# Appendix A: User Manual

Team 4: AUVSI RoboSub

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# Summary

Hello and welcome to the 2016-2017 RoboSub team. Your project is a continuation of years of work, and is very complex in nature and function. The goal of this report is to equip you, the new RoboSub team, with the tools needed to operate and improve on the existing RoboSub built by previous years of work.

The goal of this project is to create an autonomous underwater vehicle that can meet the requirements to compete in the annual AUVSI RoboSub competition. Every year, the rules of the competition change, but they always maintain a sense of similarity to the previous year's rules. Your job will be to modify the existing systems of the sub to meet the new requirements and perform the tasks assigned by the new rules released for your year's competition. One qualification that remains throughout every year is that your sub must be able to pass through a validation gate in order to even be qualified to compete. Another few basic requirements are that it must be able to follow a marker from task to task, and maintain its depth and heading. In regards to these requirements, the RoboSub you will inherit is already equipped with a few capabilities. The sub should be able to:

- Maintain depth and heading
- Identify orientation and color of objects in front of the camera
- Identify particular shapes
- Maintain pitch
- Maintain yaw
- Drop a marker
- Fire a torpedo
- Operate a pneumatic claw

As previously stated, your job will be to build off of these working systems to improve on the sub and make it operate efficiently. Additionally, there are a few essential parts missing on the sub that are needed to make it capable of competing. These will be discussed in detail in this report. The AUVSI website can be reached by the following link.
[http://www.auvsifoundation.org/foundation/competitions/competition-central/robosub](http://www.auvsifoundation.org/foundation/competitions/competition-central/robosub)

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# 1. RoboSub Components

There are many components to the RoboSub, and it can be a bit difficult to keep track of every part, where it goes, and how to connect it. This manual will list all of the major components to the sub, and give the general layout of all the systems and subsystems currently employed. Currently, there are two RoboSubs. The previous model was too buoyant for it's size, so a smaller, less buoyant sub was designed for the competition. The larger sub is the previous model, and it has been rendered unusable. Some of the waterproof ports were taken from it for the new sub, and parts of the frame were also taken for the new sub frame. The old sub can be considered as a source for spare parts should anything go wrong with the new sub. All the components listed here will be on the current sub model, but be aware that the old model is there.

## 1.1 List of Components

### 1.1.1 Hull and Frame

The hull of the sub is made from stainless steel and holds the electrical components. It has a box design, shown in Figure 1, that is 18" x 12" x 5" . The lid of the sub is made from plexiglass that is held shut by 6 toggle latches mounted onto the sub and an aluminum plate on top of the plexiglass edges. The seal between the hull body and the lid is made from a waterproof window sealer that runs around the edge of the hull. The sub is sealed at each screw port, and has two types of wiring ports on the sides. The red ports, shown in Figure 2, are cable penetrators that just run the wires through and are sealed by marine epoxy on the inside. The two black ports on the bottom rows are SEACON ports, shown in Figure 3, that connect waterproof wire connectors on the outside and inside of the sub. Ideally, all ports would be SEACON ports, but that was above the project budget and transferring ports from the old sub to the new model damaged a few of the ports that were attempted.

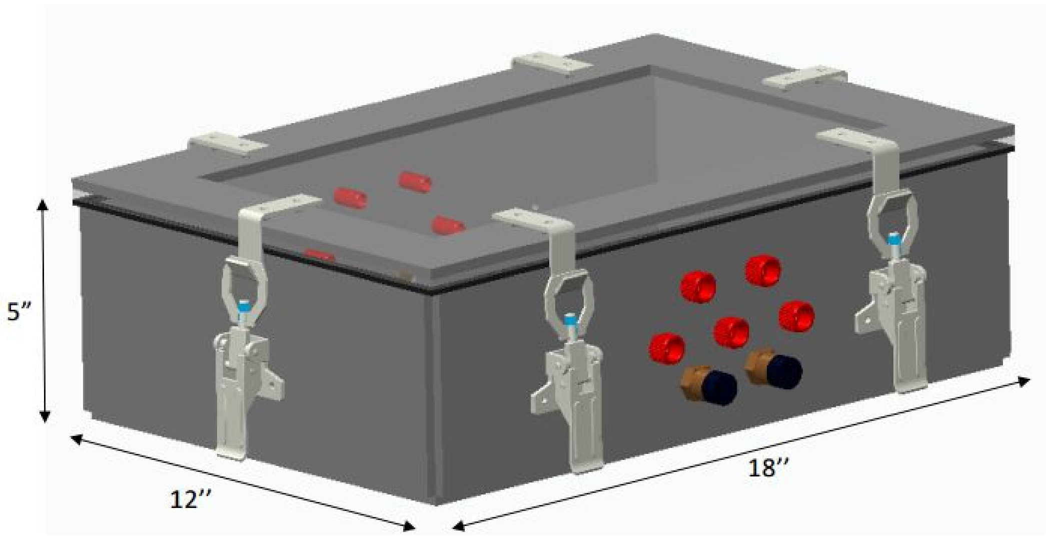


Figure 1. Hull Design

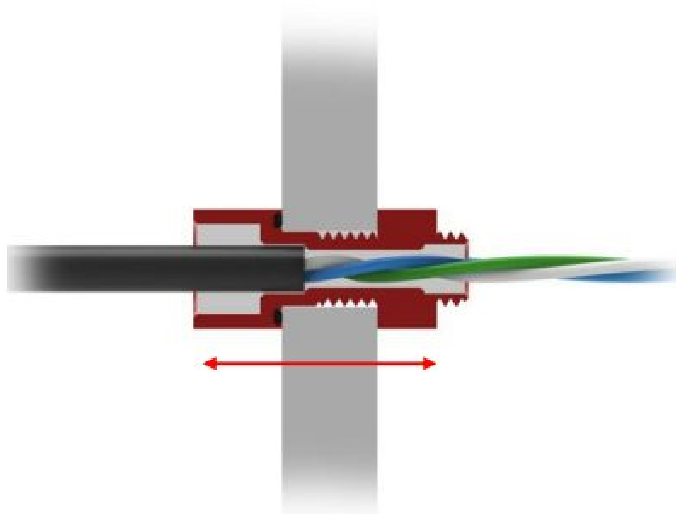

Figure 2. Cable Penetrators

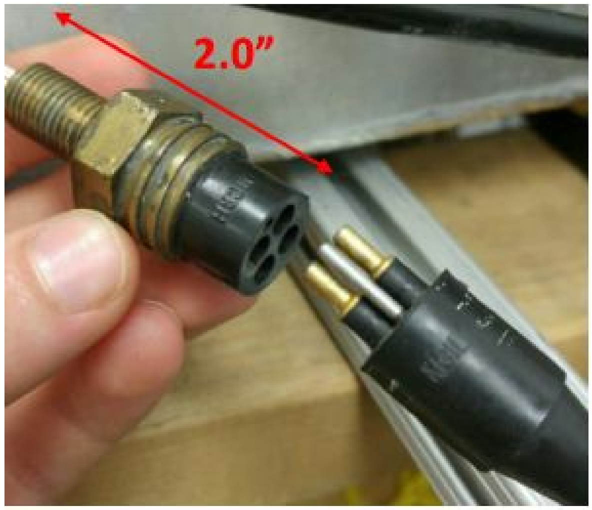

Figure 3. SEACON ports

The frame of the sub is made from 8020 aluminum bars that are connected together to make a rigid body. The frame allows the mounting of the hull, thrusters, and all external subsystems.

1.1.2 Thrusters

There are six Seabotix thrusters on the sub for vertical and horizontal movement. Four of the thrusters are mounted in a vertical position and are used to keep the sub under the water. The other two thrusters are positioned for horizontal movement. It is worth noting that when the thrusters are run under water, they retain a little water, and will spit it out the next time they are turned on. Because of this, it would be good to run the thrusters once more after the sub is taken out of the water so that if the thrusters are tested indoors, water doesn’t get everywhere.

1.1.3 Zotac

The sub is equipped with a Zotac ZBOX CI520 Nano Plus as the main processing unit. The Zotac holds the main processing power, and interacts with all systems and subsystems of the sub. It has wireless capabilities, even though wireless access is not allowed in the competition. It can also be accessed remotely by an ethernet cable to screenshare with a laptop during testing. The operating system running on the Zotac is Ubuntu.


Figure 4. Zotac

1.1.4 Arduinos

The sub also has an Arduino Mega and 2 Arduino Unos. The Arduino Mega runs the 6 thrusters. One of the Unos is used to receive data from the depth sensor. The other Uno is used to run the marker dropper and the pneumatic system connected to the torpedoes and claw. If you aren't familiar with Arduinos, they are very sensitive to electrical circuits, and even a spark from your hand can fry the board, so care should be taken when handling the Arduinos.

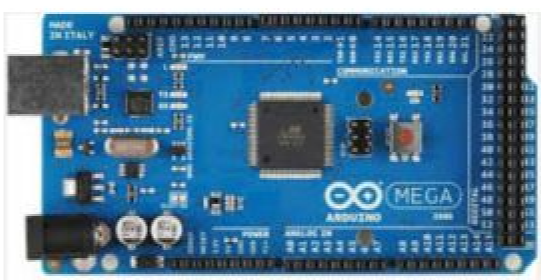


Figure 5. Arduino Mega


Figure 6. Arduino Uno

1.1.5 Motor Controllers

There are 3 Canakit motor controllers connected to the Arduino Mega that run the thrusters on the sub. They are all the same, and send signals to 2 thrusters each.

Figure 7. Motor Controller

1.1.6 Inertial Measurement Unit

The sub has a Sparkfun 9 DOF Razor intertial measurement unit (IMU) that is connected to the Zotac by a FTDI Basic Breakout Board. The wires connecting the IMU to the breakout board are soldered and shouldn’t ever need to be changed. The IMU holds the subs:

- Accelerometer
- Gyroscope
- Magnetometer

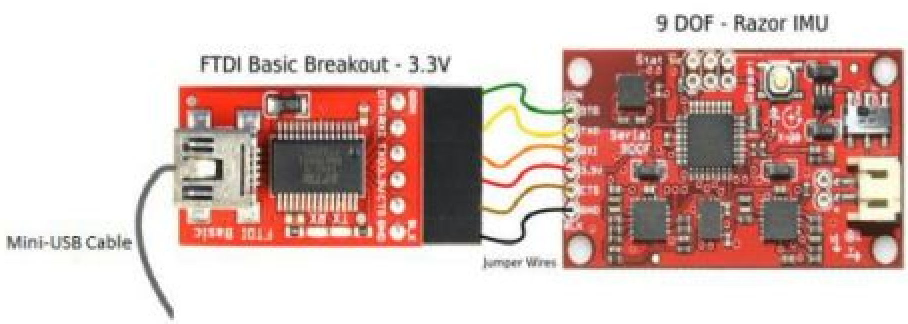


Figure 8. IMU

1.1.7 Depth Sensor

For sensing depth, the sub has a Keller America Levelgauge pressure sensor. This is mounted to the bottom of the sub, and connected to one of the Arduino Unos.

Figure 9. Depth Sensor

1.1.8 Cameras

There are two Logitech C615 Webcams mounted to the sub. One looks in front of the sub, and one looks below the sub. Both are set in a waterproofed casing and connected to the Zotac by Seacon connectors.


Figure 10. Camera

1.1.9 Compressed Air System

The sub has a compressed air tank and tubing to run the claw and the torpedo actuators. It can be seen in the bottom left of Figure 11.

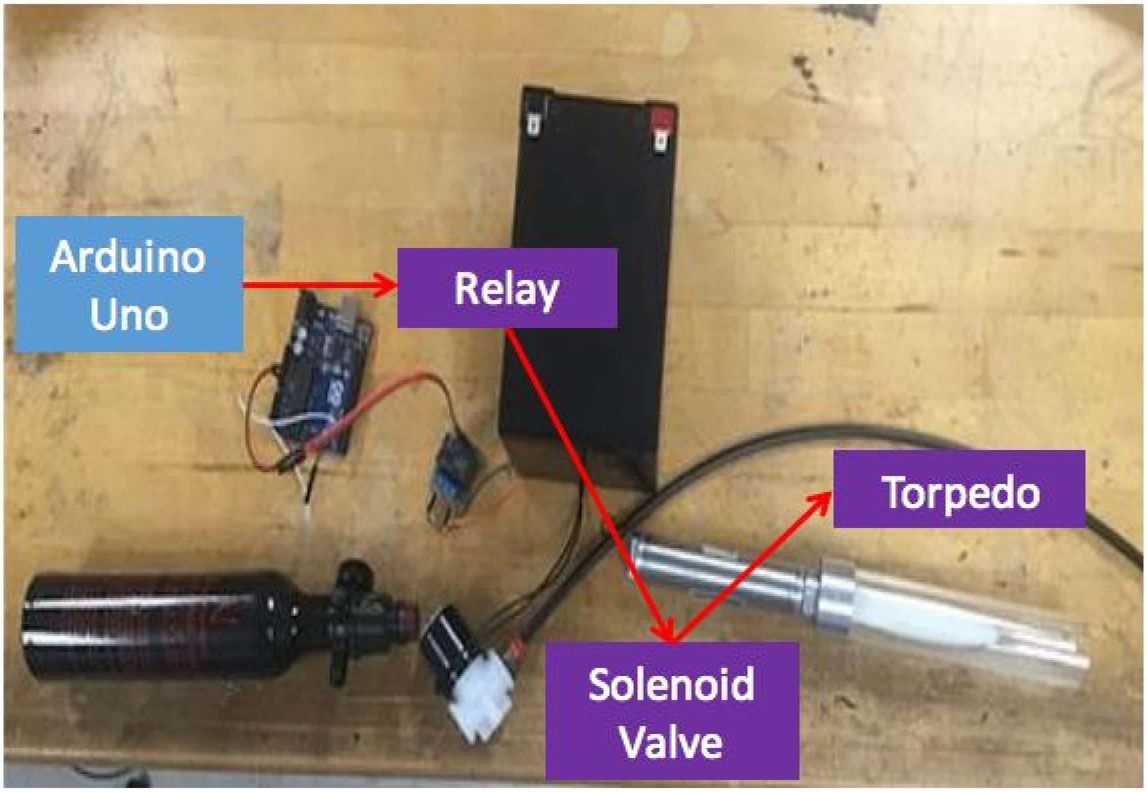

Figure 11. Air Tank and Torpedo System

1.1.10 Claw

The sub has a pneumatic claw mounted to the front of the frame. It has two ports for air; one opens the claw and the other closes the claw.


Figure 12. Claw

1.1.11 Torpedoes

The sub also has two torpedo firing mechanisms mounted by the front camera on the front of the frame. The torpedo and pneumatic firing mechanism was shown in Figure 11 with the compressed air tank.

1.1.12 Marker Dropper

The sub has a marker dropper run by a waterproof servo motor. The marker dropper holds two spherical markers that can be dropped by the turning of the motor.


Figure 13. Marker Dropper

1.1.13 Batteries and Chargers

There are three batteries on the sub powering the different systems. A universal laptop battery powers the Zotac. The Arduinos, cameras, and IMU also draw power from the Zotac current. This is a new battery and should last for quite some time before needing to be replaced. The second battery is the depth sensor battery. This battery only powers the depth sensor, which hardly uses any charge. Because of this, it should never need to be replaced and should never really need to be recharged either, as long as it is only used to power the depth sensor. The third battery is a lithium ion battery pack that is used to power the thrusters. This is a large battery pack wrapped in black shrink wrap.

1.1.14 Electrical Boxes

The majority of the circuits in the sub have been placed in two black electrical boxes. These condense the usage of space within the sub and help keep everything neat and organized. One of the larger boxes has fans in it. Due to the nature of the code running on the sub, and the actual charge used in the circuits, these fans shouldn't really be necessary, and may possibly end up creating more heat by the power they draw than they dissipate with the air they circulate. They were added as a bit of a personal touch by one of the electrical engineers, and have an on/off switch to keep them from always being on and drawing excess power. They should really never need to be used, but be aware that they are present.

# 2. Setup

The sub has many parts and many connections. Most of the wiring should not need to be tampered with, as the systems are already connected and running. If you should need to change the connections or wiring for any reason, TAKE PICTURES AND DOCUMENT. With all the wires that are present, if something is undone without proper documentation, it could take forever to find where it goes again. Be smart, and take pictures of how everything is set up before you go and pull things apart.

## 2.1 Major Systems

### 2.1.1 Connections

The Zotac, the main CPU, is at the top of the hierarchy of connections. The two cameras and three Arduinos are all connected to the Zotac through USB ports. The MPU interfaces with the microcontrollers for communication. The communication with the microcontrollers then takes the information that is received to control subunits such as the thrusters, torpedoes, or depth sensor. Through mini-USB port, the IMU is also connected to the Zotac.

The Arduino Mega is directly connected to the Zotac by UART serial link. This is done through the USB ports between the two components. The Arduino Mega is responsible for connecting to the each of the three motor controllers. In turn, these motor controllers each have two thrusters to control. There are a total of six thrusters which receive voltages from the motor controllers to control the amount of thrust they provide. A total of six pins are needed on the Arduino Mega for the motor controllers which will allow the PWM signals to be be received for the thrusters.

There is one Arduino UNO that acts as the main microcontroller for the depth sensor. The analog pins are utilized to allow the data to be passed and received between the components. Both the Arduino UNOs are connected to the Zotac by UART serial communication link.

The other Arduino UNO is responsible for controlling and connecting to the marker dropper and actuation valves. The actuation valves will assist with the torpedo firing system and the gripper mechanism. This UNO was added to extend the amount of tasks that the sub could complete.

### 2.1.2 Beginning Operation

The components and breadboard are connected with a Male to Male Breadboard Jumper Wires Ribbon Cable. The pins are labeled with a specific color that helps with connecting the correct pins with placements on the breadboard. Most of the connections are set and doesn't require any changes. There are recommendations that the connections do not be removed unless a picture is taken.

### 2.1.3 Safety Precautions

Some of the safety precautions to take are related to the components that are placed inside of the sub. Most of the important components, such as the motor controllers and Arduinos, have been placed inside of a box. The purpose of this box is to protect the components. Placing the motor controllers or Arduinos directly on the bottom of the hull could potentially cause the components to become dysfunctional.

Another safety precaution to take is to ensure that the sub is waterproof before submerging the sub with electrical components into water. If precautions are not taken, all of the electrical components could be ruined.

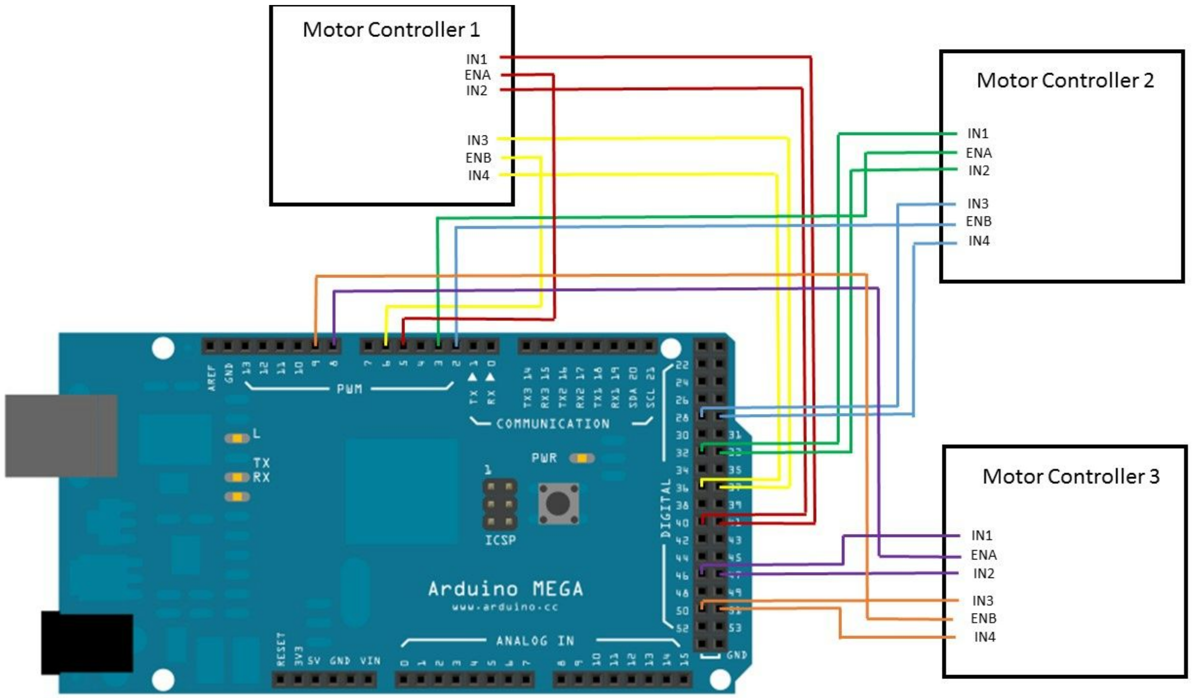


Figure 14. Arduino Mega Connections

## 3. Operation

This is the section about how to run code on the sub and actually get it to operate. There are many bugs, and there is a huge mass of code that even we don't fully understand, as it is a culmination of years of work on the sub. While not every system will work as desired 100% of the time, there is a good foundation on which to build on. This section will give the basics on running the main parts of the sub.

## 3.1 Getting Started

### 3.1.1 Turning on the Zotac

Once the Zotac is plugged in, push the power button. The Zotac has just been turned on. There shouldn't be a password to log on, however if for some reason one is called for, the user name is robosub and the password is robosub.

### 3.1.2 Running the sub out of water

Now you are ready to run the code! In the second tab, type ./ColorDetection. This should open the two camera windows. One may be hiding behind the other, so don't worry if you only see one at first. Now in the first tab, type ./RoboSub_Control_v2. And that's it, the RoboSub should be running! It takes a couple seconds for the thrusters to come on while everything is initialized.

### 3.1.3 Run in the Pool

When Running in the pool, it will all be performed through screen sharing (detailed in 3.1.5) and of course will need to have the lid sealed. It is recommended that you always run the code at least once before tightening the lid, to ensure you have plugged everything in and turned all the batteries on and such.  The code that is currently compiled is designed to get the sub to go through the gate, until killed by the person sharing screens. In order for it to do so, the diver needs to aim it at the center of the gate. For best results, the diver should keep the sub aimed correctly for just a second or so once it starts descending so that its starting heading is not messed up.

### 3.1.4 Canceling the Code

Normally the sub is supposed to run autonomously, and thus must shut down on its own. But when testing it is often most convenient to just run until you have gained all you wanted to gain. In that case, the sub can be killed with control+C in the first tab, like a normal program. However, to stop the thrusters (if they were on), you must then run ./RoboSub_Control_v2 again and kill it quickly. This is because the last values that were sent to the Arduino are still there. You will notice one of the first that things that happens in the DMCS is stopThrusters(), which is why it is actually the second run that stops them. You could probably write your own handler for control+C using SIGINT that stops the thrusters if you want.

### 3.1.5 Screen Sharing

Obviously, you cannot connect the monitor or keyboard while in the pool. This is why the wireless capabilities are essential in this sub. You can share screens with it to remotely access the Zotac. The steps for connecting with a mac via wifi are as follows:

1. Turn on the Zotac. (It assumed you left it to auto-login)
2. Connect both the mac and the Zotac to the same wi-fi (using your phone as a hotspot will also work, and it shouldn't use any data)
4. Open Finder.
5. Look for "robosub's remote desktop. Click on it. It may take a little while for it to show up.
6. Click "Share Screen..." in the top right.
7. If it asks, the password is robosub.

Now you should be able to navigate the Zotac with your Mac. Since it is running Ubuntu, some of the keyboard shortcuts are different (such as command+c not being copy), so keep that in mind. There is some lag, and you periodically lag out (with a little "Wired network Disconnected - you are now offline" box in the top right corner). This should not require you to reconnect though. Just wait a couple of seconds and control should be returned to you. If it works right, you theoretically never need a monitor, keyboard, or mouse.

#### 3.1.6 Running Subsystems Through Arduino

The torpedo, and marker dropper have been implemented on the arduino boards. In order to run them, the arduino IDE must be opened through the sudo command. By opening the serial monitor, data can be applied manually.

# 4. Troubleshooting

As time progresses, more and more bugs show up in the code, little things go wrong with the sub, and parts give out. This section gives explanation on how to fix known problems, and what new issues might come up when working with the sub. This is in no way an all inclusive section of everything that may be encountered, but it is a start for the major problems that may arise.

## 4.1 Common Issues

### 4.1.1 Thrusters

One of the thrusters had its shroud fall off in previous years. Because the thrusters are rather expensive (past the RoboSub budget), the shroud was glued back on in an attempt to remedy this, since all thrusters must have a shroud or covering for the competition. It is not very stable, and should be monitored constantly. If a new budget allows, a replacement thruster would be better than trying to salvage the old one.

### 4.1.2 Image processing

The new Zotac that was purchased for this sub was bought because it didn't rely on a fan for cooling, and because of how compact it was. However, while the new Zotac contains a newer processor, because of its compactness, the new i3 processor operates at 1.5 GHz, while the former operated at 2.2 GHz. Because of this, when the camera s used, it outputs an error citing anywhere from 1-4 "extraneous bytes" after a certain position. As far as our code is concerned, this is just a nuisance as opposed to actually causing problems for the sub.

One other nuisance is that as the code works now, the camera is not exited properly. This causes an error by trying to run the same code twice. The workaround for now is to restart the Zotac and it will run then.

The last problem that I can forsee is that there are about 5 different image processing files, all named the same, and for the most part all copies of each other, once the sub can be tested underwater, the necessary files can be determined and the duplicates can be deleted in order to prevent confusion with such

4.1.3 Y-Axis Movement

There are a few tasks that would run more smoothly, or be easier to accomplish if the sub had lateral movement capabilities. The old sub needed 4 thrusters to keep it under water, but the new sub is neutrally buoyant on its own, so some of the thrusters can most likely be diverted to achieve movement in the y-axis. This would benefit the task completion process greatly.

4.1.4 Waterproofing

Since they sub contains so many electrical components, it goes without saying that it must be waterproof. The tricky part is ensuring that it stays waterproof so that no accidents happen. The cart that the sub is on can be very shaky when transporting the sub. Because of this, some screws could be worked loose or seals could be compromised over time and excess of vibration. It is recommended to test the sub with little or no electrical components in it first to ensure proper seals, then add back the circuits. Screws should be tightened every now and then with a the appropriate size screwdriver to maintain