FAMU-FSU College of Engineering
Department of Electrical and Computer Engineering

EEL4911C – ECE Senior Design Project I

CONCEPTUAL DESIGN REVIEW

Project title: **Autonomous Underwater Vehicle – Robosub**

Team #: 04

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EEL4911C – ECE Senior Design Project I

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Project Executive Summary

Team Robosub is producing an Autonomous Underwater Vehicle, affectionately called a Robosub, to represent the Florida A&M University – Florida State University College of Engineering (FAMU-FSU CoE) and compete at the Association for Unmanned Vehicle Systems International (AUVSI) Robosub competition. This system is being developed according to the guidelines published by the competition ruling committee with an anticipated completion date of April 2012; the competition takes place in San Diego in July 2012.

Currently, the system consists of five major components: the **Hull / Frame**, supporting the peripheral sub-systems, the **Interior Hull**, housing the electronics; the **Electronics**, containing the decision making portion of the Robosub; the **Mechanical Sub-systems**, such as the torpedo launcher and marker dropper; and the **Electrical System**, controlling power expenditure of the all systems on the Robosub. These systems are used in tandem to create an autonomous underwater vehicle (AUV) capable of completing all the tasks required by the competition for the duration of the competition.

Team Robosub's AUV is designed with modularity and cost-effectiveness in mind and will achieve the competition tasks by employing a **motor system** (for movement); a **torpedo launcher** (to strike objects underwater); a **visual system** (for object recognition); a **grabber / dropper** (to grasp and release objects); a **hydrophone** (for underwater ping detection); a remote kill switch (to terminate vehicle operation); and a **inertial measurement unit** (to capture attitude).

Engagement of this inter-disciplinary design will be completed by six highly qualified engineers from both the Electrical and Computer department and the Mechanical Engineering department at the FAMU-FSU CoE. Team Robosub endeavors to deliver a cost-effective and efficient design that not only meets but exceeds the competition requirements and is firmly committed to completing the project within the aforementioned timeframe.

Table of Contents

1 Introduction

Team Robosub is developing an autonomous underwater vehicle to compete at the AUVSI Robosub competition and to represent the FAMU-FSU College of Engineering. This underwater vehicle will have all the required provisions of such a system, including, vision, senses, a main controller board, and the necessary periphery systems. Backed by a solid team of six engineers from the College of Engineering, this project is destined to be a great success.

This document is organized into four major sections: **System Design**, **Design of the Major Components**, and **Risk Analysis**, and **Administrivia**. The *System Design* contains an overview of the entire system along with the equipment that will be used in each system (there are many). *Design of the Major Components* contains an in-depth description of the various components of the AUV. Following each description is the *test plan* that will be used to verify correct performance. The *Risk Analysis* section demonstrates Team Robosub's capability to foresee future problems with the AUV and contains mitigation strategies to avoid the consequences of these risks. Finally, the *Administrivia* section contains the Schedule and Budget Estimate to which the team will be constrained.

1.1 Acknowledgements

The design team would like to thank Dr. Bruce Harvey for his helpful advice in regards to the electrical and computer engineering aspects and considerations of the AUV design, Dr. Chiang Shih (ME advisor) for his helpful advice regards to the mechanical engineering aspects and considerations of the AUV design, Harris Corporation for their generous $3,000 contribution to the execution of this project, and the FAMU-FSU College of Engineering for their $4,433 investment in the project, as well as facility resources. It is our honor to represent our sponsors and advisors throughout this project by producing a magnificent autonomous underwater vehicle that will win the competition.

1.2 Problem Statement

According to AUVSI, the autonomous underwater vehicle designed and built must be able to complete an obstacle course consisting of the following tasks:

Gate: The AUV should pass through the gate.

Buoys: The AUV should strike two of the three buoys (Red, Green, and Yellow) in the given order.

Box Crossing: The AUV should navigate through a box defined by PVC and imaginary sides (i.e. not all sides have physical boundaries).

Drop-in-bin: The AUV should drop two markers in the correct bins (four total bins). Each bin will have a distinct symbol or object which will need to be sensed and deciphered.

Torpedo: The AUV will need to fire two torpedoes (at a safe speed) through certain cut-outs of a PVC structure.

Surface-and-Recover: Guided by a specific acoustic ping signal, the AUV must position itself under a designated octagonal region on the surface of the water. After the vehicle has completely surfaced within this designated region, the AUV must successfully recover a specified object. Thereafter, the AUV must navigate to the second octagon. After the vehicle has completely surfaced within the second designated octagonal region, the AUV must release the object.

In order to successfully complete the mission tasks described above, in addition to being capable of general maneuverability, depth control, and stability control, the RoboSub will need to be equipped with several various sensory devices capable of detecting not only the surrounding environment, but also the dynamics of the vehicle itself. This intelligence information will need to be sent to control

1.3 Operating Environment

The AUV will be operating at the SSC SD TRANSDEC Facility, which houses an anechoic saltwater pool. The facility is located in San Diego, CA, and the water is obtained directly from the Pacific Ocean. The underwater obstacle course will be arranged in a region with a maximum depth of 16 ft. The temperature of the water is expected to be between 70 – 75 °F, with calm winds/currents. The practice facility that will be utilized to test the components of the AUV, as well as the end product, will be the nearby FSU Morcom Aquatics Center, which has granted the design team permission to set up replicated obstacle course environments and test the AUV at depths of up to 17 ft.

1.4 Intended Use(s) and Intended User(s)

The designed and constructed autonomous underwater vehicle is intended for the specific use of competing in the RoboSub Competition in San Diego. However, the end product and experiences gained will provide insight into the design of autonomous submarines for potential use in the Navy or other real-world applications, and will also provide the design team with further experience in regards to the proper execution of an engineering project from beginning to end.

While the intended users of this AUV are the design team, future potential users of the device that the team derives, or particular design features of the device, are people engaging in rescue operations and underwater marine researchers.

1.5 Assumptions and Limitations

1.5.1 Assumptions

1. The AUV will be completely autonomous/
2. There will be a clearly identifiable kill switch to shut down the AUV.
3. The vehicle will operate in a salt water pool.
4. The device will be battery powered.
5. The autonomous system will detect color, shape, and sound.
6. The AUV will have hoist points so that it can be slug and lowered into the water.

1.5.2 Limitations

1. The AUV will be less than 6ft x 3ft x 3ft in size.
2. The vehicle will be less than 85 pounds.
3. The device has 15 minutes to complete all tasks.
4. The current project budget is $7,433.
5. The vehicle must be operating successfully by the end of the 2011 Spring semester.
6. The AUV must utilize a ARM processor/controller.
7. The markers on the AUV will not exceed 6.0in x 0.5in x 0.5 in.
8. The battery will not have an open source voltage exceeding 60VDC.

1.6 Expected End Product and Other Deliverables

Team Robosub will deliver a complete autonomous underwater vehicle capable of completing the tasks listed by the competition ruling committee. This Robosub will be able to autonomously navigate underwater using a combination of a main control unit, computer vision system, and a guidance system.

Additionally, the AUV will be augmented with periphery systems that enable the AUV to complete the competition tasks, such as grasping a marker, launching a torpedo, and locating a pinger in the water. The competition also calls for a video and paper that details the team's submission. This and the other mentioned deliverables have an expected delivery date of April 2011 (before the term ends).

2 System Design

2.1 Overview of the System

The AUV has an open frame that supports peripheral subsystems, such as the grasp / release mechanism, and a centrally-located, water-tight hull that houses the electronics, such as the BeagleBoard-xM. The design is almost completely symmetrical in order to produce a more robust vehicle that is not only less susceptible to disturbance forces but is also easier to stabilize and maneuver. The buoyancy requirements of the competition were met by using Pro/Engineer to make detailed analysis of the buoyancy and center-of-mass. Adjustments were made to the design in order to yield a product with the desired density slightly less than that of salt water (i.e. ≈ 0.03665 lbs/in^3 for the density of the AUV versus ≈ 0.03703 lbs/in^3 for the density of salt water), and a total weight of ≈ 93 lbs—under the 110 lbs limit, resulting in the projected requirement of slightly under 1 lb of vertical thrust force in order to maintain a constant depth, yet still maintaining a positive buoyancy greater than the stipulated minimum of 0.5% of the vehicle's weight when the kill switch is engaged and the thrusters are shut down. Furthermore, the system's projected center of mass is located almost directly in the center of the vehicle in the x-y plane, and slightly below the geometrical center along the z-axis, which will yield a more naturally stable vehicle when underwater. The grasp/release mechanism, pressure vessel end caps, acrylic hull dimensions, camera enclosures, and frame dimensions all underwent design modifications leading up to these derived target mass property values, and have yielded a more reliable, intelligently designed AUV that is ready to begin construction.

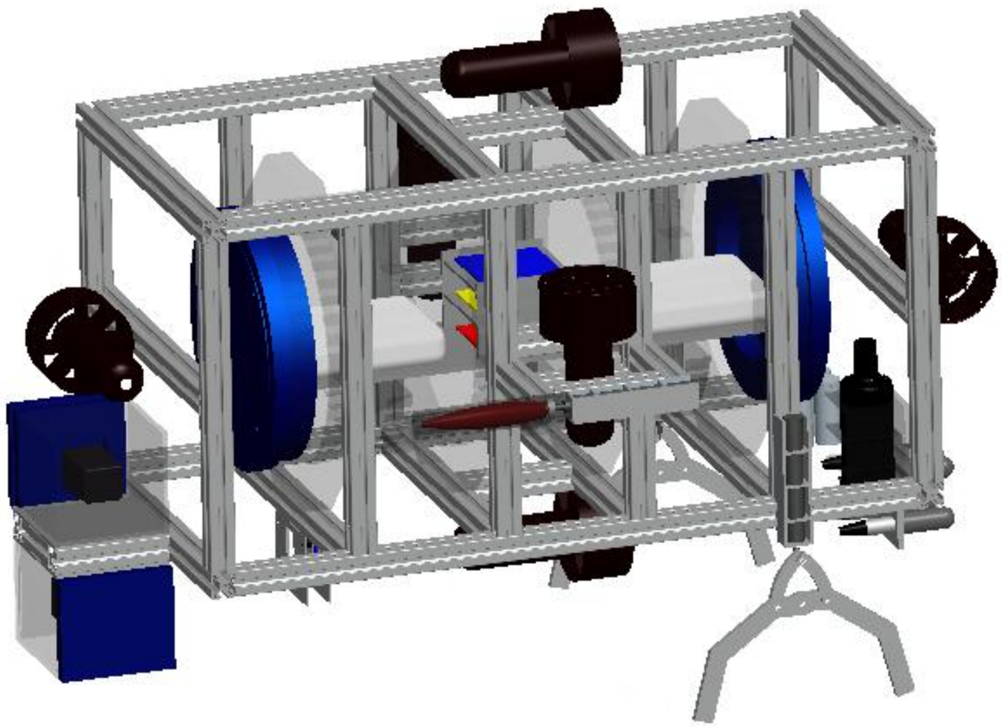

Figure 1: Angled View of AUV Design. Here the inner hull, housing the electronics, and the frame, housing the peripheral components, can be clearly seen.

2.2 Major Components of the System

2.2.1 Hull / Frame

A versatile, rectangular 80 / 20 T-Slotted aluminum frame will be used to support the peripheral subsystems (detailed below), the acrylic hull, and the acrylic transparent camera enclosures each housing a Logitech C615 web camera. The frame has all the necessary custom attachments for each of the external components of the AUV.
A cast acrylic tube with custom aluminum end caps will be used for the hull. It will be located at the center of the frame and serves as the heart of the AUV.

Components

- 80 / 20 T-slotted aluminum

2.2.2 Interior Hull

The interior of the hull will support the two lithium-ion battery packs, as well as the Arduino Board, BeagleBoard-xM, inertial measurement unit (IMU), and potentially the h-bridge motor controllers for the thrusters. It will simultaneously be designed to efficiently and effectively dissipate heat away from the electronics and into the surrounding salt water environment.

2.2.3 Electronics

The electronics consist of three major components: the main controller unit, computer vision, and the guidance system that all interact to control the AUV.

Main Controller Unit (MCU)

Regarded as the "brain" of the AUV, the main controller unit coordinates the multiple tasks required by the competition. It communicates with the guidance system and received input from the computer vision system to make sure that tasks are completed. It monitors the vehicle state in the Mission Control program.

Components

- 1x Beagleboard xM

Computer Vision (CV)

Regarded as the "eyes" of the AUV, the Computer Vision module provides the Main Controller with information regarding the navigation of the AUV and the tasks in the obstacle course.

Components

- 2x Logitech C615 Webcam

Guidance System

Regarded as the "senses" of the AUV, the guidance system monitors the vehicle's orientation, depth, acceleration and reports it to the various subsystems of the AUV. It also controls the thrusters by using the on-board pulse width modulator.

Components

- 1x Arduino Uno board
- 1x IMCL Low Cost Submersible Pressure Sensor
- 1x Phidget Spatial 3/3/3
- 4x Sensortech SQ26-01 hydrophone

2.2.4 Electrical System

Voltage Regulator Board

A DC to DC converter that converts the 14.8V battery input to 5V or 3.3V for the Beagleboard and the Arduino board.

Components

- 1x LM22676 switching voltage regulator
- 1x LM22675 switching voltage regulator

Power Supplies

Two 14.8V lithium-ion polymer batteries provide the power for the entire electrical system of the AUV.

Components

- 2x Lithium-ion polymer batteries

Kill Switch

A waterproof kill switch will be implemented to shut off the power supply to the AUV upon actuation, thus causing the vehicle to naturally rise to the surface in case of a program error or need to restart the program. A waterproof (marine-grade) mechanical switch might be used and fixed to a corner of the frame—away from the thrusters and mechanical subsystems. However, this has yet to be finalized, and further research on this component needs to be done and a kill switch implemented (either electrical or mechanical) prior to any underwater general maneuverability tests.

2.2.5 Mechanical Subsystems

Vehicle Propulsion

Thrusters will be used and strategically located to provide general maneuverability to the AUV along and about each axis. These thrusters will be able to intake PWM signal, thus providing the ability to implement stability, velocity, and depth control algorithms which will use the individual thrusters, or pairs of thrusters as the sole outputs. The thrusters are highly energy dense, simple to implement, and easy to mount to the vehicle

CO2 Distribution System

The pneumatic system will initiate mechanical motion in the grasp/release mechanism and the torpedo launcher subsystems. The current design of the CO_2 distribution system calls for a primary compressed CO_2 tank, a pressure regulator, solenoid valves and a compact network of thin tubing; this is a updated design of the original pneumatic system. Use of a secondary storage tank has been removed from the design as it has been deemed unnecessary. The compressed CO_2 tank will be connected directly to a pressure regulator which will reduce the supply pressure to a desired operation pressure. The solenoid valves will be housed in an open containment and will be connected to the pressure regulator via the thin tubing. From the solenoid valves, these tubes will be directed to the two respective mechanical subsystems.

Grasp / Release Mechanism

The grasp/release mechanism will serve to grasp the rescue object above the first located pinger during the competition, and then release the object once the vehicle has located the second pinger and surfaced. It will be connected to the CO_2 distribution system and will grasp or release the object upon actuation of the respective pair of solenoid valves via the microcontroller.

Marker Dropper

The marker dropper sub-system was inherited from FAMU-FSU 2010 Robosub team. An Aluminum housing and parabolic channels will contain the servomotor as well as the two stainless steel spherical markers to be dropped. The mechanism will be placed towards the front of the vehicle, behind the cameras. The servo arm will prevent the markers from dropper prematurely, and upon actuation via the microcontroller, it will rotate in either direction, thus releasing each marker individually upon command. This mechanism will serve to fulfill the task that requires the AUV to drop markers in designated drop-in bins.

Torpedo Launcher

The torpedo launchers will utilize mechanical motion initiated by a pneumatic system to perform a desired task. The key components of the system are the cylindrical barrel, disengaging cap, double-acting air cylinder (i.e. no spring return), air cylinder mount and cylindrical piston attachment. Successfully completing the task calls for two torpedoes; therefore, identical torpedo launchers will be developed and located on opposite sides of the vehicle for symmetry and stability. Each cylindrical acrylic barrel will have a diameter slightly larger than the maximum diameter of the torpedoes, thus providing a low-friction guide to increase launch accuracy. Each torpedo launcher will be controlled by two independent solenoid valves, allowing for the torpedoes to be fired individually.

2.3 Performance Assessment

Previously delivered by Team Robosub, the Robosub Needs Analysis and Requirements detailed the expected Needs and Requirements of the AUV. The performance of the AUV is addressed by mapping that document to the current state of the project. Elements that have been addressed will be shown as well as elements that are pending completion.

2.3.1 Needs

Section / Requirement ID	Capability Definition	Relevant Section in Report
RC2.2.1	The vehicle must operate autonomously (no external/ remote control).	3.1: Mission Control
RC2.2.2	The AUV, and any parts connected to it, must submerge and remain submerged once the vehicle has embarked on its mission.	3.5: Hull / Frame
RC2.2.3	All electronics must be preserved in a waterproof environment.	3.5: Hull / Frame
RC2.2.4	The AUV must have a remote kill switch (in case of an emergency) which, when activated, causes the vehicle to rise to the surface of the water.	Work in progress.
RC2.2.6	The device should have onboard subsystems which enable the AUV to successfully complete the course tasks.	3.1: Mission Control
RC2.2.6.1	[Gate] The AUV should pass through the gate.	3.7: Vehicle Propulsion
RC2.2.6.2	[Buoys] The AUV should strike two of the three buoys (Red, Green, and Yellow) in the given order.	3.8.4:Torpedo Launcher
RC2.2.6.3	[Box Crossing] The AUV should navigate through a box defined by PVC and imaginary sides (i.e. not all sides have physical boundaries).	3.3: Computer Vision

RC2.2.6.4	[Drop-in-bin] The AUV should drop two markers in the correct bins (four total bins). Each bin will have a distinct symbol or object which will need to be sensed and deciphered.	3.8.3: Marker Dropper
RC2.2.6.5	[Torpedo] The AUV will need to fire two torpedoes (at a "safe" speed) through certain cut-outs of a PVC structure.	3.8.4: Torpedo Launcher
RC2.2.6.6	[Surface-and-Recover] Guided by a specific acoustic ping signal, the AUV must position itself under a designated octagonal region on the surface of the water. After the vehicle has completely surfaced within this designated region, the AUV must successfully recover a specified object. Thereafter, the AUV must navigate to the second octagon. After the vehicle has completely surfaced within the second designated octagonal region, the AUV must release the object.	3.4.5: Hydrophone

2.4 Design Process

2.4.1 Significant Milestones

1. Completed and Watertight Tested Hull, Frame, Camera Enclosures, and SEACON Connector Installation (12/16/2011)
2. Thrusters Installed on Frame and General Maneuverability/Control Obtained (01/03/2012)
3. CO_2 Distribution System Installed on Frame and Integrated with the Electronics (02/21/2012)
4. Grasp/Release Mechanism Installed on Frame and Integrated with the Electronics (02/26/2012)
5. Torpedo Launchers installed on Frame and Integrated with the Electronics (02/26/2012)
6. Marker Dropper Installed on Frame and Integrated with the Electronics (03/05/2012)

2.4.2 Computer Vision (CV)

2.4.2.1 OpenCV selected as image-processing library

During the brainstorming phase of this project, research was conducted on the Computer Vision module of other teams that competed in the RoboSub competitions in previous years. Team SONIA (first place, 2011), NC State, Cornell University and University of Rhode Island (URI) all used OpenCV to implement the Computer Vision module. The University of Rhode Island used MATLAB for previous competitions; however, OpenCV in C++ significantly improved performance. Furthermore, OpenCV is available on a multitude of platforms such as Android, Windows, Mac OS X, and Linux and is compatible with a great number of USB webcams. Considering all the benefits of OpenCV and the documentation of OpenCV on the BeagleBoard, it was decided to use OpenCV as the image-processing library for the Computer Vision module of this project.

2.4.2.2 Logitech C615 Webcam selected as primary CV hardware

Regarding the hardware components for the Computer Vision module, most teams used actual computers with Dual- and Quad-core CPUs; however, the team will implement the image processing module using the BeagleBoard xM onboard Digital Signal Processor (DSP) since sponsorship by ARM requires the team to implement the project using ARM components, where possible. Regarding webcam selection, the Logitech QuickCam Pro 4000 (last year's webcam), Logitech WebCam Pro 9000 and Logitech WebCam C615 were considered. Since the QuickCam Pro 4000 proved to be incompatible with OpenCV and the BeagleBoard, the team decided not to use this webcam. The WebCam Pro 9000 and WebCam C615 almost had the same specifications; however, the C615 has a tri-pod mount which simplifies camera mounting in the enclosures. The team therefore decided to use the Logitech WebCam C615 for this project.

3 Design of the Major Components

3.1 Mission Control

During the Competition, the AUV is required to complete a series of missions. As a summary of the missions, the AUV needs to pass through an underwater gate first, strike two of the three buoys, navigate through a box, drop two markers, fire two torpedoes, and finally grab and then release certain object after successful detection of the pinger. In order to complete these tasks successfully, a software mission control system is necessary. After the AUV passes through the gate, the AUV can complete the tasks in any order. However, to simplify and avoid some control overhead, we will design our AUV to complete the tasks in the order stated above. The mission control system will control the states of the AUV during each mission, coordinate all components in the system, and handle the proper transitions between each task. The mission control system should also have error detection and self-correction capability in the software layer to proper handle as many exceptions during the operation as possible.

For example, if the AUV cannot find the underwater gate after a timeout, the mission control system should not only adjust its direction, but also its height and orientation to find the correct position of the gate as soon as possible. And after a second timeout, the mission control system should expand its search area. However, the exact implementation will be very complicated due to the complexity of the system and the proper cooperation required among all the sensors and motors. In this system level design review, a preliminary overall design of the mission control system is presented including the state diagram, the flow chart, and a preliminary mission control program which identifies the overall structure of the system (lacks of the actual implementation).

3.1.1 BeagleBoard-xM

The complexity of the mission requires the AUV to be capable of coordinating multiple tasks concurrently and process large amount of data from all the sensors. As a mission controller and the main “brain” of the AUV, the main control unit must be composed of a powerful microprocessor with low power consumption. In this case, our team decided to use the Beagleboard-xM. The main features of the Beagleboard-xM are listed in Appendix. It contains a TI cortex A8 1GHz processor, an 800MHz DSP, and 512MB DDR memory. And the power consumption is less than 15 Watts. Based on these powerful hardware features, we assume that the Beagleboard-xM is can well handle all the tasks required by the competition.

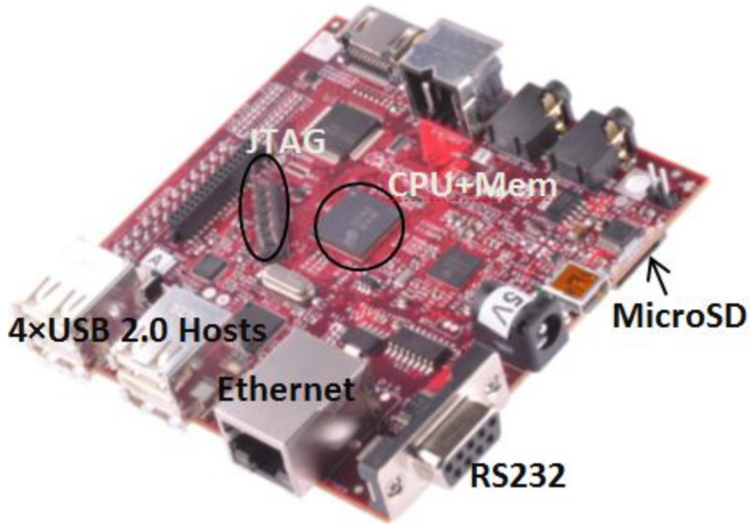

Figure 2: Beagleboard-xM

3.1.1.1 CPU, Memory, and DSP

As shown in Figure 2, the microprocessor, memory and the DSP is located at the center of the Beagleboard. The microprocessor is a 1GHz ARM® Cortex™-A8 processor and an 800MHz C64x+™ digital signal processor which provide more than 2,000 Dhrystone MIPS and up to 20 Million polygons per sec graphic. The 1GHz ARM processor will be used to perform the mission control, calculation of data from sensors, and sending out commands to components such as thrusters. The C64x+™ digital signal processor is capable of HD video and image processing and will handle all the image processing tasks from two onboard cameras on our AUV.

3.1.1.2 JTAG connector

To the left of the microprocessor, there is a JTAG connector. The 14 pin JTAG connector will be used to debug our programs. It can be utilized to perform operations such as single stepping and breakpointing. Eclipse IDE (Integrated Development Environment), OpenOCD (Open On-Chip Debugger) and GDB (GNU Project debugger) have full software support for JTAG debugging on beagleboard, which will help our debugging process to be more efficient. According to the datasheet, the JTAG connector interface is at 1.8V on all signals and only 1.8V Levels are supported. In order to use the JTAG function, a 14pin to 20pin adapter and a USB to JTAG in-circuit debugger will be used.

3.1.1.3 USB Hosts

The Beagleboard-xM contains four onboard USB 2.0 OTG host port. Each port can provide power on/off control and up to 500mA of current at 5V as long as the input DC is at least 3A. However, the maximum current supplied by all four USB Host ports total is 1.5A. The ports will not function unless the board is powered by the DC jack. These USB ports will be connected to two cameras and one Arduino board. Each of these components requires less than 500mA current from USB. And the Arduino board will be powered by its own voltage source. Therefore, no additional USB hubs will be required for our AUV.

3.1.1.4 Ethernet Port

On the Beagleboard-xM, there is a 10/100Mbps Ethernet connector. This Ethernet connector is able to provide internet access for the Beagleboard through the host computer, which will be connected to the Beagleboard with an Ethernet cable. After our programs are compiled on the host computer, they will be loaded into the Beagleboard through this Ethernet connection using SSH (Secure Shell). A sample Makefile which compiles all the source code files and loads programs to the Beagleboard is attached in the Appendix on page 77.

3.1.1.5 RS232 Connector

A RS232 serial connector is another important component on the Beagleboard. It will be provide the serial communication between the host computer and the Beaglebоad, so that the host computer can access the Beagleboard through a terminal program such as the HypertTerminal or Minicom. Access to the RS232 port is through a 9 pin DB9 connector, and a USB to DB9 adapter can be plugged direct into the board. The speed of the serial port is 115200 Baud/s.

3.1.1.6 µSD card connector

The Beagleboard supports booting from the onboard MicroSD card. The operating system will be pre-loaded on the MicroSD card, and the Beagleboard will load the OS from the card. All programs (executable binaries) will also be loaded into the card through Ethernet or direct copy to the card.

3.1.2 Software System

The Beagleboard-xM will be run on Ångström Linux, with Linux kernel 2.6.29. Ångström is a complete Linux distribution: includes the kernel, a base file system, basic tools, and a package manager to install software from a repository. It is optimized for low-power microcontrollers like the Beagleboard-xM. To run our programs on Ångström Linux on Beagleboard, a toolchain is needed. OpenEmbeded and CodeSourcery provides the cross compiling toolchains for Beagleboard. We will use the CodeSourcery Lite Edition in our project since it is free, easy to configure, and provides all the functions needed. The CodeSourcery cross compiling environment is installed on the host computer.

3.1.3 Connection Diagram

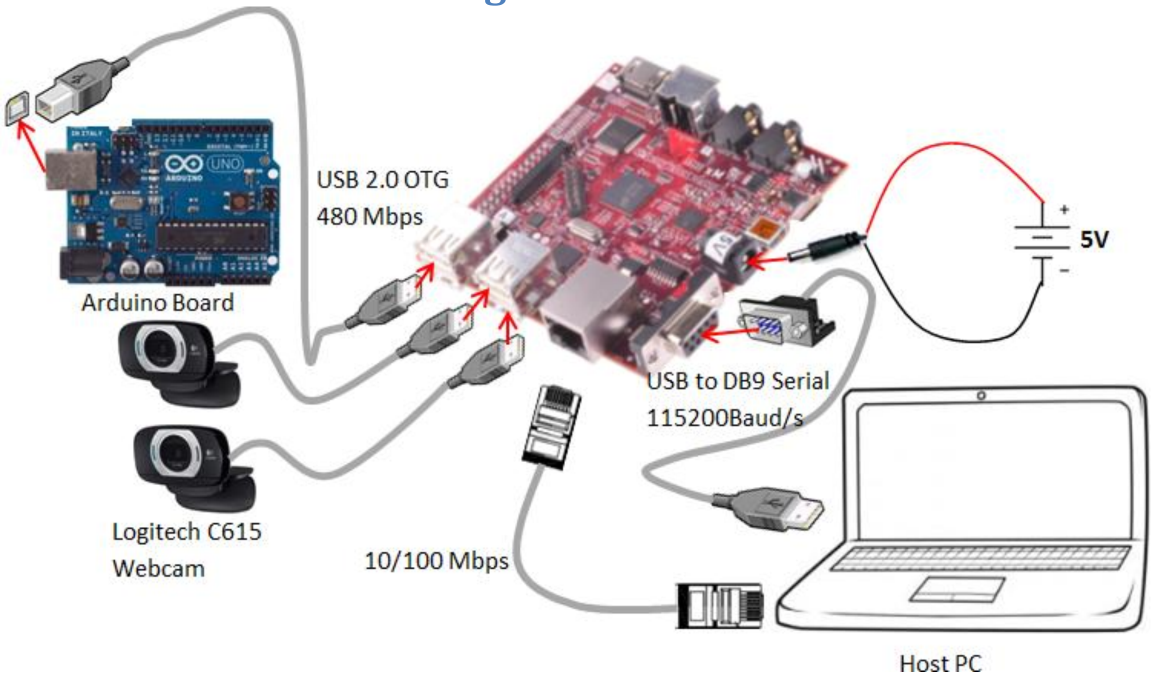

Figure 3: MCU Interface and Connection Diagram

3.1.4 State Diagram

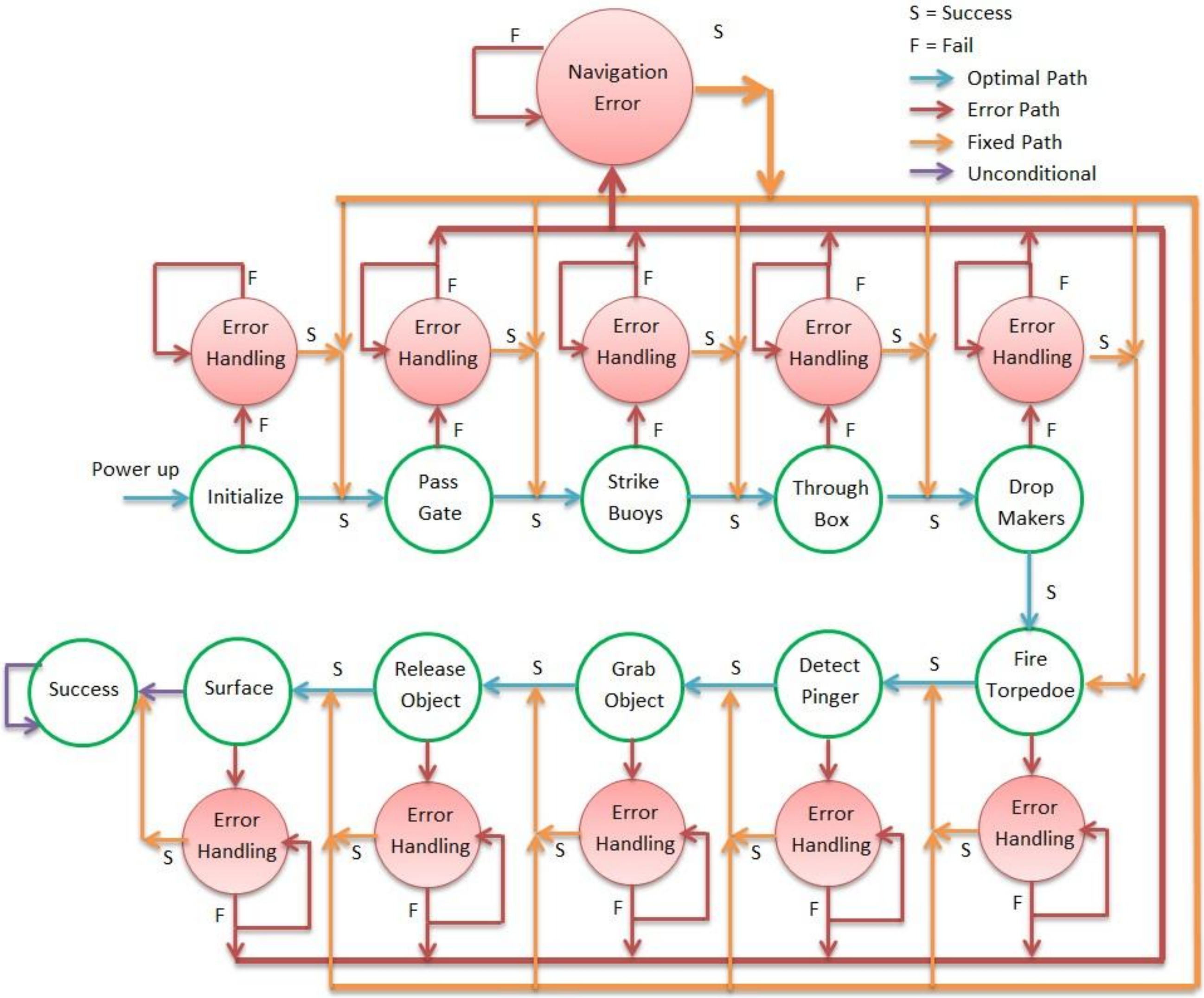

Figure 4: State diagram for Mission Control. Legend is located in top-right.

As shown in the diagram, each state has an own error handling module, which deals with all potential errors other than the navigation error. These errors include communication error between the mission control and sensors, operation timed out, memory operation violation, data misinterpretation, and etc. However, navigation error can happen at all stages except the initialization stage, the surface stage and the success stage. Therefore, when navigation error occurs, the mission control will call the Navigation Error module to get the correct path tracking and object detection.

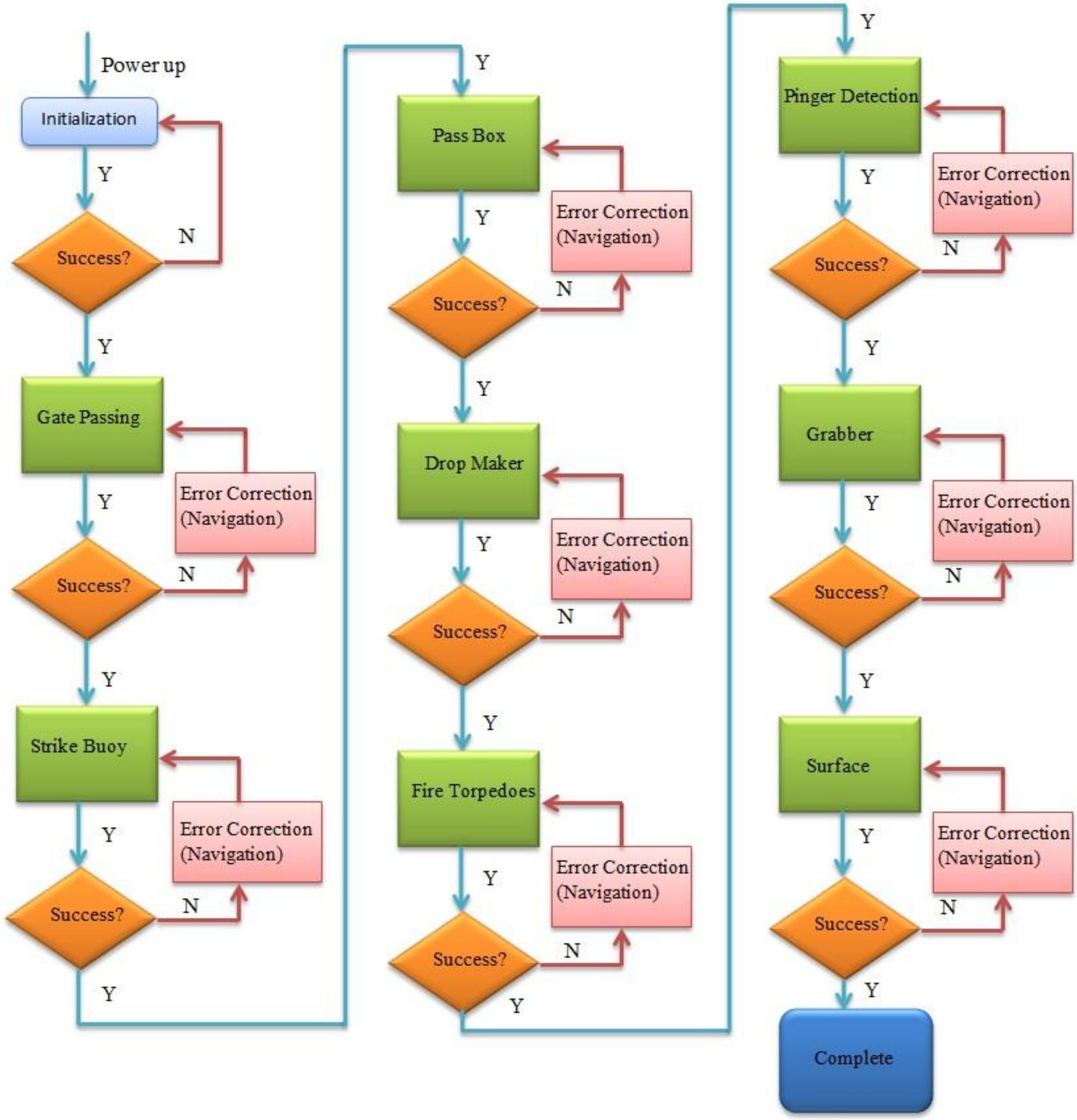

Figure 5: Flow chart for Mission Control

The following code fragments demonstrate the Mission Control function depicted in the flow chart.

Three files of the mission control system are: the header file “mission_control.h”, class implementation file mission_control.cpp”, and the main control program “main.cpp”. The class definition file or the header file, included in the appendix, defines the overall structure.

3.2 Electrical System

The electrical system of the AUV contains two lithium-ion polymer batteries which supply the power for the entire system, a voltage regulator board which step down the 29V voltage to desired voltages for each component such as 5V for the Beagleboard and Arduino board, all other power consumption components will be connected to the voltage regulator board.

3.2.1 Electrical System Diagram

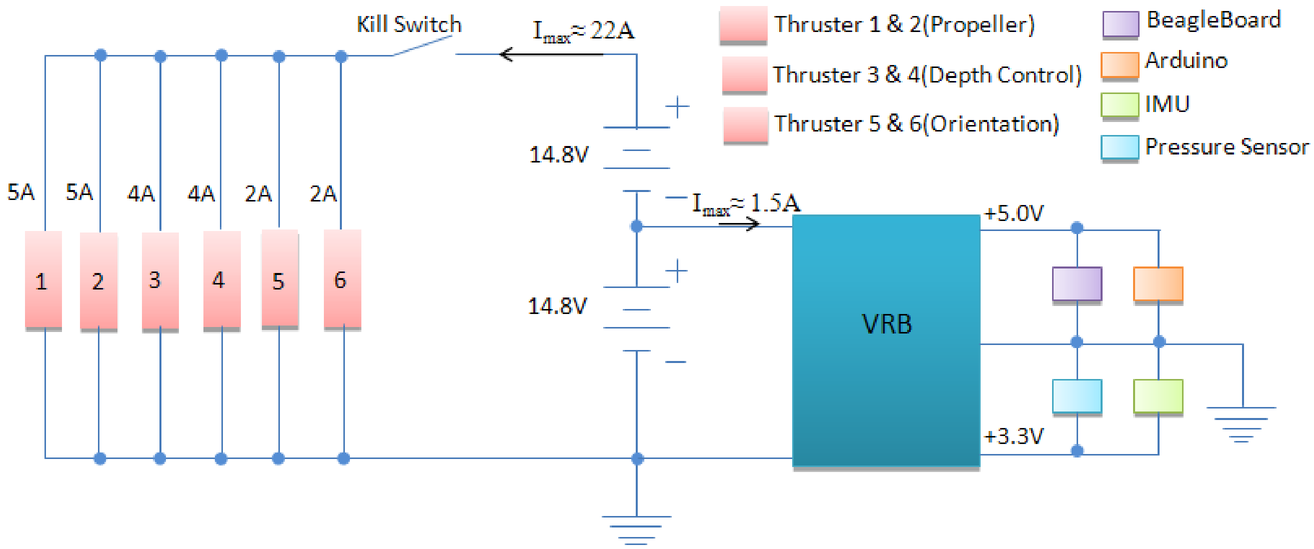

Figure 6: Electrical System Diagram for AUV

3.2.2 Power Supply

The AUV will be powered by two identical Li-ion polymer batteries. Each is rated 14.8V and the capacity is 20Ah or 296 Wh. The maximum discharging rate of the battery is 30Amps. Each battery requires ten hours to be fully charged.

Figure 7: Li-Ion Battery

Voltage	Voltage: 14.8V (working) 16.8V (peak) 11.0V (cut-off)
Capacity Prewired	20Ah or 296 wh Charge / Discharge Terminal: 6.0" 14AWG Standard male Tamiya connector
Max Discharging Rate	30 Amp limited by PCM
Dimensions (L x W x H)	166mm (6.6") x 125mm (4.9") x 54mm (2.1")
Weight	4.0 lb (1810g)

The electrical components on the AUV are estimated to draw a maximum current of 26A together. Therefore, with the two batteries, the AUV can operate continuously for about one hour. During the competition, the AUV is required to operate for less than fifteen minutes. Therefore, these two batteries can provide more than enough power for our AUV.

The table below shows the maximum current estimation. Note that the actual current (or average total current) is much less than the maximum value.

Component	Max Current(A)
Thrusters* 6	≈ 22 A
BeagleBoard-xM	≈ 1.5A
Arduino Board	≈ 1.5A
IMU, Pressure Sensor	≈ 1A
TOTAL	≈ 26A

3.2.3 Voltage Regulator Board

The AUV has different electrical components which require different DC input voltages and currents. Therefore, we propose of designing a customized voltage regulation board which take in the power from the batteries (DC) and regulate correct DC output voltage for each component. For instance, the voltage regulator board should provide a steady 5V voltage to the Beagleboard-XM, and 5V to the arduino board. A sample voltage regulator board is designed and simulated using the WEBENCH® Power Architect from TI. The block diagram is shown below.

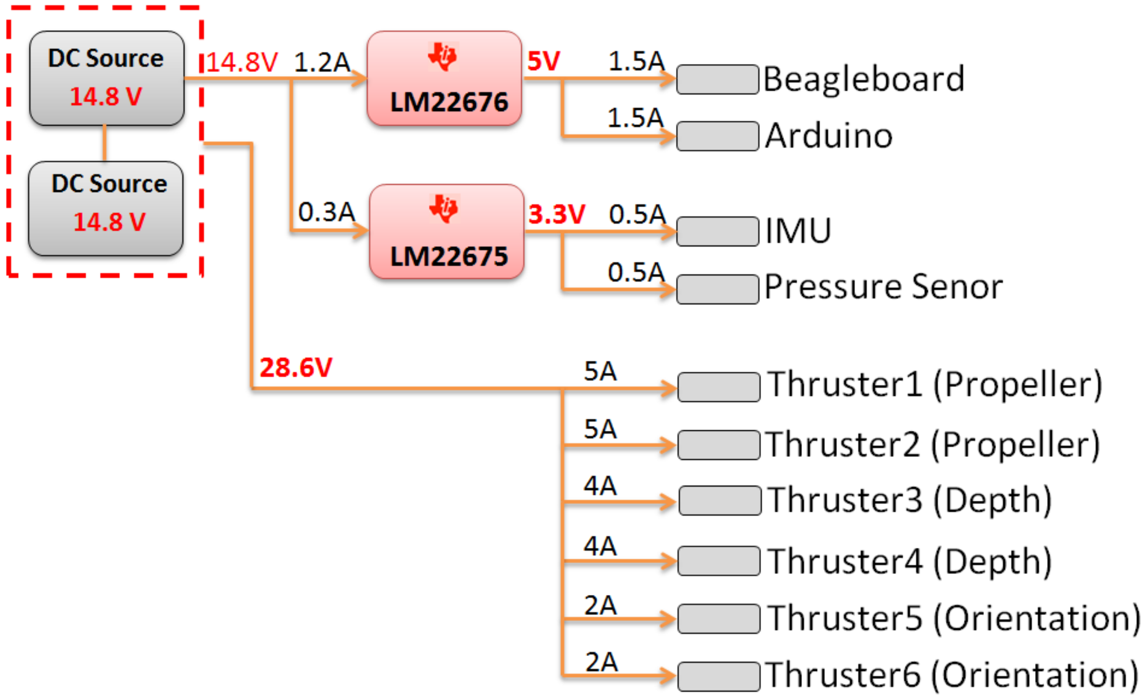

Figure 8: Voltage Regulator Block Diagram (Designed using WEBENCH® Power Architect from TI). Red boxes shown are step down switching regulators

The thrusters we are using are Seabotix SBT-150, which has an internal voltage regulator that takes an input voltage of 28V. Therefore, no additional voltage regulator circuit is needed for the thrusters. The LM22676 and LM25575 switching regulator circuits which convert 28.6V DC input to 5V and 3V DC output respectively. The circuit for each of them is shown below:

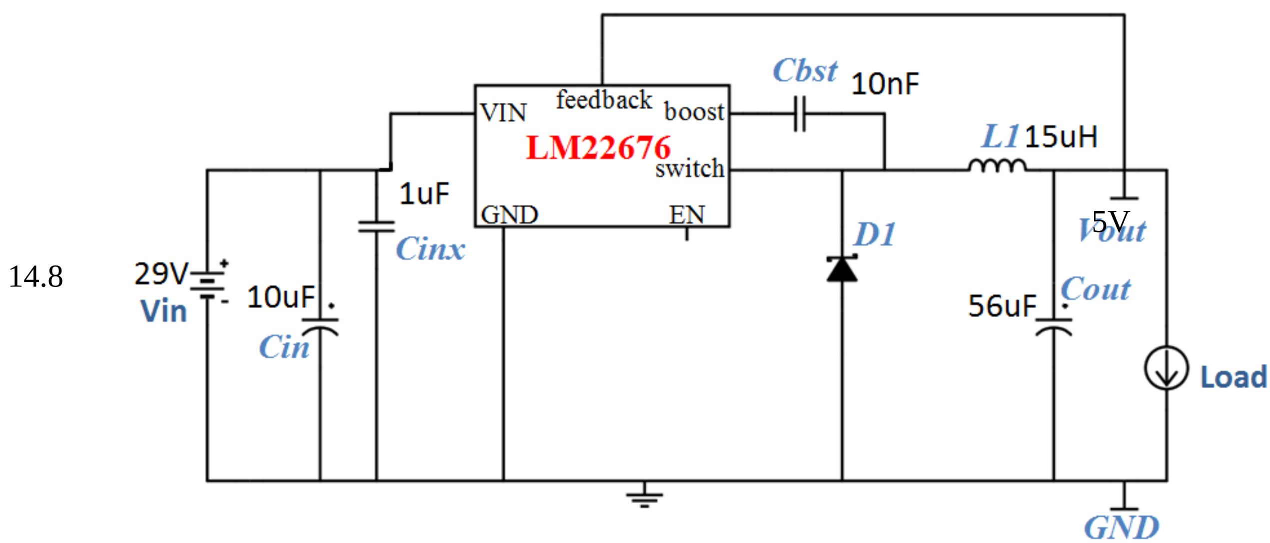

Figure 9: Detailed design of LM22676 step down switching regulator circuit

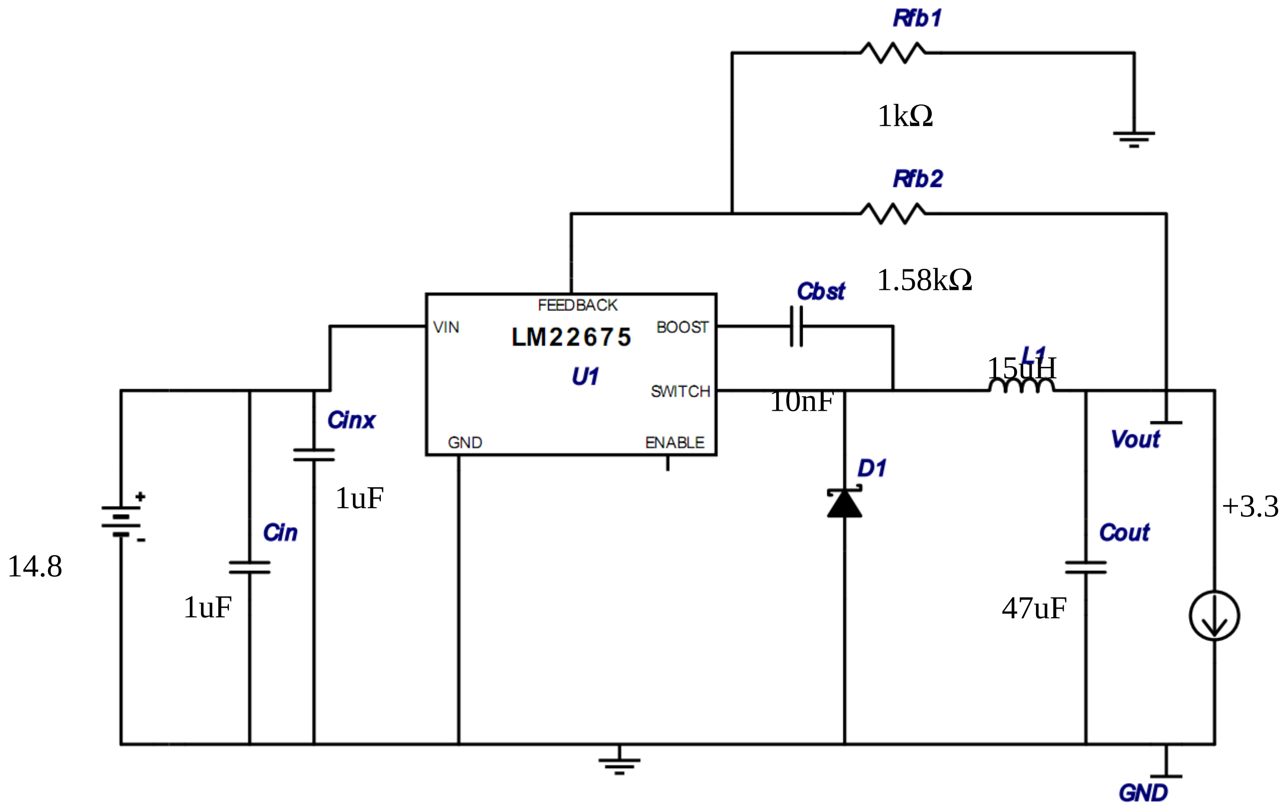

Figure 10: Detailed design of LM22675 step down switching regulator circuit

The simulation of each circuit is shown below. Simulations are done in WEBENCH® Power Architect from TI.

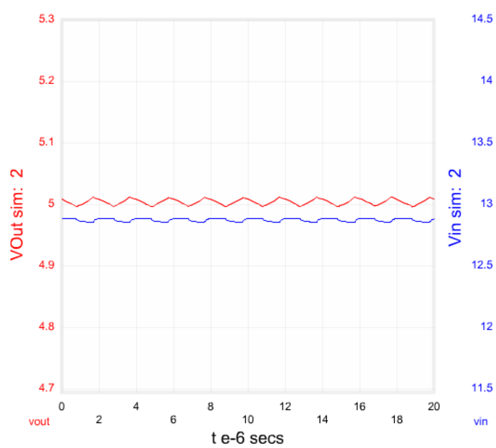

Figure 11: Simulation of LM22676

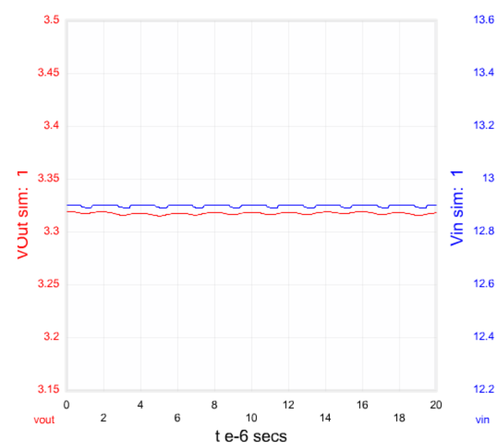

Figure 12: Simulation of LM22675

The total efficiency of these two voltage regulators are 86.1%. And the power Dissipation is 3.0 W for the VRB. A heatsink may be needed in this case. The ripple shown is due to the switching regulator which takes a small amount of energy from the input source and output the energy to the load one at a time. The voltage ripple amplitudes are very small.

3.2.4 Test Plan

	Module	Test Type	Test Plan
1	Electrical System	System	After confirming the performance of the two unit tests, everything will be connected to the voltage regulator board, including the Arduino board and Beagleboard, and mechanical periphery components. If the system functions correctly then the voltage regulation board will be approved for further use.
1.1	Voltage Regulation Board	Unit	Voltage regulator board will be testing for correct current and voltage output. This output will be monitored through the use of a digital multi-meter. In the event that the voltage regulator does not satisfy the voltage requirement, commercial alternatives will be sought.
1.2	Thruster Speed	Unit	Six thrusters will be connected to the battery and by altering the PWM speed (thus changing the thruster rotation rate) the best PWM setting and current delivery will be determined.
1.3	Battery	Unit	The battery will be tested regularly (i.e., once a month) for correct power dissipation.

3.3 Computer Vision

The Computer Vision module serves as the “eyes” of the RoboSub. The module is responsible for task management and navigation through the obstacle course. The Computer Vision module consists of three systems: General Image Processing, Navigation System and Task Management System.

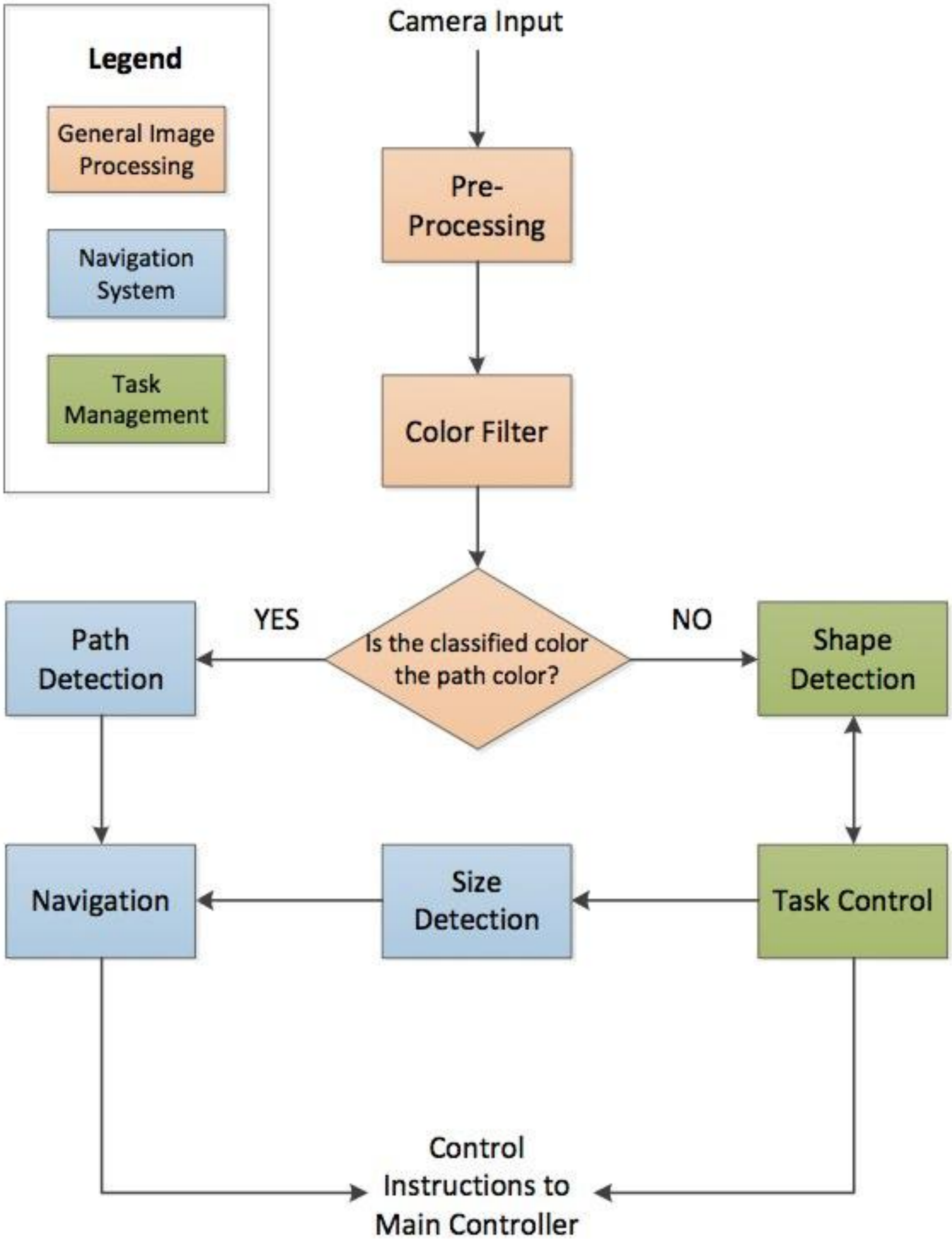

Figure 13: Computer vision flowchart.

3.3.1 General Image Processing

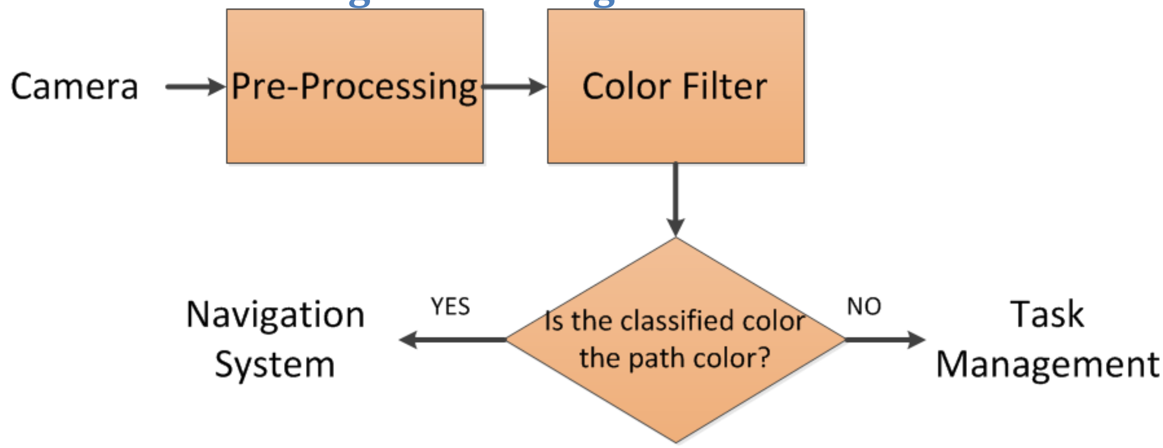

Figure 14: General Image Processing

3.3.1.1 Pre-Processing Module

The Pre-Processing Module prepares the images obtained from the cameras for image processing. The current design grabs image frames in RGB (Red Green Blue) color space from the camera and converts them to the HSV (Hue Value Saturation) color space. This conversion is to minimize the effects of light in the images. The HSV color space provides the best performance when classifying colors in each image frame.

Alternatively, one could use images in the RGB color space or grayscale images to obtain the necessary information for task management and navigation. However, as mentioned earlier, the RGB color space is more affected by light than the HSV color space. It is, therefore, decided to use the HSV over RGB color space. Grayscale images can be used for task management and navigation; however, obtaining color information would be rather difficult. Since the HSV color space can be used to extract information regarding color, direction and shape, it was decided that the conversion of RGB to HSV would be best suitable for the Pre-Processing module.

There is a low risk that the HSV color space will not be suitable for the extraction of certain information. In the event of this happening, the consequences will be minor and a modification will be made to the design to address the problem. For example, if grayscale images prove to be better than HSV-format images, the Pre-Processing module will output both grayscale and HSV images. Additional risk information is available in section 7.1.1.3.2.

3.3.1.2 Color Filter Module

The Color Filter module identifies colors in the images obtained from the Pre-Processing module and sends the relevant information to the appropriate sub-modules. The current design uses threshold HSV values to isolate pixels with a certain color. The module labels the color in each image and also provides information regarding the location (coordinates and/or relative position) of the color in the image.

Alternatively, RGB threshold values could be used instead of the HSV threshold values. This would be the case when the Pre-Processing module would output images in the RGB color space. The disadvantage of using RGB is that colors are greatly affected by the sunlight. Considering that the surrounding environment of the RoboSub is water, reflection of light could greatly change the RGB values of a certain color pixel in the image. It is, therefore, much better to use the HSV color space since this minimizes the effect of sunlight.

There is a very low risk that the Color Filter will incorrectly classify a certain color. The consequence of this happening can be severe since task management depends heavily on color identification. In order to minimalize the risk, the module will be extensively tested to assure proper operation in various lighting conditions and environment. Additional risk information is available in section 7.1.1.3.3.

3.3.2 Navigation System

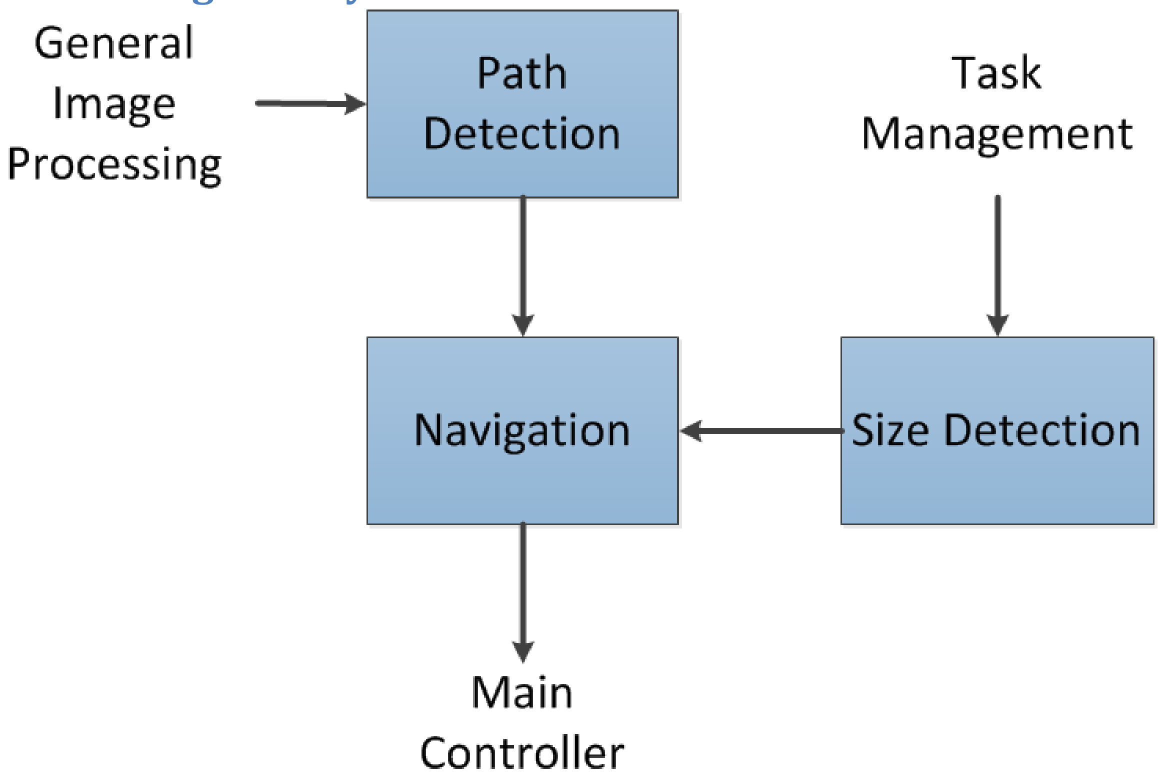

Figure 15: Navigation system

3.3.2.1 Path Detection Module

The Path Detection module delivers critical information regarding direction to the Navigation System. Using images obtained from the Color Filter, the edges of the path segments are detected using Canny Edge Detect. Using the Probabilistic Hough Transform, the edge lines are determined. These edge lines can be used to calculate the direction angle of the path segment. The computer vision engineer has started the development of this module and is making progress. The challenge is to find a way to extract information regarding the location of the path segment and angle of the path segment with the heading of the vehicle.

Alternatively, a custom algorithm can be designed to find the direction of the path segment in each image. For example, one can find the four coordinates of the corners of the path segment and use that to find the direction and location of the path segment. Since this would require a lot more effort to implement, the Canny Edge Detect and Hough Transform were chosen for the implementation of the Path Detection Module.

Considering the complexity of this module, there is a moderate risk that the module will not work properly or will not be finished on time. In the event of this happening, the consequence would be catastrophic. Considering the risk, it is extremely important that enough time is spent developing the module since this is one of the most important modules of the Computer Vision system. Additional risk information is available in section 7.1.1.3.4.

3.3.2.2 Size Detection Module

The Size Detection module estimates the size of an object and its distance from the AUV. Using the dimensions of the actual objects and the dimensions of the objects in each image frame, a scaling factor relating to the vehicle-to-object distance can be obtained. One can therefore determine the scaling factor for each image and extract relevant information regarding vehicle-to-object distance.

Alternatively, one could use an active sonar system to obtain vehicle-to-object distance information. However, considering the time and budget constraints of the project, developing the active sonar system and interface would be impossible. The team, therefore, decided to use the scaling factor method to determine the vehicle-to-object distance.

There is a low risk that the Size Detection module will fail to provide an accurate estimate of the vehicle-to-object distance. In the event of this happening, the consequence would be moderate. For navigational purposes, the distance information is helpful but not essential. As long as the objects/task get bigger, one knows that the RoboSub is heading in the right direction. For task management, especially for the tasks that require accurate measurement of the distance (e.g. torpedo launch), the consequences have a higher impact on the performance of the Computer Vision module. In order to minimalize the risks, the module will undergo extensive testing. Additional risk information is available in section 7.1.1.3.5.

3.3.2.3 Navigation Module

The Navigation module will provide the Main Controller with instructions on how to properly navigate the RoboSub. The Path Detection and Size Detection modules will pass on the relevant information to the Navigation module that will then use a custom algorithm to determine which instructions to send to the Main Controller.

Since the team is in the early development stages, implementation of this module has not been thoroughly worked out. Alternatives will be considered when the Path Detection module has been completed.

There is a low risk that the Navigation module will send incorrect navigational instructions to the Main Controller. The consequence of the failure is catastrophic since the RoboSub heavily depends on the Navigation module in order to control/navigate the vehicle. Additional risk information is available in section 7.1.1.3.6.

3.3.3 Task Management System

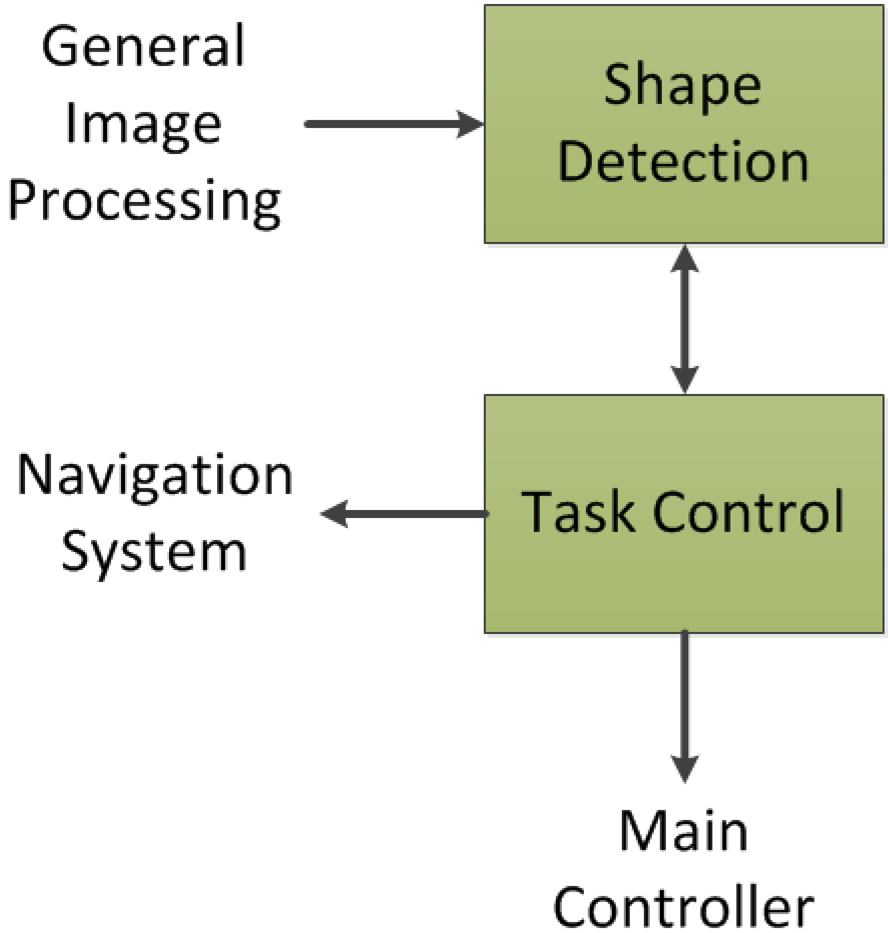

Figure 16: Task Management System

3.3.3.1 Shape Detection Module

The Shape Detection module will classify the shape of the objects to assist in task identification and management. Using the Hough Transform (line and circle), the various tasks are identified and labeled. In order for this module to perform as desired, the algorithms will need a great amount training data. The team will spend extensive amounts of time configuring the algorithms for a classification accuracy of at least 80%.

There are alternative ways to classify the shape of objects such as blob detection (OpenCV function); however, the Hough Transform provides all the useful information without the need for any special/custom functions. For example, the cvHoughCircles utilizes the Hough Transform to determine the center and edges of a circular object. The coordinates of the center of the object are also available. The Hough Transform is, therefore, the best alternative.

There is a very low risk that the Shape Detection module will fail to classify the shapes in an image. Since the algorithm only has to classify a few distinct shapes, the risk of failure is very low. In the event of a failure, the consequence would be moderate in a sense that the module would wrongly identify a task at hand. The consequence is moderate because the algorithm receives a feed of images and one wrong classification would not have a significant impact on the task management. Additional risk information is available in section 7.1.1.3.7.

3.3.3.2 Task Control Module

The Task Control module provides the Main Controller with instructions to successfully complete the obstacle course. Using information from the Shape Detection module, the current task will be determined. The module requires bidirectional data flow since it will keep track of which tasks have been completed. Since the module keeps track of the completed tasks, it will narrow down the task list for the Shape Detection module. This will improve accuracy and efficiency for the Shape Detection module.

Since the team is in the early development stages, implementation of this module has not been thoroughly worked out. Alternatives will be considered when the Shape Detection module has been completed.

There is a low risk that the Task Control module will incorrectly identify a task in the obstacle course. The consequence of the failure is severe since the failure may result in the team failing to complete the obstacle course. Additional risk information is available in section 7.1.1.3.8.

3.3.3.3 Test Plan

	Module	Test Type	Test Plan
1	Computer Vision	Overall	After the sub-systems have been completed, the overall computer vision will undergo extensive testing. Experiments will be conducted for a variety of lighting conditions, mission scenarios and simulated failures. The system will also be tested in the Morcom Aquatics center to verify correct operation in the pool.
1.1	General Image Processing	System	After completion of its sub-modules, the output of the module will be tested for correct color space and color identification.
1.1.1	Pre-Processing	Unit	The image feed will be analyzed to verify that the module provides images in the correct color space. Testing has started for this module and has almost been completed with positive test results.
1.1.2	Color Filter	Unit	The module identifies and labels each color. The image feed will be analyzed for several colors to verify the correct identification and label. The color module has been tested for red and needs to be tested for other colors.
1.2	Navigation System	System	After completion of its sub-modules, the output of the module will be tested for correct path direction and distance estimation.
1.2.1	Path Detection	Unit	For path detection, the Hough Transform will overlay the edges of the path segments. The module will be tested in a lab environment with a variety of path segment directions and viewing angles. The purpose of the testing is to make this module robust and accurate.
1.2.2	Size Detection	Unit	With a specific set of objects (with known dimensions), the distance from camera to the objects will be verified. An equation will be determined that uses the actual dimensions of the object and the dimensions of the object in the image to find the distance between camera and object.

1.3	Task Management	System	After completion of its sub-modules, the output of the module will be tested for correct task identification and control.
1.3.1	Shape Detection	Unit	The module will recognize and label all the pre-defined shapes in an image. The image feed will be analyzed to verify the correct output of the module.
1.3.2	Task Control	Unit	Using stub modules, the module will be tested for correct task control. For example, the module will be notified that a certain task has been completed. It will then be verified that the task control interfaces with the shape detection to rule out the completed task for classification.

3.4 Guidance System

Successful autonomous operation requires detailed environmental awareness. Devices such as gyroscopes (to measure orientation), accelerometers (to measure acceleration), and magnetometers (to measure direction) contribute to the positional component of environmental awareness. When these devices work in tandem an inertial measurement system (IMU) results which can be used in an inertial guidance system (IGS) to precisely track vehicular heading and contribute to the vehicle's internal model of its location.

3.4.1 Block Diagram

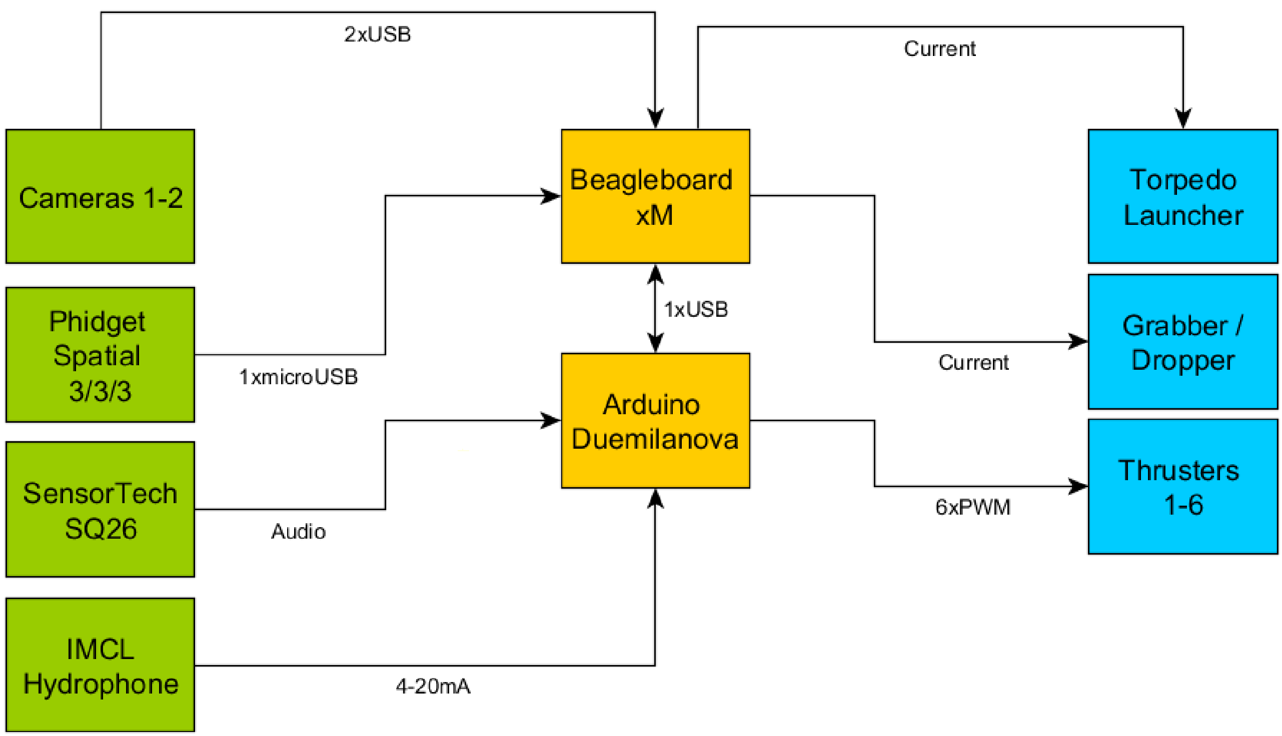

Figure 17: Block diagram of the guidance system. Note the IMU (Phidget Spatial 3/3/3), Pressure Sensor (SensorTech SQ26), and hydrophone (IMCL Hydrophone) which are connected to the Beagleboard and Arduino board.

3.4.2 Software System

The software system is essential a finite state machine that monitors the inputs from the sensors, consolidates them, and forwards them to the Beagleboard for post-processing.

1. State 1 - Calibration
   1.1. Take an initial reading of the environment to calibrate the sensors.
   1.2. If readings failed, return to State 1; otherwise, continue to State 2.
2. State 2: Measurements
   2.1. Take readings from all the attached sensors.
   2.2. If readings failed, return to State 2; otherwise, continue to State 3.
3. Stage 3: Calculation
   3.1. Use readings to determine vehicular heading, depth, and orientation.
   3.2. If determined heading, depth, or orientation seems incorrect / incomplete, return to Stage 2; otherwise, continue to Stage 4.
4. Stage 4: Consolidation
   4.1. Combine heading, depth, and orientation into a format understandable by the Beagleboard.
   4.2. If combination results in a malformed packet, return to Stage 3; otherwise, continue to Stage 4.
5. Stage 4: Forwarding
   5.1. Check the sentOnce flag.
      5.1.1. If sentOnce = ‘0’, send the data to the Beagleboard and wait for ACK.
      5.1.2. If sentOnce = ‘1’, send the data to the Beagleboard without waiting for ACK, clear the sentOnce flag, and continue to Stage 5.
   5.2. If no ACK received, set sentOnce flag to ‘1’ and return to Stage 4. Furthermore, begin a new FSM continuing from Stage 2.
6. Stage 5: Termination
   6.1. Clean up the FSM by removing any network connections.
   6.2. If a new FSM is not already in place, create a new one continuing from Stage 2 (i.e., already calibrated).

3.4.3 Inertial Measurement Unit

Phidget 3/3/3

The Inertial Measurement Unit is paramount to correctly determining the position of the vehicle during the course of the competition. This IMU allows for 3-axis measurement of acceleration, orientation, and magnetic vectors. It is fed an initial input that is then referenced throughout the course of the competition to calculate vehicle position relative to that position. Because this IMU, left over from the previous year’s project, uses a microUSB connector, it will be connected to the Beagleboard and any required calculations will be performed on it. Even though the Beagleboard is performing the calculations for the IMU and not the Arduino board, it is still considered part of the guidance system.

Figure 18: Phidget 3/3/3 IMU

3.4.4 Submersible Pressure Transducer

IMCL Low Cost Submersible Pressure Sensor

Since the Robosub will be underwater, an additional level of measurement is required to create a comprehensive guidance system: depth. The IMCL Low Cost Submersible Pressure Sensor is designed for use in continuous submersion in liquids such as water. It has a ceramic sensor, reducing corrosion, and a stainless steel diaphragm for use in aggressive environments. This pressure transducer was selected after careful analysis of the alternatives and was the most cost effective option are this analysis was completed.

The pressure transducer will be read during Stage 1 and Stage 2 of the Software System Cycle – its results, delivered by a current ranging between 4-20mA will be sent directly to a port on the Arduino board and quantized according to the accuracy of the model. The nominal pressure for the gauge is 10 mWG. A potential risk with this pressure sensor is that it is not accurate enough. Additional risk information is available in section 7.1.1.2.2.

Figure 19: IMCL Low Cost Submersible Pressure Sensor

3.4.5 Hydrophone

Sensortech SQ26 Hydrophones

One of the competition tasks require that the AUV be capable of detecting a pinger located in the salt-water pool. The best way to detect the sounds emitted by the frequency is by the use of an underwater microphone called a hydrophone. This hydrophone should be capable of detecting a range of frequencies. Through the use of triangulation and multiple hydrophones, the heading of the pinger can be determined by using basic geometry and trigonometry.

The Sensortech SQ26, like the IMCL Submersible Pressure Sensor, can withstand immersion in liquids such as water. However, unlike the Pressure Sensor, it can only stay underwater for a relatively short period of time ~ a day ~ before it has to be dried completely. With a frequency response of 1Hz to 28,000Hz, this device will be sensitive enough to locate the pinger underwater. The hydrophone will be read during Stage 1 and Stage 2 of the Software System Cycle. A potential risk is that the hydrophone is not calibrated correctly while being used. Additional risk information is available in section 7.1.1.2.1.

Figure 20: SQ26 Hydrophone

3.4.6 Test Plan

	Module	Test Type	Test Plan
1	Guidance System	Overall	After testing of the sub-systems has been completed, the guidance system will tested in the Morcom Aquatics center to verify correct operation in aquatic conditions by comparing known movements to the measurements of the Guidance System.
1.1	IMU	Unit	The IMU will be tested for correct operation by accelerating it to a known velocity and measuring the system's response.
1.2	Hydrophones	Unit	Hydrophones will be tested by connecting them to an oscilloscope while a known frequency is emitted.
1.3	Pressure Sensor	Unit	The pressure sensor will be tested by submersing it in increasing depths and checking for correct readings.

3.5 Hull / Frame

The frame will be in the shape of a rectangular prism, and will be constructed of 80 / 20 *Inch Solid* extruded aluminum due to its supreme versatility, ease of manufacture, and ease of assembly. Aluminum corner connectors will be used to secure each component of the frame to one another at junctions. The camera enclosure supports have been modified so that there will now be a single support located at the front of the vehicle along a centerline, that will house a camera enclosure on both the top (for the front-facing camera) and bottom (for the bottom-facing camera). A thin aluminum plate will be fixed to either side of the T-slotted frame supports to provide a clean mating surface for the acrylic enclosures. This modification will also provide a cleaner view for the bottom-facing camera, and yield a more sensible positioning of the cameras to assuage the programming difficulty that would result from the cameras being offset from the center of the vehicle, or being located at severely different locations along the frame.

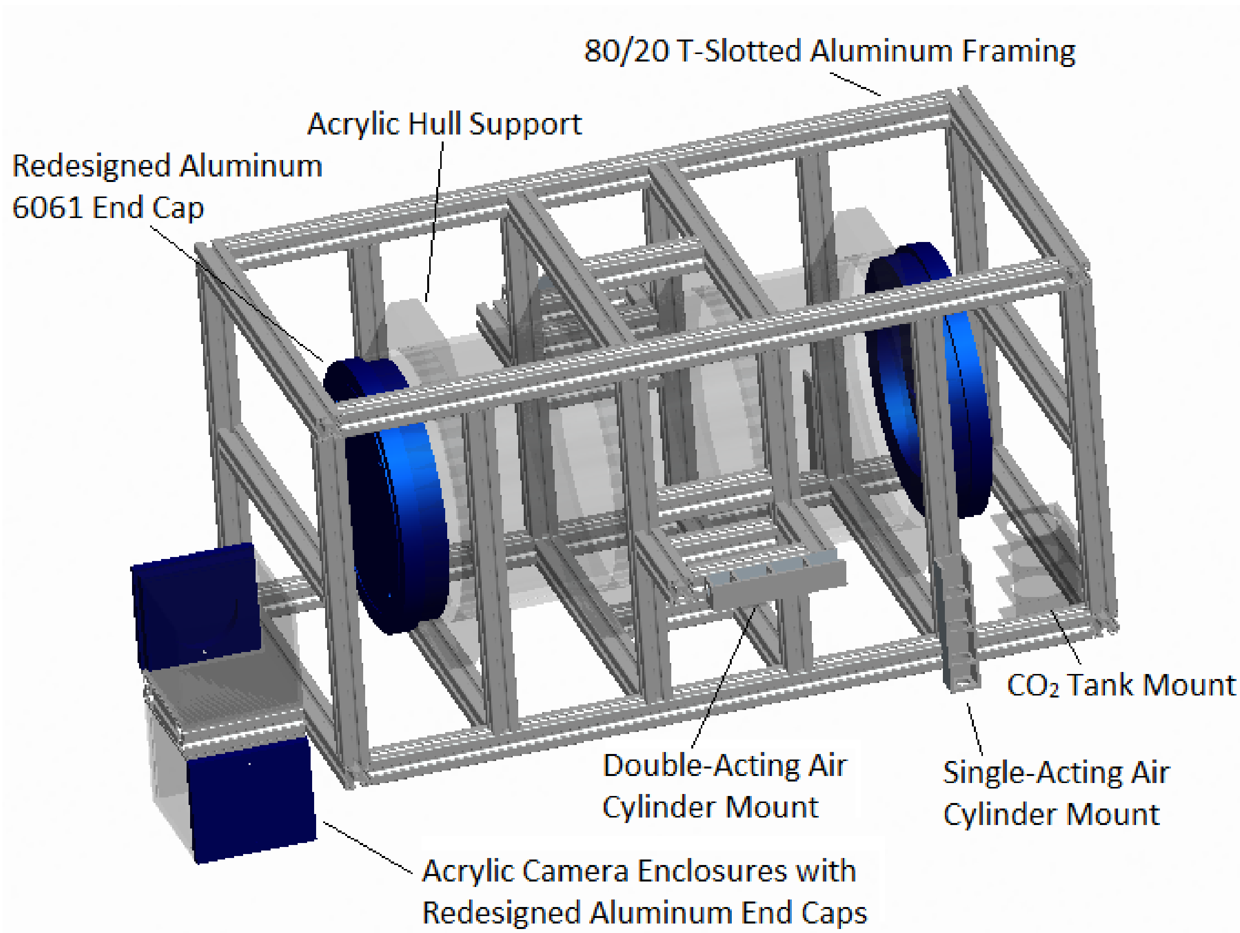

Figure 21: Close-up view of the Hull / Frame.

The hull/pressure vessel will be cylindrical in form, and will be made out of cast acrylic. It will be will have an outside diameter of 10”, and inside diameter of 9.5”, and a length of 20.5”, and will serve to house the electronics. The ¼” thick walls of the acrylic tube will yield it capable of withstanding the relatively insubstantial hydrodynamic and hydrostatic pressure that it will encounter at its maximum depth of 16 ft in salt water without any measureable deflection or deformation. Furthermore, the clear acrylic material has a low density (only slightly greater than salt water), has proven applications in similar environments (e.g. used for walls of aquariums), provides enough positive buoyancy to counteract the denser surrounding components of the AUV, and will allow the electronics to be seen from the exterior of the system—an aesthetic bonus, as well as a desired feature for future sponsors of electronic components.

The end caps have undergone a design modification in order to yield a more reliable water-tight seal. Instead of using a double o-ring method to provide a press-fit between the outside surface of the aluminum end caps and the interior surface of the acrylic tube, a two-part end cap design will be implemented (Figure 7). The outside part of each end cap will be rigidly attached to the inside and ends of the acrylic hull via marine-grade caulking, and will contain an open center with a lip containing four threaded holes—thus resulting in a ring-like structure. Another solid aluminum circular piece will be placed on top of this lip and will be screwed into the threaded holes, with a rubber gasket serving as the intermediary at the interface between both parts of each end cap. These gaskets will be compressed as the removable inside part of each end cap is screwed into the complementary fixed outer aluminum ring, thus creating a more secure watertight seal. This end cap design will also be implemented on the camera enclosures—although on a proportionately smaller scale, and with the outer end cap square in shape rather than circular.

Submersible SEACON All-Wet and Micro Wet-Con connectors will be attached to each of these end caps (one on each of the camera enclosure end caps, and about 3 multi-split connectors on each of the two hull end caps. By using split contact configurations, the amount of holes that need to be drilled into each end cap will be significantly reduced, resulting in more reliable water-tight seals, as well as a more compact and direct wiring scheme. For example, a quad configuration will be used to connect to each of the four solenoid valves on the end cap right next to the CO_2 distribution center, a bi configuration will provide connections for both cameras, and a tri configuration on either end cap will each support the connections to the three nearest thrusters.   Additional risk information available in section 7.1.2.1.

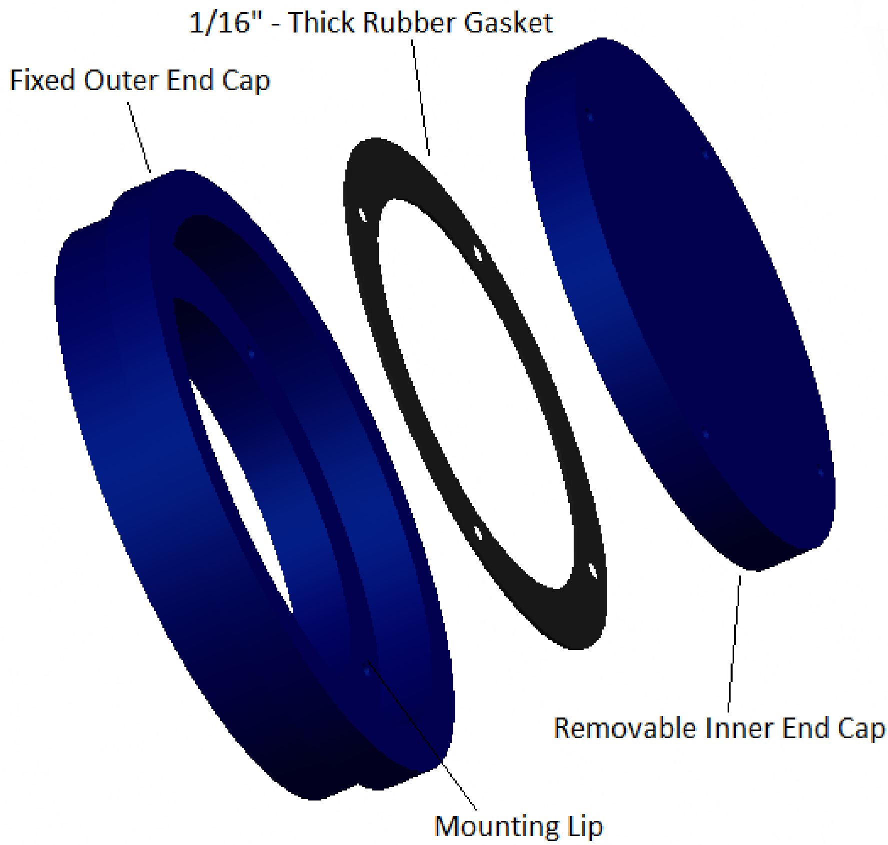

Figure 22: Close-up view of the Hull End Caps

3.5.1 Test Plan

	Module	Test Type	Test Plan
1	Hull / Frame	Overall	The hull will be brought to the FSU Morcom Aquatics Center for a preliminary watertight test. At this stage, no holes will be drilled or tapped into the aluminum end caps of the hull, and thus no SEACON connectors or cables will be attached. The empty hull will be submerged underwater at the maximum depth of about 17 ft for a period of fifteen minutes (i.e. the duration of the mission). After this time has elapsed, the hull will be recovered and brought to the surface, where it will be analyzed for any leakage or slippage of the end caps. Once the peripheral subsystems have been attached to the AUV, and the SEACON connectors have been attached to the end caps of the hull and camera enclosures specifically, another similar test will be performed (with the electronics removed) in order to verify the complete watertight integrity of the hull and camera enclosures.

3.6 Interior Hull Design

The interior of the hull will contain a 3/16”-thick aluminum sheet which will support the power supplies, the control units, and the inertial measurement unit. It is also likely that the motor drivers for the thrusters will also rest on this multi-level rack inside the hull in order to result in far less wiring issues or concerns. Using compact L298 motor drivers (two on each chip), only a power and ground wire (two-pin cable) will need to connect from the respective SEACON connectors on the end caps to each of the thrusters. This Aluminum 6061 platform has been reduced in width in response to the modifications to the end cap design, and will rest on a bed of three 1”-thick, watermelon-shaped acrylic cut-outs which will match the curvature of the inside of the hull. Caulking will be used to fix the curved surface of each of these cut-outs to the interior surface of the pressure vessel. These acrylic supports will not only serve to create a flat resting surface for the aluminum plate, and thus the electronics and lithium-ion battery packs, but will also provide insulation so that heat will be dissipated from the electronics to the exterior of the device more efficiently as it travels through the aluminum plate and aluminum end caps via conduction.

Figure 23: L298 Dual Motor Driver for Thusters

The 3/16" – thick aluminum platform will be removable for easy access to the microcontrollers, battery packs, and IMU. Since the power supplies are expected to generate the most heat, they will be placed at either end of the aluminum plate—closest to the aluminum end caps, and thus the external surroundings. This positioning also helps maintain symmetry and balance. A condensed multi-level rack will be located at the center of the hull. This structure will have two sets of horizontal racks which will support the control units and the inertial measurement unit. Should it be decided to house the motor controllers for the thrusters inside the hull as well, the upper racks will be extended laterally (i.e. partially cantilevered over each of the batteries) to accommodate this addition. Additional risk information is available in section 7.1.2.1.

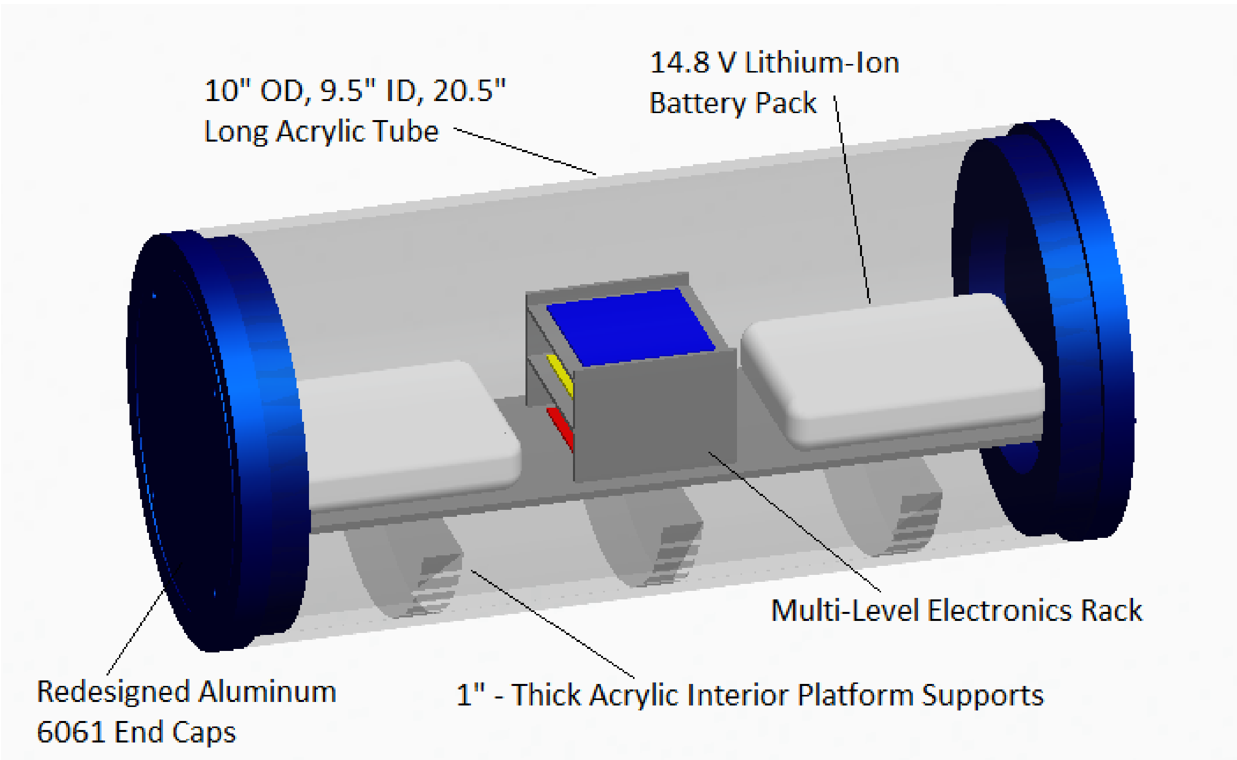

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Figure 24: Close-Up View of the Interior Hull Design

3.7 Vehicle Propulsion

Six thrusters will be integrated into the design of the AUV in order to propel the vehicle and provide general maneuverability under water. Four SeaBotix SBT150 thrusters and two SeaBotix BTD150 thrusters will be used for their proven quality, relatively large energy density (see Appendix A), and because inherited ownership of the SBT150 thrusters was already granted. The SBT150 and BTD150 thrusters have the same exact dimensions and weight since the I^2C controllers in the SBT thrusters were extracted. Thus, each thruster will have an H-bridge motor controller installed in their place. The data and clock ports on the SBT150 thrusters will not be used. A single thruster will be placed along one of the two centerlines of each face of the open, rectangular frame in order to absolve any undesired torque on the system during operation. Each thruster will be oriented in such a way to provide the ability for three-axis translation and three-axis rotation, resulting in an agile, easily maneuverable vehicle. The bidirectional nature of the thrusters via the simple alteration of the motor direction is another convenient feature.

The thrusters will serve to guide the vehicle, as well as provide stability, depth, and velocity control throughout the mission. The thrusters will receive PWM commands from the Arduino Board in response to interpreted IMU readings, thus controlling the speed (and thrust force) of each thruster. Due to the aforementioned projected density of the vehicle relative to the density of salt water, and applying Equation 1 below, only 0.75 – 1.5 lbs of thrust force is expected to be required from the side thrusters in order to maintain a constant depth (i.e. zero velocity and zero acceleration).

This will yield minimal continuous power consumption from these thrusters. Similarly, since the pressure and frictional drag forces on the vehicle are expected to be relatively low at the expected nominal travel speed of the vehicle, only minimal thrust force will be required from the top and bottom thrusters in order to maintain a constant longitudinal velocity. Furthermore, each of the thrusters has a built-in voltage regulator at approximately 19.1 V, and thus will maintain a constant voltage as long as the supply is greater than this value and less than about 30 V. Provided the expected 28.6 V from connecting both of the lithium-ion battery packs in series, and manageable current draw from the thrusters, there should be no problem supplying ample power to the thrusters.

3.8 Mechanical Subsystems

3.8.1 CO_2 Distribution System

The CO_2 distribution system stores and distributes pressure-regulated carbon dioxide to the grasp/release mechanism, as well as the torpedo launchers; actuation is initiated upon command from the main control unit. The distributed CO_2 will cause the air cylinder pistons to extend (up to 2.5”), thus thrusting the torpedoes forward. The major components of the pneumatic system are the primary compressed CO_2 tank, a pressure regulator, solenoid valves and a network of tubing. The previous design called for a secondary storage tank that would serve as an intermediate stage for compressed CO_2 prior to its distribution. Removing this phase reduces unnecessary mass in the system. The primary gas tank will utilize a CO_2 storage tank typically used in paintball gun; the tank was chosen for its small size and sufficient storage capacity of 4 oz of liquid CO_2. Furthermore, it is capable of being refilled. The CO_2 tank features lightweight aluminum material with a high-quality brass pin valve. The pressure regulator to be used has yet to be finalized, but it must be able to reduce the supply pressure from approximately 800 – 1,500 psi to approximately 100 psi as an operational pressure. There will be a total of four submersible stainless steel solenoid valves; one for each of the double acting air cylinders for the torpedo launchers and two for the grasp/release mechanism. The solenoid valves will require 12 VDC, require 1/8" – diameter tubing, and are 1” in diameter and 2.5” in height. The network of tubing will ensure the proper distribution of the pressure regulated CO_2 to the grasp/release mechanism and torpedo launchers. A splitter will be used following the second solenoid valve for the grasp/release mechanism in order to simultaneously distribute compressed CO_2 gas to (or release compressed CO_2 gas from) each of the single-acting air cylinders upon actuation. A system diagram for this distribution network can be seen below.

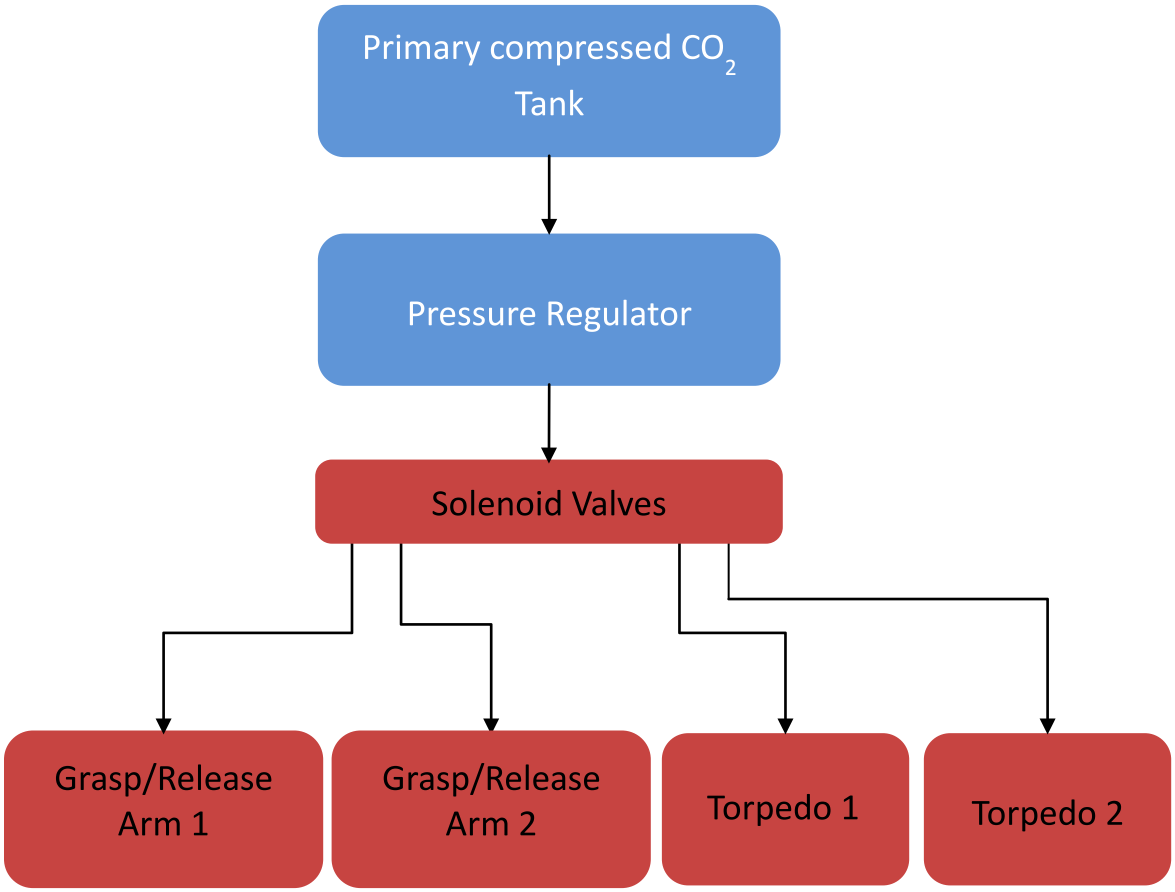


Figure 25: Compressed CO_2 tank system diagram.

In the above figure, the blue blocks correspond to the storage and regulation of carbon dioxide and the red blocks correspond to its distribution. The network of tubing is represented by the direction arrows leading from the block labeled solenoid valves to the blocks for grasp/release arms 1 and 2 and torpedoes 1 and 2. Additional risk information available in section 7.1.2.4.

3.8.1.1 Test plan

	Module	Test Type	Test Plan
1	CO_2 Distribution System	Overall	The proper operation of CO_2 distribution system will be verified by measuring the pressure within the system at various locations, including the outlet of the compressed CO_2 tank before and after the pressure regulator, and the CO_2 pressure in the gas lines after each solenoid valve has been directly actuated to open via a power supply. Thereafter, each of the solenoid valves will be integrated with the corresponding microcontroller where they will be actuated via a simple code in order to ensure proper functionality. Upon a successful test, this code will be finalized and saved as the solenoid valve function, to be integrated into the overall code. This function will be called upon when actuation of the grasp / release mechanism or torpedo launchers is required.

3.8.2 Grasp / Release Mechanism

Mechanical motion will be actuated in the grasp/release mechanism by the pneumatic system. Revisions have been made to the original grasp/release mechanism, which now features two vertically downward facing single-acting (i.e. contains an internal spring return) air cylinder—one on either side of the vehicle, and toward the back; each will be fitted with an attached C-shaped pair of jaws at the end of the respective air cylinder piston that are allowed to rotate about a pivot point, and two solenoid valves (which will simultaneously operate both claws via a splitter). The C-shaped claws will be formed by joining two jaws at a central pivot via a pin-hole method; each jaw will be made of 0.25"-thick aluminum, and will be actuated to open or close via an adjustable set of arms that will induce rotation upon extension or retraction of the air cylinder piston. Proper operation of the jaws requires two submersible, stainless steel solenoid valves—one to close the jaws and grasp the rescue object, and the other to open the jaws (by releasing the stored compressed CO_2 into the environment) and release the rescue object upon command. The air cylinders are single-acting and will attach along the center line on either side of the vehicle. Introducing these design revisions removes unneeded mass and increases the grasp region of the mechanism to approximately 9 – 10". Furthermore, by simply shifting the location at which each of the arms contact or pivot the respective jaw, the amount of grasp force can be adjusted to compensate for a scenario in which the supply force is too large due to a necessarily greater CO_2 pressure for the torpedo launchers. Additional risk information available in section 7.1.2.6.

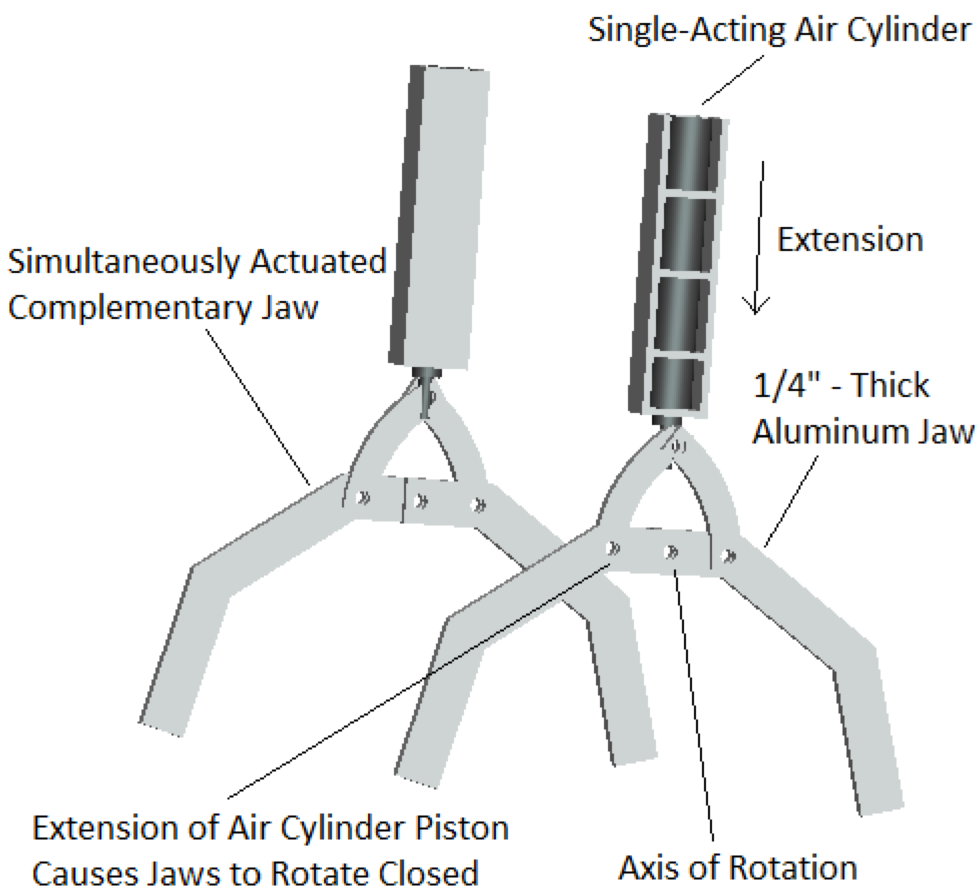


Figure 26: Close-Up View of Grasp / Release Mechanism

3.8.2.1 Test Plan

	Module	Test Type	Test Plan
1	Grasp / Release Mechanism	Overall	The proper dynamics of the grasp / release mechanism will be tested by manually extending and retracting the air cylinder piston to which the completed device is attached. Thereafter, the mechanical system will be integrated with the microcontroller, where it will be electrically actuated. This will serve as the final test to verify the proper operation of this subsystem.

3.8.3 Marker Dropper

The design team has opted to use the design created by the mechanical engineers on the previous 2010 FAMU-FSU RoboSub team due to its simplicity and effectiveness. The mechanical subsystem is made out of Aluminum 6061 and contains a parabolic track on which rests the two steel balls. The parabolic track is bound on both sides by aluminum walls in order to prevent the markers from accidentally falling off the device, as well as any undesired motion. Furthermore, there is a servo that is oriented vertically downward, located directly between each of the two markers. Upon command, the servomotor induces rotation to a desired angle, thus allowing the release of one of the two steel balls. After returning to its initial orientation, the servo can then be autonomously commanded to rotate to the same angle in the opposite direction in order to allow the other steel ball to drop into the desired bin. The servomotor will be controlled by one of the two control units located inside the pressure vessel. The wires that will need to run from the servo motor the microcontroller will be protected via thin tubing that will run to a connector on the nearest end cap. Additional risk information available in section 7.1.2.5.

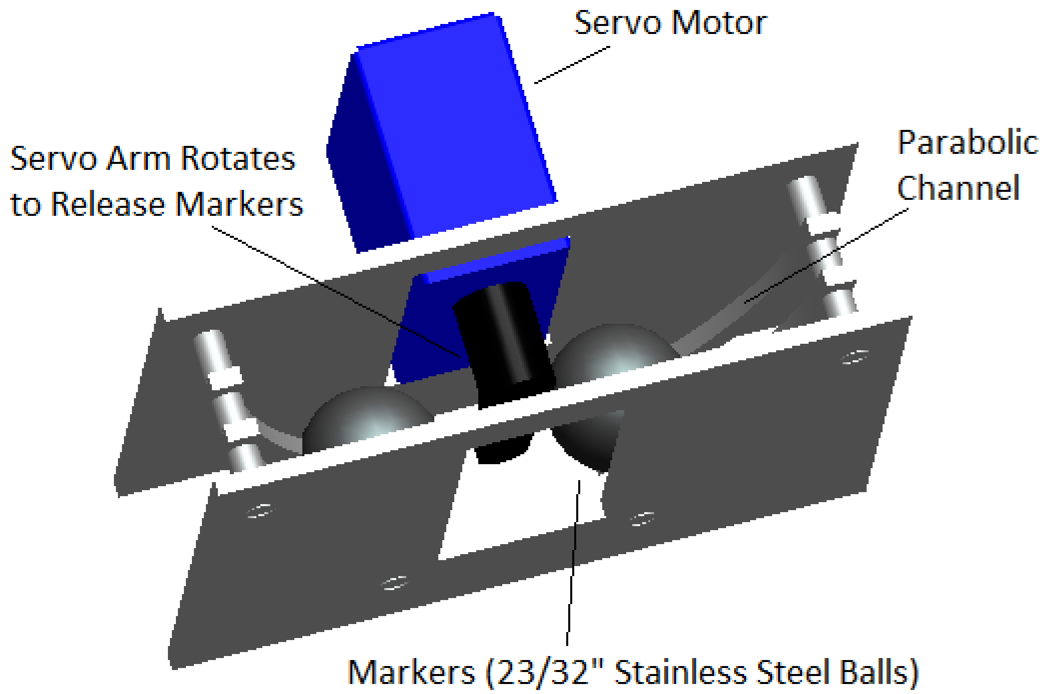


Figure 27: Close-Up View of Marker Dropper

3.8.3.1 Test Plan

	Module	Test Type	Test Plan
1	Torpedo Launcher	Overall	The proper operation of the launcher mechanisms will be verified by attaching the torpedo launchers to the CO_2 distribution system and directly actuating the respective solenoid valves via an external power supply. The flight characteristics (i.e. distance, accuracy, and trajectory) will be observed, and after successful lab tests, the integrated subsystems will be tested underwater at the FSU Morcom Aquatics Center. The regulated CO_2 pressure will be adjusted until the desired initial torpedo velocities are achieved.

3.8.4 Torpedo Launcher

Similar to the grasp/release mechanism, the torpedo launchers will incorporate a pneumatic system to perform the desired task. The key components of the system are the cylindrical barrel, disengaging cap, double acting air cylinder, air cylinder mount and disk piston attachment. Each of the two cannons will be placed on the horizontal neutral axis on opposite sides of the vehicle. The cannons will have a cylindrical shape with an inside diameter slightly larger than the maximum diameter of the torpedoes (dimensions of the torpedoes will be a function of the air cylinder used since the barrels will surround the air cylinder as well). This will be done to restrict the amount of relative motion between the torpedo and cannon walls, providing a theoretically more accurate launch. The cannons will be controlled by two independent solenoid valves, allowing for the torpedoes to be fired individually. In order to accomplish this, an electronic control board overseeing each of the pneumatic systems' valves will be used. Each of the valves will be located in a valve box, which will be attached to the outlet of a pressure regulator. The first solenoid valve for the grasp/release mechanism would also be located here as well. Revisions have been made to the torpedo to include fins that will be attached to bottom of torpedo; this will introduce uni-axial rotation during flight and increase stability and accuracy. In addition the density of ABS plastic (material used to make the torpedo) will be slightly greater than that of water; this will prevent the torpedo from rising during flight allowing for a relatively straight flight with minimal vertical drop and sufficient velocity. The most important design criterion governing the design of the subsystem is the safety of the mechanism; the mechanism should not be capable of causing bodily harm. In order to ensure safety of these identical mechanical subsystems, the launch velocity of the torpedoes will be controlled via adjustment of the pressure regulator, which connects the compressed CO_2 storage tank to the valve box. In addition, the accuracy of the launcher mechanism can be controlled by slight design modification to the torpedoes if necessary. Additional risk information available in section 7.1.2.7.

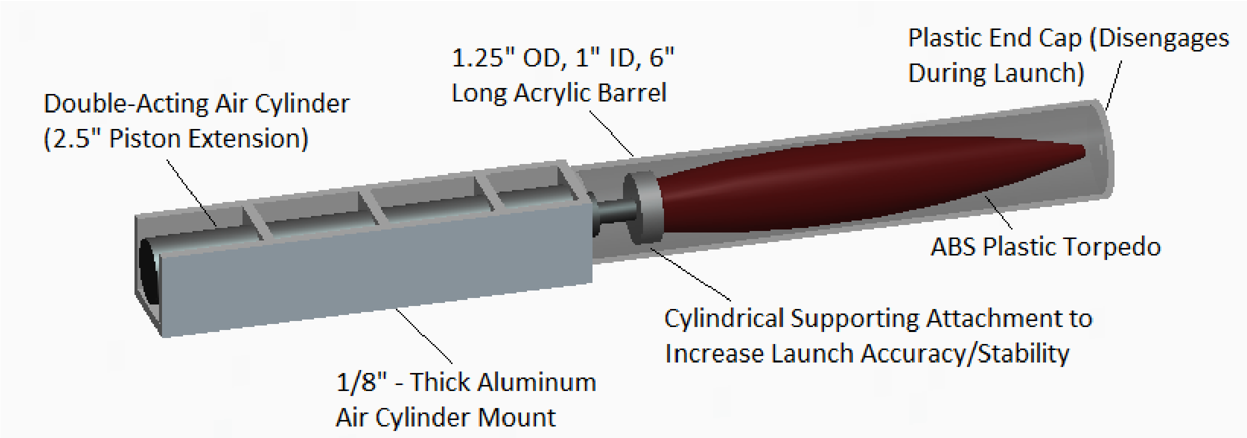


Figure 28: Close-Up View of Torpedo Launcher

4 Schedule

Schedule is available in an extended Gantt chart at the end of the report.

5 Budget Estimate

5.1 Previously Estimated Budget

AUV ESTIMATED BUDGET				
A. Personnel				
Name	**Job Description**	**Base**	**Hours**	**Total**
Antony Jepson	Power Supplies + Hydrophone Implementation	$30.00/hour	12 hours/week for 25 weeks	$9,000.00
Ryan Kopinsky	Cameras/Computer Vision	$30.00/hour	12 hours/week for 25 weeks	$9,000.00
Hang Zhang	Propulsion System + Stability/Depth Control (IMU/Pressure Transducer)	$30.00/hour	12 hours/week for 25 weeks	$9,000.00
Eric Sloan	Hull/Frame + Stability/Depth Control (IMU/Pressure Transducer)	$30.00/hour	12 hours/week for 25 weeks	$9,000.00
Kashief Moody	Torpedo Launchers + Frame	$30.00/hour	12 hours/week for 25 weeks	$9,000.00
Tra Hunter	Grasp/Release Mechanism + Marker Dropper	$30.00/hour	12 hours/week for 25 weeks	$9,000.00
Subtotal of Personnel				$54,000.00
B. Fringe Benefits	= 29% of A			$15,660.00
C. Total Personnel Salary	= A + B			$69,660.00

D. Expenses (Supplies and Items Under $1,000)				
Name	**Description**	**Unit Price (Including Estimated Shipping and Handling Fees)**	**Quantity**	**Total**
Cameras	Computer vision	$55.00	2	$110.00
Hydrophones	Pinger detection	$300.00	4	$1,200.00
Inertial Measurement Unit (IMU)	Stability control	$150.00	1	$150.00
BeagleBoard-xM	Control of thrusters and mechanical subsystems	$150.00	1	$150.00
Communication Cables, Connectors, and Adaptors	Connect peripheral Subsystems and sensors to control units inside the pressure vessel	$50.00	1	$50.00
Voltage Regulation Board	Regulates voltage from external power sources to an acceptable voltage for the BeagleBoard-xM	$200.00	1	$200.00
2' Long, 12" OD, 11.5" ID Acrylic Tube	Hull/pressure vessel	$350.00	1	$350.00
8' *Inch Solid* 80/20 Extruded Aluminum (T-slotted) Framing	Frame	$28.00	5	$140.00
4' *Inch Solid* 80/20 Extruded Aluminum (T-slotted) Framing	Frame + grasp/release mechanism supports	$15.00	1	$15.00

3’ Long, 8” Wide, ¼” Thick Aluminum 6061 Sheet	Support electronics inside pressure vessel + external cameras	$45.00	1	$50.00
12” Long, 12” Wide, 1/8” Thick Acrylic Sheet	Individual camera enclosures	$10.00	1	$10.00
18” Long, 18” Wide, 2” Thick Aluminum 6061 Sheet	End caps for pressure vessel	$495.00	2	$990.00
48” Long, 24” Wide, 1” Thick Acrylic Sheet	Supports for pressure vessel and interior aluminum plate	$285.00	1	$285.00
Polyurethane Adhesive/Sealant for Underwater Use	Attach acrylic supports for the pressure vessel to the frame, and acrylic supports for the interior aluminum plate to the inside of the pressure vessel	$10.00	2	$20.00
SeaBotix BTD150 Thrusters	General vehicle maneuverability	$750.00	3	$2,250
Pressure Transducer	Vehicle depth sensor	$155.00	1	$155.00
Submersible Stainless Steel Solenoid Valves	Control flow of compressed CO_2 to grasp/release mechanism and torpedo launchers	$68.75	4	$275.00
Single-Acting Air Cylinder	Grasp/release mechanism	$35.00	1	$35.00
Double-Acting Air Cylinders	Torpedo launchers	$30.00	2	$60.00
Pressure Regulator	Pneumatic control for grasp/release mechanism + torpedo launchers	$130.00	1	$130.00
ASME-Code Horizontal Pressure Tank	Containment of pressure-regulated CO_2 prior to passing through actuated solenoid valves	$230.00	1	$230.00
2” OD, 1.5” ID Acrylic Tubes	Cannons/barrels for torpedo launchers	$27.50	2	$55.00
Subtotal of Expenses				$6,910
Total Direct Cost	= C + D			$76,570
Overhead Costs	= 45% of Total Direct Cost			$34,457
E. Total Cost	= Total Direct Cost + Overhead Costs			$111,027
F. Travel Expenses	Airfare and hotel for trip to competition in San Diego, CA			$3,000
G. Total Project Cost	= E + F			$114,027

5.2 Current Budget

AUV ESTIMATED BUDGET				
A. Personnel				
Name	**Job Description**	**Base**	**Hours**	**Total**
Antony Jepson	Guidance System	$30.00/hour	12 hours/week for 25 weeks	$9,000.00
Ryan Kopinsky	Cameras/Computer Vision	$30.00/hour	12 hours/week for 25 weeks	$9,000.00
Hang Zhang	Mission control unit	$30.00/hour	12 hours/week for 25 weeks	$9,000.00
Eric Sloan	Hull/Frame	$30.00/hour	12 hours/week for 25 weeks	$9,000.00
Kashief Moody	Torpedo Launchers + Frame	$30.00/hour	12 hours/week for 25 weeks	$9,000.00
Tra Hunter	Grasp/Release Mechanism + Marker Dropper	$30.00/hour	12 hours/week for 25 weeks	$9,000.00
Subtotal of Personnel				$54,000.00
B. Fringe Benefits	= 29% of A			$15,660.00
C. Total Personnel Salary	= A + B			$69,660.00

D. Expenses (Supplies and Items Under $1,000)				
Name	**Description**	**Unit Price (Including Estimated Shipping and Handling Fees)**	**Quantity**	**Total**
Cameras	Computer vision	$55.00	2	$110.00
Hydrophones	Pinger detection	$300.00	4	$1,200.00
Inertial Measurement Unit (IMU)	Stability control	$150.00	1	$150.00
Submersible Pressure Transducer	Determine vehicle depth	$400	1	$330.00
BeagleBoard-xM	Control of thrusters and mechanical subsystems	$150.00	1	$150.00
Communication Cables, Connectors, and Adaptors	Connect peripheral Subsystems and sensors to control units inside the pressure vessel	$50.00	1	$50.00
Voltage Regulation Board	Regulates voltage from external power sources to an acceptable voltage for the BeagleBoard-xM	$200.00	1	$200.00
Clear Cast Acrylic Sheet 1" Thick, 24" X 36"	Hull/Aluminum Platform Supports	$213.42	1	$213.42
Scratch-Resistant Clear Cast Acrylic Sheet 1/8" Thick, 12" X 24"	Camera Enclosures	$28.96	1	$28.96
Multipurpose Aluminum (Alloy 6061) 1-3/4" Thick, 12" X 12"	Fixed Outer End Cap	$118.13	2	$236.26
Precision-Cast Multipurpose Aluminum (MIC 6) 7/8" Thick, 12" X 12"	Removable Inner End Cap	$99.43	3	$298.29

Corrosion-Resistant Aluminum (Alloy 5052) #4 Satin Finish, .187" Thick, 12" X 24"	Electronics Rack	$57.92	1	$57.92
Aramid/Buna-N Gasket 1/16" Thick, 15" X 15"	End Cap Gasket	$17.73	2	$35.46
3M Scotch-Weld Rubber and Gasket Adhesive NO. 847 Brush Application, 5-Ounce Tube	End Cap Gasket Adhesive	$12.07	1	$12.07
Submersible SS Solenoid Valve Fluoroelastomer Seal, 1/8 NPT Fem, 175 PSI, 12 VDC	Grasp/Release Mechanism Torpedo Launcher	$65.15	4	$260.60
Stainless Steel Air Cylinder Nose-Mount, Spring Return, 3/4" Bore, 2" Stroke	Grasp/Release Mechanism	$17.96	2	$35.92
Stainless Steel Air Cylinder Nose-Mount, Double Acting, 3/4" Bore, 2-1/2" Stroke	Torpedo Launcher	$23.65	2	$47.30
Cast Acrylic Tubing 10.000OD x .250 Wall Thickness per foot - 20.5 inches	Hull/Pressure Vessel	$135.04/ft	1	$230.69
Cast Acrylic Tubing 1.250OD x .125 Wall Thickness per foot - 6 inches	Torpedo Cannons	$27.11/ft	2	$27.11
Clear Anodized 80/20 Extruded 6105-T5 Aluminum T-Slot Framing 1.0" x 1.0" - 27.00" long (7042 in A both ends)	Frame	$0.23/in	4	$24.84
Cut-to-Length for 1010	Frame (service)	$1.95	4	$7.80
10 Series Anchor Fastener Counterbore	Frame (service)	$2.25	8	$18.00
Clear Anodized 80/20 Extruded 6105-T5 Aluminum T-Slot Framing 1.0" x 1.0" - 15.00" long	Frame	$0.23/in	4	$13.80
Cut-to-Length for 1010	Frame (service)	$1.95	4	$7.80
Clear Anodized 80/20 Extruded 6105-T5 Aluminum T-Slot Framing 1.0" x 1.0" - 13.00" long (7042 in A both ends)	Frame	$0.23/in	12	$35.88
10 Series Anchor Fastener Counterbore	Frame (service)	$2.25	24	$54.00

Clear Anodized 80/20 Extruded 6105-T5 Aluminum T-Slot Framing 1.0" x 1.0" - 4.50" long (7042 in A both ends)	Frame	$0.23/in	6	$6.21
Cut-to-Length for 1010	Frame (service)	$1.95	6	$11.70
10 Series Anchor Fastener Counterbore	Frame (service)	$2.25	12	$27.00
Clear Anodized 80/20 Extruded 6105-T5 Aluminum T-Slot Framing 1.0" x 1.0" - 3.125" long	Frame	$0.23/in	1	$0.72
Cut-to-Length for 1010	Frame (service)	$1.95	1	$1.95
10 Series Anchor Fasteners	Frame	$2.90	22	$63.80
SBT150 Thruster	SeaBotix SBT150 Thruster	$495.00	2	$990.00
Subtotal of Expenses				$4,937.50
Total Direct Cost	= C + D			$74,597.50
Overhead Costs	= 45% of Total Direct Cost	$33,568.88		
H. Total Cost	= Total Direct Cost + Overhead Costs	$108,166.38		
I. Travel Expenses	Airfare and hotel for trip to competition in San Diego, CA	$4,000		
J. Total Project Cost	= E + F	$112,166.38		

6 Test Plan

For the mission control system, the test plan is divided into three stages. The first stage is the individual mission tests. For example, after the program for the initialization task is finished, we will conduct tests on this set of program to make sure that all components of the AUV can be properly initialized. After the initialization stage is successfully tested, we proceed to finish the gate pass mission program, and conduct tests to make sure the mission controller can receive correct signals from cameras, IMU, and pressure sensors and send proper commands to thrusters to controls their speeds. This test will be conducted first in lab, and then in the pool, which will be simulated as a competition environment. The test on gate pass mission will require enormous effort and a lot of time, since it also involves testing on proper operation and collaboration of other components in the system. After the gate pass test is successfully finished, the rest mission tests can conducted similarly. The second stage is functional tests on the entire mission control program (will be conducted nearly the end of this project after all individual components have been successfully finished). During this stage, the vehicle will be place in the pool and complete each task autonomously. The mission control program will be fully tested during this stage. The third stage will be stress test stage. We will conduct extensive tests on the mission control of the AUV to fix bugs so that the mission controller can handle as many situations as possible.

7 Overall Risk Assessment

This section covers the technical risks, or design, integration, and project competition risks, schedule risks, that may impact project completion in a timely manner, and budget risks, which may produce budget overruns.

7.1 Technical Risks

7.1.1 Electronics

7.1.1.1 Mission Control

7.1.1.1.1 Main Control Unit Failure

Risk	Beagleboard-xM malfunction
Probability	Low
Consequence	Catastrophic
Strategy	1. Have the old version of Beagleboard as a backup 2. Use Beagleboard-xM properly to avoid static charges that may cause damage to the board. 3. Over current protection to the board 4. Ensure good heat dissipation within the pressure vessel 5. Ensure water tight of the pressure vessel

Description

The main control unit (Beagleboard-xM) of our AUV may subject to sudden malfunction due to electrostatic charges, careless handling of the board such as dropping it to the ground, overheating once placed in the water tight pressure vessel, damage due to water leaks in the pressure vessel, and also the defects of board itself.

Probability: **Low**

The probability of the Beagleboard-xM malfunction is low. The board will have protection against electrostatic charges, and be placed in the secured box. Once placed in the AUV, the board will be firmly fixed on a rack. The heat dissipation problem within the pressure vessel will be carefully simulated and tested before we fix the board in the pressure vessel. And the probability of a defect board is also low.

Consequences: **Catastrophic**

The consequence of the main control unit malfunction is catastrophic. All sensors and motors rely on the main control unit to function properly. Once the main control unit is broken down, the whole AUV system will not be functional. During development stage, if the Beagleboard-xM suddenly broke down, it will significantly delay our developing process. If the beagleboard broke down during the competition, the result will be catastrophic, and we will not be able to finish all the tasks in the competition.

Strategy

1. Have the old version of Beagleboard as a backup. Since we have an old version of Beagleboard, we will use it as a backup. If something is wrong with the Beagleboard-xM, we will continue our development on the old Beagleboard, and get the malfunctioned Beagleboard-xM replaced as soon as possible so that it will minimize the impact to our development process.

2. Use Beagleboard-xM properly to avoid static charges that may cause damage to the board. To avoid any damage to the board, the Beagleboard-xM should be handled carefully. The board itself will be well protected with sponges and boxes. Touching the board directly with hands should be prohibited due to the electrostatic hazard which may damage the board.
3. Over current protection to the board. Since the maximum current the Beagleboard-xM draws should be less than 3Amps, a 3Amps fuse will be used for over current or surge current protection to minimize the probability of the board being damaged by the current.

4. Ensure good heat dissipation within the pressure vessel. We will ensure the heat generated within the pressure vessel will be effectively pumped out. Numerous stress tests will be conducted for the heat dissipation. One way to test the heat conduction is to estimate the total heat dissipation in the vessel, and place a lamp of similar or higher power dissipation in the vessel and measure the temperature overtime to ensure that all the heat and be pumped out effectively to avoid overheating that may damage the board.

5. Ensure water tight of the pressure vessel. The pressure vessel needs to be water tight before we can place the Beaglebord-xM inside to avoid any water leaks that may damage the board. Stress tests will be conducted to ensure the water tight of the pressure vessel.

7.1.1.1.2 Software Bugs May Cause Operation Failure of Some Tasks

Risk	Software bugs may cause operation failure of some tasks
Probability	Very High
Consequence	Severe
Strategy	1.Careful design of the software system 2.Extensive debugging and testing 3.Simulate the competition environment during tests

Description
The mission control software system is a large program that coordinates all the components onboard and determines what the AUV should perform at each stage. This program will be designed and written by our team. Bugs are inevitable in this large and complex program. Some bugs may be minor, but some may lead to operation failure during performing some tasks. For instance, a communication error between the camera and the mission control system may lead to an incorrect path for the AUV.

Probability: **Very High**
The probability of this risk is very high due to the fact that software bugs are almost inevitable in such a complex program.

Consequences: **Severe**
The consequences of the software system bugs varies, some bugs maybe minor, some maybe moderate, and some can be severe, but none of the bugs should produce catastrophic consequence which disables the entire system of the AUV (horrible design of the control system or hardware failure). Severe consequence may occur when some bugs cause failure in performing certain tasks.

Strategy
1. Careful design of the software system. During design stage, the mission control system should be very carefully designed to minimize the probability of severe bugs.
2. Extensive debugging and testing. At developing stage, debugging and testing should be conducted as much as possible. Testbench could be designed to conduct tests in the lab.
3. Simulate the competition environment during tests. After significant amount of testing in lab, the system will be put into a simulated competition environment to test possible bugs and functionalities.

7.1.1.1.3 Power Supply Failure

Risk	Batteries fail to supply enough power
Probability	Very low
Consequence	Severe
Strategy	1. Carefully design electrical system with current limitation 2. Test batteries regularly to ensure the quality

Description
The power supply of our AUV or the two lithium-ion batteries may fail to supply enough power. This can be caused by the worn out of the battery or battery defects. This can also be caused by the system which tries to draw more power than the amount that the battery can supply.

Probability: **Very low**
The probality of having a power supply failure during the competition or design stage is identified to be very low. The batteries has been recently tested, and is fully charged at almost 100 percent capacity. The possibility of having the batteries worn out is also very low because these two batteries are almost new. Lithium batteries can be used for at least a couple years. Therefore, the possbility to have battery failure is very low.

Consequences: **Severe**
If the battery of our vehicle failed, the AUV will not function properly. In fact, the thrusters will all lose

their power. The AUV would not be able to move autonomously. The battery then must be replaced as soon as possible. But during the early design stage, we can use other power supply to power our system if any batteries fails, therefore, the battery failure to our design is relatively small.

Strategy

1. A Careful design of the electrical system can avoid the total amount of current draw exceeds the maximum discharging rate of the battery. For instance, only the two thrusters that controls the movement of the vehicle should draw signicant amount of power. The rest four thrusters which control the orientation and depth should draw very small amount of power. And therefore reducing the total amount of current the system draws.
2. Since batteries usually fails slowly and will not be subject to sudden failure, there is no need to have a back up battery, since an extra battery is very expensive. However, to ensure the good quality of the battery, our team needs to test the battery regularly. If the battery fails before the competition, we shall purchase an replacement battery as soon as possible.

7.1.1.1.4 All thrusters draw maximum current concurrently

Risk	All thrusters draw maximum current concurrently results in power deficiency of other components
Probability	Very low
Consequence	Catastrophic
Strategy	1. Limit the current through software control 2. Conduct extensive tests to minimize the probability of such situation

Description

The maximum current rating that each thruster will draw is 5A. However, the maximum discharging rate of the battery is 30A. Therefore, if all thrusters draw maximum current at the same time, there will not be enough current to supply power to other components such as the Beagleboard.

Probability: ***Very Low***

The probability of all thrusters drawing maximum current at the same time will be very low. Only the two thrusters that are responsible for propelling the vehicle will have a possibility to reach 5A maximum current. Other thrusters such as the orientation control thrusters only requires a small amount of current to carefully adjust the vehicle's orientation. If the current is too large, the orientation of the vehicle will be very difficult to be controlled. If the vehicle is at the desired orientation, these two thrusters can even be powered off.

Consequences: ***Catastrophic***

If all six thrusters are drawing maximum 5A current, no current will be available for other components such as the Beagleboard, arduino board, and other sensors. Therefore, the AUV will lose its control completely. And the vehicle may not stop until it hit the edge of the pool and be damaged. This result is catastrophic to our AUV.

Strategy:

To avoid all thrusters drawing maximum current at the same time, we limit the current for four of the thrusters which control the depth and orientation through software control. The PWMs on the Arduino board can provide 255 speed levels to each thruster. Using only low speed levels to the four thrusters will limit the current draws by these thrusters.

An extensive amount of tests shall be conducted on the electrical system to ensure such risk can be minimized and avoided. The maximum force from each thruster will be calculated and therefore the maximum current needed will be known. The current draws by each thruster will be monitored during tests.

7.1.1.1.5 AUV balance affected by different current draw among thrusters

Risk	Imbalance of the AUV due to different current draw between each thruster pair
Probability	Very High
Consequence	Severe
Strategy	1. Balance the vehicle through weight distribution 2. Add additional weight so that the effect of force difference caused by small current difference will be minimized 3. Optimize the dynamic control of the system using IMU

Description

The AUV will lose its balance underwater if one propelling thruster draws more current than the other propelling thruster. The thruster that draws more current will produce more force, which will cause imbalance problems while the AUV is moving.

Probability: **Very High**

Due to the face that it is almost impossible to control all the thrusters to draw exactly the same amount of power, it is a very high possibility that the thrusters in each thruster pair namely the propelling pair, vertical depth control pair, and the orientation control pair will draw slightly different amount of current. And this different amount of current will result in different amount of forces.

Consequences: **Severe**

The consequence of having an imbalanced vehicle underwater is severe. It will be very difficult for the vehicle to complete each task properly. Besides, the vehicle may keep trying to rebalance, and therefore cannot proceed to finish the tasks.

Strategy

1. The stability of the AUV can be achieved through a perfect symmetric weight distribution so that the vehicle can achieve balance naturally underwater when there is no external water current influence. This requires a careful design of the mechanical structure of the AUV.
2. Additional weight can be added under the condition that it will not result in exceeding the maximum allowed weight for the competition. With additional weight added, the impact of the force difference can be minimized, since it will require larger force to disturb the vehicle's balance.
3. A dynamic stability control system can be used to help the AUV achieve balance during operation. The dynamic stability control system will use the sensor data from IMU which provides data on AUV's acceleration, orientation, and rotation to adjust itself back to a balance state. Since the stability control system involves knowledge of fluids that none of our team members have experience with, we will consult professors and do some more research in this area before we start design this system.

7.1.1.2 Guidance System

7.1.1.2.1 Incorrect calibration of components

Risk	Components used for the guidance system are incorrectly calibrated.
Probability	Moderate
Consequence	Severe
Strategy	1. Soak instruments in the water for at least 10 minutes before performing a calibration. 2. Perform multiple calibrations (initial sensor readings) before continuing on with the competition.

Description

As with any measurement system, calibration must take place to ensure that further measurements are accurate. Because of the dependence on calibration, a mis-calibrated measurement device will consistently produce faulty results.

Probability: **Moderate**

This is a likely occurrence simply because there isn't a known reference available around the COE with which to base the initial measurements at the AUVSI pool. The competition requirements can best be emulated with the pool located at the FSU / MORCOM aquatic center.

Consequence: **Severe**

The guidance system is paramount to correct operation of the AUV. If the calibration fails, the AUV will be forced to rely on the Computer Vision system for correct orientation readings. Since the guidance system is more accurate than the Computer Vision, the AUV will likely only be able to execute the path following algorithm.

Strategy

1. Both the hydrophone and the submersible pressure transducer require submersion for at least 10 minutes before taking readings. This allows the output to stabilize before it is read. To reduce the probability of this occurring, they will be both be soaked before taking readings.
2. Calibration is not a one-time affair – multiple calibrations can take place both at the start of the competition and later on during the competition. The probability of mis-calibration will be furthered reduced by taking multiple readings when the AUV is first submersed.

7.1.1.2.2 Not enough accuracy in components

Risk	Components used are not accurate enough for useful measurements in the AUV
Probability	Low
Consequence	Moderate
Strategy	1. Test components thoroughly for accuracy. 2. Order new components if necessary.

Description

An autonomous underwater vehicle needs as much data with as much precision as possible. This enabled the AUV to dynamically determine how much accuracy is required to continue on to the next task. If the components used are not accurate enough then the AUV will not be able to sufficiently determine the next task because not enough input is sent into the system.

Probability: **Low**

The probability of this taking place is low because significant attention was spent analyzing the data sheet to confirm that it will meet the requirements of the Robosub – even in the event that the data sheet readings do not exactly mirror real-life performance.

Consequence: **Moderate**

In the event that a component is deemed not accurate enough for the AUV, the consequence will be moderate because time will be lost waiting for a new component to arrive. Furthermore, this new component may require different programming than the previous version entailing more time spent not working on completing the project.

Strategy

1. This risk will be mitigated by, as mentioned, carefully reading the data sheet provided by the vendor.
2. Furthermore, the budget should allow for one or two low-cost components to be repurchased at a later date during the development of the AUV.

7.1.1.3 Computer Vision

7.1.1.3.1 Camera failure

Risk	No image feed from camera(s)
Probability	Very Low
Consequence	Catastrophic
Strategy	1. Carefully use cameras to avoid failure as much as possible 2. Ensure water-tightness of the camera enclosures 3. Have a spare camera on hand

Description

The webcams may fail due to careless handling or water in the camera enclosures.

Probability: **Very Low**

The probability of webcam failure is very low since there is an avoidance plan intact. It is part of the team's strategy to carefully handle the cameras and to ensure that the camera enclosures are water-tight.

Consequences: **Catastrophic**

Since the navigation and task management systems heavily rely on the image processing and computer vision module, the result of camera failure would be catastrophic in a sense that the team would not be able to successfully complete the obstacle course.

Strategy

1. The team will use extreme caution when handling and mounting the cameras. It is the team's goal to avoid camera failure as much as possible.
2. The water-tight camera enclosures will undergo extensive testing to ensure that there are no water leaks in the enclosures.

There will be a spare camera on hand in case one of the cameras fails. If both cameras on the RoboSub fail, the team will have to borrow or buy a camera.

7.1.1.3.2 HSV Color-Space Not Suitable

Risk	HSV color space not suitable for extraction of certain information
Probability	Low
Consequence	Minor
Strategy	1. Extensively test the module to ensure that the HSV color space is suitable for the extraction of all the necessary information 2. The module will output images in a format or color space that will ensure successful extraction of all the necessary information

Description

The Pre-Processing module may fail to extract all the necessary information from the images in the HSV color space.

Probability: **Low**

The probability of failure of the Pre-Processing module is low. Since each software module will undergo extensive testing for a variety of scenarios, failure of such modules is low.

Consequences: **Minor**

The consequence of failure of the Pre-Processing module is minor because the code for this module can be easily rewritten to output images in a different color space or format.

Strategy

1. Each software module will undergo extensive testing for a variety of scenarios. The testing of the Pre-Processing module will ensure that the HSV color space is suitable for the extraction of all the necessary information.
2. If for some reason image features or information cannot be extracted from the image in the HSV color space, the code will be changed to output images in a different color space or format. It only takes one function to determine the output color space or format so it should be rather easy to implement any modifications to the module.

7.1.1.3.3 Incorrect Color Classification

Risk	Incorrect color classification
Probability	Very Low
Consequence	Severe
Strategy	1. Add enough training data for correct classification 2. Adjust color thresholds for accurate color classification

Description
The Color Filter may fail to correctly classify a certain color in an image frame.

Probability: **Very Low**
Since all software modules will undergo extensive testing, the probability of failure is very low. In addition to extensive testing, enough training data will ensure a very low probability of failure.

Consequences: **Severe**
The consequences of failure for this module are severe because the task management system heavily relies on the output of this module. If the Color Filter fails to classify certain colors, the RoboSub has very little chance of successfully completing the hit-buoys and torpedo-through-cutout tasks.

Strategy
1. In order to minimize incorrect color classification, the system will be tested with enough training data. The training data will ensure that the system successfully classifies the colors in various scenarios and lighting conditions.
2. If the module incorrectly classifies a specific color, the threshold HSV values will be adjusted accordingly to maximize the accuracy of the classification.

7.1.1.3.4 Path Detection Failure

Risk	Failure to detect the direction of the path
Probability	Moderate
Consequence	Catastrophic
Strategy	1. Extensively test and debug code in order to minimize failure 2. Develop an algorithm to get back on track in the case of failure

Description
The Path Detection module may fail to detect the correct direction of the path (segments).

Probability: **Moderate**
The probability of failure is moderate considering the complexity of this module. This module is most likely the most complex software module in the Computer Vision system and will require a lot of effort to complete.

Consequences: **Catastrophic**
The consequence of failure of the Path Detection module is catastrophic. If the module fails to detect the correct direction of the path, the vehicle will go off-course and will most likely struggle to come back on track. The completion of the obstacle course heavily relies on this module and failure is, therefore, catastrophic.

Strategy

1. In order to avoid getting off-track, the Path Detection module will be extensively tested and debugged. The software engineers will spend a great deal of time on this module to ensure accurate tracking of the path segments.
2. If the RoboSub goes off-track due to failure of the Path Detection module, a custom algorithm will need to kick in to bring the RoboSub back on track. The custom algorithm will be part of the Path Detection module.

7.1.1.3.5 Inaccurate Vehicle-To-Object Distance

Risk	Inaccurate estimation of the vehicle-to-object distance
Probability	Low
Consequence	Moderate
Strategy	1. Provide the module with more training data

Description

The Size Detection module may fail to accurately estimate the vehicle-to-object distance.

Probability: **Low**

The probability of failure is low because the module will have enough training data to accurately determine the vehicle-to-object distance.

Consequences: **Moderate**

The consequence of failure is moderate. For certain tasks (hit-buoys and torpedo-through-cutout) in the obstacle course, accurate measurement of the vehicle-to-object distance is required. If the module fails to provide accurate distance information, two of the tasks cannot be completed.

Strategy

1. In the case of failure, the Size Detection module would be provided with even more training data to improve upon classification accuracy. More training data requires more space from the storage system, so it is important that the module obtains maximum accuracy with minimal training data.

7.1.1.3.6 Incorrect Navigational Instructions

Risk	Incorrect navigational instructions sent to the Main Controller
Probability	Low
Consequence	Catastrophic
Strategy	1. Extensively test the module to minimize failure

Description

The Navigation module may send incorrect navigational instructions to the Main Controller.

Probability: **Low**

The probability of failure of the Navigational module is low. The objective of this module is to gather information from the Size Detection and Path Detection modules and send the information in the form of navigational instructions. If the Size Detection and Path Detection modules operate as desired, the Navigation module will not be likely to fail.

Consequences: **Catastrophic**

The consequence of failure is catastrophic because the navigation of the RoboSub depends on the instructions sent from the Navigation module.

Strategy

In order to minimize failure, the module will undergo extensive testing to ensure that the correct output is provided to the Main Controller.

7.1.1.3.7 Incorrect Shape Detection

Risk	Incorrect shape classification
Probability	Very Low
Consequence	Moderate
Strategy	1. Extensively test the module to minimize failure 2. Provide more training data to minimize failure

Description

The Shape Detection module may fail to classify the shape of a certain object.

Probability: **Very Low**

Since the algorithm only has to classify a few distinct shapes, the risk of incorrect classification is very low.

Consequences: **Moderate**

The consequence of failure is moderate in a sense that the module would wrongly identify the task at hand. The consequence is moderate because the algorithm receives a feed of images and one wrong classification would not have a significant impact on the task management.

Strategy

1. In order to minimize failure, the software engineers will spend a great amount of time testing the module.
2. If a specific shape is incorrectly classified, the software engineers will provide more training data for that specific shape. This will improve the robustness and accuracy of the module.

7.1.1.3.8 Incorrect Task Identification

Risk	Incorrect identification of the current task
Probability	Low
Consequence	Severe
Strategy	Extensively test the module to minimize failure

Description
The Task Control module may fail to correctly identify the task at hand.

Probability: **Low**
The probability of failure is low because most of the task management is done by shape detection.

Consequences: **Severe**
In the case of incorrect identification of the task at hand, the team may fail to successfully complete the obstacle course or may be penalized. The consequence of failure is, therefore, severe.

Strategy
In order to minimize failure, the software engineers will spend a great amount of time testing the module. Rigorous test plans will ensure that the Task Control module correctly identifies each task in the obstacle course.

7.1.2 Mechanical System

7.1.2.1 Vehicle density greater or less than optimal target density

Risk	Vehicle density greater of less than optimal target density
Probability	Low
Consequence	Moderate
Strategy	Symmetrically add material of greater or less density than the vehicle's target density to either side of the bottom of the AUV until the nominal system density has been obtained.

Description
The density of the completed AUV will potentially be a considerable amount greater or less than the desired target density of the system.

Probability: **Low**
Due to the very detailed Pro/Engineer model which contains accurate density values for each of the carefully dimensioned parts, the projected system density, weight, center of mass, and inertia values should yield accurate and trustworthy projections. Thus, the probability of the end product density not being near the nominal value is relatively low.

Consequences: **Moderate**
The consequence of not having the proper system density is deemed moderate because it would either yield an increased demand from the thrusters, or worse, a vehicle that would naturally sink when the kill switch is activated and the thrusters are shut off.

Strategy

If the vehicle density ends up being greater or less than the optimal target density to a significant extent, material of greater or less density than this target density will be added to either side of the bottom of the AUV until the nominal system density has been obtained. Symmetry and balance will be maintained through this process. However, the use of "dummy material" will likely be implemented during the vehicle progression and testing phases anyway since the density of the AUV will progressively change with the addition of components and functionality. Still, it is desired to have the density of the completed AUV in the nominal range so that this "dummy material" will not be necessary to implement on the final product, yielding a more aesthetically appealing and well-designed product.

Test Plan

While the detailed Pro/Engineer calculations should provide an accurate theoretical projected system density should the design be followed as carefully planned, the actual system density will be derived using one or both of the following methods:

1) Weigh the vehicle on a scale, and calculate the density based off the known volume of each of the components of the vehicle (which should all eventually be implemented into the Pro/Engineer model).

2) Perform a water test where the vertical side thrusters would be progressively given a greater duty until neutral buoyancy was achieved. Then, derive the density based off the corresponding thrust and the known density of the pool water in which the vehicle will be tested.

This experimentally derived density calculation will enable the design team to determine whether the addition of "dummy mass" is necessary, and if so, the quantity (in volume or mass) that is required.

7.1.2.2 Electronics overheat due to insufficient heat dissipation system

Risk	Electronics overheat due to insufficient heat dissipation system
Probability	Low
Consequence	Moderate
Strategy	Install a battery-powered fan inside the hull in order to circulate the heat away from the electronics and into the surrounding air inside the hull. The fan would induce forced convection, and provide the necessary heat extraction from the electronics.

Description

The electronics could potentially overheat if the heat dissipation system (i.e. conduction through the aluminum platform, thin aluminum end cap walls, and into the surrounding environment) is insufficient.

Probability: **Low**

Since the heat generation from the electronics is expected to be low however—particularly due to a relatively low power demand from the thrusters, the relatively large convection coefficient of flowing water against the end caps, and the thin wall through which the heat will need to conduct in order to escape the hull and reach the external environment—the probability of a fan being required is relatively low.

Consequences: **Moderate**

While overheating could cause the electronics to malfunction or burn out, and would thus provide a moderate consequence, a simple solution is available.

Strategy

Should the aluminum platform inside the hull prove unsuccessful in efficiently and effectively dissipating heat away from the electronics and into the surrounding salt water environment via conduction, a battery powered fan will be installed inside the hull at one end, and will serve to induce forced convection and circulate heat away from the electronics.

Test Plan

Thermocouples or thermistor-integrated wheat stone bridges will potentially be able to be used in order to determine the temperature at various locations inside the hull during an underwater test or operating level. There may be a way the design team can have the temperature readings captured and stored as a .txt file, so that a plot of temperature versus time can be obtained and analyzed following an underwater test. If this proves to be unsuccessful or excessively challenging, a theoretical FEM model of the closed system will be derived based on the theoretical average heat generation rates from each of the electrical components (mainly a function of the average required thrust from each thruster over a period of time).

7.1.2.3 Hull is not completely watertight

Risk	Hull is not completely watertight and experiences leakage or potential flooding
Probability	Low
Consequence	Severe
Strategy	1. Use new end cap design and SEACON underwater wet-mate split connectors and cables 2. Apply caulking to the interface between the outer face of each end cap and the corresponding threaded SEACON connector

Description

The hull could potentially leak—posing a threat to the integrity of the lithium-ion batteries and electronics.

Probability: **Low**

The new end cap design should provide a more secure, reliable seal. The gaskets should serve to get rid of any significant air pockets (and thus sources for water leakage) along the mating surface of the removable inner and fixed outer component of each end cap that might otherwise have been present due to natural surface roughness of the materials. Furthermore, extensive testing will be done to ensure the hull is completely and reliably watertight prior to introducing the electronics. The integrity of the hull will also be visual analyzed every time the vehicle is to undergo a water test. As a result of these procedures, the probability of water leakage or even flooding is determined to be low.

Consequences: **Severe**

The consequence of the watertight nature of the hull being compromised during an underwater test is severe. If water were to enter the hull with the electronics and battery packs inside as well, the circuits could short, sparks could fly, and the electronics could be destroyed.

Strategy

1. Carefully attach the fixed outer ring of each end cap using marine-grade caulking. Ensure that the adhesive is applied cleanly and methodically to eliminate any minute air gaps between the mating surfaces.
2. Use SEACON split underwater wet-mate connectors to link the internal electronics to the external peripheral subsystems. SEACON connectors are specifically made for underwater use. Furthermore, by using split connectors, the number of holes that need to be drilled and tapped into each end cap will be significantly reduced—thus reducing the risk of leakage through any of these connections and into the hull. Loctite might also be applied to the threads of each of these connectors to secure these seals.

7.1.2.4 CO_2 Distribution System Failure

Risk	CO_2 Distribution System malfunction
Probability	Moderate
Consequence	Severe
Strategy	1. Verify the proper pressure of all the CO_2 lines 2. Regulate the pressure at the outlet of the compressed CO_2 tank to the desired operational level 3. Purchase a backup CO_2 tank (inexpensive) in case the supply runs out, or runs low at the competition site

Description

Since the compressed CO_2 tank will have an excessively high outlet pressure of ≈ 800 – 1,500 psi, it is critical that this supply is regulated down to ≈ 100 psi prior to entering the solenoid valves in order to result in a reasonable operational pressure. Failure of the pressure regulator or the integrity of the gas lines would be damaging. Thus, these aspects of the CO_2 distribution system will be carefully inspected and tested in order to prevent a pressure blow out (leakage) from occurring.

Probability: **Moderate**

The probability of the CO_2 distribution system failing due to leakage is moderate. The relative pressure of the system is high but the components of the system are designed to meet significantly higher pressure standards. Furthermore, hydrostatic pressure from the surrounding water will slightly resist the outward pressure of the compressed gas, thus slightly reducing the stress on the 1/8" diameter tubes. In addition, the solenoid valves and air cylinders will be firmly secured to the frame, and thus, exposed forces due to the sudden release of the high-pressure CO_2 into the distribution gas lines should be able to be easily withstood without resulting in significant vibrations or slippage of the connections.

Consequences: **Severe**

Failure of the compressed CO_2 tank or the gas distribution lines would yield the grasp release mechanism and the torpedo launchers inactive, thus significantly reducing our maximum attainable points during the mission. Furthermore, if the lines were to unintentionally release compressed gas into the environment due to a leak or a loose connection, water could infiltrate the solenoid valves, causing a slight increase in the system's density. The side thrusters which control the vertical depth of the vehicle would have to compensate for this. Fortunately, the team is afforded three attempts at the mission, so if a leak were to occur during competition, new tubing could be quickly installed, or the original tube could be readjusted to fix the problem. However, the immediate consequences of such a failure deem it to be considered severe.

Strategy

1. Verify the proper pressure of all the CO_2 lines.

The gas lines will be tested to make sure there are no leaks. The lines will be filled with pressure-regulated CO_2 and the actual initial pressure will be measured and documented. The gas-filled tubes will be allowed to rest for a period of time and thereafter, the pressure will again be checked to ensure there is no significant drop in pressure due to a loose attachment or faulty gas line. This will simulate, for example, sustained extension of the grasp release mechanism air cylinders when the object is being grasped.

2. Regulate the pressure at the outlet of the compressed CO_2 tank to the desired operational level.

The outlet pressure of the compressed CO_2 tank must be regulated so that the working pressure is 100 psi. This will allow for a safer system by reduce the potential for gas line failure and will also allow the peripheral subsystems to operate under proper conditions. The pressure at the outlet of the regulator will be checked via a pressure gauge in order to verify the desired pressure reduction has been achieved.

3. Purchase a backup CO_2 tank (inexpensive) in case the supply runs out, or runs low at the competition site

The compressed CO_2 tank holds a finite amount of liquid CO_2. So, as the boiled-off high-pressure gas is distributed to the subsystems and, in the case of the grasp/release mechanisms, dissipated into the surrounding environment (upon release of the object), the CO_2 level will decrease with usage. Since it is not expected that there will be a supply of CO_2 on the competition site (although there may be) to refill the original tank, in order to ensure full tank during competition, a backup tank will be purchased and used before the mission.

7.1.2.5 Marker Dropper Failure

Risk	Marker Dropper malfunction
Probability	Very Low
Consequence	Minor
Strategy	Consider purchasing an identical backup servomotor

Description

There is the potential that the servo arm does not actuate properly either due to loose wires or motor failure. The electrical wires could potentially come loose following a sudden acceleration of the vehicle (e.g. during the torpedo launches or during actuation of the solenoid valves). The stability of the connections will need to be monitored in order to prevent this from occurring.

Probability: **Very Low**

The probability of the marker dropper failing will be low. The servomotor is the main at-risk component in the design and it is water proof, so failure from water intrusion will not be likely. Furthermore, the vehicle's acceleration during the course of the mission is not expected to approach a level to where the integrity of the wire connections is a concern. Furthermore, the design is so simple that failure of proper operation is also unlikely.

Consequences: **Minor**

The consequences of the marker dropper failing for the aforementioned reasons would be relatively minor. Since three attempts at the mission are allocated to each design team, the AUV would simply be taken out of the water, either the wires would be secured, or a backup servo motor implemented, and another trial run would be attempted.

Strategy

If it is deemed that there is a decent risk of the servo motor failing, an identical backup motor will be brought to competition. Furthermore, if it is determined during the testing phases that wires tend to become loose during actuation of the solenoid valves or launching of the torpedoes, they will be soldered to the respective pins on the microprocessors (most likely scenario).

7.1.2.6 Grasp / Release Mechanism Failure

Risk	Grasp / Release Mechanism malfunction
Probability	Low
Consequence	Moderate
Strategy	1. Verify proper rotation of the grasping jaws during the range of motion of the corresponding single-acting air cylinder 2. Verify proper actuation of the corresponding solenoid valves

Description

Should one of the two solenoid valves connected to the gasp / release mechanism fail to actuate, the jaws could be locked in either a closed or open state, thus restricting the ability for the object to either be grasped or released.

Probability: **Low**

The likelihood of the solenoid valves failing to operate properly during competition is low. The actuation of the valves will be extensively testing during the testing phases in similar conditions, and thus there is no foreseen indication that the solenoid valves would fail to actuate during the competition. If there is a sudden failure to actuate when expected, the code would be verified as it would likely be the source if this incident.

Consequences: **Moderate**

The consequences of the grasp release mechanism failing would be moderate. If the mechanism were to fail, the AUV would not be able to complete the pinger task of the obstacle course, thus resulting in a loss of potential points. However, again, since each competing design team is afforded three attempts at each mission, the source of this error would likely be able to be easily detected and fixed.

Strategy

1. Proper rotation of the jaws throughout the entire range of motion of the air cylinder piston will be ensured via careful attention to the alignment of the axis of each piece of the jaws, in conjunction with the potential application of lubricant to the pin joints.

2. Proper actuation of the two corresponding solenoid valves will be extensively tested leading up to

the competition in order to reduce the potential of a malfunction during competition.

7.1.2.7 Torpedo Launcher Failure

Risk	Torpedo Launcher malfunction
Probability	Moderate
Consequence	Minor
Strategy	Use an alternative end cap design or temporary securing method

Description
Should the plastic end caps not disengage properly or consistently, the AUV will be unable to successfully launch the torpedoes through the PVC cutouts, as required.

Probability: **Moderate**
The probability of the designed plastic end caps not disengaging properly is deemed moderate because a relatively small range between securing the projectile and easily disengaging upon actuation of the respective torpedo launcher will have to be found. If not, the end cap could prematurely disengage or not disengage at all during actuation. This will be discovered during the testing phase.

Consequences: **Minor**
The consequence of a malfunctioning barrel end cap is relatively minor, since it would result in a loss of points, but not a complete abortion of the mission. Also, by the time the team has reached competition, a more reliable temporary securing method will very likely have taken place, so an unexpected failure during completion is highly unlikely.

Strategy
If it is deemed too difficult to find the balance between security and ease of release, an alternative method will be used, such as rubber flaps in place of the plastic end cap, or low strength magnets will be applied to the cylindrical piston attachment to each air cylinder and the bottom surface of each torpedo in an attempt to better secure each torpedo during inactivity, and easily release each torpedo when actuated.

7.1.3 Competition Requirements May Change

Risk	Competition rule changes that necessitate major redesign
Probability	High
Consequence	Severe
Strategy	1. Get the official rule as soon as it is released 2. Focus on design that most likely would not be affected by rules first based past year's rules 3. Ensure flexible design so it can be modified easily later once rules are released

Description
At this moment, the official rules for the RoboSub 2012 competition has not been released yet. Therefore, there is a risk that our design may needs to be modified to satisfy the new rules, and our

design at this stage has to be based on rules from previous years.

Probability: **High**

The probability of the competition rule changes is high. However, according to past several years' rules, there are certain requirements that remain constant. For example, the AUV needs to have color and shape detection capability, propelled by thrusters, pass through a gate, touch buoys, and so on. Therefore, for these tasks, the risk of changing them is moderate. And our design should focus on these tasks first. However, there is a very high probability that the rules may change the requirements such as shapes, weight, and operation procedures for torpedoes, markers, or the object that needs to be grabbed.

Consequences: **Severe**

The consequence of the competition rule changes that require us to redesign certain components or functions is severe. If the change was significant, then a lot effort has to be spent on the new design, and all the effort spent on the previous design are wasted. Some parts purchased at a high price may not be needed anymore, which results in a waste of our budget. The most severe consequence is that we have to completely redesign the AUV system.

Strategy

1. Our team should constantly visit the official website so that we can get the official rules as soon as it is released. Once the new rules comes out, we need to study the new rules thoroughly and determine what part of our design needs to be modified, and estimate how much effort and resources needs to be spend on it.
2. In order to minimize the risk of redesign major components later, our team should focus on design that is most unlikely to be changed before the rules come out. And focus less on all designs that have a high possibility to be changed before the rules are released. Therefore, at this stage, our team should focus on computer vision, thrusters, IMUs, and mechanical design especially the water proofing. Design such as the grabber and the pinger system that has a high possibility of changing rules should not be our focus now.
3. Before the 2012 competition rules come out, in order to minimize the risk of redesigning major components, our team should make sure the flexibility to be modified of major components. For example, for the computer vision, the AUV should be able to detect various shapes such as circular, rectangle, or triangle, and also various colors.

7.1.4 Unexpected problems may arise when using tools and toolsets

Risk	Unexpected problems with tools including software and hardware tools
Probability	High
Consequence	Moderate
Strategy	1. Read user manual of tools carefully and follow instructions if possible to use tools 2. Use available resources to solve the problems if they occur 3. Search for alternative tools if the problem cannot be solved

Description

During our design process, numerous tools shall be used. They include both software tools for software development and debugging, and hardware tools for constructing the mechanical system. Problems may occur when using these tools if we do not know how to correctly use them or some tools are difficult to use. If such problems occur, our design can be delayed if we spent too much time on these problems. For example, when setting up the software developing environment, certain unexpected errors may occur such as missing certain header files in some libraries

Probability: **High**

The probability of having unexpected problems with tools are high, since many different tools will be used, and most of them are used for the first time.

Consequences: **Moderate**

The consequence of having unexpected problems with the tools is estimated to be moderate. If unexpected problems with tools arise, we should be able to solve these problems within a short amount of time using available resources to minimize the delay to our project. If the problem cannot be solved, alternative tools could be used. Therefore, unexpected problems with tools shall not bring a huge impact to our design process.

Strategy

1. In order to minimize the risk of having unexpected problems with tools, we should be familiar with each tool. Reading user manuals carefully will be a crucial step before we start using the tools. Following instructions carefully when using certain tools can also avoid certain problems.
2. Once unexpected problems occur, we can refer to the internet or libraries which should have enough resources on solving those problems. Or, we can ask someone who has previous experience on using these tools.
3. Alternative tools can always be used if certain tool has problems that cannot or is very difficult to be solved. For example, there are several toolchain that can be used for software development on the Beagleboard such as the CodeSourcery and OpenEmbeded. Our team is using CodeSourcery toolchain and if problems occurred with it, OpenEmbeded can be used as an alternative.

7.2 Schedule Risks

7.2.1 Team member availability

As mentioned in the previous report, all team members are required for this project to be completed on time. This project, typically completed by teams of 30 or more, will required 100% commitment from all members. Given that Team Robosub has a solid team of engineers, the likelihood of a team member defecting is low.

However, in the event that a team member becomes ill or withdraws from the school, Team Robosub will be forced to find another team member. Fortunately, because the project is split evenly (in terms of workload) between MEs and ECEs, the consequence of this is relatively low.

7.3 Budget Risks

Risk	Underestimate of budget which results in sufficient fund
Probability	Moderate
Consequence	Severe
Strategy	1. Carefully estimate our budget 2. Avoid unnecessary purchases 3. Seek additional sponsorship

Description
An under estimation of the team's budget can significantly delay our design process. So far, our team has a total of $7,432.72 funds available. However our budget exceeds the total amount of funds available after including travel expenses. And we are currently at around $2600 short if the travel expense is estimated to be around $5000. Therefore, our team must seek for additional sponsorship.

Probability: **Moderate**
The risk of having an under estimation of team's budget is moderate since the prices for most expensive parts we need to purchase such as thrusters and hydrophones are known. The probability of a sudden increase of prices for these parts before we order them is low. Under estimation of the travel expense can be high due to the fact that air tickect price, hotel price changes very often.

Consequences: **Severe**
The consequence of underestimate our budget is severe. If the budget is under estimated, we will have to spend additional time (which may not be in the plan) to seek for sponsiship. And this may significantly delay our design process. The underestimation may also result in having insufficient funds to purchase necessary parts, which will pose a big risk of not being able to complete the design.

Strategy
1. To minimize the risk of having an understimation of buget, we need to carefully estimate all the expenses required by this project. When estimating the budget, a small amount of safe budget should be included for emergencies.
2. For every purchase, we need to have a concious choice of what purchase is really necessary so that we can avoid unecessary purchases. And our team decides to only purchase the parts that are necessary to our design at current stage. Therefore,we will not purchase the parts that may be needed in the future at this moment. In this way, if the design is modified, we will not have to risk that certain parts purchased may not be needed in the future.
3. Since our team already have a negative budget, we will continously seek for sponsorship. We are currently seeking sponsorship from ARM to ask for a donation on the Beagleboard-xM.

7.4 Summary of Risk Status
Presently, most risks have concrete mitigation statements. The largest threat to the successful completion of the project is modification to the competition rules later on in this semester. Because the rules have not been published yet, Team Robosub has focused on making a venerable and modular AUV that can address most of the tasks previously undertaken at older competitions. However, if a major change is announced with the 2012 Competition, the team will need to back-pedal to address the change.

Team Robosub is certain that the competition ruling committee is aware of this, given that interest request forms were available back in October. The team is confident that the modular design presented in this document thoroughly mitigates this issue and is adaptable to most changes that will be required. The only limitation with this stance is the budget. Components are expensive; to mitigate this issue, we will continue to seek outside funding and sponsorship.

A large quantity of time has been invested in this project to reduce risk. Awareness is the largest component in mitigating risk and by identifying all the major risks with the design of the AUV, Team

Robosub is confident that most risks can be avoided.

8 Conclusion

Team Robosub consists of six solid engineers from the ECE and ME departments at the FAMU-FSU College of Engineering. This team aims to compete at the Association for Unmanned Vehicle Systems International Robosub competition in July 2012. The goal of this competition is to further the exploration of engineering fields typically not explored at University (or even in high school). This team is confident that the provisions listed in this document have been completed with 100% dedication and vigor.

Slight design modifications may take place during the construction to overcome unforeseen obstacles. Most of the information not listed in this document will be derived via experimental testing and these results create a feedback loop that will be used to continually improve the design. Detailed density, center of mass, weight, inertia, and power consumptions calculations enforce the decisions made by the team.

The submission of this report marks the completion of the initial design process and the beginning of construction – a milestone in the Team's project roadmap. The design team endeavors to complete the design successfully by March 2012 and will secure additional funding to enable the team to travel to the competition in San Diego, CA.

9 References

BeagleBoardEclipse. (2009, Oct 2). Retrieved Nov 06, 2011, from http://elinux.org/BeagleBoardEclipse

Flyswatter. (n.d.). Retrieved Nov 06, 2011, from Tincan tools: http://www.tincantools.com/product.php?productid=16134&cat=251&page=1

Sourcery CodeBench Lite Edition. (n.d.). Retrieved Nov 7, 2011, from MentorGraphics: http://www.mentor.com/embedded-software/sourcery-tools/sourcery-codebench/lite-edition

10 Appendices

10.1 Sample MakeFile for Preparing Beagle Board

```
# Makefile for BeagleBoard
BB_IP = 192.168.X.XXX     # The IP address of the Beagleboard, use command “ifcon-
fig”
USER = root        # username @ Beagleboard
DIR = /home/root/programs  # folder where programs are stored on Beagleboard
MOD_NAME = RobSub2012   # Module names can be used here
# Compiler options
CC = arm-none-linux-gnueabi-gcc  # cross compiler for C language (gcc)
PP = arm-none-linux-gnueabi-g++ # cross compiler for C++ language (g++)
CFLAGS = -Wall -O2 -mcpu=cortex-a8 -march=armv7-a -I  # compiling flags
# compile ALL *.c files in the folder
OBJFILES := $(patsubst %.c,%.o,$(wildcard *.c))
# RULES
all: $(MOD_NAME)
load:       all
@echo "Copying to BeagleBoard..."
scp $(MOD_NAME) $( USER)@$(BB_IP):$( DIR)
@echo "Done!"
$(PROJ_NAME): $(OBJFILES)
               $(CC) -o $(MOD_NAME) $(OBJFILES)
%.o:  %.c
$(CC) $(CFLAGS) -c -o $@ $<
clean:
              rm -f $(OBJFILES)
```

10.2 Mission Control Class Definition File

```
/*************mission_control.h***************//
//This file contains the declaration for parent//
//class Task, and children class for each task //
//Each child class will have similar structure //
//Author: Hang Zhang                           //
//Rev:                                         //
//Project: RoboSub2012a                        //
/*************mission_control.h***************//

#ifndef MISSION_CONTROL_H_
#define MISSION_CONTROL_H_
#include <iostream>
#include <string>
using namespace std;

// each state will have at least these four main states

enum state {INCOMPLETE, SUCCESS, TIMED_OUT, FAILED};

// INCOMPLETE:  current task is still being executed
// SUCCESS:  current task has been successfully finished. Transit to the next task
// TIMED_OUT: the mission is not finished during allocated time.
// FAILED: The current task is failed. The mission controller should decide on
//         whether keep working on current task or skip to the next task


// the Task class definition
Class Task
{
Public:
  Task(); // default constructor
  Task(String task_name,State s = INCOMPLETE);// constructor;
  State TaskInit(Task* task);   // initialization of each task
  Void setname(String task_name); // set the state name
  Void setstate(cur_state); // change state of the task
  Void execute_Task(state st, Taks* cur_Task,String task_name); // execute task
```

```
   State Navigation_Error(Task* task);  // handles the navigation error
   // more functions will be added later

   ~Task();
 Private:
   state cur_state;    // current state of the task
   Task* cur_Task;     // current task the AUV is excuting
   String task_name;   // the name of current task

 };

#endif
 class Gate : public Task   // class gate is the sub class of class Task
 {
 public:
         Gate( Task * parent, ... ) : Task( parent, ... )
         {  // initialize the task
         }
         State execute_Task()
         {


                if (ERROR) return FAILED.



                 if ( timeElapsed >= taskTime ) return TIMED_OUT;
                 else if
                      return INCOMPLETE;
                 else return SUCCESS;
         }
 };
class Buoy : public Task   // class Buoy is the sub class of class Task
{
public:
        Buoy( Task * parent, ... ) : Task( parent, ... ) // default contsructor
        {  // initialize the task
        }
        State execute_Task()
        {
               if (Buoy NOT striked)
                  return FAILED;

                if ( timeElapsed >= taskTime )
                      return TIMED_OUT;
                else if
                      return INCOMPLETE;
                else return SUCCESS;
        }
};

class Box : public Task   // class Box is the sub class of class Task
{
public:
        Box( Task * parent, ... ) : Task( parent, ... ) // default contsructor
        {  // initialize the task
        }
        State execute_Task()
        {
               if (!Box_Passed)
                  return FAILED;

                if ( timeElapsed >= taskTime )
                      return TIMED_OUT;
                else if
                      return INCOMPLETE;
                else return SUCCESS;
        }
};
class Marker : public Task   // class Marker is the sub class of class Task
{
```

```
public:
        Marker( Task * parent, ... ) : Task( parent, ... ) // default contsructor
        {  // initialize the task
        }
        State execute_Task()
        {
               if (!marker_dropped)
                  return FAILED;

                if ( timeElapsed >= taskTime )
                      return TIMED_OUT;
                else if
                      return INCOMPLETE;
                else return SUCCESS;
        }
};

class Torpedo : public Task   // class Torpedo fires the two torpedoes
{
public:
        Torpedo( Task * parent, ... ) : Task( parent, ... ) // default contsructor
        {  // initialize the task
        }
        State execute_Task()
        {
               if (!torpedo fired)
                  return FAILED;

                if ( timeElapsed >= taskTime )
                      return TIMED_OUT;
                else if
                      return INCOMPLETE;
                else return SUCCESS;
        }
};

// class Pinger is the sub class of class Task which detects the pinger
// location
class Pinger : public Task
{
public:
        Pinger( Task * parent, ... ) : Task( parent, ... ) // default constructor
        {  // initialize the task
        }
        State execute_Task()
        {
               if (!pinger_detected)
                  return FAILED;

                if ( timeElapsed >= taskTime )
                      return TIMED_OUT;
                else if
                      return INCOMPLETE;
                else return SUCCESS;
        }
};

// class Grabber will first grab the object and then release it
class Grabber : public Task
{
public:
        Grabber( Task * parent, ... ) : Task( parent, ... ) // default constructor
        {  // initialize the task
        }
        State execute_Task()
        {
               if (Grabbing_failed)
                  return FAILED;

                if ( timeElapsed >= taskTime )
                      return TIMED_OUT;
                else if
                      return INCOMPLETE;
```

```
                else return SUCCESS;
        }
};
class Surface : public Task
{
public:
        Surface( Task * parent, ... ) : Task( parent, ... ) // default constructor
        {  // initialize the task
        }
        State execute_Task()
        {
               Read data from pressure sensor
               if (time_Elapsed < TaskTime && not surfaced)
                  return FAILED;

                  Turn off power if necessary
        }
};
```

10.3 Beagleboard-xM Features

	Feature	
Processor	Texas Instruments Cortex A8 1GHz processor	
POP Memory	Micron 4Gb MDDR SDRAM (512MB) 200MHz	
PMIC TPS65950	Power Regulators	
	Audio CODEC	
	Reset	
	USB OTG PHY	
Debug Support	14-pin JTAG	GPIO Pins
	UART	3 LEDs
PCB	3.1" x 3.0" (78.74 x 76.2mm)	6 layers
Indicators	Power, Power Error	2-User Controllable
	PMU	USB Power
HS USB 2.0 OTG Port	Mini AB USB connector	
	TPS65950 I/F	
USB Host Ports	SMSC LAN9514 Ethernet HUB	
	4 FS/LS/HS	Up to 500ma per Port if adequate power is supplied
Ethernet	10/100	From USB HUB
Audio Connectors	3.5mm	3.5mm
	L+R out	L+R Stereo In
SD/MMC Connector	MicroSD	
User Interface	1-User defined button	Reset Button
Video	DVI-D	S-Video
Camera	Connector	Supports Leopard Imaging Module
Power Connector	USB Power	DC Power
Overvoltage Protection	Shutdown @ Over voltage	
Main Expansion Connector	Power (5V & 1.8V)	UART
	McBSP	McSPI
	I2C	GPIO
	MMC2	PWM
2 LCD Connectors	Access to all of the LCD control signals plus I2C	3.3V, 5V, 1.8V
Auxiliary Audio	4 pin connector	McBSP2
Auxiliary Expansion	MMC3	GPIO,ADC,HDQ

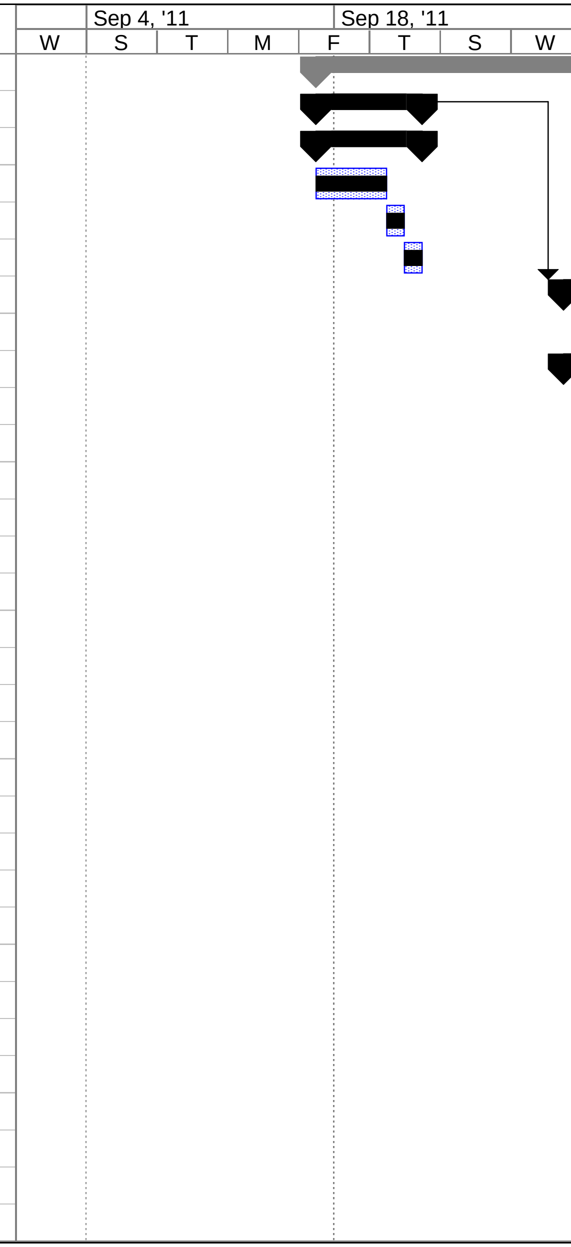
10.4 Comparison between the three MCUs

	Beagleboard REV B7	Beagleboard XM	Intel Core i3 PC
Released Date	2008	2010	2011

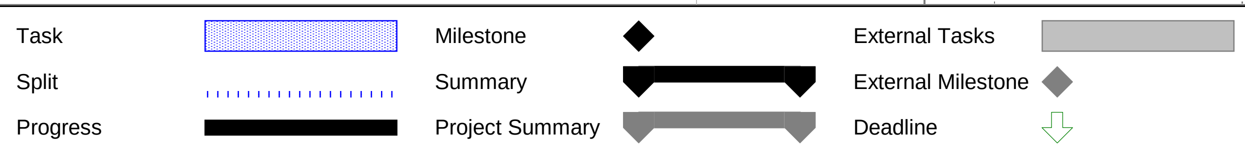
Processor	OMAP 3530 600MHz	Texas Instruments Cortex A8 1GHz processor	Intel Core i3-2120T Sandy Bridge 2.6GHz 2 x 256KB L2 Cache 3MB L3 Cache
DSP	430MHz	800MHz	650MHz Intel HD Graphics 2000
Memory	128MB DDR (166MHz)	512MB DDR (200MHz)	3GB DDR3 RAM(1366MHz)
MIPS[1]	< 1,400 Dhrystone MIPS	> 2,000 Dhrystone MIPS	
Onboard USB Port	None	4	≥ 4
MicroUSB	Yes	Yes	No
SD	SD/MMC	MicroSD	SD/MicroSD/MMC
Ethernet	No	Yes	Yes
Power	5W	5W	104W
Cost	Free	$149.00/Free	> $300

[1]MIPS: Million Instructions Per Second

ID	Task Name	Resource Names
0	**Autonomous Underwater Vehicle (AUVSI RoboSub Competition)**	
1	**1 Ramp-up (Analysis/Synthesis)**	
2	**1.1 Needs Analysis and Specification**	
3	1.1.1 Individual team composition	
4	1.1.2 Combine submissions	
5	1.1.3 Submit combined needs analysis	
6	**2 System Design (Development)**	
7	2.1 Professional engineering assignment	
8	**2.2 Project proposal**	
20	2.3 Project management	
21	**2.4 Complete the Hull and Frame of the AUV**	
22	2.4.1 Develop a Pro/Engineer Model of the Finalized Hull and Frame Design	Eric Sloan
23	2.4.2 Order Components for Hull and Frame	Eric Sloan
24	2.4.3 Manufacture and Assemble the Hull and Frame	Eric Sloan
25	2.4.4 80/20 T-Slotted Frame	Eric Sloan
26	2.4.5 Hull Supports	Eric Sloan
27	2.4.6 Acrylic Hull	Eric Sloan
28	2.4.7 Aluminum End Caps	Eric Sloan
29	2.4.8 Camera Enclosures	Eric Sloan
30	2.4.9 SEACON Connectors	Eric Sloan
31	2.4.10 Test for Watertight Integrity	All ME
32	**2.5 Develop the Computer Vision System**	
33	2.5.1 Develop the Pre-Processing Module	Ryan Kopinsky
34	2.5.2 Design a Color Filter Module	Ryan Kopinsky
35	2.5.3 Design the Path Detection Module	Ryan Kopinsky
36	2.5.4 Design the Size Detection Module	Ryan Kopinsky
37	2.5.5 Design the Navigation Module	Ryan Kopinsky
38	2.5.6 Design the Shape Detection Module	Ryan Kopinsky
39	2.5.7 Design the Task Control Module	Ryan Kopinsky
40	**2.6 Develop the Guidance System**	
41	2.6.1 Develop a system to capture IMU data	Antony Jepson
42	2.6.2 Design a system to capture depth sensor data	Antony Jepson



Project: Autonomous Underwater Veh
Date: Thu 11/17/11

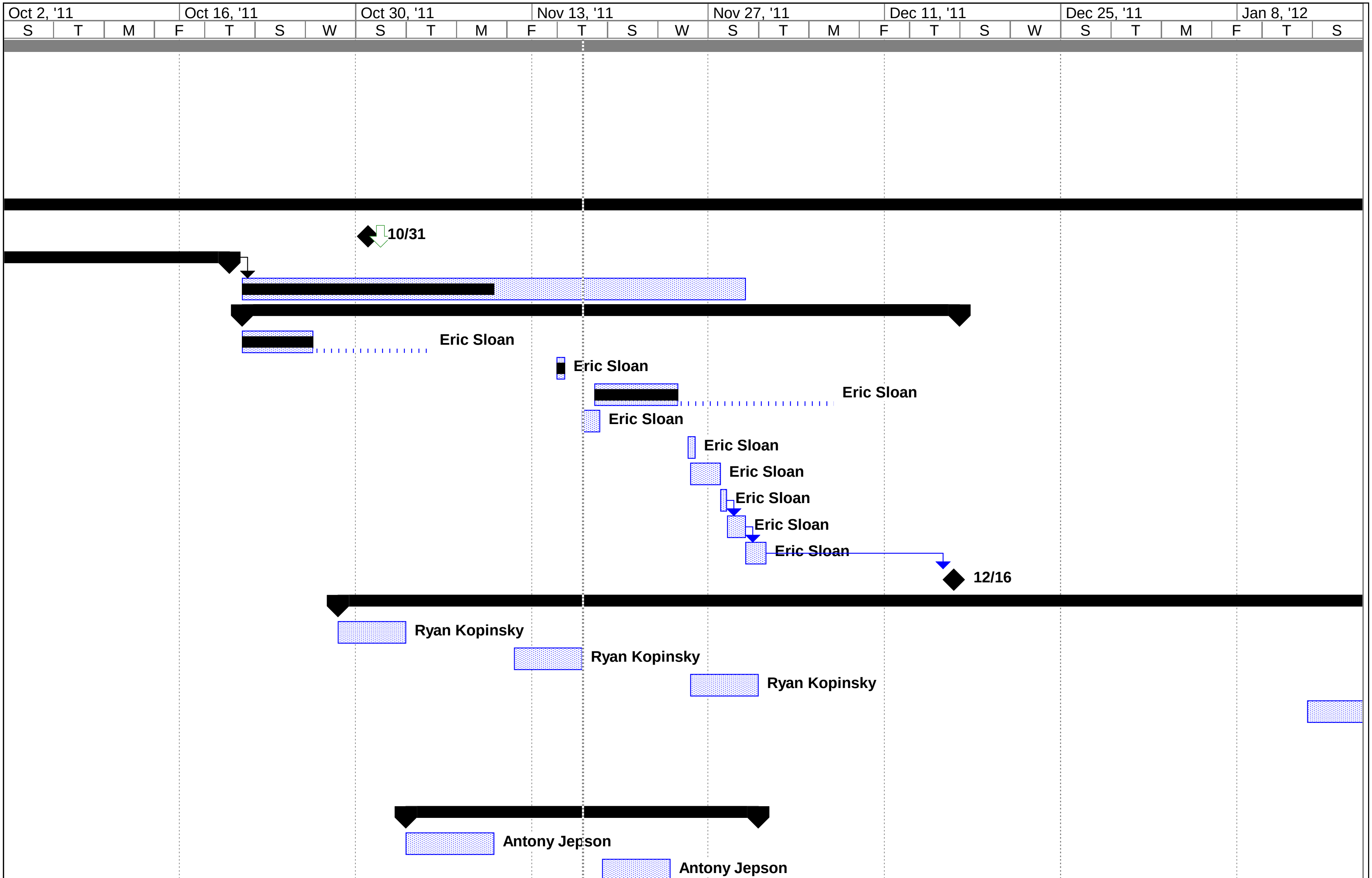


ID	Task Name	Resource Names
43	2.6.3 Design a system to capture AUV heading and locate pinger	All ECE
44	**2.7 Develop Software to Control the Thrusters**	
45	2.7.1 Develop Software to Control the Thrusters	Hang Zhang,Eric Sloa
46	2.7.2 Order SeaBotix BTD150 Thrusters	Eric Sloan
47	2.7.3 Attach Thrusters to Frame of AUV and Begin General Maneuverability Testing	Eric Sloan
48	**2.8 Complete the CO2 Distibution System for the AUV**	
49	2.8.1 Select a Compressed CO2 tank	All ME
50	2.8.2 Select a Pressure Regulator	All ME
51	2.8.3 Select Solenoid Valves and Pressure Lines/Tubing	All ME
52	2.8.4 Order Components for the CO2 Distribution System	All ME
53	2.8.5 Design Open Housing for Solenoid Valves	Tra Hunter,Kashief Mc
54	2.8.6 Manufacture and Assemble the Solenoid Valve Housing	Tra Hunter,Kashief Mc
55	2.8.7 Test Proper Functionality of the CO2 Distribution System	Tra Hunter,Kashief Mc
56	2.8.8 Install the CO2 Distribution System on the AUV and Integrate with the Electronics	Tra Hunter,Kashief Mc
57	**2.9 Complete the Grasp/Release Mechanism for the AUV**	
58	2.9.1 Develop a Pro/Engineer model of the finalized Grasp/Release Mechanism Design	Eric Sloan,Tra Hunter
59	2.9.2 Order Components for the Grasp/Release Mechanism	Eric Sloan,Tra Hunter
60	2.9.3 Manufacture and Assemble the Grasp/Release Mechanism	Eric Sloan,Tra Hunter
61	2.9.4 Test Proper Functionality of the Grasp/Release Mechanism	Eric Sloan,Tra Hunter
62	2.9.5 Install the Grasp/Release Mechanism on the AUV and Integrate with the Electronics	Eric Sloan,Tra Hunter
63	**2.10 Complete the Torpedo Launchers for the AUV**	
64	2.10.1 Develop a Pro/Engineer model of the finalized Torpedo Launcher Design	Eric Sloan
65	2.10.2 Order Components for the Torpedo Launchers	Eric Sloan
66	2.10.3 Manufacture and Assemble the Torpedo Launchers	Kashief Moody
67	2.10.4 Test Proper Functionality of the Torpedo Launchers	All ME
68	2.10.5 Install the Torpedo Launchers on the AUV and Integrate with the Electronics	Eric Sloan
69	2.11 Install Marker Dropper on AUV and Integrate with the Electronics	Eric Sloan
70	2.12 System Level (Conceptual) Design Review	
71	3 System Testing/Verification	
72	4 Documentation and Review	

Sep 4, '11 — Sep 18, '11
W S T M F T S W

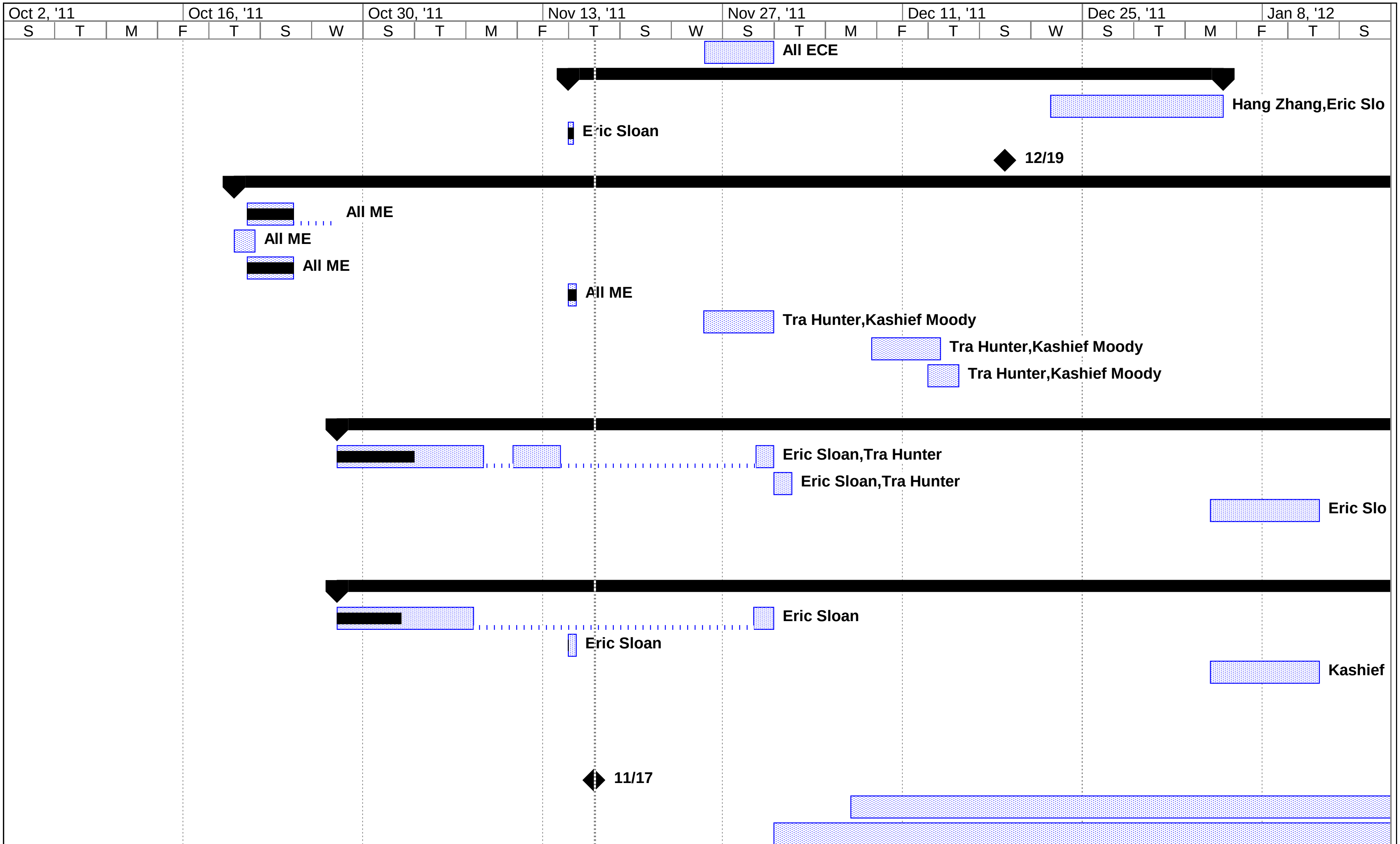
Project: Autonomous Underwater Veh
Date: Thu 11/17/11

Task — Split — Progress — Milestone — Summary — Project Summary — External Tasks — External Milestone — Deadline



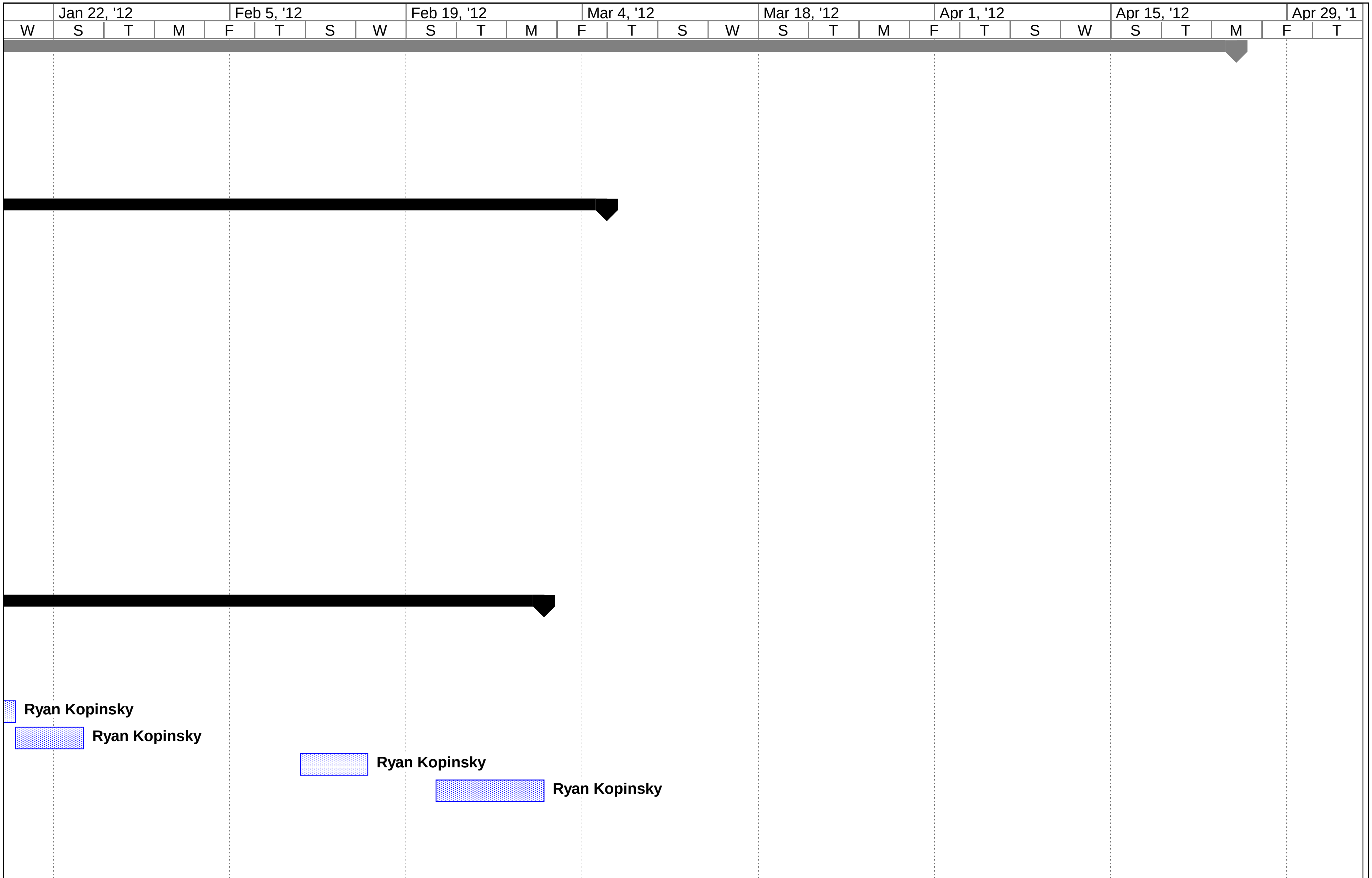
Project: Autonomous Underwater Veh
Date: Thu 11/17/11

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	



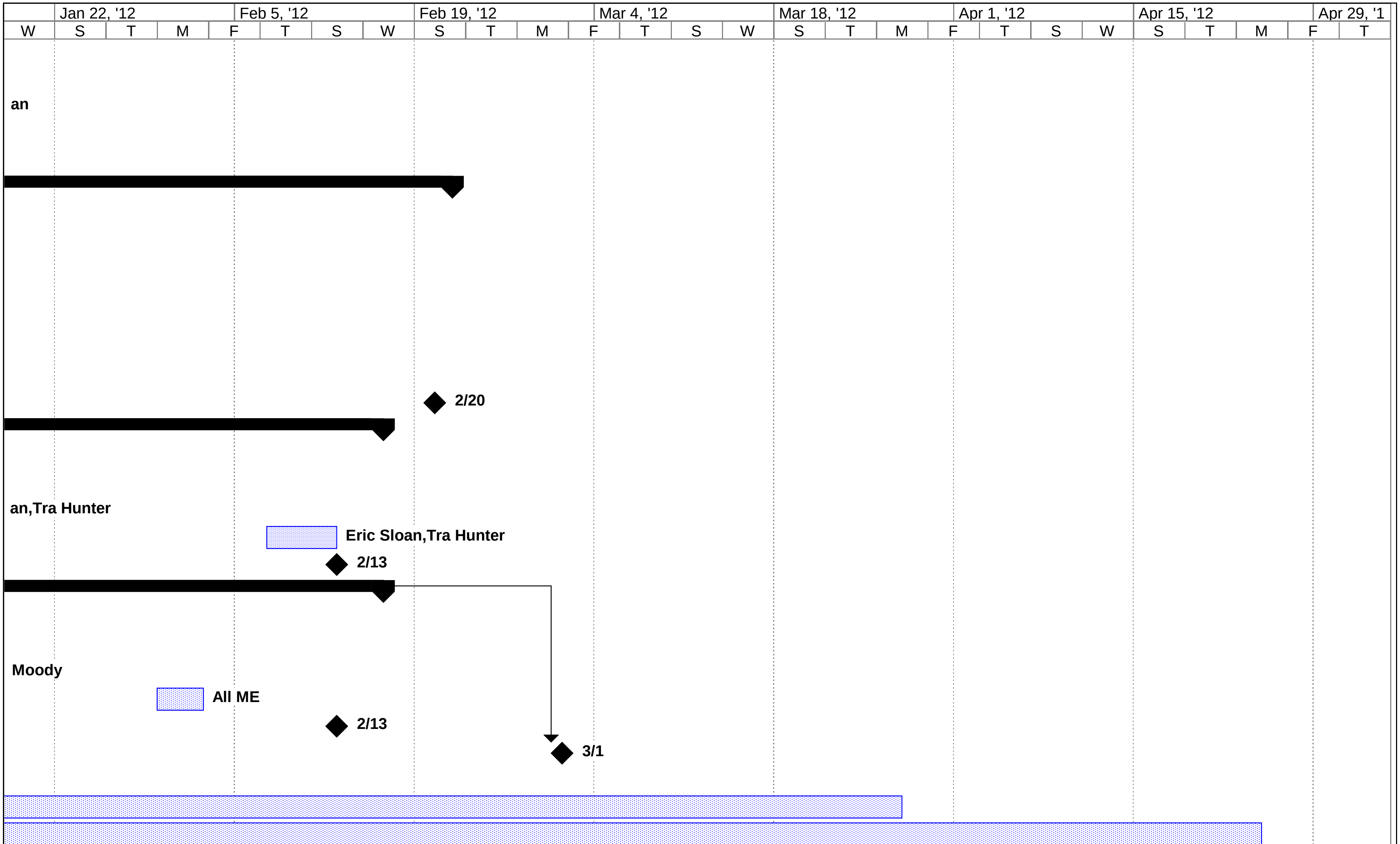
Project: Autonomous Underwater Veh
Date: Thu 11/17/11

Task	Milestone	External Tasks
Split	Summary	External Milestone
Progress	Project Summary	Deadline



Project: Autonomous Underwater Veh
Date: Thu 11/17/11

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

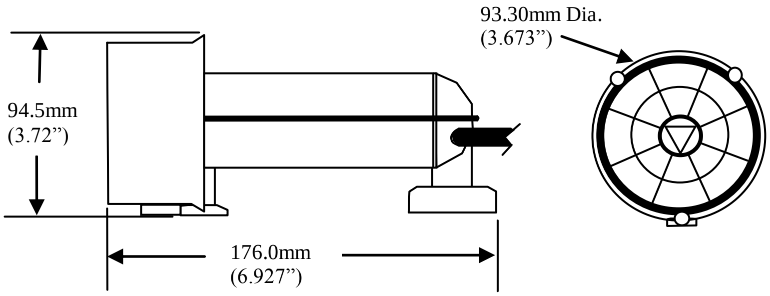


Project: Autonomous Underwater Veh
Date: Thu 11/17/11

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

DATA SHEET
BTD150 BRUSHED DC THRUSTER

SEABOTIX BTD150 DATA

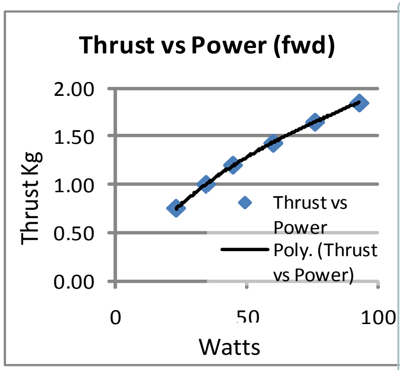


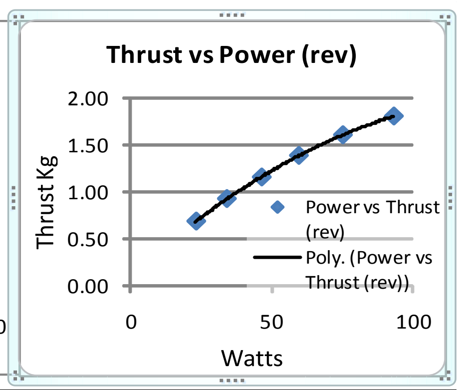
SPECIFICATIONS:

VOLTAGE NOMINAL…………………….. **12VDC**
MAX CURRENT
OF MOTOR WINDINGS………………….. ***4.0AMPS**
(a current regulator is highly recommended)

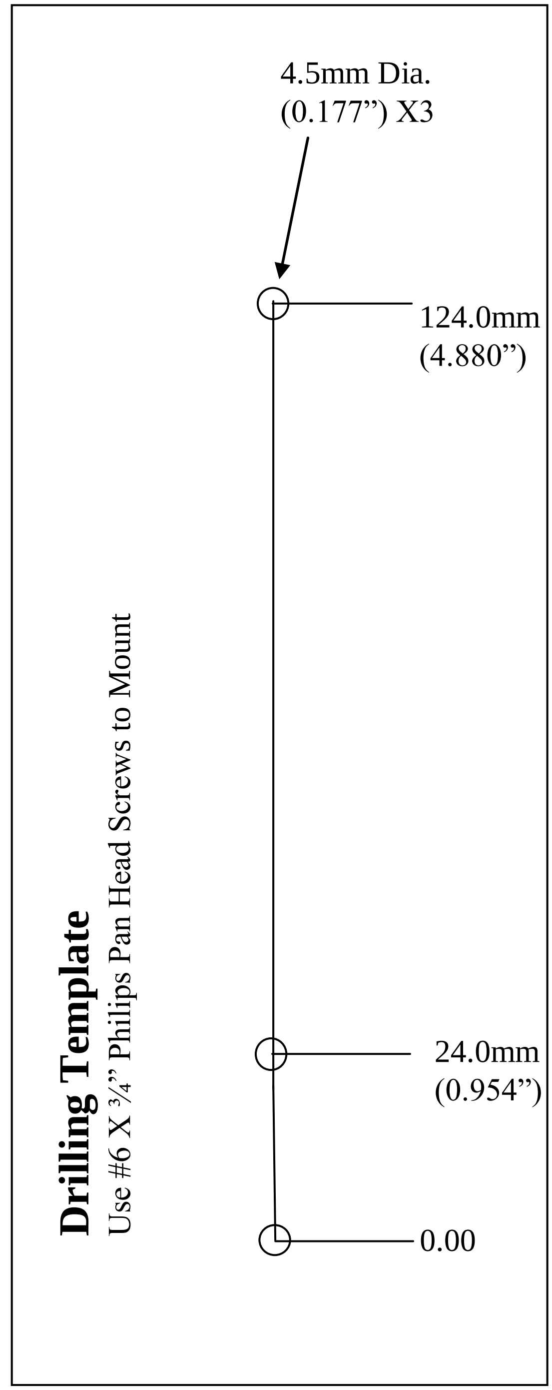
WEIGHT:
Dry …………………………………… 718grams
Wet…………………………………… -413grams (in fresh water)

WIRING CONFIGURATION:
Red..…………………………..Positive VDC
Black …………………………Negative VDC





Direction	Voltage(DC)	Current Draw (A)	Thrust (kg)	Power (W)
Forward	12.0	1.91	0.75	22.92
	14.0	2.45	1.00	34.3
	16.0	2.78	1.20	44.48
	18.0	3.32	1.43	59.76
	20.0	3.78	1.65	75.6
	22.0	4.20	1.85	92.4
Reverse	12.0	1.92	0.68	23.04
	14.0	2.42	0.92	33.88
	16.0	2.89	1.15	46.24
	18.0	3.30	1.38	59.4
	20.0	3.75	1.60	75
	22.0	4.23	1.80	93.06



* Higher currents (up to 6A) may be used, but will drastically shorten the life of the thruster if ran continuously in this mode. 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.

SEABOTIX, 2877 Historic Decatur Road, Suite 100, San Diego, CA, 92106, USA (619) 450-4000
Specifications Subject to Change without Prior Notice 30 July 2010

IMCL

Submersible Level Transmitter - Ceramic Sensor

- Ceramic, piezo-resistive sensor
- Accuracy: <±0.25% FS BFSL (0.1% optional)
- Pressure ranges from 10mWG to 100mWG
- Selection of housing & cable materials
- Variety of outputs including mV, Volts and mA

The IMCL has been designed for use in continuous submersion in liquids such as water, oil and fuels. This submersible device uses a ceramic sensor which has excellent corrosion resistance, it is ideal for applications where the media may be aggressive, as it has a conventional thin stainless steel diaphragm. Housed within a 316L stainless steel, high grade Duplex stainless steel or PVC housing, this submersible level transmitter is the ideal product for hydrostatic level measurement where stability and repeatability are critical in harsh environments. Every device is temperature compensated and calibrated, supplied with a traceable serial number and calibration certificate. The electronics incorporate a microprocessor based amplifier, this means there are no pots and therefore very stable.

There are many options available on the IMCL level transmitter. These include the following :

- Pressure range and engineering units
- Pressure reference (Gauge or Absolute)
- Output type
- Accuracy Level (Non-linearity & hysteresis)
- Thermal accuracy
- Cable material in PUR, FEP or TPE
- Housing material
- O ring seal material

IMCL Submersible Level Transmitter

Suitable for the following applications:

- River level
- Tank level
- Borehole level
- Aquifer level
- Environmental monitoring

IMCL Submersible Level Transmitter

IMCL

Submersible Level Transmitter Ceramic Sensor

Input Pressure Range

Nominal pressure, Gauge	mWG	10	15	20	25	40	50	75	100
Nominal pressure, Absolute	mWG	-	15	20	25	40	50	75	100
Permissible Overpressure	mWG	15	30	30	75	75	75	150	150

Output Signal & Supply Voltage

Wire system	Output	Supply Voltage
2-wire	4 - 20mA	9 – 32V dc
3-wire 1)	0 – 5V dc	9 – 32V dc
	0 – 10V dc	13 – 32V dc
	0 – 2.5V dc	6 – 32V dc
	0.5 to 4.5V dc	5V dc
	(others on request)	(others on request)
4-wire	Passive mV/V (See mV/V output table below)	2 – 30V dc
	2mV/V (rationalised)	2 – 12V dc
	10mV/V (amplified)	3 – 12V dc

Performance

Accuracy (Non-linearity)		<±0.25% / FS (BFSL) <±0.1% / FS (BFSL) optional
Hysteresis		<±0.1% / FS
Setting Errors (offsets)	2-wire	Zero & Full Scale, <±0.5% / FS
	3-wire	Zero & Full Scale, <±0.5% / FS
	4-wire	See table
Permissible Load	2-wire	Rmax = [(Voltage Supply – 9 min) / 0.02] Ω
	3-wire	Rmin = 10 k Ω
Output Resistance	4-wire	Rmin = 11 k Ω
Influence Effects	Supply	mV/V & 0.5 to 4.5V – Ratiometric, other outputs - <0.005 % FS / 1V
	Load	0.05 % FSO / kΩ

Permissible Temperatures & Thermal Effects

Media temperature	-20°C to +60°C (non freezing)
Storage temperature	-20°C to +70°C
Compensated temperature range	20°C ±25°C
Thermal Zero Shift (TZS)	<±0.02% / FS / °C (option code 2) <±0.01% / FS / °C (option code 1)
Thermal Span Shift (TSS)	<-0.015% / °C

IMCL

Submersible Level Transmitter Ceramic Sensor

Electrical Protection

Supply reverse polarity protection	No damage but also no function
Lightning Protection	Internally fitted
Electromagnetic compatibility	CE Compliant

Mechanical Stability

Shock	100 g / 11 ms
Vibration	10 g RMS (20 ... 2000 Hz)

Materials

Housing	316L Stainless Steel High Grade DUPLEX Stainless Steel UNS31803 (optional)
‘O’ ring seals	Viton
Diaphragm	Ceramic Al_2O_3 96 %
Cable sheath material	PUR PVC (optional) FEP (optional)
Media wetted parts	Housing, ‘O’ ring seal, diaphragm & Cable sheath

Miscellaneous

Current consumption	2-wire, 3-wire & 4-wire	Limits at 25mA, Typ. 6mA, Typ.2 – 5mA
Weight	Transmitter: Approx. 250g including nose cone Cable: Approx. 48g per mtr	
Installation position	Any	
Operation Life	> 100 x 10^6 cycles	

Typical Passive mV/V Outputs

Nominal pressure	mWG	10	15	20	25	40	50	75	100
Output	mV/V	3.6..6.0	1.8..3.0	2.5..4.0	2.0..3.3	3.2..5.2	4.0..6.5	2.3..3.6	3.1..4.8
Zero Setting Error	mV/V	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

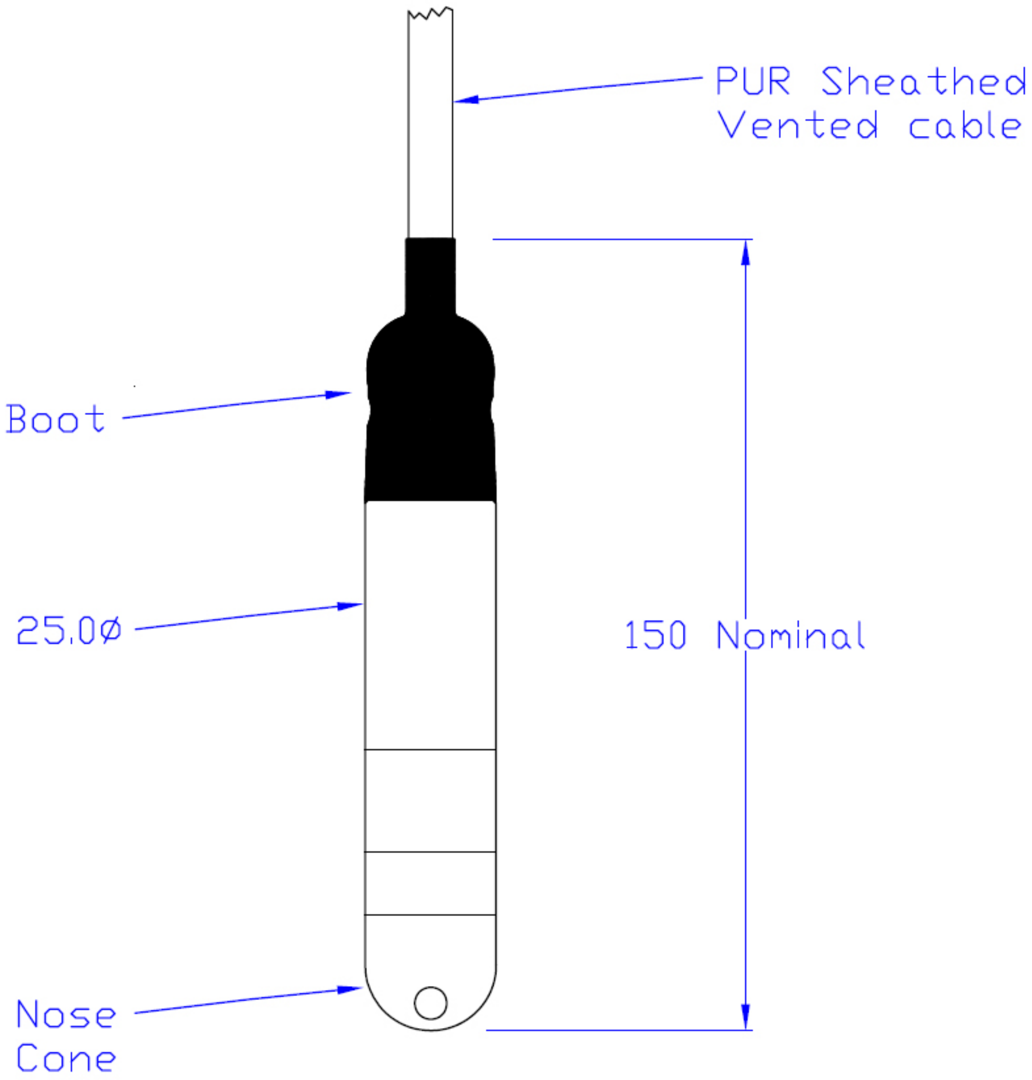
Wiring Designation

		PUR Sheath	PVC Sheath	FEP Sheath
2-wire	+ve Supply	Red	Brown	Brown
	-ve Supply	Blue	White	White
	Ground	White	Pink	Pink
	Cable Screen	Green	Green	Green
3-wire	+ve Supply	Red	Brown	Brown
	-ve Supply	Blue	White	White
	+ve Output	Yellow	Yellow	Yellow
	Ground	White	Pink	Pink
	Cable Screen	Green	Green	Green
4-wire	+ve Supply	Red	Brown	Brown
	-ve Supply	Blue	White	White
	+ve Output	White	Pink	Pink
	-ve Output	Yellow	Yellow	Yellow
	Cable Screen	Green	Green	Green

IMCL

Submersible Level Transmitter Ceramic Sensor

Outline Drawing



Accesories

Cable support hanger

Cable Terminal Box with Vent

Wall mounted digital indicator

SensorsONE
Pressure Measurement Instrumentation

Website

www.SensorsONE.co.uk

Email

enquiries [at] SensorsONE.co.uk

QR Code

Save the SensorsONE website address to your mobile smartphone by scanning this QR code

Preliminary Mission
15th Annual 2012 RoboSub Competition
"Ides of TRANSDEC"

Discuss this and other questions on the AUVSI Underwater competition forum
28-Oct-2011

We are releasing this preliminary mission statement for comment by the teams. Please direct your comments and questions to the underwater forum (link above). Teams are encouraged to participate in the forum and to help guide the final rules for the competition. Discussion of the rules will be open for a while. After which, the final rules will be released.

Reminder: Along with the paper, each team will also submit a 3-5 minute video. The video will "introduce" the team and their approach to the event. This video will be scored, and will be used online and onsite during the webcast. It will not be used for the oral presentation. More information to follow.

Reminder: A team may choose to have their own playlist playing during their semi-final runs (but not during the webcast of the finals). Please remember, this is a family event, so no explicit lyrics. This privilege can be revoked.

JAUS: The JAUS portion of the competition is currently in limbo. If it is included, information will be released about the tasks and how it fits into the competition in a timely manner.

Mission: The fundamental goal of the mission is for an AUV to demonstrate its autonomy by completing an underwater Ides of TRANSDEC mission. They will be able to commence in training (dock/release buoys), pass over an obstacle course (PVC pipe to pass over), enter the gladiator ring (drop markers), kill Caesar (shoot torpedoes through a cutout), feed grapes to the emperor (manipulate a cylinder), and finally collect the Laurel wreath and crown the new emperor (find a pinger, grab an object and move/release the object).

We expect each vehicle to have 15 minutes to complete the tasks (with an additional 5 minutes of dock preparation time). Any vehicle that touches a buoy, places at least one marker in the bin or on the lip (or fires at least one torpedo through the cutout) and surfaces fully within the octagon (no part outside the structure) will receive bonus points proportional to the unused time. Each vehicle must begin the run by passing under a validation gate. At any time during the run, if a vehicle breaches the surface, the run is terminated (See the section "Breaching" for the exception).

Weight and Size Constraints: For the RoboSub Competition, each entry must fit within a six-foot long, by three-foot wide, by three-foot high "box" (1.83m x 0.91m x 0.91m). Table 1 shows the bonuses and penalties associated with a vehicle's weight in air.

	Bonus	**Penalty**
AUV Weight > 110 lbs (AUV Weight > 50 kg)	**N/A**	**Disqualified**
110 lbs ≥ AUV Weight > 84 (50 kg ≥ AUV Weight > 38)	**N/A**	**Loss of** **250 + 5(lb - 84)** **250 + 11(kg - 38)**
84 lbs ≥ AUV Weight > 48.5 (38 kg ≥ AUV Weight > 22)	**Bonus of** **2(84 - lb)** **4.4(38 - kg)**	**N/A**
AUV Weight ≤ 48.5 lbs (AUV Weigh ≤ 22 kg)	**Bonus of** **80 + (48.5 - lb)** **80 + 4.7(22 - kg)**	**N/A**

Pingers: The pingers will be ORE model 4330B transponder/responder units. They will be operated in responder mode, and each unit will be preset to one of the following frequencies: 22, 23, 24, 25, 26, 27, 28, 29 or 30 kHz.

Placement of Competition Elements in the Arena: The launch point, gate, path, training, obstacle course, Gladiator ring, kill Caesar, feed Emperor grapes and the laurel wreath will be placed in such a way as to not have any three elements along a line.

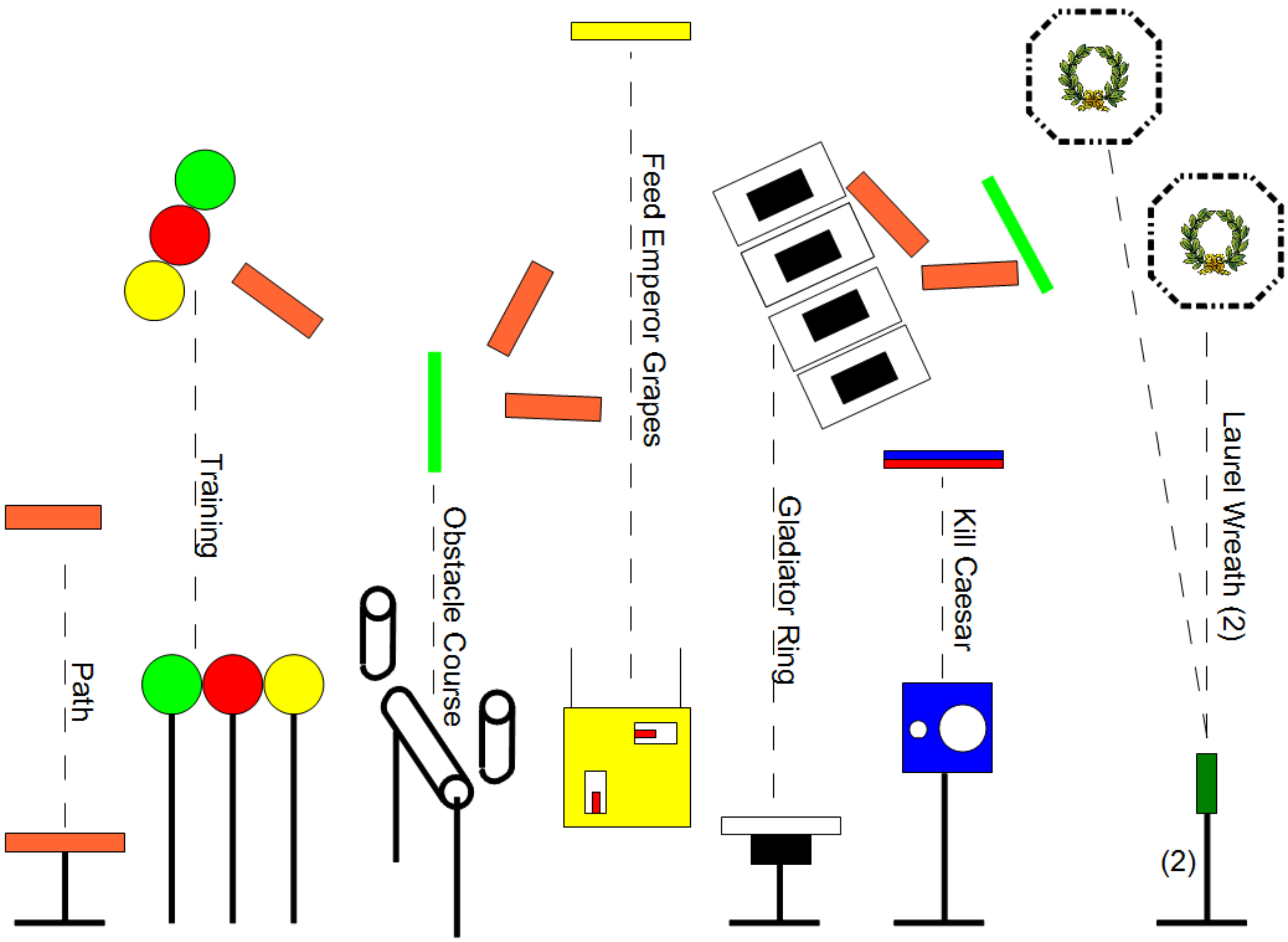


Figure 1: Various Competition Tasks

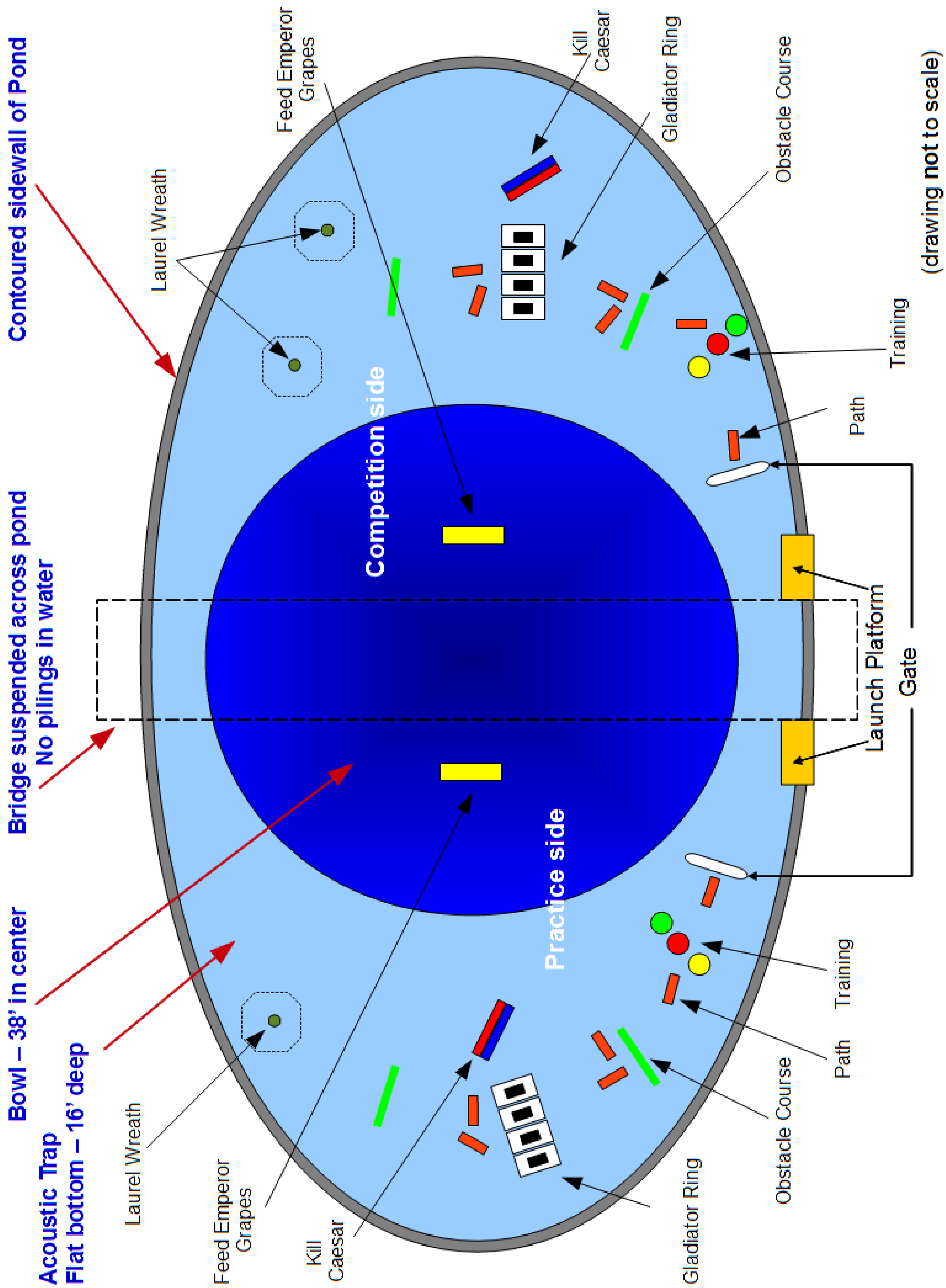


Figure 2: Overview of course layout

Description of Tasks:

The Path – There will be six sections of the path which are 4 feet (1.2 m) long by 6 inches (15 cm) wide PVC sheet. The path will be covered in **BLAZE ORANGE** colored Duck Tape. Each path segment will be directly after the current task, and point to the next task or tasks. There will be one following the gate that points to the training (buoy) task. After the training task, one will point to one of the two obstacle courses (structure to pass over). There will be two after the first obstacle course, one which points to the feed the Emperor grapes task (cylinder manipulation), and one which points to the Gladiator Ring (bins)/kill Caesar (cutouts) tasks. Note that there will be no directional markers from the cylinder manipulation task. Following the bins and cutouts, there will also be two paths. One which points to the cylinder manipulation task, and one that passes over the second obstacle course, and towards the laurel wreaths (object pickup / octagons).

Training (Buoy) – The task consists of a **green**, **red** , and **yellow** (**Question: use other colors?**) 9" float. If all goes well, there will be two methods for scoring. The first it to bump the buoy. The second will be to touch a similarly colored square plate (colored Duck Tape: Neon **Green**, **Red**, **Yellow**), located below the buoy, to release the buoy.

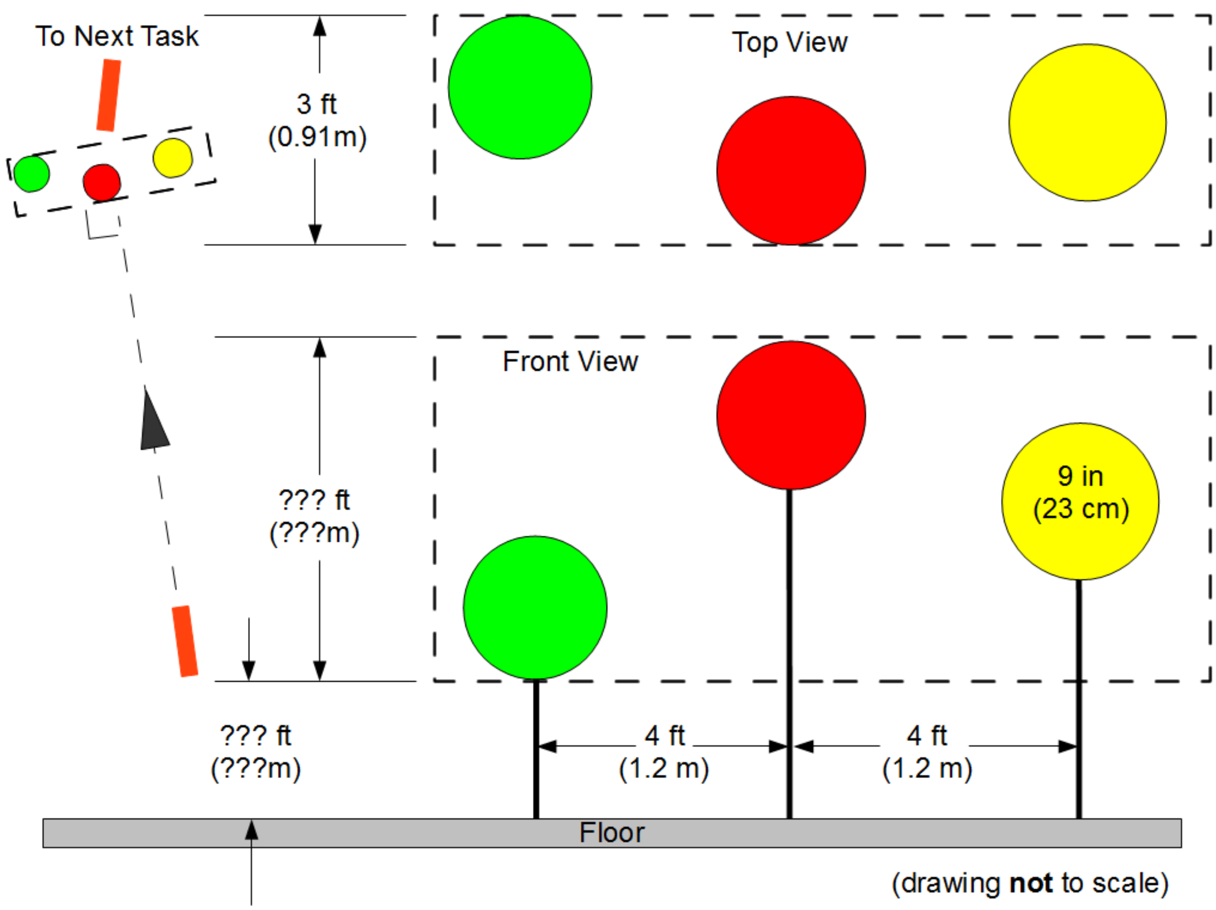


Figure 3: Training

Obstacle Course (PVC to pass over) – A “U” shaped section of 2” PVC pipe (**Question: Color?**) will be moored to the floor and consist of one long horizontal section, with two smaller vertical posts secured to the horizontal section and suspended above it. To get full points, a vehicle must pass inside the vertical segments and ½ or more of it's height below the plane created by the top of the vertical segments.

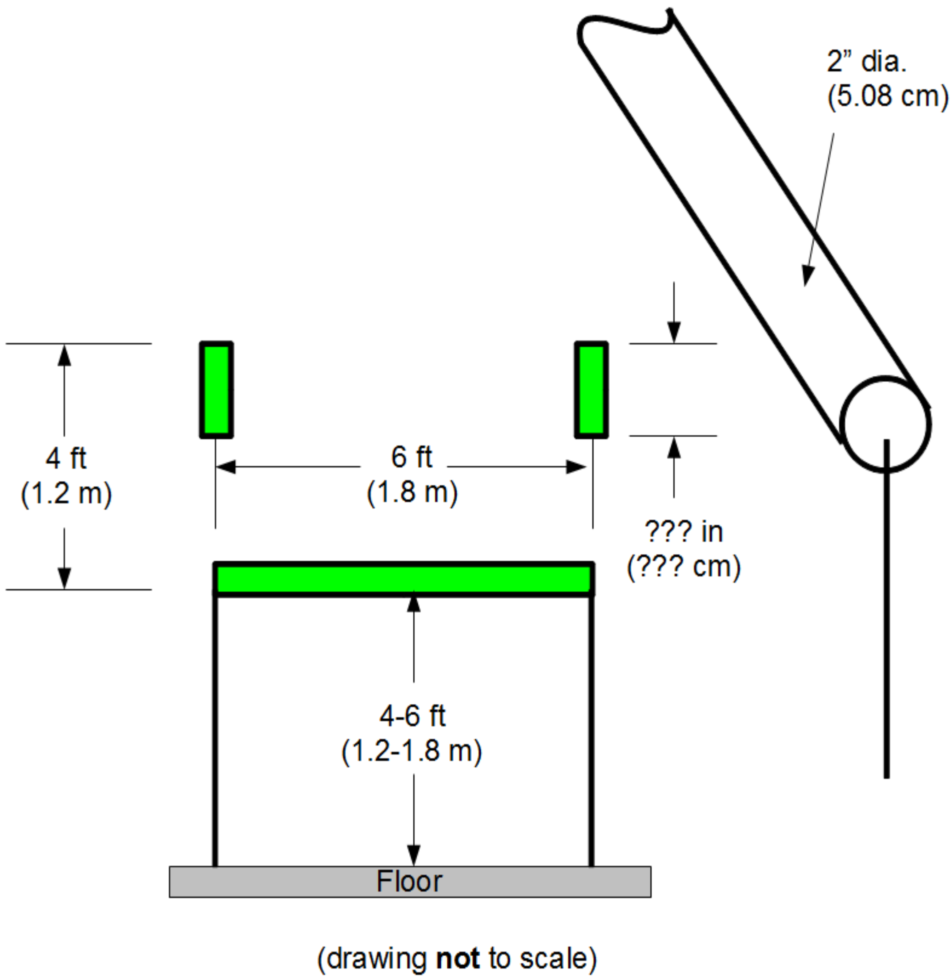


Figure 4: Obstacle Course

Gladiator Ring (Bins) - Each black bin will be surrounded by a 6” white border. A total of two markers can be dropped from the vehicle. Inside the bins will be silhouettes. There will be 2 types of gladiator weapons and two types of shields (total of 4 bins) (**Question: suggestions for silhouettes, color?**). Maximum points awarded for dropping a marker in the correct weapon and shield, some points awarded for dropping a marker in any bin (or landing on the white border).

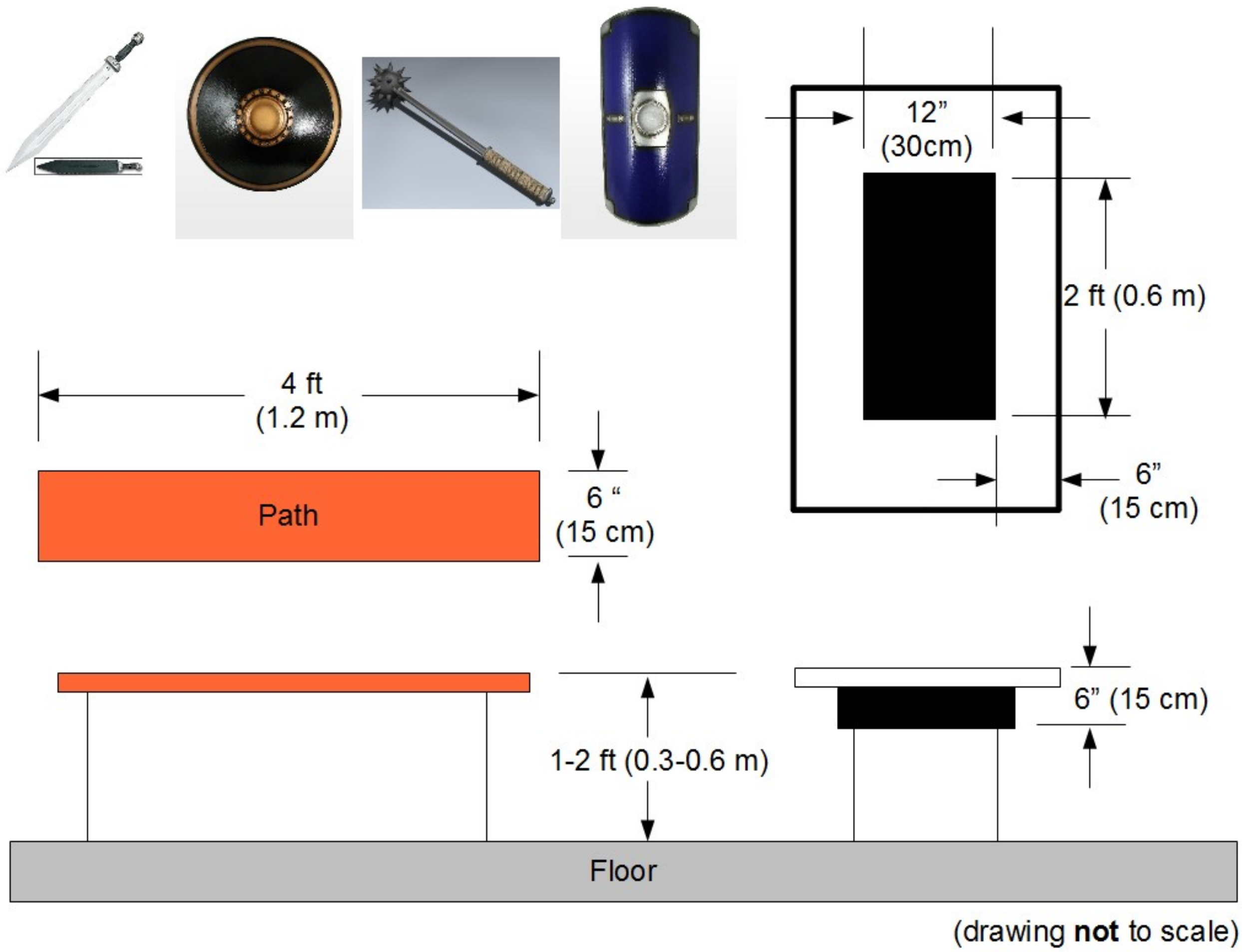


Figure 5: Path and Bins

Kill Caesar (Window Cutouts) – A 24" x 24" (61 x 61 cm) window, **red** on one side, **blue** on the other (**Question: different size, colors?**). It will be moored to the floor, and will have two different size circular cutouts on the face (**Question: size, different shape?**). One torpedo must be marked as blue, and one as red. Maximum points for firing the red torpedo through the small circle on the red side and the blue torpedo through the small circle on the blue side. Other points will be awarded for firing any torpedo through any cutout.

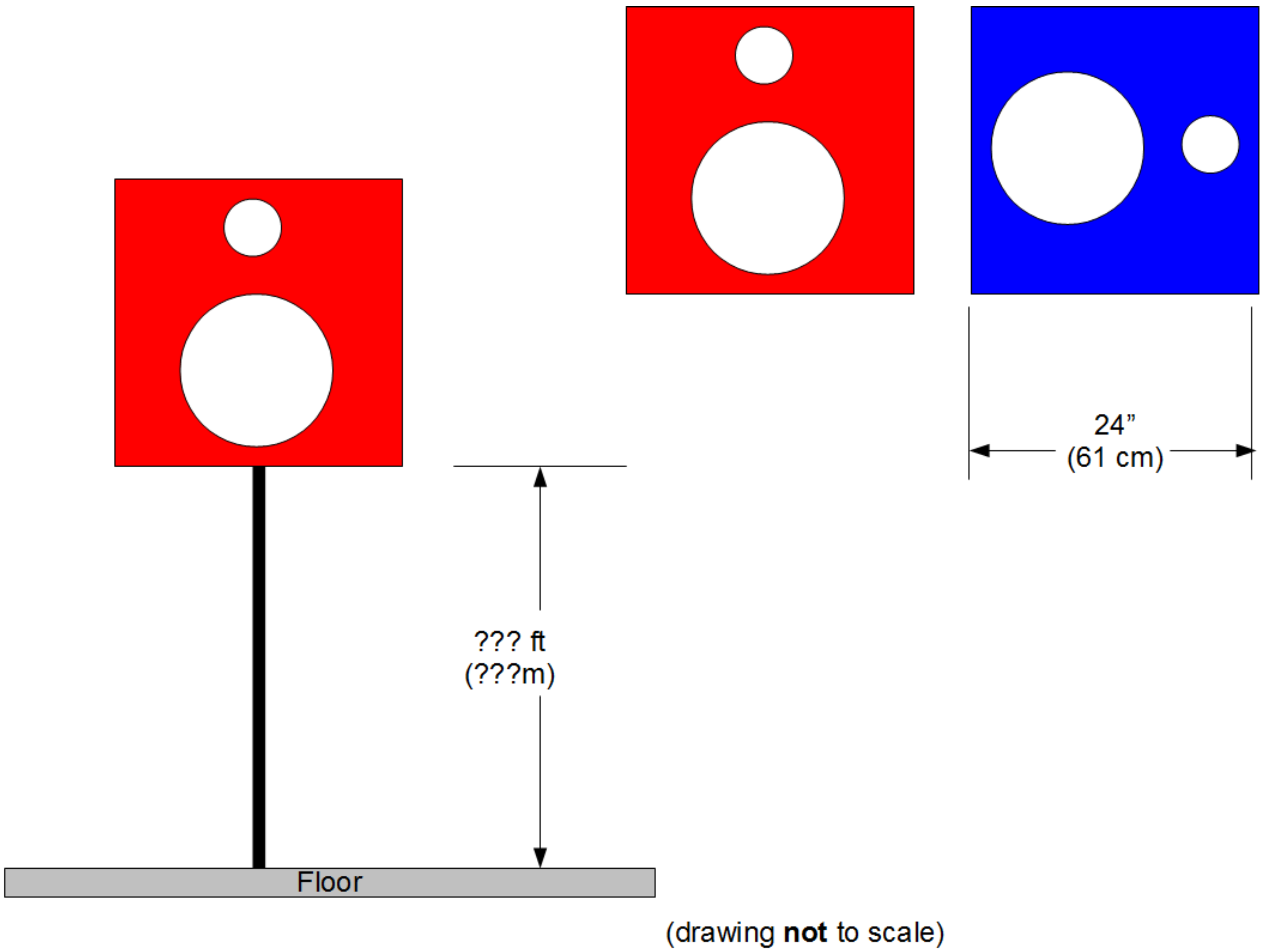


Figure 6: Window with cutouts

(NEW) **Feed Emperor Grapes (Manipulation Task)** – A single 4ft x 4ft (1.2 x 1.2 m) PVC square is place vertically in the water column (**Question: color?**). It will be suspended from the water surface (from the cantilevered bridge across the TRANSDEC pond, see Figure 2). Two 1” (2.5 cm) PVC cylinders are placed within the cutout in the square (**Question: size of the cylinder, size of the cutouts?**). The cylinders must be removed from the square. They are held in place by a tab and must be moved either vertically (for the vertically orientated cylinder), or horizontally (for the horizontally orientated cylinder), and then released (they will be tied to the square so they can't be lost).

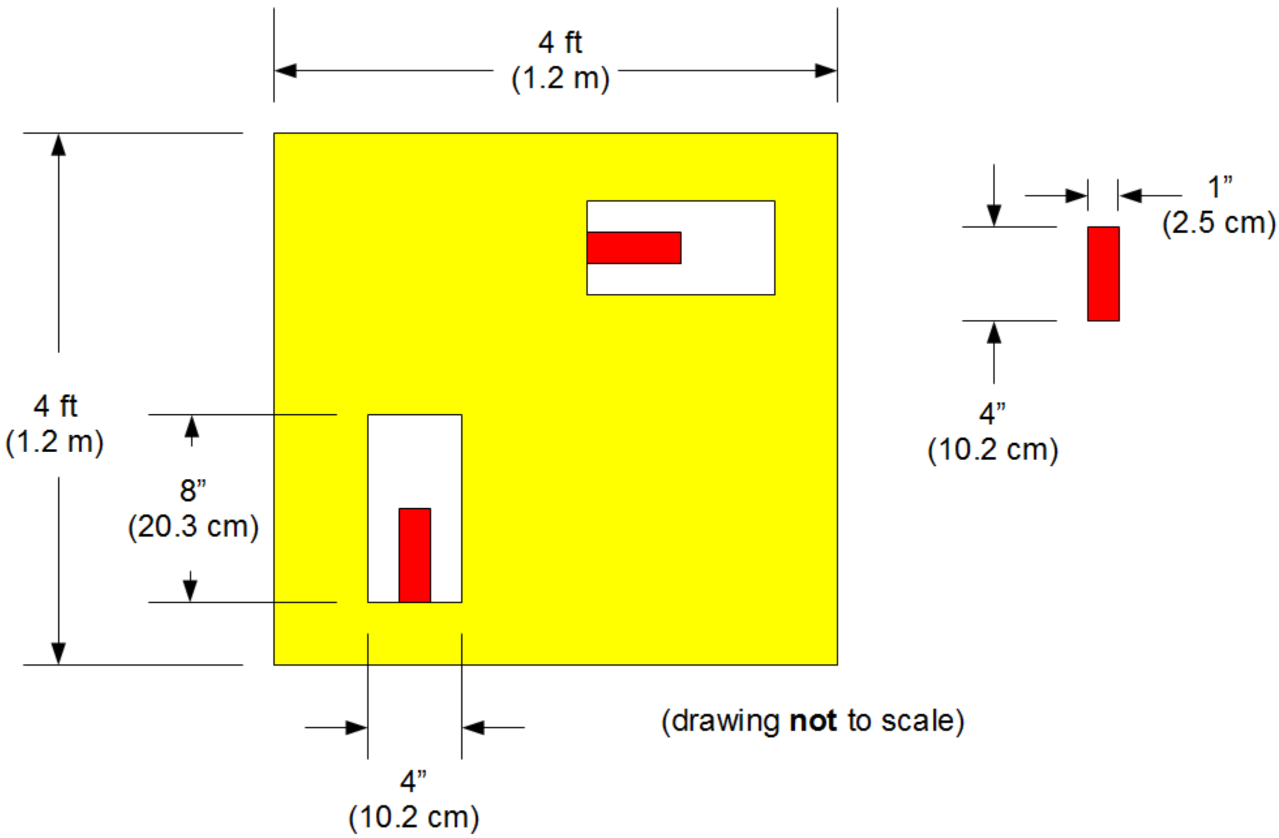


Figure 7: Feed Emperor Grapes

Laurel Wreath (PVC recovery and octagon) – This task consists of an acoustic pinger located off the floor of the pool. Placed directly above the pinger is the laurel wreath (**Question: different object, color?**) for the vehicle to retrieve. Floating above the pinger on the surface will be an octagon representing the emperors palace. In order to obtain full points for the zone, the vehicle must surface fully inside the octagon.

There will be two different octagons on the competition side, and a team will get points for surfacing within either area. However, only one pinger will be on during a particular run (active), and a vehicle surfacing within the octagon with the active pinger will receiver more points.

Points are awarded if the vehicle retrieves (maintaining control) the object. When the vehicle surfaces, more points will be awarded if the object is released. **(NEW)** Additional points will be awarded if, after the vehicle surfaces, it submerges to replace the object (a moot point if you knock over the stand, *you know who you are!*). A team may elect, before the vehicle surfaces, to switch the active pinger and traverse over and surface in the second octagon for extra points.

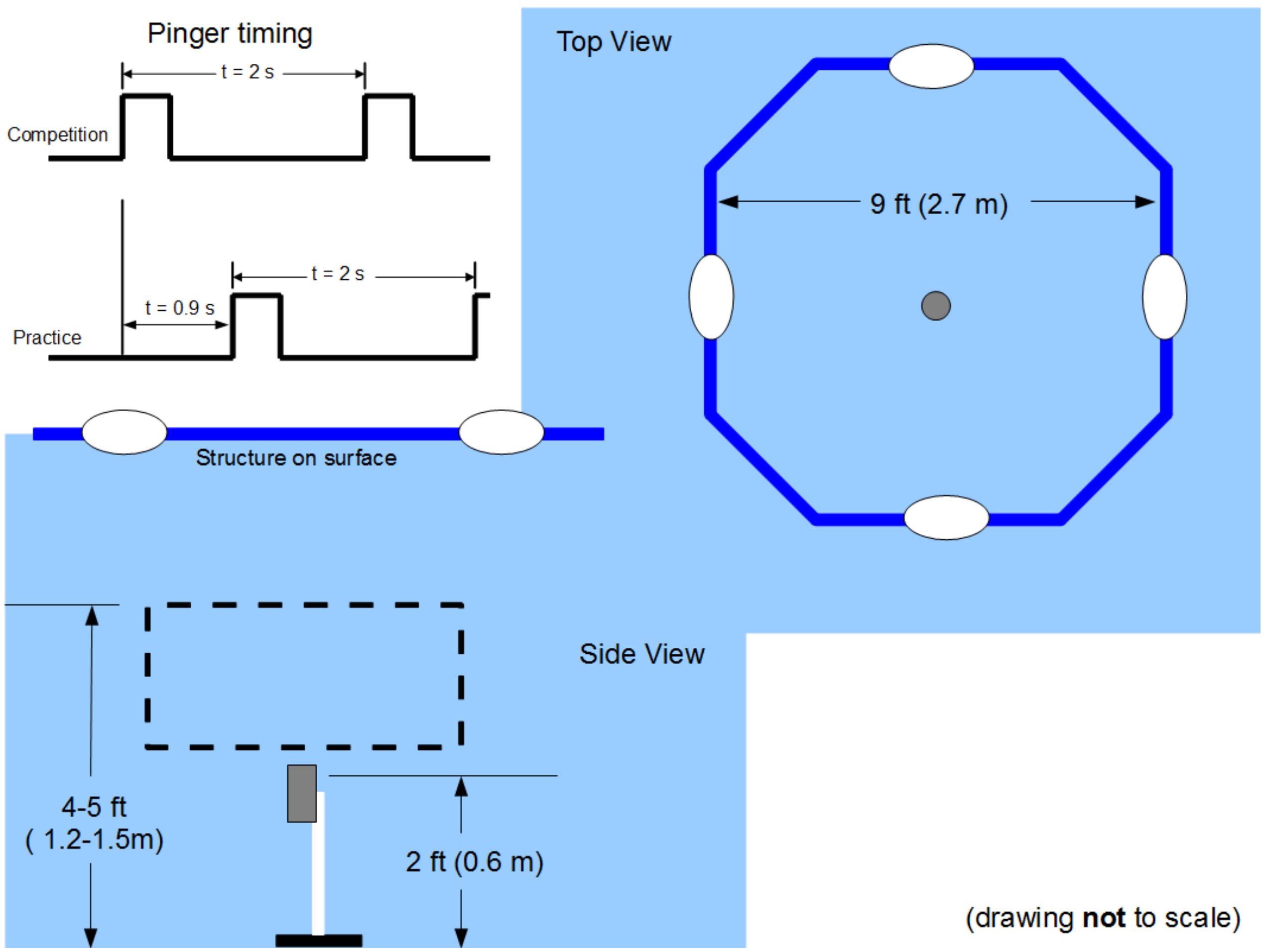


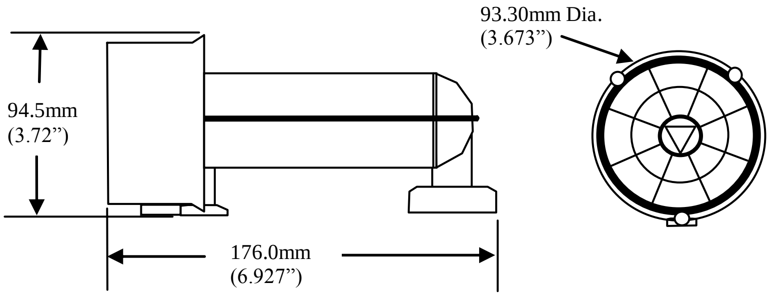
Figure 8: Laurel Wreath and delivery

Scoring: Each of the tasks has a point value associated with it. The tasks can be completed in any order. However, the recovery object must be attached to the vehicle at the end of the run in order to get full points for the recovery. Once the vehicle surfaces, it may then choose to drop/place the object for more points.

Breaching: When completing the sequence of tasks, the octagon may not be the last task attempted. In this case, if the vehicle surfaces fully or partially within the octagon it can then submerge again to accomplished the remaining tasks.

Interference: Vehicles that interfere with competition elements may be disqualified at the judges' discretion. "Interference" does not include cases where, in the opinion of the judges, a vehicle is attempting to complete one of the tasks. If a vehicle becomes entangled on a competition element the run will be declared complete. Teams may keep the points earned on that run, or may have the vehicle returned to the launching platform and start another new run. If a new run is begun, all points from the previous run are lost.

DATA SHEET
SBT150 SPARE BRUSHED THRUSTER



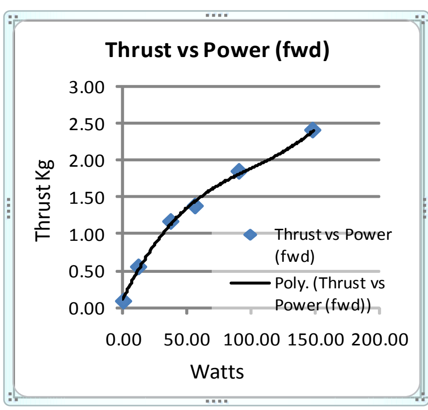
SPECIFICATIONS:

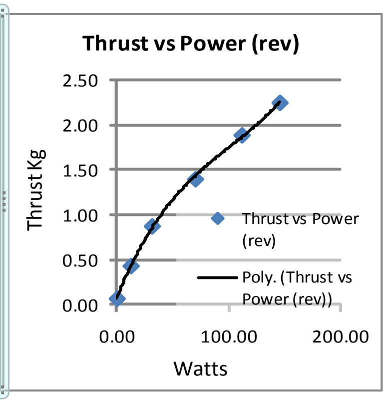
VOLTAGE NOMINAL……………………. **28VDC**
MAX CURRENT
OF MOTOR WINDINGS………………….. ***5.0AMPS**
(a current regulator is highly recommended)

WEIGHT:
Dry …………………………………… 686grams
Wet…………………………………… -393grams (in fresh water)

WIRING CONFIGURATION:

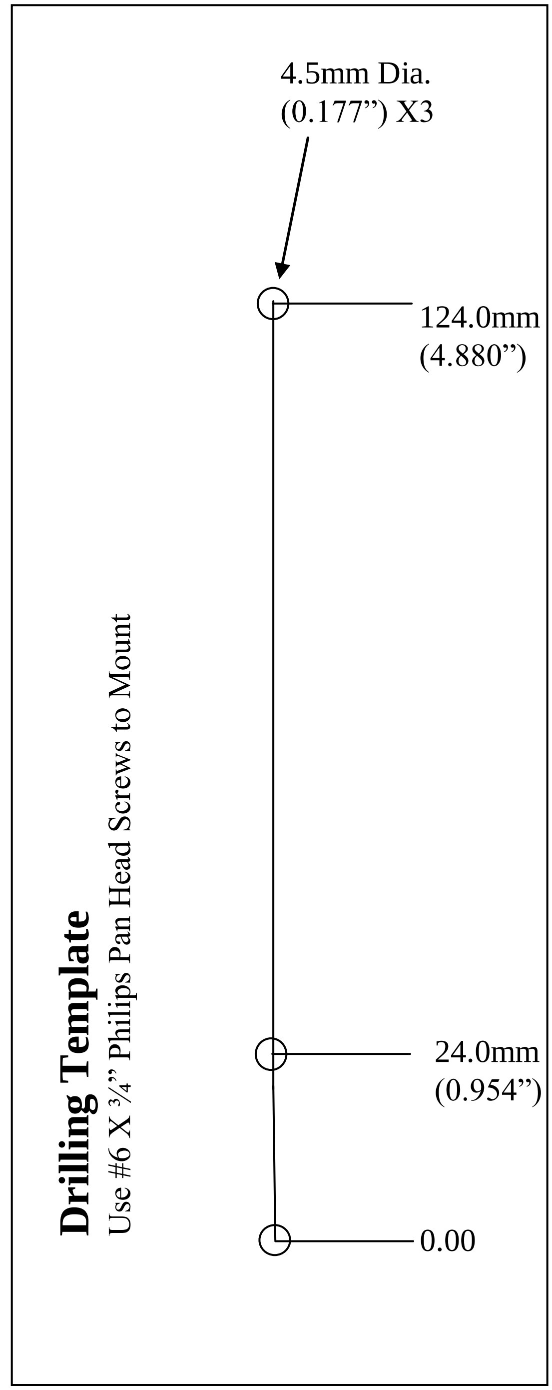
White………………………… Clock
Black ………………………… Ground
Grn/Ylw……………………… Data
Red…………………………….28VDC





Direction	Voltage(DC)	Current Draw (A)	Thrust (kg)	Power (W)
Forward	28	0.000	0.09	0.00
	28	0.420	0.55	11.80
	28	1.320	1.17	37.10
	28	2.000	1.38	56.20
	28	3.240	1.84	90.70
	28	5.300	2.40	148.50
Reverse	28	0.000	0.07	0.00
	28	0.440	0.43	12.44
	28	1.120	0.87	31.42
	28	2.500	1.40	70.20
	28	4.000	1.89	111.90
	28	5.210	2.25	145.90

SEABOTIX SBT150 DATA



* Higher currents (up to 6A) may be used, but will drastically shorten the life of the thruster if ran continuously in this mode. 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.

SEABOTIX, 2877 Historic Decatur Road, Suite 100, San Diego, CA, 92106, USA (619) 450-4000

SQ26 Seismic & Towed Array Hydrophone

Overview

The SQ26 is a general-purpose low-cost hydrophone. It has good sensitivity, wide bandwidth and good stability. Custom configurations of these hydrophones are also available. For additional data on frequency response or outline drawings, please call our technical support.

All parameters measured after hydrophones have been subjected to pressures of 200 bar. The polyurethane-encapsulated hydrophone will withstand continuous immersion in isoparaffinic hydrocarbon fluids and sea water.

Specifications

Voltage sensitivity:	-193.5 ± 1.0 dBV re 1 μPa @ 20 °C, 20 V/bar
Charge sensitivity:	24 nC/bar
Capacitance:	1.4 nF ± 10 % @ 20 °C
Capacitance variation with temperature:	0.33% increase per °C
Capacitance variation with depth:	7% loss per 1,000 m (3,300 ft)
Operating depth:	down to 2,000 m
Frequency response:	flat from 1 Hz to 28,000 Hz
Acceleration sensitivity:	< 0.2 mbar/g when properly mounted
Diameter:	25.4 mm (1.0”)
Length:	25.4 mm (1.0”) max.
Mass:	16 grams (0.56 oz)
Electrical leads:	30cm (12”) twisted pair with shielded Hytrel Jacket
Electrical insulation:	> 500 M Ohms
Water blocked leads:	Yes
	Also available with integral shield in a low noise configuration (SQ26-01)

Features

- Low cost
- Rugged
- Good depth capability

Applications

- General-purpose research
- Towed arrays

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