HMAUV - Highly Maneuverable Autonomous Underwater Vehicle

User Manual

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1 Product Name

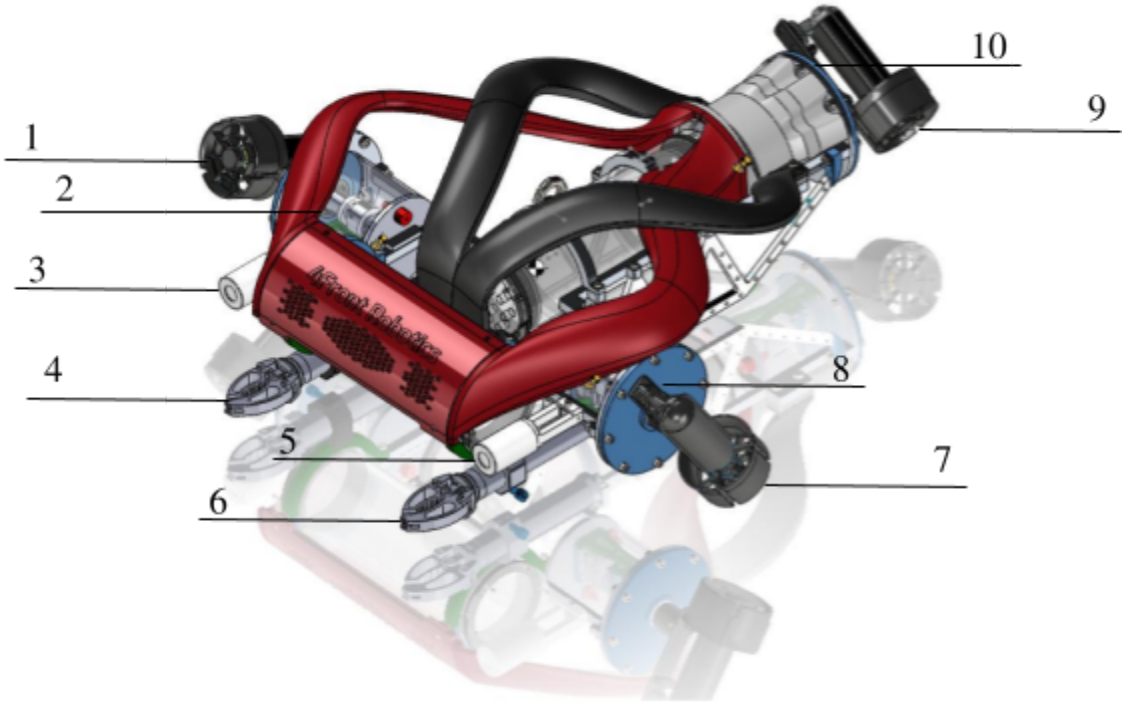
HMAUV - Unmanned Underwater Robot (Version 3)

2 Intended Use

The Robotarium Research Lab at the University of Calgary has been developing an HMAUV since 2014. There have been three hardware vehicle prototypes, each enhancing the previous design. This project aims to develop an improved version of the electronic and software systems for the HMAUV under the supervision of Dr. Alex Ramirez-Serrano.

The Robotarium Research Lab designed this HMAUV to be capable of deploying and navigating within underwater confined spaces (e.g., oil and gas underwater infrastructure, coral reefs, etc.). The main objective of the current design was to be more cost-effective compared to traditional underwater vehicles. The mechanical system was simplified to achieve this goal by implementing a three-thruster configuration. These thrusters provide independent motion control in all six dimensions.

3 Description of the Main Product Elements



1	Right Thruster	6	Left Gripper Arm

2	Right Thruster Servo Motor	7	Left Thruster
3	Right Camera	8	Left Truster Servo Motor
4	Right Gripper Arm	9	Rear Thruster
5	Left Camera	10	Rear Thruster Servo Motor

4 Vehicle Features

The HMAUV - Unmanned Underwater Robot has the following features that enables it to navigate underwater confined spaces:

- Three thrusters to provide the HMAUV with movement and maneuverability in multiple axes of motion.
- Three servo motors for each thruster, to control the tilt of the thrusters and provide 6 degrees of freedom.
- Two grippers that have an open and close state.
- Two front facing cameras.
- GPS tracking system.

5 Technical Specifications

Component	**Rating**
Seabotix Thruster	110W Maximum (19V x 5.8A) and 80W Continuous (19V x 4.25A)
Hitec HS422 Servo Motor	5W (4.8-6V and 0.8A)
Subsea Gripper	108W
Pixhawk 4	12.5W USB Supply
Pololu Motor Controller	15W
HolyBro PM07-V21Board	45W
Raspberry Pi 3B	12.5W USB Supply
BlueRobotics LiPo 4s Battery	14.8V at 15.6Ah

6 Description of the User Interface

The user interface consists of seven different sections to control the underwater vehicle.
The thruster angle sections have the following capabilities:

- Slider that changes the thruster angle for the left thruster, right thruster and tail thruster

The thruster RPM sections have the following capabilities:

- Slider that changes the RPM value for the left thruster, right thruster and tail thruster

The open/close gripper sections have the following capabilities:

- Slider that changes the PWM signal for the left gripper
- Slider that changes the PWM signal for the right gripper

The **Reset State** button has the following capabilities:

- Reset the servo motors to their default angles
- Reset the grippers to a closed state

The **Command Mode** dropdown menu has the following capabilities:

- Only send one command at a time to the components i.e only controlling one element at a time directly through each corresponding slider (Single Command Mode)
- Control multiple components at the same time with multiple commands (Multiple Commands Mode). The user is able to set all sliders before sending commands simultaneously (moving sliders will not send commands as in Single Command Mode)

The **Send Commands** button has the following capability:

- When Multiple Commands Mode is engaged and after all sliders are set to the user's desired values, this button sends all commands to the Pixhawk at the same time

The user interface also displays IMU data from the HMAUV shown on the life of the figure, such as the acceleration and angular speed in the x, y and z direction

7 Safety Warnings

All safety warnings give specific details of the potential danger/warning present and indicate how to reduce risk of injury, damage and electric shock resulting from improper use of the vehicle. Carefully observe the following instructions:

7.1 General Safety Guides

- Before operating the HMAUV, verify that all individuals involved are qualified and are knowledgeable about the vehicle.
- Always practice caution when working with electricity, especially in water.
- Verify that all connections are watertight and secure.
- Keep all body parts away from motors and propellers when operational.
- Ensure all equipment is in good working condition before operating the robot.

7.2 Battery Safety Guides [1]

Lithium-ion batteries have a high energy density and must be treated with care to ensure safe operation and a long lifespan.

- Avoid discharging below 3.0 V per cell (12.0 V total voltage) and never below 2.5 V per cell (10.0 V total voltage)
- Never charge over 4.20 V per cell (16.8 V total voltage)
- Do not puncture, crush, cut, or disassemble
- Do not burn or expose to temperatures above 60°C (140°F)
- Always use a lithium-ion compatible balance charger
- Do not leave unattended while charging
- Do not exceed maximum charge (20 A) or discharge (60 A) rate
- Do not pick up by discharge leads, always handle by gripping battery body.

7.3 Gripper Safety Guides [2]

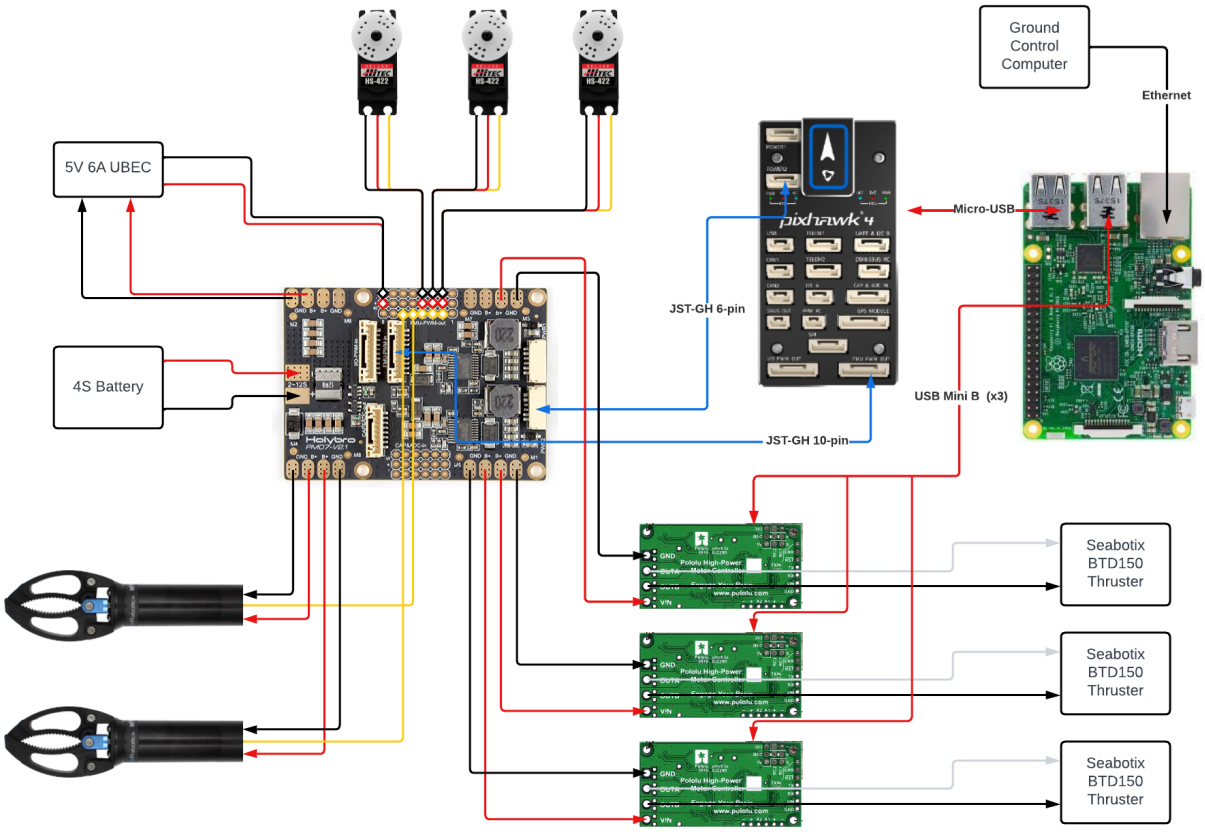
- Keep fingers and other body parts away from the gripper when operating. It’s strong and has the potential to do some damage. Notify other crew members to do the same.
- If the gripper is continuously cycled rapidly for over a minute, the motor may overheat and melt the rotor frame. Do not cycle open and close for over a minute and allow for a proper cool-down between quick cycles.

7.4 Thrusters Safety Guides

- High current bursts of 1 minute or less can be performed as long as the running average current is kept at 4.0 Amps MAX to prevent the motor windings from building up excessive heat.
- Keep fingers and other body parts away from the thrusters when operating.

8 Installation Instructions

The following pin diagram displays the connections and installation for the HMAUV:



9 Software Operation

Installing Python and Packages

To execute the GUI, Python is required to be installed on the GCS. The version used for development was Python 3.8 and is recommended. Python 3.8 can be installed on any operating system from the following link: https://www.python.org/downloads/.

Once installed, the user can use the following command from the command line to install the required packages:

```
pip install package_name
```

The following packages are required to execute the GUI from the GCS:

1. customtkinter (UI components and GUI)
2. numpy (calculations)
3. Pillow (images)

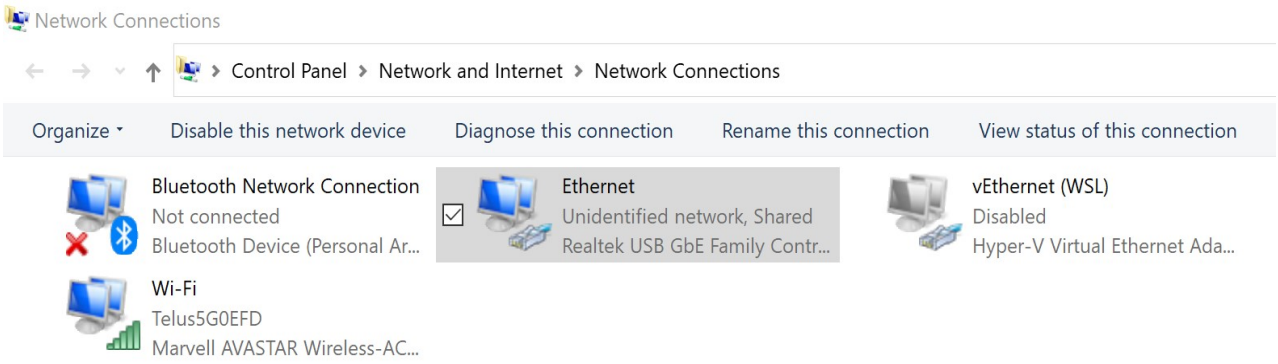
The following packages are required to be installed on the RPi (currently installed):

1. pymavlink (communication with Pixhawk 4 from RPi to Pixhawk 4)
2. smc (control motor controllers, currently inoperable)
3. MAVProxy (MAVLink protocol proxy and can be used as a GCS)

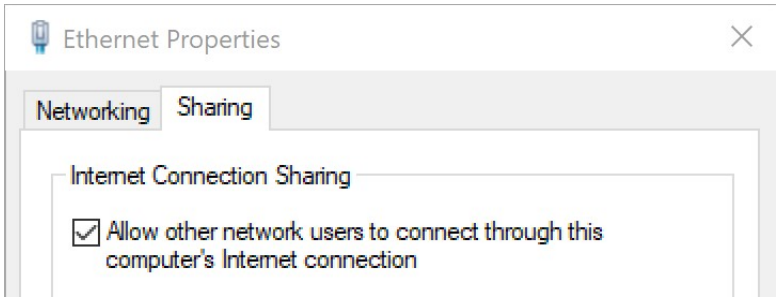
Network Configuration Settings

Since the connection from GCS to the RPi is through a local ethernet connection, the user must change their network to a local ethernet connection. The following example is based on Windows 10:

1. Ensure that the RPi is connected to the GCS using an Ethernet cable. If a USB to ethernet adapter is used, the adapter must be disabled under network connections
2. If connected to Wi-Fi, then disconnect from Wi-Fi
3. Go to network connections settings (displays ethernet, Wi-Fi, Bluetooth, etc.) On Windows, this is Control Panel > Network and Internet > Network Connections



4. Right click on the Ethernet connection or go to “Ethernet properties” to enable “Internet Connection Sharing” by allowing other network users (RPi) to connect through the GCS internet connection locally



SSH Into the RPi From the Command Line

Once the packages are installed, open a command line and SSH into the RPi with the following command:

```
ssh raspberrypi
```

Input the password which is the following:

```
raspberry
```

Set Mavlink Version From the SSH RPi Command Line

After SSHing into the RPi, the MAVlink version must be set to version 2.0, this can be done by entering the following command into the SSH RPi command line:

```
mavproxy.py --mavversion=2.0
```

Once the module has been executed, enter Ctrl + C to terminate the Mavproxy.py program that is currently running.

Execute Model.py From the SSH RPi Command Line

Execute the Model.py file to initiate the server connection which waits for the GCS to connect:

```
python Model.py
```

Execute Main.py From the GCS Command Line

Extract the zip file and place the “DeepFlightENEL500-main” folder in the local directory of your choice on the GCS. Then, open a second command line for the GCS. Now, change directories (simply dropping the file into the command line and using the **cd GUI** command or using the **cd** command in general) such that the path is similar to the following:

```
your_local_path\DeepFlightENEL500-main\GUI
```

Lastly, the file that executes the GUI is named Main.py, we can execute this by entering the following command in the the second GCS command line:

```
python Main.py
```

If successful, the GUI should now be running. The communication follows a client-server architecture so it is important to execute Model.py before Main.py. This is because Model.py acts as a server that awaits the connection from Main.py, which is the client that makes requests to the autopilot.

10 Maintenance Information

11.1 Charging the battery [1]

The Blue Robotics H6 PRO Lithium Battery Charger is recommended for use with this battery. It is preconfigured with the correct settings to safely charge all Blue Robotics batteries.

To charge this battery using the Blue Robotics H6 PRO Lithium Battery Charger, change the cell count option to 4S (14.8V) and start the charging task. Make sure to keep it away from flammable materials and always monitor the battery as it charges, discontinue charging if it becomes hot or changes in appearance. You can view the full H6 PRO Charger user instructions here.

If you are not using the Blue Robotics H6 Pro Lithium Battery Charger, use the following instructions:

Only use a lithium-ion/polymer compatible balance charger to charge this battery, attempting to use another type of charger will damage the battery. The charger should have a balance charge function and be able to balance a lithium battery with 4 cells (4S). Make sure to keep it away from flammable materials and always monitor the battery as it charges, discontinue charging if it becomes hot or changes in appearance.

Use your charger's lithium polymer (LiPo) charging setting and set it to 4S (14.8V). The LiPo setting will charge the battery to the fully charged voltage of 4.20 V per cell, 16.8 V total battery voltage. We recommend balance charging/balancing the battery at every charge to keep all cells at the same level of charge. If quick charging is a priority, balancing should be done at least every third charge. Cells that are not properly balanced may become overcharged. An overcharged cell is unstable and can lead to battery failure, property damage, or personal injury.

This battery can be safely charged at up to 20 A, which will bring it back up to full charge in about one hour. However, we recommend charging at 10 A regularly in order to maximize capacity and lifespan. A summary of the correct charging settings is provided below.

Lithium-ion Battery (14.8V, 15.6 Ah) Charge Settings			
Charge Profile	LiPo	**Number of Cells**	4S
Nominal Voltage	14.8V total / 3.7V per cell	**Fully Charged Voltage**	16.8V total / 4.2V per cell
Recommended Charge Rate	10 A	**Maximum Charge rate**	20 A

11.2 Discharging the battery [1]

After charging, connect the XT90S discharge plug to your vehicle, and the battery is ready to use. This battery does not have a built-in battery management system to prevent over discharging. The battery voltage must be monitored to prevent discharging below the minimum safe voltage level of 12 V.

The battery can sustain a constant discharge of up to 60 A, and up to 132 A in short bursts of up to 10 seconds. Make sure to never short the battery discharge plug or plug it into a circuit that may be shorted.

Note that the maximum safe discharge rating is dependent on adequate cooling to keep the battery below 60°C. If used in an enclosed space without airflow, constant current draw must be decreased appropriately to keep the battery at a safe temperature.

Temperature can be monitored with the integrated 3435 K negative temperature coefficient (NTC) thermistor, which has a resistance of 10 kΩ at 25°C.

11 Glossary

ESC - Electronic Speed Control

FXTI - Fathom X Tether Interface
GUI - Graphical User Interface
HMAUV - Highly Maneuverable Autonomous Underwater Vehicle
IO - Input/Output
LiPo - Lithium-Ion Polymer Battery
MVC - Model-View-Controller
PCB - Printed Circuit Board
PWM - Pulse-Width Modulation
UI - User Interface
RPi - Raspberry Pi 3B
SSH - Secure Shell Protocol

12 References

[1] "Lithium-ion battery (14.8V, 15.6AH)," *Blue Robotics*. [Online]. Available: https://bluerobotics.com/store/comm-control-power/powersupplies-batteries/battery-li-4s-15-6ah/. [Accessed: 30-Mar-2023].

[2] "Newton Subsea Gripper," *Blue Robotics*. [Online]. Available: https://bluerobotics.com/store/rov/bluerov2-accessories/newton-gripper-asm-r2-rp/. [Accessed: 30-Mar-2023].