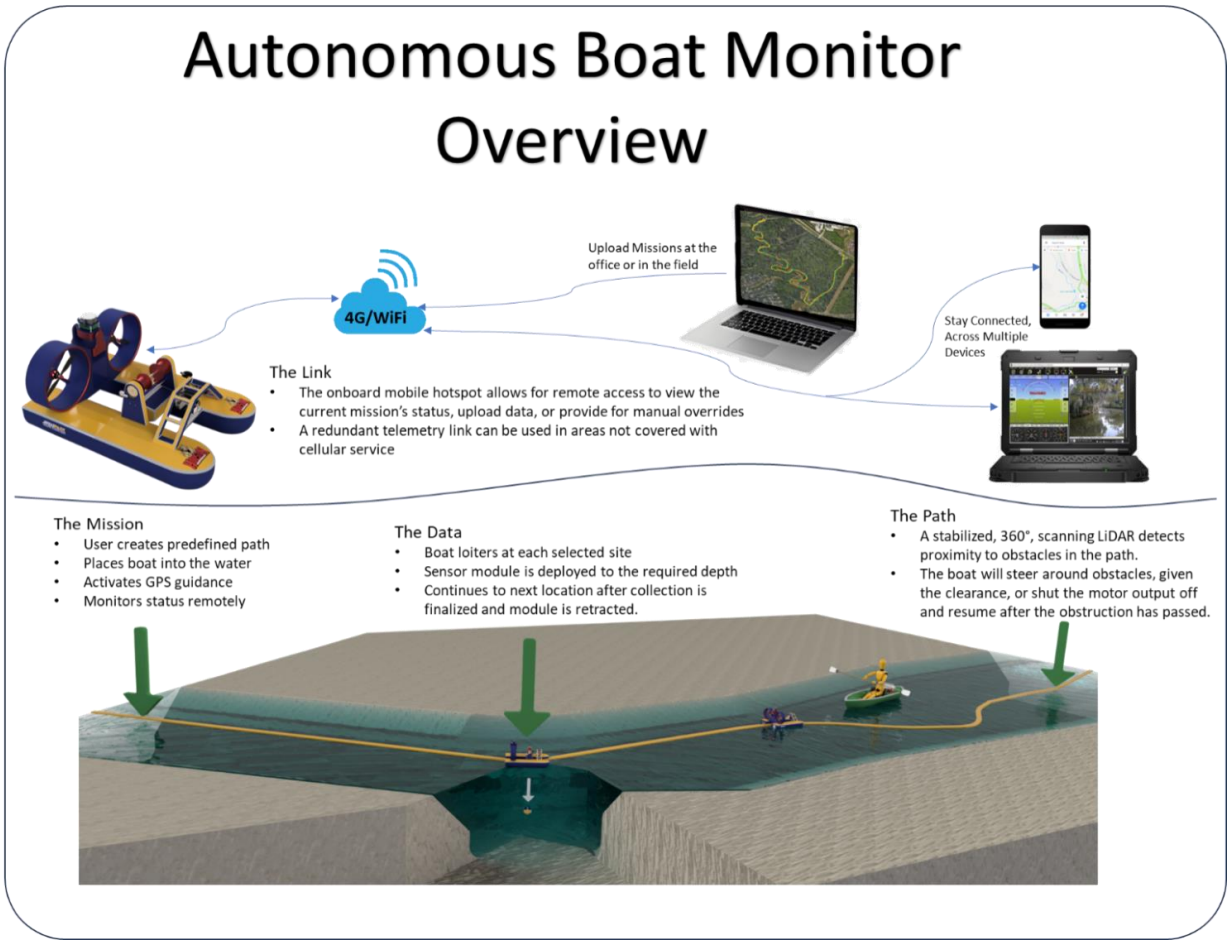

Figure 1: Overview diagram for the autonomous boat monitor

2 Technical Specifications

2.1 Product Specifications

- Autonomous system with object avoidance system
- Remote control ability to override autonomous system with remote control
- System capable of taking Water quality data at:
    - 1 ft for depths above 3ft
    - 1/3 the distance of depths below 3 ft
- Able to take temperature, pH, total dissolved solids, and turbidity water quality measurements
- Post mission processing data tool to analyze the obtained data and identify regions of interest

2.2 Engineering Specifications

- Performance Characteristics
    - Max Speed: 5 m/s (no water current present)
    - Cruise Speed: 1 m/s
    - Max Pivot Turn Rate: 60 Degrees per second
- Environmental Constraints
    - Max Operational Wind Speed: 15 MPH
    - Max Opposing Water Current: 10 MPH
    - Max Lateral Tilt: ±30^{o} Lateral Tilt
    - Optimal Temperature Range: 40^{o}F - 110^{o}F
    - Optimal in clear to no rain
    - Not optimal in heavy fog (LIDAR range max of 10 meters)
    - Heavily cloud cover yields unreliable GPS
    - Not Optimal Indoors due to signal integrity
    - AVOID excessive exposure to light (3D print susceptible to be warping)
    - Fog causes lidar to have less range (10m initally)

3 Safety Instructions

1. Users should be cautious when handling the airboat post-mission as unintentional leaks may occur in the electrical compartment and may result in a short circuit if not handled correctly.
2. The airboat has two spinning propellers and should be handled with care.
3. Properly balance charge the LIPO batteries to 4.2 [V] each, to avoid fires.
4. Remove batteries when working or maintaining the airboat.
5. Avoid hitting obstacles to not puncture the airboat hulls.

4 Part Names

- Structural and Mechanical Components
    - Gimbal platform, roll, for LIDAR
    - Gimbal platform, pitch, for LIDAR
    - Propeller shroud/electrical housing
    - Propeller
    - Access cover, cargo bay
    - Access cover, electrical housing
    - Cable spool, guide
    - Twin-Hull
    - Support brace, hull
    - Support frame, camera gimbal
- Boat Electrical Hardware
    - Power distribution module
    - 360 LIDAR scanner
    - Roll servo, for LIDAR
    - Pitch servo, for LIDAR
    - Raspberry PI 3B
    - Brushed DC gearmotor, Winch
    - Brushless DC motor
    - Flight controller module
    - Electronic speed controller
    - Telemetry radio
    - Camera
    - GPS compass module
    - 3s LIPO batteries
- Water Quality Module
    - ESP-32 microcontroller
    - Temperature sensor
    - Turbidity sensor
    - TDS sensor
    - PH sensor
    - Liquid level sensor
    - 2s LIPO battery

Figure 2 illustrates the structural and mechanical components of the autonomous boat monitor. Meanwhile, Figure 3 provides an in-depth look into the electrical components. In Figure 4, the integration of electrical components within the structural and mechanical framework is showcased, alongside the placement of the laptop ground station.

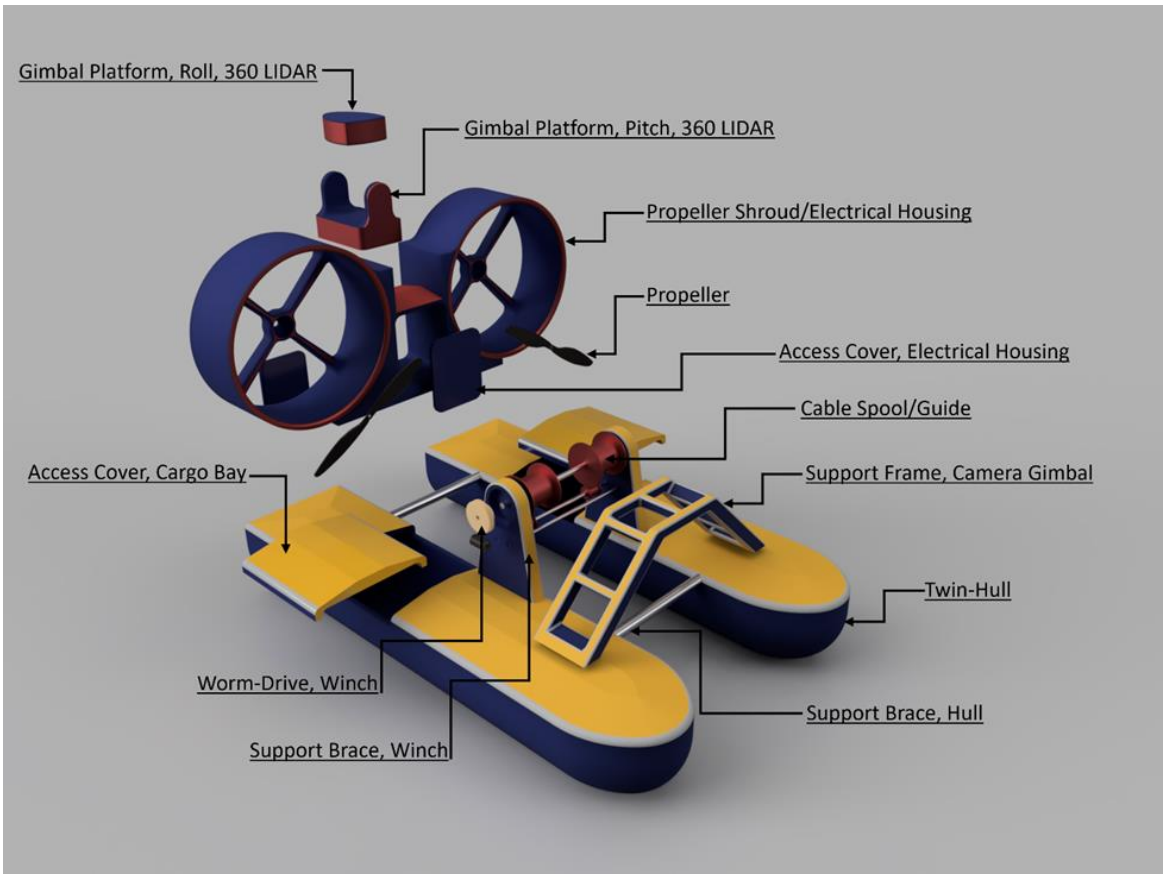

Figure 2: The major structural and mechanical components for the airboat.

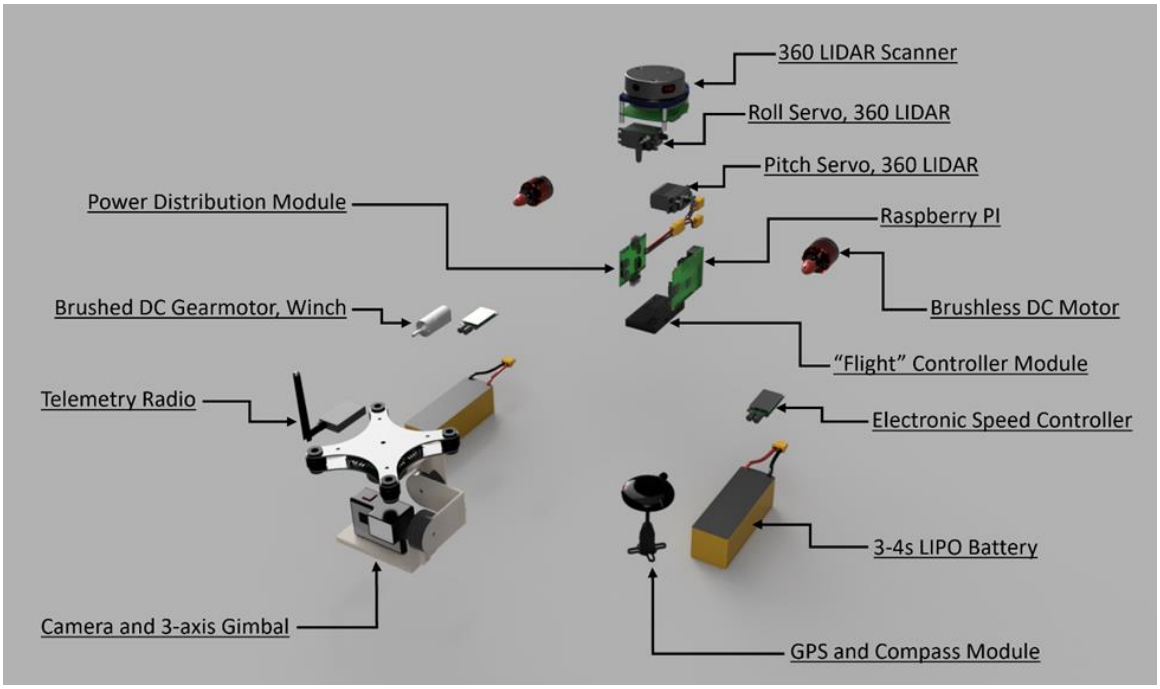

Figure 3 – The major electrical components for the airboat's main functionality.

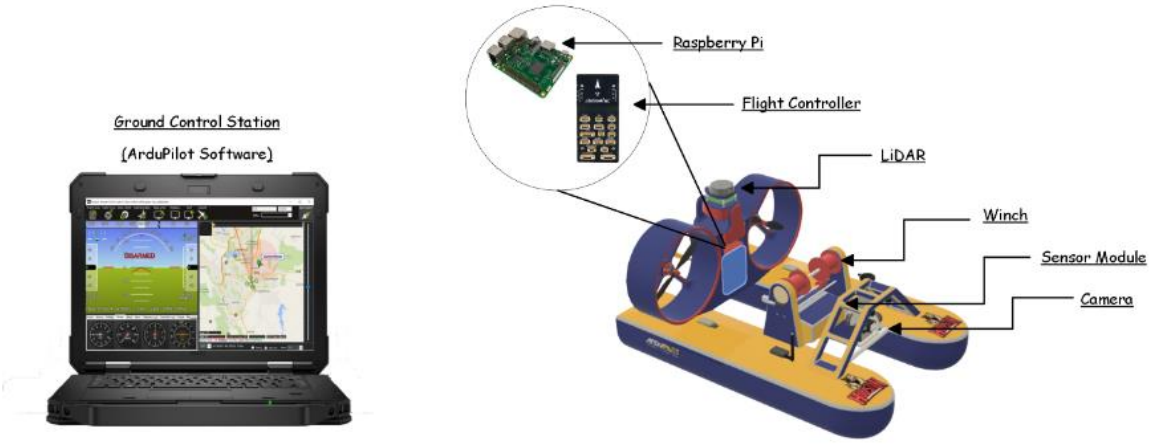

Figure 4 – Integration of electrical and mechanical components along with the laptop ground station

5 Installation & Bring Up

The boat system will have 2 battery connectors, one in each hull, for powering the system. Only 1 battery is required but both can be used to lower consumption of one battery. The battery appropriate for the system will be the Tattu 11.1V (1800mAh, 45C) battery as it has all necessary connectors to be compatible with the system, while also having the correct voltage/power distribution ratings.

Upon activation of the boat, the water quality module will automatically power up and be ready for deployment. To integrate new sensors into the water quality module, users must modify or design a new water quality capsule, as the existing module is specifically configured to accommodate the current pH, turbidity, TDS, and temperature.

6 Operation

6.1 Navigation

The airboat is designed with 2 separate methods of navigation, autonomous mode, and remote mode.

6.1.1 Remote Mode

Using the remote control, power it on (if not done already), switch the SE Button up to arm the boat. When the SE switch is not armed (down) no function of the boat will work, this feature is a fail-safe to make sure the boat isn't receiving input from the remote when powered on or idle. The Reverse and forward movement is toggled by SF, up is to go forward and down is to move in reverse. To control the acceleration of the boat, you will use the left joystick. The left joystick only moves north and south, and the neutral (0 Velocity) point is the most south point, as the most north point is the most acceleration/deceleration on the boat. Steering for the boat uses the

right joystick, it only can move east/west and the neutral position (no turn) is in the center position.

Table 1: Remote control functions

	Arm (SE)	**Direction (SF)**	**Accelerator (Left Joystick)**	**Steering (Right Joystick)**
Down/Left	Off	Reverse	No Movement	Left
Up/Right	On	Forward	Max Speed	Right

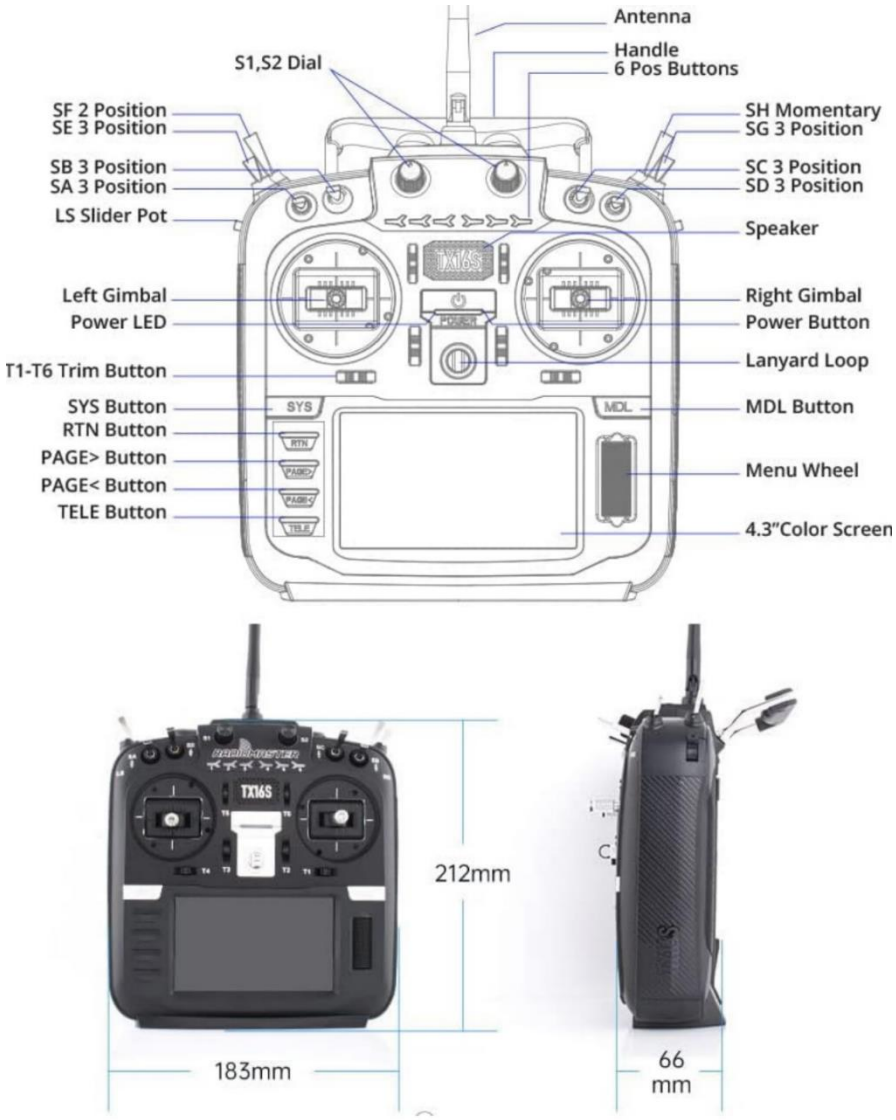

Figure 5: Airboat remote controller.

The remote mode also has sub modes within it to control specific functions of the boat, allowing for extra control or for more automated navigation. The arrow buttons to operate these modes are in the middle of the controller. The modes are manual, acro, linear mode, revolve, loiter, and return. For the standard manual mode, this is like driving a car, it will drift (roll in a car's case) if no acceleration is applied and floating on water this can cause the boat to be taken by currents.

Due to this the acro mode is implemented so the boat is driven like manual but when no input is applied the boat autocorrects itself to stay at the same geographical coordinate. Loiter mode is simply the same as acro modes stand still feature, so the boat will not move and will be stationary at the same coordinate, correcting itself against the movement of water. Linear mode is used to make the boat to stay in a perfect linear path, where the right joystick is disabled, and the boat self corrects itself if it moves east or west. In that mode one can only move forward or backward, being useful in situations of precision. Revolve mode is the opposite of linear mode, where forward and backward movement is disabled and self-corrected to stay in the same coordinate. This mode essentially makes the boat rotate a loiter coordinate, this is useful for necessary situations where turning is required but movement isn't. The return mode is simply an autonomous way to make the boat return to the launch point with the same travel path.

Table 2: Manual controller modes

Modes	Manual (Button 1)	Acro (Button 2)	Linear (Button 3)	Revolve (Button 4)	Loiter (Button 5)	SMART Return
Function	Full remote driving	Full Remote driving, no drifting due to water current	Control disabled in right joystick	Control disabled in left joystick	Control removed; no drifting due to water current	Control removed; Boat returns with the same navigation path
Different kinds of movements	Full movement paths	Full movement paths; no drift	Movement in a linear path	Rotation about a coordinate	No movement paths; no drift	No movement; autonomous control

6.1.2 Autonomous Mode

- Boot up ArduPilot Mission Planner on ground station (PC)
- Click Connect to control boat
    - Must have boat antenna connected to PC
- To Save a Multi Waypoint Mission
    - Go onto the flight planner tap
    - Set the home position (should be a green pin with a circle around it)
    - Click the different points on the map API of where you want the drone to go to
        - Expand the bottom Waypoint tap to be able to configure your waypoints for different purposes,
        - In the dropdown menus on each row, select the command you want
            - Waypoint, loiter, loiter unlimited, or return to launch
            - WARNING: Waypoints you want to take water quality measurements must be on loiter unlimited
    - To save mission, right click, pick file load/save, then pick save WP file
- To Load a Multi Waypoint Mission onto drone
    - Go onto the flight planner tap

- Right click, pick file load/save, then pick load WP file
- Click write WPs on the bottom right of screen

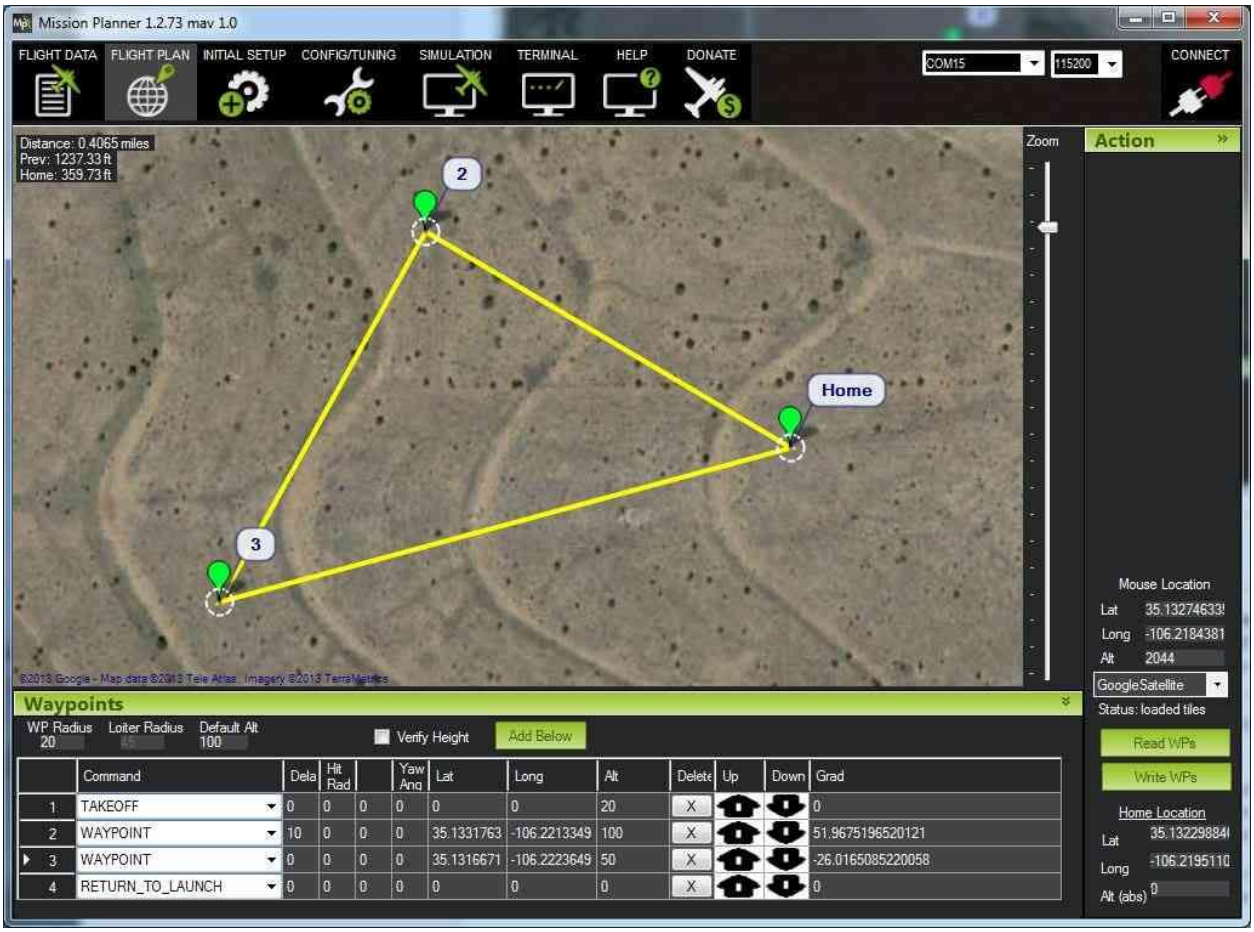

Figure 6: Mission planer mission creator

6.1.2.1 Water Quality Deployment

To deploy the water quality module and gather data, follow these steps when setting up a mission in mission planner: designate the desired data collection zones as loiter unlimited waypoints. As the boat follows these designated waypoints, the onboard computer will pause at each loiter unlimited waypoint. Upon reaching one, it will initiate the deployment of the water quality module to commence data collection. After gathering the necessary data, the onboard computer will prompt the boat's flight controller to proceed to the next waypoint, repeating this process until the mission concludes.

7 Programming

7.1 Autonomous Boat Monitor Computer

The instructions to configure and install all necessary software for the autonomous boat monitor computer are:

1. Flash the boat's computer: Raspberry Pi 3b with Raspbian OS lite 64 bit
2. Connect to the Raspberry Pi through ssh and enable uart
3. Clone down the airboat computer software, click the following for the full autonomous boat monitor Github repo
4. Install necessary libraries:
    a. NOTE: if the python pip installer is not recognized in your Raspberry Pi. Follow these steps
    b. The syntax for installing the necessary python libraries is "pip install library", where library is replaced with whichever library is needed to install. The needed library for the boat computer is: dronekit
5. Lastly, add the airboat.py file to the raspberry pi system scheduler to start execution at startup.

After this configuration, the boat's computer software will automatically start execution upon turning on the boat. The boat's computer will remain idle until a mission is uploaded to the boat's flight controller and the boat is engaged into autopilot, thus starting the mission. Upon engaging the boat's autopilot, the boat's computer will wait until a data collection waypoint is reached. Once at a data collection waypoint, the boat's computer will begin the deployment of the boat's water quality module and acquire the water quality data from the water quality module. Once the data is acquired, it is stored on board on a SD card. The boat's computer will continue this process until the mission is complete.

To incorporate your own custom mission functionality, refer to the dronekit documentation.

7.2 Autonomous Boat Monitor Water Quality Module Microcontroller

1. Download and install ESP-IDF
2. Configure the Arduino library to ESP-IDF. For full instructions, click the following link https://www.youtube.com/watch?v=kioRPsvfyzs
3. Clone down the water quality tool folder, click the following link for the full autonomous boat monitor Github repo
4. Download and include any necessary .h or .c files

7.3 Post Mission Data Processing Tool

The instructions to configure and install all necessary software for the post mission data processing tool are:

1. Clone down the post mission data processing tool folder, click the following for the full autonomous boat monitor Github repo
2. Install miniconda to create your python environment & install the following libraries
    a. streamlit, pandas, pydeck, matplotlib, numpy, & scikit-learn
3. Using the miniconda terminal, cd into the data_processing folder and execute the command: "streamlit run main.py". This will open the tool on your default browser.
4. Select which .csv data file you want to analyze & the anomaly score along with the 3D map graph will be generated.

5. .csv file must be formatted correctly if the user wishes to use their own .csv file and not generated by the water collection process.
6. Order does not matter but capitalization does. For example:

Time	Latitude	Longitude	PH	Turbidity	Temperature	TDS

The post mission data processing tool will read the csv file you select and generate an anomaly score on your data to identify regions of interest. If the sensor flag is 1, then that will be marked as an area of interest. These values will be plotted in a 3D map graph to illustrate the water quality measurements with respect to their coordinates. The input .csv file should be formatted as the example provided in the data_processing/data/fake_data.csv. Figure 7 displays the post mission processing tool.

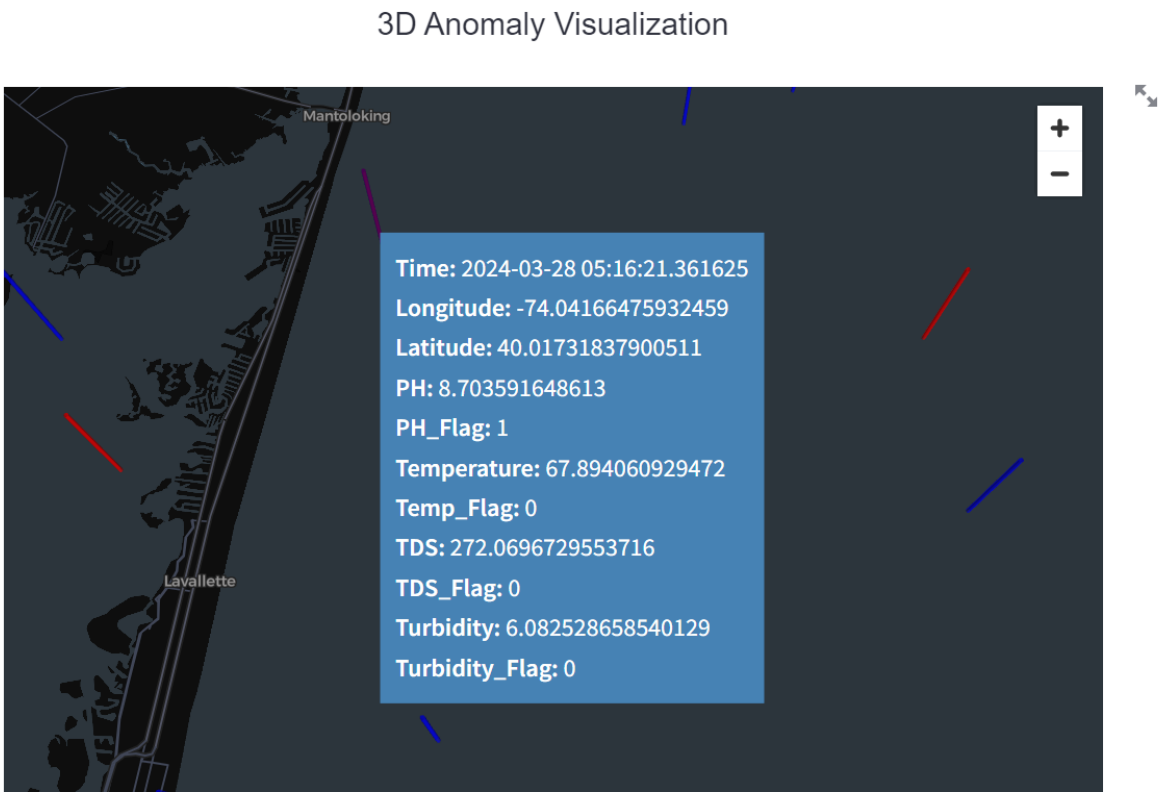

Figure 7: Post mission processing tool display screenshot

8 Maintenance

- Sensor calibration:
  - To calibrate the pH sensor, refer to the following documentation

- For the pH sensor, make sure to cap it when boat isn't deployed with the solution provided by the vendor
- Make sure all seals are clean
- Grease up electrical housing grooves to ensure there are no water leaks
- When storing the airboat, charge the batteries to the storage volts of 3.8

9 Troubleshooting

If connection is lost between the ground station and the airboat during the mission, the boat will perform a smart return to launch. The boat also contains a triggered alarm that will disarm the boat, turning off all motors but still providing power to the airboat flight controller and onboard computer to locate the airboat.

9.1 Onboard Computer and Water Quality Module Connectivity

If raspberry pi is unable to connect to the esp32 socket server. Ensure that esp32 can access the given wireless network.

1. Open the main.c file for the esp32 in Espressif-IDF and enter in the name of the wireless network and the password

```
/* Socket server parameters*/
static char TAG[] = "socket server";
const char* ssid = ""; // Set your WiFi SSID
const char* pass = ""; // Set your WiFi Password
int client_socket; // For the client socket of the raspberry pi
int retry_num = 0; // Tracks the number of times esp32 is unable to connect to access point
```

Figure 8: Network configuration on the water quality module microcontroller

2. Run the program to confirm that the esp32 can connect

```
WiFi CONNECTED
I (3346) wifi:<ba-add>idx:0 (ifx:0, f4:0e:83:9b:dd:45), tid:6, ssn:2, winSize:64
I (3356) wifi:AP's beacon interval = 102400 us, DTIM period = 1
I (4316) esp_netif_handlers: sta ip: 10.0.0.84, mask: 255.255.255.0, gw: 10.0.0.1
Wifi got IP...
```

3. Copy the "sta ip" address printed in green from the step prior to the wqm.py file and set SERVER_IP equal to it.

```
SERVER_IP = '10.0.0.84'
SERVER_PORT = 8001
SLEEP_TIME = 15
OUTPUT_FILE = 'message_log.txt'
```

Figure 9: Network configuration on the airboat computer

4. Run the Python script to make sure that the raspberry pi can connect to the socket server as a client. The raspberry pi and esp32 should be on the same wireless network.

9.2 Failing Sensors

If any of the sensors fail to provide an output open up the sensor module and verify that all of the connectors are secure on the perfboard. Performing a continuity test with a multimeter on the soldered components of the perfboard can ensure that every sensor is connected to power and its output is connected to a pin on the esp32.

9.3 Onboard Computer SD Card

A common problem when dealing with Raspberry Pi products, is the SD cards containing the OS and data corrupting due to sudden loss of power. When this happens, it will be necessary to reformat the SD cards and in the worst case re-flash the OS to the SD card. To avoid this problem, turn off the airboat with the off button, instead of just cutting off power.

10 Regulatory Code

The legality surrounding the use of autonomous watercraft depends on the area of operation and is influenced by the US Coast Guard. For instance, local regulations may prohibit or restrict the use of drones for certain areas and times [1]. Since the team's proposed design will be smaller, slower, and carry fewer than the minimum number of passengers required, the Coast Guard does not consider this project worthy of any noteworthy regulations.

11 Parts List

Table 3 - Bill of Materials for the water quality monitoring airboat.

Group	Description	Qty	Price Ea	Purchased	Web Link
	Boat Electronics				
	Flight Controller, PDB, and GPS	1	$290.99	yes	https://holybro.com/collections/autopilot-flight-controllers/products/pixhawk-6c?variant=43018722508989
	Raspberry Model 3B	1	$48.99	yes	https://www.amazon.com/ELEMENT-Element14-Raspberry-Pi-Motherboard/dp/B07P4LSDYV
	360°, 2D Scanning Lidar Module	1	$90.99	yes	https://www.amazon.com/dp/B09VKZ9YNT?ref=ppx_yo2ov_dt_b_product_details&th=1
	Short Range Telemetry RX/TX	1	$58.99	yes	https://holybro.com/collections/telemetry-radios/products/sik-telemetry-radio-v3
	Long Range Telemetry RX	1	$29.95	yes	https://www.team-blacksheep.com/products/prod:crossfire_nano_se
	3G/4G Hotspot (Telemetry + Video)	1	$59.90	no	https://www.amazon.com/HUAWEI-E3372-Broadband-Unlocked-Network/dp/B013UURTL4
	Brushless Motors (4-piece set)	1	$68.99	yes	https://www.amazon.com/gp/product/B07D9367RZ/ref=ppx_yo_dt_b_asin_title_o03_s02?ie=UTF8&psc=1

ESC for Brushless Motor (4-piece set)	1	$39.99	yes	https://www.amazon.com/Electronic-Controller-Brushless-Multicopter-Quadcopter/dp/B09F3G4KNB?ref_=ast_sto_dp
4s LiPo Battery 5000mAh	2	$44.99	no	https://www.amazon.com/HRB-5000mAh-Connector-Airplane-Helicopter/dp/B06XK8WWX1
USB Webcam	1	$24.20	no	https://www.amazon.com/Microsoft-cancelling-Microphone-Correction-Connectivity/dp/B005BZNEKM?th=1
25kG Hobby Servo	2	$17.99	no	https://www.amazon.com/ANNIMOS-Digital-Torque-Waterproof-Control/dp/B07GJ6ZCVY
2kG Hobby Servo	2	$12.99	yes	https://www.amazon.com/DSPOWER-Profile-Waterproof-Helicopter-Airplane/dp/B0CDGM6C51?th=1
5V Step Down Regulator 3pcs	1	$14.99	yes	https://www.amazon.com/Adjustable-Step-Down-Regulator-Quadcopter-Martian/dp/B07MS1ND5M?th=1
		$879.92		
Water Quality Module				
ESP32 Development Board	1	$15.95	yes	https://www.amazon.com/gp/product/B09BC5CNHM/ref=ppx_yo_dt_b_asin_title_o07_s00?ie=UTF8&th=1
Temperature Sensor	1	$10.99	no	https://www.amazon.com/HiLetgo-DS18B20-Temperature-Stainless-Waterproof/dp/B00M1PM55K
PH Sensor	1	$31.95	no	https://www.amazon.com/Sensor-Arduino-PH0-14-Detect-Electrode/dp/B0946D4RSV
PH Buffer Solution	1	$7.99	no	https://www.amazon.com/BOJACK-Buffer-Solution-Precise-Calibration/dp/B09DCP4HNH
Turbidity Sensor	1	$12.50	no	https://www.amazon.com/KEYESTUDIO-Turbidity-Sensor-V1-0-Arduino/dp/B07Q657288?ref_=ast_sto_dp
Total Dissolved Solids Sensor	1	$11.99	no	https://www.amazon.com/CQRobot-Ocean-Compatible-Scientific-Laboratory/dp/B08KXRHK7H
2s LiPo Battery 450mAh 2pcs	1	$21.99	yes	https://www.amazon.com/GAONENG-450mAh-Battery-Trashcans-Quadcopter/dp/B085C1TVRT
		$113.36		
Control Electronics				
Laptop or Remote Desktop PC	1	N/A	yes	
RC Transmitter	1	N/A	yes	https://holybro.com/collections/rc-radio-transmitter-receiver/products/boxer-radio-controller-m2
Long Range Telemetry TX	1	N/A	yes	https://www.team-blacksheep.com/products/prod:crossfire_micro_tx
SIM for Hotspot, Subscription*	1	*$50.00*	no	https://www.t-mobile.com/cell-phone-plans/affordable-data-plans/hotspots
Assembly				
3D Printer Resin	1	$40.09	yes	https://www.amazon.com/gp/product/B0BV1DH3MN/ref=ppx_yo_dt_b_asin_title_o03_s00?ie=UTF8&th=1
3D Printer Filament	2	$19.99	partial	https://www.amazon.com/eSUN-Upgraded-Filament-Excellent-Adhesion/dp/B0B9MN7TXG
Aluminum Tubing 6'	1	$30.14	yes	https://www.mcmaster.com/6546K52/

10-24 All-Thread, 2'	2	$1.95	yes	https://www.mcmaster.com/90034A011/
Silicon Conformal Coating	1	$25.16	yes	https://www.amazon.com/MG-Chemicals-Silicone-Conformal-Coating/dp/B085G42TGS
CorisionX	1	$30.39	yes	https://www.amazon.com/CorrosionX-Corrosion-Technologies-90102-aerosol/dp/B0CLBNN77R
Solder	1	$6.50	yes	https://www.amazon.com/60-40-Rosin-Solder-Electrical-Soldering/dp/B09D42PF3Q?th=1
30 Gage Silicone Wire	1	$12.99	yes	https://www.amazon.com/gp/product/B01KQ2JNLI/ref=ppx_yo_dt_b_asin_title_o00_s02?ie=UTF8&th=1
14 Gage Silicone Wire	1	$6.88	yes	https://www.amazon.com/gp/product/B017U6PGLO/ref=ppx_yo_dt_b_asin_title_o00_s00?ie=UTF8&th=1
Heat Shrink Tubing	1	$7.77	yes	https://www.amazon.com/gp/product/B00BY8L4W0/ref=ppx_yo_dt_b_asin_title_o05_s00?ie=UTF8&th=1
M2 x 25mm SHCS 100pcs	1	$8.96	yes	https://www.amazon.com/dp/B089JF99KM?ref=ppx_yo2ov_dt_b_product_details&th=1
M2 x 7mm SHCS, 100pcs	1	$5.99	yes	https://www.amazon.com/gp/product/B07PWXMWKJ/ref=ppx_yo_dt_b_asin_title_o05_s00?ie=UTF8&th=1
M3 Button Head Cap Screw Set	1	$11.99	yes	https://www.amazon.com/dp/B0B88LC5H2?ref=ppx_yo2ov_dt_b_product_details&th=1
M2 Nuts, 100pcs	1	$5.49	yes	https://www.amazon.com/dp/B07H3TGLB8?ref=ppx_yo2ov_dt_b_product_details&th=1
XT60 Male and Female Connectors	1	$7.99	yes	https://www.amazon.com/MCIGICM-Female-Bullet-Connectors-Battery/dp/B07DVDKL42
10-32 x 1" SHCS 50pcs	1	$9.99	yes	https://www.amazon.com/gp/product/B09WHX6B9M/ref=ppx_yo_dt_b_asin_title_o03_s01?ie=UTF8&th=1
10-32 x 0.5" SHCS 50pcs	1	$8.99	yes	https://www.amazon.com/gp/product/B09WHXKLXD/ref=ppx_yo_dt_b_asin_title_o04_s00?ie=UTF8&th=1
10-32 Hex Nut, 100pcs	1	$8.28	yes	https://www.amazon.com/Fullerkreg-Machine-Stainless-Bright-Quantity/dp/B078SLFGS5?th=1
Projected Expense for Unlisted Items	1	$100.00	no	
		$371.48		
Software				
			Working	
ArduRover		$0.00	Yes	https://firmware.ardupilot.org/Rover/
MissionPlanner		$0.00	Yes	https://firmware.ardupilot.org/Tools/MissionPlanner/
Raspberry Pi OS (Legacy or Bullseye64)		$0.00	Yes	https://www.raspberrypi.com/software/operating-systems/
DroneEngage		$0.00	In Progress	https://cloud.ardupilot.org/de-install.html

APSync	$0.00	Not Started	https://ardupilot.org/dev/docs/apsync-intro.html
BlueJay	$0.00	Yes	https://esc-configurator.com/
EdgeTX	$0.00	Yes	https://github.com/EdgeTX/edgetx/releases
CRSF TX/RX	$0.00	Yes	https://www.team-blacksheep.com/download/
Yaapu	$0.00	Yes	https://github.com/yaapu/HorusMappingWidget
Projected Total			
	$1,414.76		

12 Citations

[1] “Park Rules — Texas Parks & Wildlife Department,” tpwd.texas.gov. https://tpwd.texas.gov/state-parks/park-information/rules (accessed Nov. 03, 2023).