Robosub Project Proposal

EEL 4911C – Senior Design – Fall 2011 Deliverable

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Project Executive Summary

The Association for Unmanned Vehicle Systems (AUVSI) desires to provide opportunities for students to experience the challenges of system engineering, to develop skill in accomplishing realistic missions with autonomous vehicles, and to foster relationships between young engineers and the organizations developing and producing autonomous vehicle technologies. As part of this mission, AUVSI has partnered with the U.S. Office of Naval Research (ONR) to design and host the RoboSub competition which requires students to design and build an Autonomous Underwater Vehicle (AUV) that is capable of navigating through an elaborate obstacle course while completing several specified tasks in a timely manner. The competition will be held in July 2012, and will be located in San Diego, California at the SSC SD TRANSDEC Facility which houses a large anechoic saltwater reservoir, to be used as the competition arena (Figure 1).

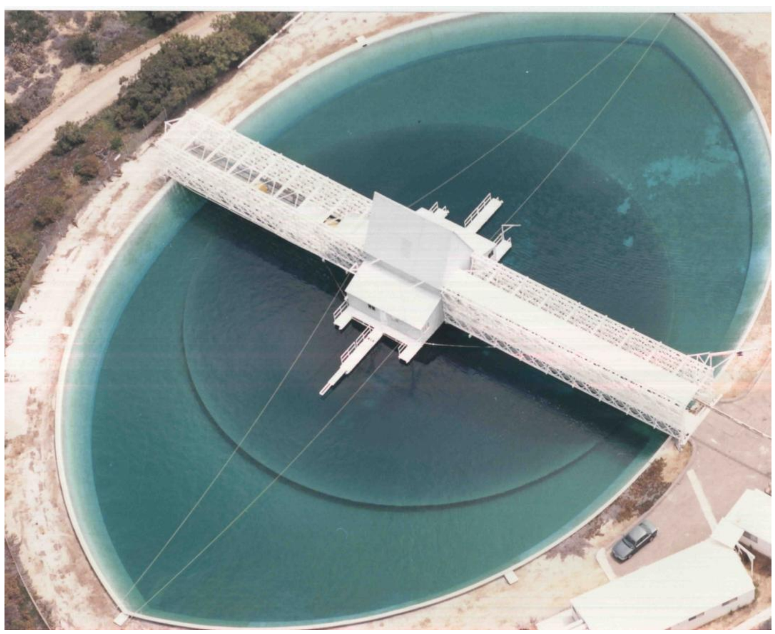

Figure 1: SSC SD TRANSDEC Facility Featuring the Anechoic Saltwater Pool

In order to successfully complete the obstacle course, the AUV will require various sensors, mechanical subsystems, control units, and programming. Due to the complexity and diversity of the system, the design will be carried out by six highly qualified engineers: Antony Jepson (Computer Engineer), Hang Zhang (Computer Engineer), Ryan Kopinsky (Electrical Engineer), Eric Sloan (Mechanical Engineer), Tra Hunter (Mechanical Engineer), and Kashief Moody (Mechanical Engineer). The feasibility of this project has been carefully analyzed, and due to the organizational skills of the design team, well-developed component designs, and manufacturing resources available, it has been determined that this team is highly capable of executing this project to completion—all in a clean, efficient, cost-effective design. The design team desires to obtain necessary funding in order to implement a design that will win the competition and showcase the talent and dedication at the FAMU-FSU College of Engineering.

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1 Introduction

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 units for interpretation, ultimately yielding the desired output response from onboard subsystems that are capable of completing these specific physical tasks.

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.

Figure 2: FSU Morcom Aquatics Center

1.4 Intended Uses and Intended Users

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/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

2 Concept Generation and Selection

2.1 Hull / Frame

Table 1: Hull/Frame Concept Descriptions

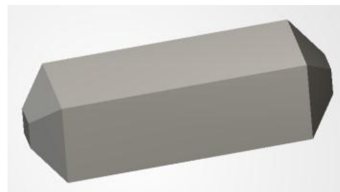
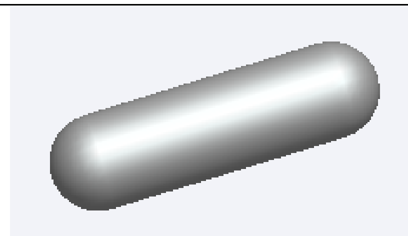
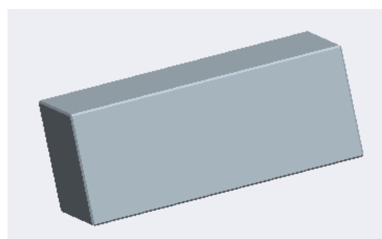
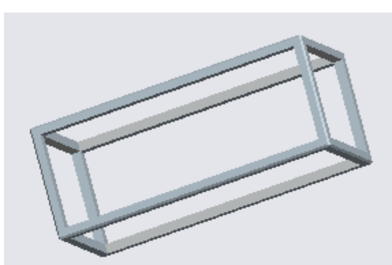
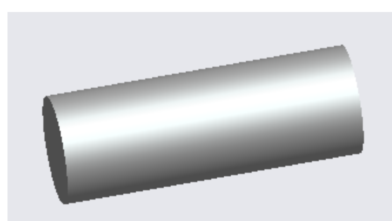
	Shape		Material	
	Frame	Hull	Frame	Hull
Concept 1	None		None	Aluminum 6061/Acrylic
Concept 2	None		None	Acrylic
Concept 3	None		None	Aluminum 6061/Acrylic
Concept 4			80/20 Extruded Aluminum	Acrylic
Concept 5	None		None	Carbon Fiber

Table 2: Hull/Frame Decision Matrix

Design Criteria	Ease of Manufacture		Waterproof Reliability		Hydrodynamics (Drag Force)		Weight		Versatility/Ease of Peripheral Subsystem Attachment		Cost		Sum
Weighting Factor	0.25		0.20		0.10		0.15		0.20		0.10		1.00
Concept 1	6	1.50	5	1.00	8	0.80	5	0.75	7	1.40	7	0.70	6.15
Concept 2	3	0.75	7	1.40	9	0.90	7	1.05	2	0.40	4	0.40	4.90
Concept 3	8	2.00	6	1.20	3	0.30	6	0.90	10	2.00	8	0.80	7.20
Concept 4	7	1.75	8	1.60	6	0.60	7	1.05	9	1.80	6	0.60	7.40
Concept 5	2	0.50	6	1.20	10	1.00	9	1.35	1	0.20	4	0.30	4.65

In reference to the above decision matrix, ease of manufacture, waterproof reliability, and versatility/ease of peripheral subsystem attachment were deemed the most critical determining factors in the selection process of the hull/frame. Furthermore, considerations in regards to the visibility of the electronics from an external perspective, natural stability of the structure, and ease of implementing access to the interior of the hull were also given. Thus, following analysis, it was decided that concept 4 provided the best design with which to move forward in the project.

2.2 Interior Hull Design

Various concepts were considered for the layout of the interior of the pressure vessel. Driven by the need to securely support the electronics (i.e. the power supplies, control units, and inertial measurement unit), as well as to efficiently and effectively dissipate heat away from the electronics, it was determined that a thermally conductive, flat platform would need to rest inside the hull. Since the hull was decided to be made out of a thermal insulator in acrylic, the goal was set to direct the heat toward the aluminum end caps of the pressure vessel via this thermally conductive plate. However, in order to transfer heat effectively to the end caps—the only viable outlet to the cooler surrounding environment—the thermally conductive plate would need to share surface area with the end caps. It was determined that the most logical way to achieve this would be to add slots to the custom-designed end caps, thus providing surface area for the ends of the plate to rest and continue to efficiently transfer heat via conduction. In order to provide support for this flat plate, it was determined that acrylic would be the best candidate because due to its thermal insulation properties, it can also serve to prevent heat convection into the internal surroundings of the pressure vessel, and thus increase the efficiency of heat conduction through the plate. Due to cost, thermal conductivity, and weight considerations, it was determined that Aluminum Alloy 6061 would be the best material for the job. In regards to the arrangement of the electronics on top of this aluminum plate, it was decided that in order to keep with the themes of compactness and symmetry, a vertically-stacked set of racks be implemented to support the control units and the inertial measurement unit in an organized, stable fashion. After determining that the vast majority of the heat generation inside the pressure vessel would derive from the power supplies, it was decided that they not only rest directly on top of the aluminum plate, but also be located on either side of the central multi-level structure, close to the aluminum end caps, in order to facilitate the heat transfer process to the surrounding saltwater environment via conduction through the aluminum plate and end caps, followed by forced convection from the flowing water along the end caps.

2.3 Electronics

2.3.1 Main controller unit

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. Since image processing and sensor controls involve numerous amounts of data processing and storage, a large onboard memory for fast transferring of data becomes an important factor in choosing the main control unit for the AUV. Other important factors include the cost, I/O functionality and compatibility, power consumption and dissipation, and the compatibility of the software system with sensors. Here are three concepts that were explored and discussed for the team to decide which computer system best fits our project.

Option 1: Use the existing BeagleBoard

The first option is to use a BeagleBoard (REV B7) that was left from last year's project donated by ARM. The BeagleBoard features a 600MHz ARM OMAP3530 processor and a separate 430MHz DSP processor. The beagle board also has 128MB DDR RAM.

Benefits:

- Economic: no cost (donated)
- Readiness: Software system is already setup and ready to run programs
- Peripherals availability and accessibility: most accessories are and we can get started programing on this board immediately
- Low power consumption: The total power required by the system is less than 5W

Drawbacks:

- Performance: slow clock rate of microprocessor and Low MIPS performance (< 1400MIPS)
- Memory: small onboard memory and slow memory speed. The board only has 128MB RAM. With Angstrom Linux running, only 80MB memory is left. The memory bus runs at 166MHz
- I/O constraints: No USB connector onboard due the PCB defect in this version of BeagleBoard. A microUSB connector onboard requires a miniA type connector to function as a USB host

- Defect: Power jack is in a poor condition. It is very easy to lose external power. This problem could be fixed but might require some effort.

Option 2: Purchase the Intel x86-based PC
The second option is to purchase an Intel x86 based PC. Intel x86 based microprocessor could deliver us abundant computing power for all the functionalities that the AUV needs to perform. The components we are looking at are Intel Core i3 2.6GHz LGA 1155 35W dual core processor, 3GB of DDR3 RAM, and a 32GB Solid State Drive for storage.

Benefits:

- Performance: Very high performance compared to the Beagleboard we currently have. Multicore and the Hyperthread technology enable multithread parallel computing, which further improve the system performance
- Software system: With this Intel PC onboard, the AUV could use full featured operating system such as Ubuntu, Debian or Windows OS instead of embedded operating systems. The full support for compilers such as GCC and G++ and the familiar programming environment could make the programming process more efficient
- Computer vision support: For computer vision and image processing, OpenCV will be used since it provides lots of libraries and functions which could make the most challenging problem easier. Since the OpenCV optimized for the Intel architecture, using an Intel platform will boost the performance of the imaging processing.

Drawbacks:

- Power consumption: The CPU itself has a TDP (Thermal Design Power) of 35W. The total power required by the computer system is estimated to be about 104W[1]. The high power consumption requires the AUV to efficiently transfer heat from the enclosed pressure chamber to the surroundings Additional cooling device is required.
- Cost: The total cost of the system is estimated to be more than 300 Dollars.
- Communication overhead: Since the project is sponsored by ARM, the BeagleBoard is required to be used. Therefore communication between PC and the BeagleBoard becomes an overhead. If a PC is used, the BeagleBoard is not necessary for other functions due to the fact that one PC is powerful enough to handle all the tasks.

Option 3: Purchase the latest BeagleBoard model (i.e. BeagleBoard-xM)
The third option is to update the current BeagleBoard to a newer version. The current BeagleBoard was released in 2008. And the newest version BeagleBoard-xM was released in 2010. The new version features a faster Texas Instruments Cortex A8 1GHz processor, separate 800MHz DSP, and a 512MB DDR memory.

Benefits:

[1] See Appendix A2.1

- Performance: Compared to the original BeagleBoard, the BeagleBoard-xM contains a much more powerful Cortex A8 1GHz processor which can achieve 2000 Dhrystone[2] MIPS and is about 1.5 times faster than original BeagleBoard. 800MHz DSP and the 512 MB RAM will significantly boost the performance of image processing compared to the original BeagleBoard.
- Low cost: This new version of BeagleBoard costs about 150 Dollars, which about half the price of the Intel PC. Our team is actively seeking on this new version of BeagleBoard.
- I/O Ports: The BeagleBoard-xM has onboard USB hub which provides 4 connectors. Therefore the need for additional USB hub is eliminated. The USB ports provide full USB host and OTG supports with a data transfer rate of 480Mbps. A DB9 connecter is provided for the RS232 port. And a full functional Ethernet port is provided.
- Backward compatibility: Most cables, peripherals, accessories and software used for the original BeagleBoard are compatible with the newer version.
- Resources: The BeagleBoard-xM has a very broad online community. A lot of open source projects that were done on the BeagleBoard-xM can help us to design our programs faster and more efficient.
- Low power consumption: The total power required by the system is less than 5W

Drawbacks:

- Availability: Since our team is still asking for possible donation on this product from ARM, it may take some amount of time for us to get the product. We can purchase this product if sponsorship is not given or it tends to take a long period to obtain the sponsorship.

After an in-depth research and discussion on all three possible solutions according to their benefits and drawbacks, our team has come to an agreement to use the **Beagleboard-xM system**, which has high performance, low power consumption, low cost and abundant available resources. And the old BeagleBoard can serve as a backup unit. The specific comparison of these three systems is listed in Appendix A2.2.

2.3.2 Computer vision

When selecting the cameras for the Computer Vision module, the cameras have to satisfy a certain set of requirements in order for them to be suitable for the system. In table 1 three potential cameras have been listed and will be compared in order to select the best camera for the project.

[2] A synthetic computing benchmark program developed in 1984 by Reinhold P. Weicker intended to be representative of system (integer) programming

Table 3: Camera Selection

Feature	**Logitech QuickCam Pro 4000**	**Logitech WebCam Pro 9000**	**Logitech WebCam C615**
Driver	Philips USB Webcam (PWC)	USB Video Class (UVC)	USB Video Class (UVC)
Number of Pixels	1.3MP	2MP	2MP
Max Resolution	1280 x 960	1600 x 1200	1920 x 1080
Auto-Focus	No	Yes	Yes
Auto-Light Adjust	No	Yes	Yes
USB Interface	1.1	2.0	2.0
Tri-pod Mount	No	No	Yes
Price	Free (inherited hardware)	$55	$55

In order for the cameras to interface with the BeagleBoard and OpenCV libraries, it is important that the webcams are USB Video Class (UVC) compatible cameras. The Logitech QuickCam Pro 4000 did not satisfy this requirement and is, therefore, not suitable for the implementation in the Computer Vision module. The number of Pixels and maximum resolution are also important features since more detailed images will result in better accuracy for the algorithms. Both the Webcam Pro 9000 and Webcam C615 have satisfactory specs in regards to pixels and resolution. Auto-Focus is a definite must since this will result in a sharp and detailed image, which is a requirement for image processing. Furthermore, due to the fact that the image processing is done under water, lighting conditions vary greatly; it is, therefore, important that the camera automatically adjusts the light settings. Auto-Light Adjust will result in better pictures in low or harsh lighting conditions. USB 2.0 is needed for interfacing with the camera since this will enable faster transmission rates. Both the WebCam Pro 9000 and WebCam C615 satisfy the requirements for Auto-Focus, Auto-Light Adjust and the USB interface. Since the price of these two cameras is the same, the only thing that differs is the tri-pod mounting capabilities of the WebCam C615. The tri-pod mounting capabilities will give the team more flexible options in regards to mounting the cams in their enclosures/pressure vessels. Considering all the advantages, it was decided that the Logitech Webcam C615 will be used as the cameras for the Computer Vision module.

2.3.3 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 vehicule heading and contribute to the vehicle's internal model of its location.

2.3.3.1 Inertial measurement unit (IMU)

An IGS is programmed with an initial input and then uses its IMU to update its position relative to that initial position. This initial input can be provided by many sources such as the Global Position System, human input, and input from other machines. For the purposes of this investigation and because wireless communication is prohibited to and from the Robosub (per the competition guidelines) and GPS does not work underwater, concept generation was restricted to IMUs that do not include GPS sensors. The following devices were considered for inclusion in the device:

Table 4: IMU Selection

Developer	Name	Instruments	Power Consumption	Dimensions	Interface	SDK	Price
Razer	9 Degrees of Freedom Sensor Stick	3-axis (gyro, accel, magno)	3.3V	35mm x 10.5mm	I2C	None	$89.95
Razer	9 Degrees of Freedom IMU	3-axis (gyro, accel, magno)	3.3V	28mm x 41mm	serial TX and RX pins with a 3.3V FTDI Basic Breakout	example firmware on Arduino bootloader	$124.95
Microstrain	3DM-GX2	3-axis (gyro, accel, magno)	90mA @ 4.5 - 16V	41mm x 63mm x 32mm w/ enclosure and 32mm x 36mm x 24mm w/o enclosure	USB / RS-232 / TTL	comprehensive software	$1,895.00
Oceanserver	OS5000-USD	3-axis (accel, magno)	35ma @ 3.3V	7.62mm x 25.4mm x 25.4mm	USB / RS-232	ASCII interface	$499.00
CH Robotics	UM6	3-axis (gyro, accel, magno)	52mA @ 3.5 - 5V	27.9mm x 35.6mm x 12.7mm	TTL	open-source firmware with demo software	$199.00

These devices were rated based upon their ability to measure orientation (pitch, yaw, and roll), dimensions, price, and software support. Based on the criteria, the 9 Degrees of Freedom Razer IMU was the best match. It features a 3-axis gyroscope, magnetometer, and accelerometer; a serial interface which can be connected to an Arduino board; Arduino firmware which has great community support, and is available for $124.95 which fits within the team budget.

2.3.3.2 Water pressure sensor

Since the Robosub will be underwater, an additional level of measurement is required to create a comprehensive IGS—depth. There are various methods of measuring depth:

- sending an acoustic signal towards the floor and measuring the amount of time it takes to receive a response
- taking discrete measurements of water pressure

- measuring the downward movement of a cylindrical rod until it hits the ground
- using a combination of the IMU and the Robosub's initial position to calculate up/down movement in the water

From the options listed, using a water pressure sensor was selected. The water pressure sensor allows the Robosub to know how far it has dived or risen from its initial position. Using only the IMU to determine depth is tricky because it requires high frequency and high resolution polling of both the accelerometer and gyroscope which could be catastrophic if they are not precisely calibrated. The cylindrical rod method was not selected because additional mechanical systems would need to be installed to have the rod descent and ascent in the water until it reached the ground. In addition, storage mechanisms would be required to house the rod. The following water pressure sensors were considered for inclusion in the design:

Table 5: Water Pressure Sensor

Developer	Name	Power Consumption	Interface	Accuracy	Price
AMSYS	MS5541	4V	3 serial lines	1.2mbar (12mm)	Pending quote response from AMSYS
BOSCH	BMP085	12microA @ 3.6V	I2C	0.25m	\$8.95 + \$19.95 breakout board

Only a few documented water pressure sensors have evidence of being used with the Arduino board. High-resolution is required so the AMSYS MS5541 was selected because of its ±12 mm accuracy (assuming ~1,025 kg/m^3 density of saltwater). The BOSCH BMP085 was not selected due to its low accuracy of ±250 mm.

2.3.3.3 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.

For this project, the Reson TC-4013 hydrophones were selected because of their frequency response range from 1 kHz to 170 kHz. Their sensitivity is omnidirectional, which means it maintains this frequency response range radially. It has an operational depth of up to 700 m as well, yielding it easily qualified for its application in our design.

2.4 Power supplies

Several options were available to use as power supplies for the components of the AUV. Lead-acid batteries, Nickel Metal Hydride (NiMH) batteries, and Lithium-Ion Batteries were deemed the most viable options to consider. Due to their high energy density and relatively low cost, it was decided that Lithium-Hydride batteries would be the best option to use in the design of the AUV. Lead-acid batteries, while extremely robust, have a low energy density and would add too much unnecessary weigh to the system. Furthermore, since the batteries will be stored in an enclosed environment, the robustness of the lead-acid batteries held relatively low value in our decision-making process. NiMH batteries were too expensive and unnecessary for the power requirements of the AUV.

2.5 Mechanical Subsystems

2.5.1 Vehicle Propulsion System

Thrusters were used by every single team in competitions past, and were the obvious choice for the vehicle propulsion system. Similar to normal DC motors, they are able to rotate both clockwise and counterclockwise, and thus can provide equal force in both directions. They are also easily controllable by a microcontroller. Their speed and thrust force can be adjusted simply by introducing a different PWM signal. This characteristic would provide dynamic versatility for the vehicle. In addition, since the 2011 FAMU-FSU College of Engineering RoboSub design team handed down three functioning quality thrusters, it was yet another incentive to use these established devices for vehicle propulsion and general maneuverability.

2.5.2 Grasp/release mechanism

One of the functional requirements of the AUV is that it be able to pick up a PVC structure (exact dimensions not yet disclosed), surface within a particular region, and then release the PVC object upon command. Thus, a grasp/release mechanism must be designed and constructed. Four viable concepts for this mechanical subsystem were derived. Each of these designs uses a claw to physically grab/squeeze the PVC object—one side of the claw is fixed, and the other side is actuated to grasp the object.

Concept 1 uses a pneumatic system—it releases high-pressure gas in order to drive the actuated c-shaped arm to close around the object. The claw would be linearly driven by the opening of a solenoid valve and subsequent release of compressed gas into a single-acting air cylinder that houses a piston. The end of the piston would be rigidly attached to the center of the actuated claw, and while being rapidly driven along the cylindrical chamber, would cause the c-shaped arm to pin the PVC object against the complementary, stationary c-shaped arm. Rubber would be added to each of the arms along the region of contact in order to produce a more compliant compression, as well to provide increased friction between each claw and the PVC structure. When the object is to be released, a second solenoid valve located between the entrance to the air cylinder and the first valve would be opened and closed by actuation, thus releasing the pressure inside the chamber and allowing the spring to retract the piston/claw and dismiss the PVC object.

Concept 2 is similar to concept 1 in that it also incorporates the use of an air cylinder driven by the actuated opening of a solenoid valve and subsequent release of compressed gas. However in this design, rather than inducing linear motion of the actuated claw, the thrust of the piston would induce rotation of the c-shaped arm about an axis—the result being the natural motion that occurs when a person grasps an object with his or her fingers.

Concept 3 implements an electric linear actuator in order push the actuated c-shaped arm horizontally into the PVC object and against the complimentary, stationary claw. Concept 3 is essentially the integration of a linear motor into Concept 1, in place of the pneumatic device and solenoid valves.

Concept 4 implements an electric linear actuator in order rotate the actuated c-shaped arm into the PVC object and against the complimentary, stationary claw. Concept 4 is essentially the integration of a linear motor to Concept 2, in place of the air cylinder and solenoid valves.

Table 6: Grasp/Release Mechanism Decision Matrix

Design Criteria	Ease of Manufacture/ Implementation		Reliability/ Durability		Weight		Grasp Force Per Unit Power Consumption		Cost		Sum
Weighting Factor	0.30		0.30		0.10		0.20		0.10		1.00
Concept 1	5	1.50	7	2.10	7	0.70	9	1.80	8	0.80	6.90
Concept 2	4	1.20	6	1.80	7	0.70	8	1.60	8	0.80	6.10
Concept 3	7	2.10	8	2.40	6	0.60	7	1.40	1	0.10	6.60
Concept 4	6	1.80	7	2.10	6	0.60	6	1.20	1	0.10	5.80

In review of the above decision matrix, ease of manufacture/implementation and reliability/durability were deemed the most important factors in the selection process for the grasp/release mechanism design. Concept 1 was deemed the best option due to its relatively high reliability, high grasp force, low weight, and low cost. Although the integration of automated solenoid valves may provide a challenge, the design team deems it sufficiently viable, particularly with the aid of external resources.

2.5.3 Marker dropper

One of the functional requirements of the AUV is that it be able to drop markers in specific bins during its mission. Thus, a marker dropper mechanism needed to be designed. After extensive research and brainstorming, four viable concepts were developed for this mechanical subsystem, and are described below:

Concept 1 is a slight modification of the 2011 FAMU-FSU RoboSub team's design. In this design, two markers (0.5-inch diameter steel balls) are stored in a parabolic channel made out of Aluminum 6061—one on either side of the downward-facing servo. Upon command, the servo motor is actuated, causing the servo to rotate in one direction and release one of the two markers. After returning to its initial position, the servo can then rotate in the opposite direction upon command, thus releasing the other marker into the desired bin. In order to ensure that each of the markers drops vertically rather than at a slight angle (as occurs in the current design), a vertically oriented funnel will be added to the outlet of the device as a guide for each of the steel balls upon release.

Concept 2 involves the use of a pre-pressurized pneumatic air cylinder, a thin rectangular plate, and individual storage compartments for the markers. In this design, each of the two steel balls would be surrounded by an individual cylindrical enclosure, which would be attached to the bottom of the vehicle's frame. Both markers would rest on a thin rectangular plate that is fixed to the piston of an air cylinder so that when one of the two solenoid valves is actuated to open, the pressure would be released into the surrounding water, the spring inside the single-acting air cylinder would retract the piston/rectangular plate, and each marker would thus be independently released into the appropriate bin. The pressure could be released in stages via the timed, multi-stage opening and closing of the pressure release valve (similar to the second valve in the design of the grasp/release mechanism).

Concept 3 implements a servomotor with a thin, cylindrical, horizontally-oriented disk attached to the end of its shaft. The disk would have a circular cutout with a diameter approximately 25% larger than that of the steel balls. The markers would rest above the disk, surrounded by individual cylindrical enclosures similar to those in concept 2. The actuation of the servo motor would cause rotation of the disk, allowing the cutout to lie directly underneath one of the two markers, thus allowing it to drop into the designated bin. After returning to its initial position, the servo would then be able to rotate the same amount in the opposition direction in order to allow the other marker to drop upon command.

Concept 4 requires the use of two electromagnets to hold onto each of the two markers during the mission. Once the target (i.e. the proper bin) is detected and reached, one of the electromagnets would shut off, thus allowing the release of the respective steel ball. Each electromagnet would be independently controlled.

Table 7: Marker Dropper Decision Matrix

Design Criteria	Ease of Manufacture/ Implementation	Reliability/ Durability	Weight	Power Consumption	Cost	Sum

Weighting Factor	0.35		0.30		0.10		0.15		0.10		1.00
Concept 1	9	3.15	9	2.70	6	0.60	9	1.35	10	1.00	8.80
Concept 2	5	1.75	7	2.10	7	0.70	7	1.05	7	0.70	6.30
Concept 3	9	3.15	8	2.40	9	0.90	9	1.35	8	0.80	8.60
Concept 4	4	1.40	7	2.10	8	0.80	4	0.60	4	0.40	5.30

Upon analyzing the decision matrix, it has been determined that the best approach is to make the slight modification to the design developed by the 2011 FAMU-FSU RoboSub team. Although concept 3 may be a slightly better design, the benefits gained do not outweigh the time and energy saved by settling for an established mechanical subsystem that already works relatively well. The pneumatic air cylinder required for concept 2 would have yielded a more complicated design that would be more difficult to implement than those that utilized a servo motor as the actuator instead. Furthermore, the difficulty of manufacture, relatively large power consumption, and relatively high cost involved in the production of concept 4 yielded it as a poor option.

2.5.4 Torpedo launcher

The AUV must also be capable of independently shooting two torpedoes through a PVC cut-outs—each with a different, size, shape, and color. Thus, the design team will construct two identical torpedo launchers, and place each of these mechanical subsystems on the horizontal neutral axis on either side of the vehicle for symmetry, balance, and stability. Three viable design concepts were generated following research of previous years' successful designs, as well as original brainstorming. Descriptions of each of these concepts can be found below:

Concept 1 involves the design of self-propelled torpedoes, initially guided by a cylindrical barrel. An on-board power supply and motor would drive the rotation of attached propellers, thus driving the torpedo out of the barrel via thrust. The torpedo, as in all of the designs, will be made out of ABS plastic via the 3D printer. Its general shape will be similar to an elongated blimp (i.e. a prolate spheroid), with a flat bottom.

Concept 2 utilizes a pneumatic system, similar to that proposed for the grasp/release mechanism. Two solenoid valves would control the flow of compressed $C0_2$ to each of the two torpedo launcher. Each torpedo launcher would contain an air cylinder and a surrounding barrel to house the torpedo. Upon command, one of the two solenoid valves would be electrically actuated to open, thus releasing the high pressure gas from the regulator into the respective air cylinder propelling the torpedo. Immediately thereafter, the entry valve would be electronically closed. Each torpedo could be actuated independently via the independent control over each solenoid valve.

Concept 3 implemented the use of a spring-loaded device. This design is similar to both concepts 1 and 2 in regards to the shape of the torpedoes and use of cylindrical barrels as guides. However, this concept would incorporate a pre-loaded spring in each of the torpedo launchers, on which one of the torpedoes would rest. A stepper motor would be used to trigger the release of the spring, and thus stored energy, into the torpedo.

Table 8: Torpedo Launcher Decision Matrix

Design Criteria	Versatility/Safety Regulation		Reliability		Ease of Manufacture/ Implementation		Cost		Weight		Dynamic Effects on AUV		Sum
Weighting Factor	0.25		0.25		0.15		0.10		0.15		0.10		1.00
Concept 1	5	1.25	5	1.25	3	0.45	6	0.60	5	0.75	10	1.00	5.30
Concept 2	8	2.00	8	2.00	6	0.90	8	0.80	7	1.05	8	0.80	7.55
Concept 3	8	2.00	7	1.75	5	0.75	8	0.80	8	1.20	9	0.90	7.40

In reference to the above decision matrix, the design team concluded that the most important design criterion to consider in the design of this mechanical subsystem was the safety of the mechanism; according to the competition committee, the torpedoes should not be capable of causing bodily harm upon accidental impact. The safety of the mechanism will be ensured via the control of the launch velocity, as well as the accuracy of the subsystem. Therefore, the mechanisms' versatility, or ability to be adjusted/tuned was taken into account. The reliability of the device and ease of manufacture/implementation were also given strong consideration in the decision process, as high scores in these factors would likely yield the efficient production of a consistently executable device. Due to these factors, along with the strong possibility of using the same compressed air tank, regulator, and solenoid valve box to power the grasp/release mechanism as well, Concept 2 was deemed the best design concept and will be carried out in the overall design of the AUV.

3 Proposed Design

3.1 Overview

The AUV will have an open frame which will support peripheral subsystems such as the object grasp/release mechanism, marker dropper, and torpedo launcher, sensory devices such as a pressure transducer and cameras, six thrusters for propulsion, and a centrally-located, water-tight hull which will house the electronics (i.e. central control unit, microcontrollers, inertial measurement unit (IMU) and power supplies). The design will be almost perfectly symmetrical in order to produce a more robust vehicle that is not only less susceptible to disturbance forces, but also easier to stabilize and maneuver. The AUV will have an overall density slightly greater than salt water so that it will naturally rise to the surface when the kill switch is manually activated and the thrusters are shut down. Furthermore, the mass of the vehicle will be reduced as much as possible to not only obtain the maximum amount of bonus points for weight, but also to provide for a more agile vehicle which can obtain high speeds with greater ease, thus yielding the maximum amount of bonus points for time of completion of the mission.

3.2 Hull / Frame

The frame will be in the shape of a rectangular prism. It will be constructed of 80/20 extruded aluminum due to its relatively low cost, low density, and ease of manufacture/assembly. The result will be a versatile frame which will be able to be easily adapted in order to provide custom attachments and structural support for the peripheral sensors, mechanical subsystems and a central hull/pressure vessel. The hollow frame should yield a manageable increase in the mass and density of the system, as well as a relatively trivial decrease in the hydrodynamics of the vehicle.

The hull/pressure vessel will be cylindrical in form. It will be made out of acrylic, and will serve to house the electronics (i.e. central control unit, microprocessor, power supplies, and inertial measurement unit (IMU)). The hydrodynamic shape of the pressure vessel should not only reduce drag on the device, but also yield it capable of withstanding the hydrodynamic and hydrostatic pressure that it will encounter underwater. 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), 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.

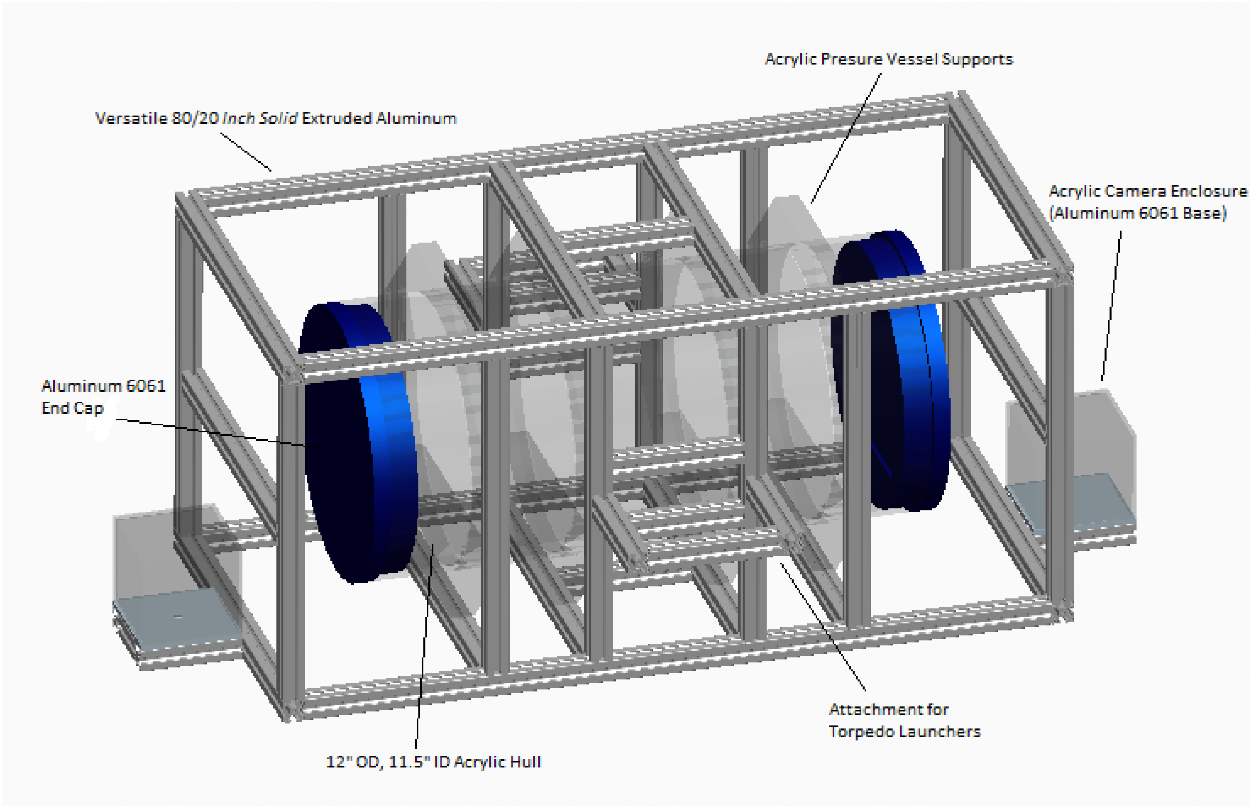


Figure 3: Close-Up View of the Hull and Frame

3.3 Interior Hull Design

The interior of the hull will contain an aluminum sheet which will support the power supplies, the control units, and the inertial measurement unit. This Aluminum 6061 platform will rest on a bed of watermelon-shaped acrylic cut-outs, which will match the curvature of the pressure vessel's inside diameter. Caulking will be used to adhere 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, but will also provide insulation so that heat will be dissipated from the electronics (particularly the power supplies) to the exterior of the device more efficiently as it travels through the aluminum plate and aluminum end caps via conduction. To further increase the insulation around the aluminum sheet, and thus the efficiency and effectiveness of the heat transfer process, rectangular acrylic cut-outs will be attached to the bottom surface of the aluminum plate, and will be bounded by one of the watermelon-shaped acrylic cut-outs on either side. This should provide for effective heat dissipation away from the electronics and into the surrounding saltwater environment without adding a significant amount of additional mass to the system. Since the power supplies should 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. A multi-level structure will be developed and located at the center of the pressure vessel. This structure will have several sets of horizontal racks which will support the control units and the inertial measurement unit.

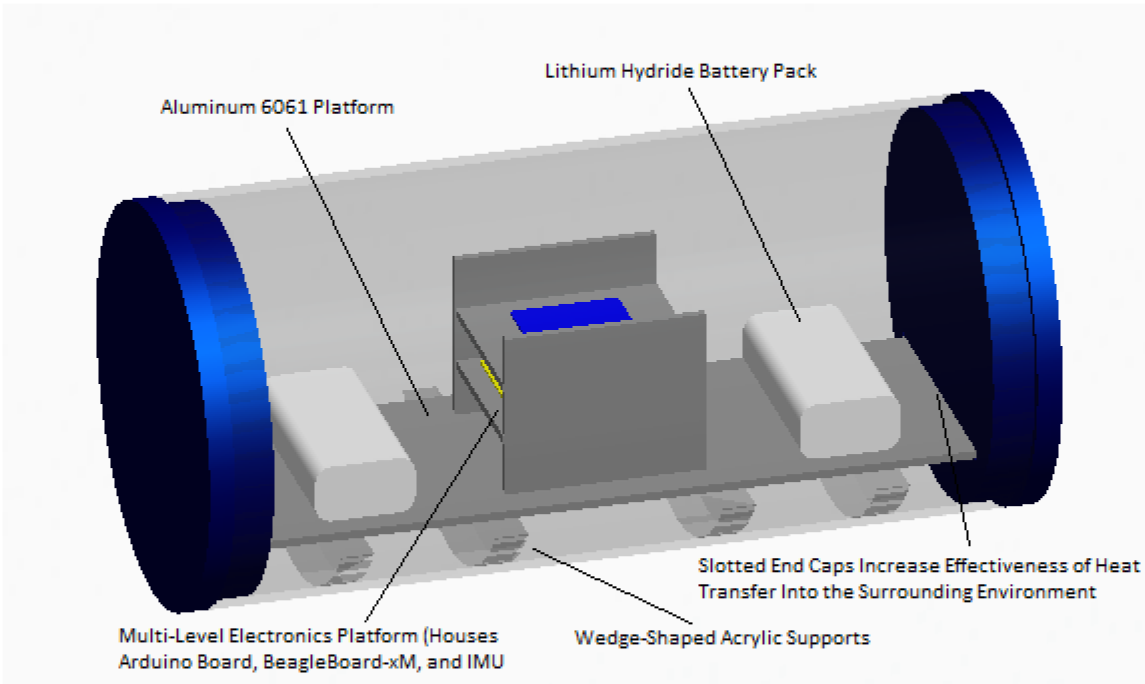


Figure 4: Close-Up View of the Interior Hull Design

3.4 Electronics

3.4.1 Main controller unit

3.4.1.1 Overall design and methodology

The main control unit of the AUV is proposed to be the BeagleBoard-xM which features a 1GHz TI microprocessor and an 800MHz DSP. This is an upgrade from the previous project which used a less powerful version of the BeagleBoard[3]. The BeagleBoard-xM serves as the “brain” of the AUV, which coordinates other components such as sensors and makes decisions such as what direction and speed the vehicle should be operating at. The main control unit is one of the key components of the AUV and the microprocessor and DSP are the key components of the main control unit. The DSP will be fully utilized for image processing, while the microprocessor will be handling all other mission control tasks.

[3] See Appendix A2.2

3.4.1.2 Input

3.4.1.2.1 Data input

Data input are provided as streams from cameras through USB, IMU, and pressure transducer through the serial ports. Confirmation data should be sent from grabber, dropper, and the torpedo launcher after each of these components successfully completes its mission.

3.4.1.2.2 Power input

Power input of the Beagleboard-xM will be from a voltage regulator which provides a stable 5.17V DC voltage. Typical current input through DC jack for the BeagleBoard is 750mA.

3.4.1.3 Output

The output of the main control unit should contain commands to initialize all the sensors, adjust the speed of each thruster, release the marker, fire the torpedo, and perform grabbing function.

3.4.1.4 Outcomes

The anticipated outcomes of using the BeagleBoard-xM as the main control unit are listed as following:

- Ability to collect data from sensors efficiently through serial input
- Ability to output correct commands to each sensor (Commands sent out to motor controllers, droppers, grabbers, and torpedo launchers)
- Image processing must be done with small latency (Time elapsed between capturing the frame and before sending out commands based on the frame information)
- Image processing provides correct results
- Ability to process all data in real time
- Safe memory sharing, buffer managing, and interrupt handling

3.4.1.5 Contingency Plan

If the Beagleboard-xM was not available or failed to function properly, the original BeagleBoard will be used to replace the Beagleboard-xM. If the BeagleBoard did not provide all the outcomes mentioned in 3.2.1 due to its hardware limits (not software or programming issues), other main control unit solutions such as an Intel PC will be used to replace the Beagleboard-xM. In this case software compatibility issue must be resolved.

3.4.2 Software system design

3.4.2.1 Overall design and methodology:

Since the BeagleBoard-xM is chosen as the main control unit of the AUV, the software system must be compatible with the BeagleBoard. We will use the Angstrom Linux that is specifically designed for embedded systems. This is the same approach as last year's team since the similar hardware platform is used. Angstrom Linux is a distribution based on OPENembeded, which offers a cross-compile platform. Therefore, using Angstrom Linux, we can easily programming all the programs using C, C++ or some other high level languages such as Python. C or C++ can also be used to program the Arduino board. Assembly may be used in some situations where low level control and performance is really needed. The software system relies on the stability of the Linux operating system. The Angstrom Linux is stable as long as our programs do not conflict with the operating system. A structured block diagram with different levels is shown below.

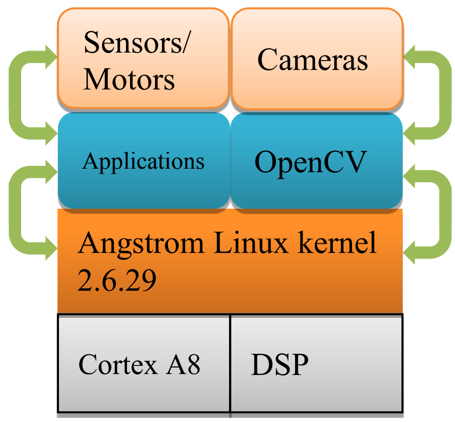


Figure 5: Block Diagram of Software System Design

Arrows represent data communication links. The OpenCV module for image processing will communicate with DSP through the interface of Angstrom Linux operating system. Other sensors and motors will communicate with their own driver applications first. And then the driver application will communicate with the Cortex A8 microprocessor through the operating system.

3.4.2.2 Outcomes

- Programs written are compatible with the operating system. They do not crash the operating system.
- Each program can perform its function and hardware control correctly
- Programs for each component must be compatible and do not crash with each other
- Programs utilize limited hardware resources such as the memory and the communication bandwidth efficiently

3.4.2.3 Contingency Plan

There are other open source operating systems that can be installed on the Beagleboard-xM, such as the Ubuntu, Debian, Android, and Windows CE. These operating systems can be backups of the Angstrom Linux.

3.4.3 Computer vision

During the brainstorming phase of this project, research was conducted on the Computer Vision systems of other teams that competed in the RoboSub competitions in previous years. Team SONIA (first place), NC State, Cornell University and University of Rhode Island (URI) all used OpenCV (Computer Vision) 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.

Regarding the hardware 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 onboard Digital Signal Processor (DSP) since sponsorship by ARM requires the team to implement as much of the project using ARM components.

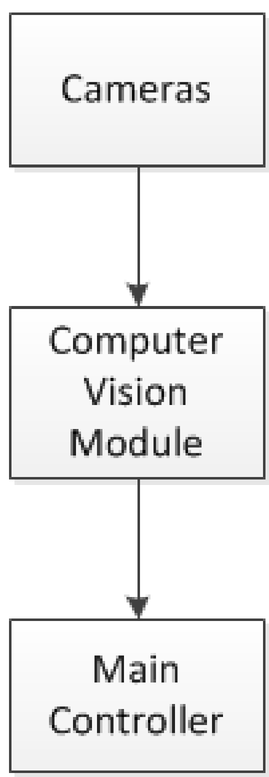


Figure 6: Hardware Design for Computer Vision

Computer Vision Module (CVM)

- Determine the location of each task relative to the vehicle's position
- Keep track of the completed tasks
- Provide output to the Main Controller with instructions for navigation

Cameras

- Provide color image frames to the CVM for image processing
- USB Video Class (UVC) compatible camera (in order to be compatible with the BeagleBoard)
- Auto Light Correction for dim and harsh lighting
- Autofocus

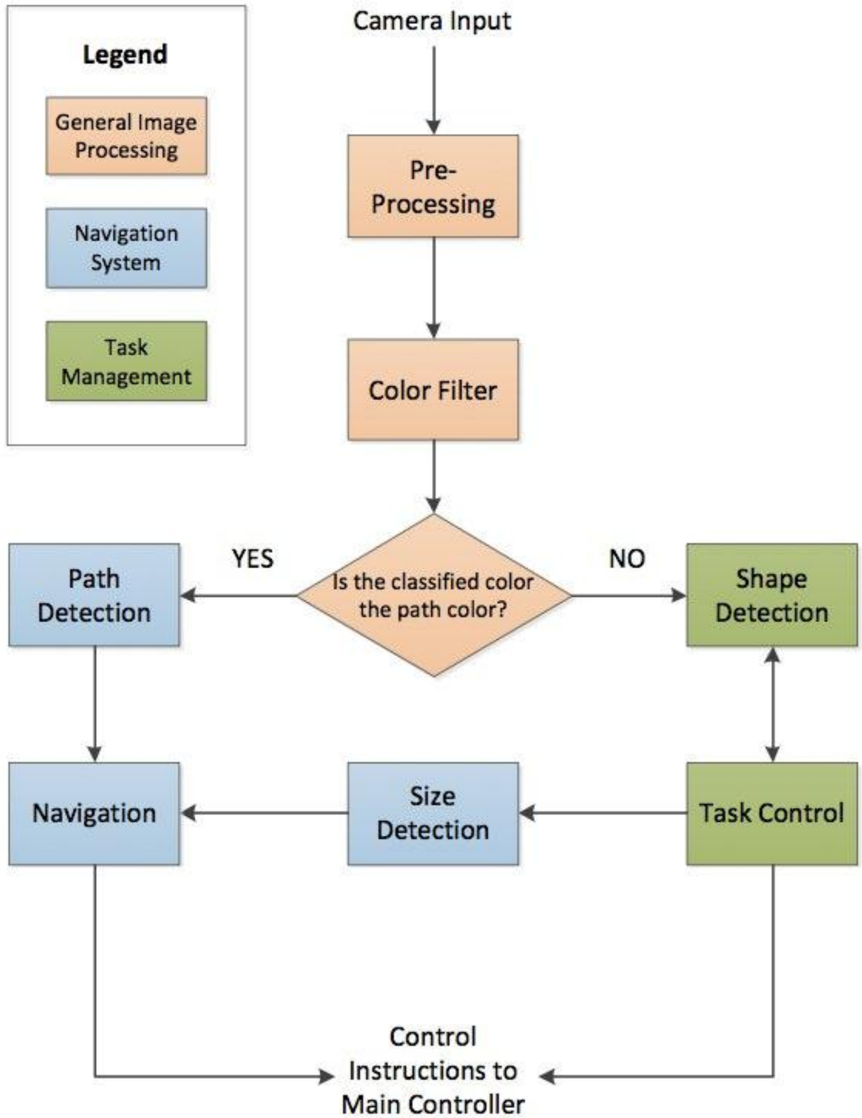


Figure 7: Software Design for Computer Vision

General Image Processing

- *Pre-Processing*: Receives images from the Cameras and prepares each image for the Color Filter.
- *Color Filter*: Isolates and classifies the colors in each image frame obtained from the Pre-Processing phase.

Navigation System

- *Path Detection*: Classifies the path direction and sends relevant information to the Navigation module.
- *Size Detection*: Determines the size of an object/task in each image frame and uses a scaling factor (obtained by camera calibration) to determine an estimation of the vehicle-to-task distance.

- *Navigation*: Provides the Main Controller with essential information for the navigation of the vehicle.

Task Management System

- *Shape Detection*: Based on the shape and color, this module will classify the current task and communicate with the Task Control module in order to complete the task at hand.
- *Task Control*: Keeps track of which tasks are completed and which tasks are yet to be completed; Provides valuable task management instructions and information to the Main Controller.

3.4.4 Guidance system

3.4.4.1 Overview

The guidance system of the Robosub will consist of a 9 degree-of-freedom Razer IMU and an AMSYS MS5541 water pressure sensor. When programmed upon the Arduino board these systems create a total inertial guidance system that can be used to determine the position of the AUV relative to its starting position. While other past teams used more expensive IMUs, the listed IMU is appropriate for the team's limited budget.

3.4.4.2 Block diagram

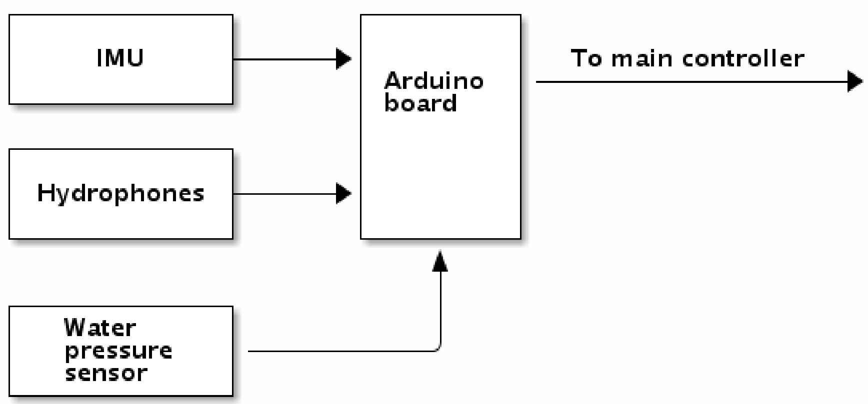


Figure 8: Block Diagram for Guidance System

IMU: Measures acceleration, rotation, and roll
Pressure Transducer: Measures pressure (translates into depth)
Hydrophone: Detects pinger
Arduino board: Converts the sensor measurements into interpretable data and passes the data to the main controller

In this diagram the IMU and Depth sensor are shown interfacing with the Arduino board. Here, the IMU connects to the Arduino board using a FTDI Basic Breakout Board which converts the input from serial to USB. This allows the depth sensor, which uses a serial interface, to connect to the Arduino board on the remaining connectors.

Table 9: Specifications of the Arduino Board

Microcontroller	**ATmega328**
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328)—0.5 KB used by boot loader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz

3.4.4.3 Hydrophones

The hydrophones will be arranged in a 2x2 array on the AUV. This will allow for accurate heading determination of the pinger which will allow the AUV to complete the pinger task. Furthermore, the hydrophones can also be used to determine the heading of the vehicle when the pinger is not engaged. As a result, the hydrophone system will augment the readings taken by the IMU and the water presser sensor (presser transducer).

3.4.4.4 Pressure transducer

A pressure transducer will be attached to the frame, and will be used to detect the relative pressure of the vehicle underwater, and after calibration, the depth of the vehicle. The pressure transducer generates a current that is linearly proportional to the pressure/depth of the vehicle. Following integration into a designed circuit, this current-depth proportionality will be converted to voltage-depth proportionality. This analog signal will then be converted into a digital signal via the microprocessor, and commands will be given to specific thrusters in order to yield the desired vehicle depth. The pressure transducer to be used has yet to be finalized.

3.5 Electrical system

3.5.1 Kill switch

3.5.1.1 Overall design and methodology

The kill switch system is required by the competition. It must be clearly marked on the AUV. And once the kill switch is activated, it must disconnect all the propulsion components (i.e. thrusters) from the battery system. A kill switch system was designed by previous team but it is not functional since the AUV is completely disassembled. We will design the kill switch system based on previous team’s work. According to the block diagram of previous team’s design, the kill switch is placed between the battery and the whole electrical system. Therefore, when the switch is activated, all components onboard will lose their power. In our design, however, we propose to have the kill switch to only turn on and turn off the thrusters. Another switch will be used to turn on and off the onboard computer. Therefore, we the computer is turned on, the thrusters can remain off. This is useful for debugging and testing purposes and can possibly prevent any damage caused to the computer system by suddenly cutting off the power supply.

3.5.1.1.1 Input

A human user controls the switch to turn on or off the propulsion components.

3.5.1.1.2 Output

Disconnect the battery from all propulsion components (thrusters). Thrusters must completely lose the power.

3.5.1.1.3 Outcomes

- Completely turn off thrusters
- Ease of testing and debugging by separating the propulsion system

3.5.1.1.4 Contingency Plan

Since switches are relatively cheap, we can easily get several of them to be used as backups.

3.5.2 Power supplies

3.5.2.1 Overall methodology

The AUV must be battery powered. Two 14.8 V lithium DC batteries were used by last year's team. This year we will continue to use these two batteries and connect then in serial to provide 29.6V DC output. The batteries should be capable of supplying all the power required by all the electrical components on the AUV.

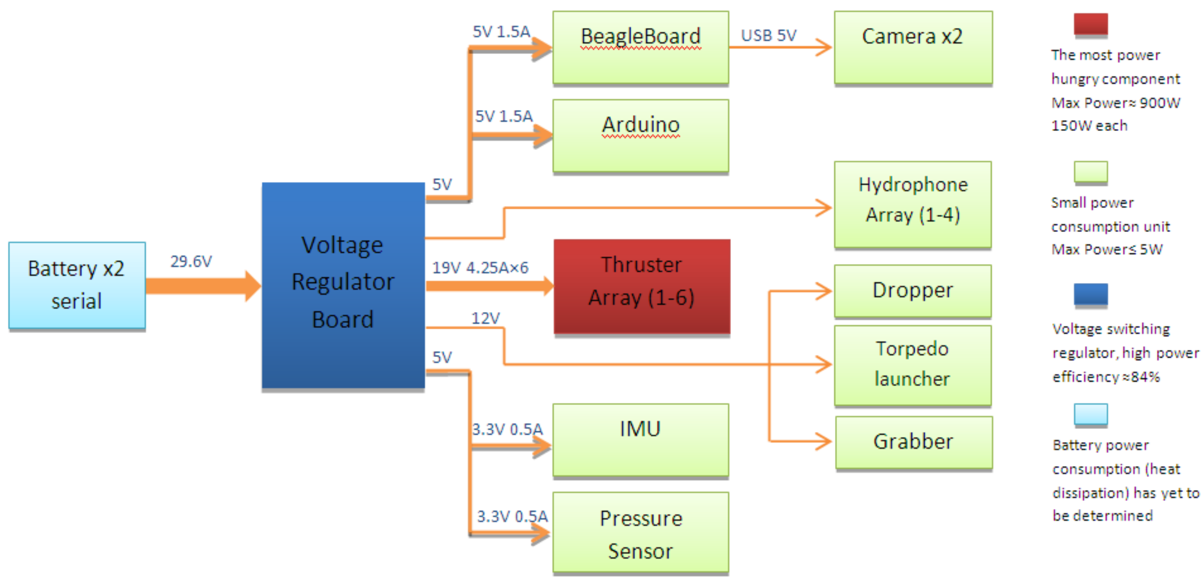


Figure 9: Block diagram of the AUV's Electrical System

3.5.2.2 Input

N/A

3.5.2.3 Output

The battery should output steady DC current and provide enough power so that the AUV can finish all the operations before the batteries are depleted.

3.5.2.4 Outcome

AUV can be battery powered and have enough power to complete all tasks. And the AUV can function properly.

3.5.2.5 Contingency Plan

Lithium batteries are resistant to failure (if handled properly and carefully). Since the battery is very expensive, we cannot afford to have a backup battery. Therefore in case of a battery failure, we will temporally operate on one battery and get a replacement battery as soon as possible.

3.5.3 Voltage regulator board

3.5.3.1 Methodology and Design

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. This is a completely new design compared to the last year's project. A sample voltage regulator board is designed and simulated using the WEBENCH® Power Architect from TI. The block diagram is shown below.

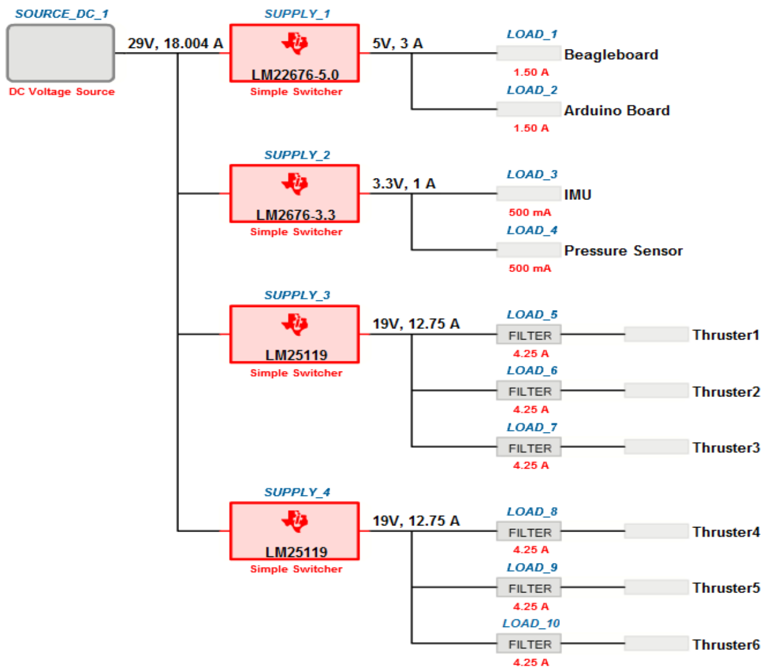


Figure 10: DC to DC Converter Block Diagram (Designed using WEBENCH® Power Architect from TI)—Red Boxes Shown are Step-Down Switching Regulators

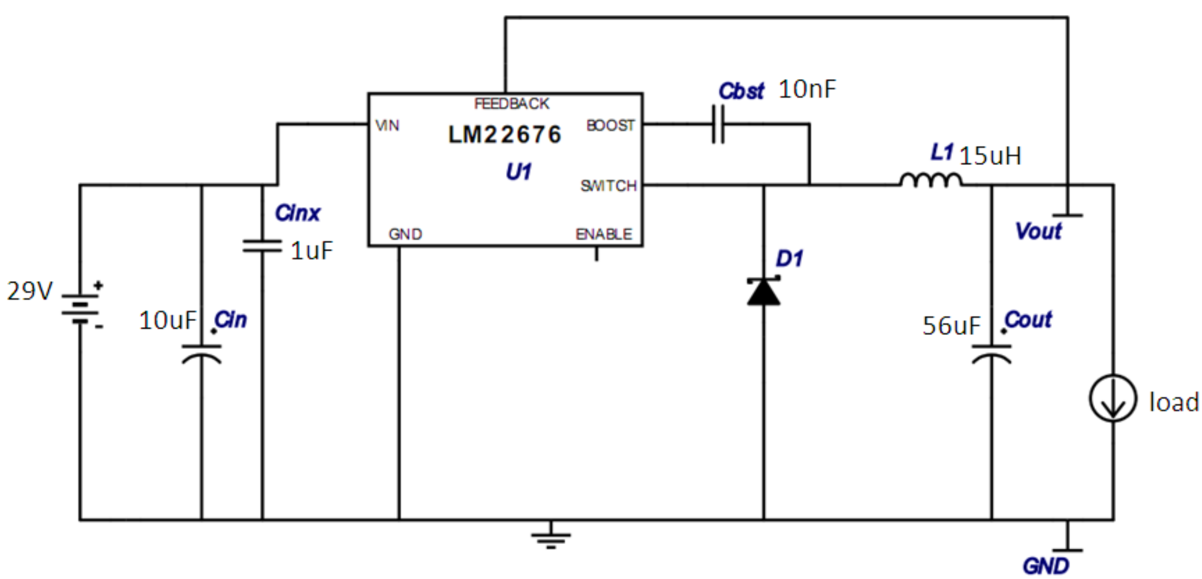


Figure 11: Detailed Design of LM22676 Step-Down Regulator Switching Circuit

3.5.3.2 Input

The input of the power regulation board is the batteries system, which provides a total voltage of 29.6V.

3.5.3.3 Output

Correct voltage for each component should be the output of the power regulation board.

3.5.3.4 Contingency Plan

If the design of the voltage regulation board does not work very efficiently or does not provide correct stable output voltage for each electrical component, we will seek commercial products which can be used in this project. Before we start designing this board, we will consult our technical advisors for advices.

3.6 Mechanical Subsystems

3.6.1 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. SeaBotix BTD150 thrusters will be used for their proven quality, and because inherited ownership of three of these thrusters has already be granted. 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.

3.6.2 Grasp/release mechanism

A pneumatic system will be incorporated into the grasp/release mechanism. One of two c-shaped arms will be rigidly attached to the bottom of the aluminum frame. The other claw will be attached at its center to the piston of a single-acting air cylinder (i.e. a built-in spring causes the retraction of the piston when the internal air pressure is below a certain level). Both claws will be made out of acrylic for its relatively low density, and will have a rubber strip adhered to the contact region of each claw. The thickness of each claw will be determined by the dimensions of the PVC object that is to be rescued from underwater. Sufficient surface area will be desired so as to ensure a secure grasp on the object. A compact compressed air storage tank will be attached to the bottom of the AUV, and will supply the air to this mechanical subsystem. Two automated solenoid valves will be implemented in order to allow or prevent the flow of the high-pressure gas into the air-cylinder. These two valves will be controlled in such a way as to enable actuation of the claw via the opening of one valve, and then release the pressurized gas into the surrounding water when it is time for the object to be released, via the opening of the other valve and closing of the initial valve. Due to its relative accessibility and low cost, carbon dioxide (CO_2) will likely be used as the gas source.

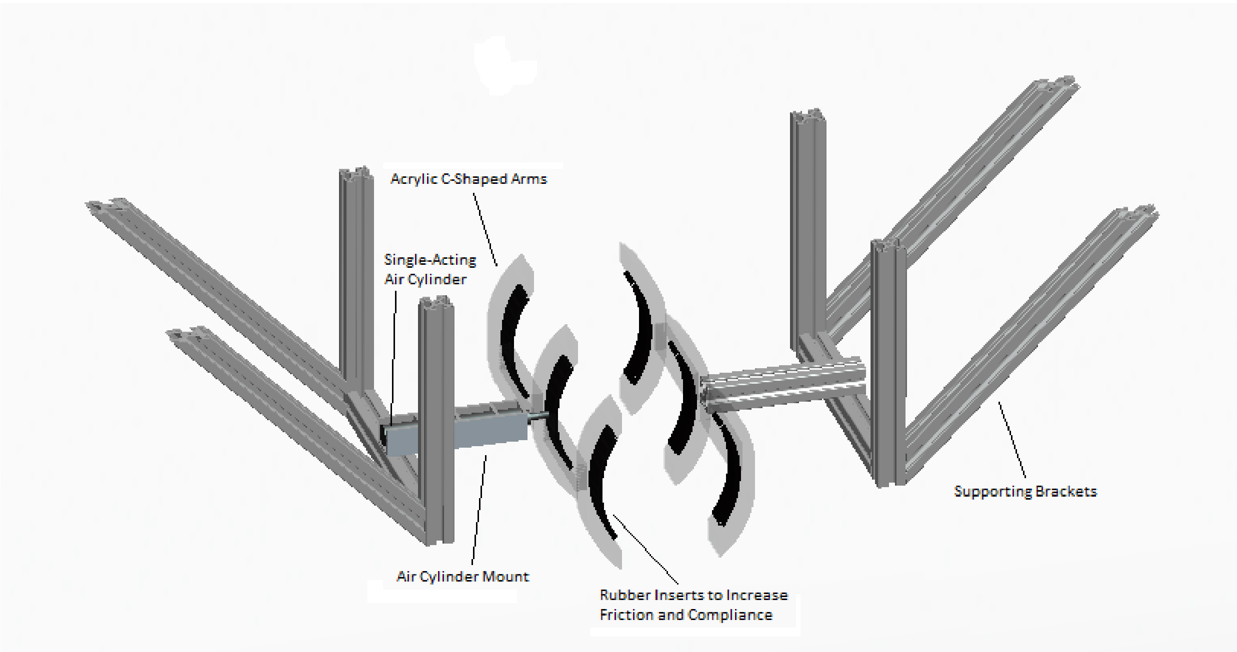


Figure 12: Close-Up View of Grasp/Release Mechanism

3.6.3 Marker dropper

The design team has opted to use the design created by the mechanical engineers on the 2011 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. Due to the slight downward angle at which the balls will be released, tests will need to be conducted to determine if this will cause a sufficient amount of deviation from a completely vertical drop. If it is deemed a slight concern, a vertical funnel will be implemented at the outlet of the system in order to guide the projectiles toward a completely vertical exit.

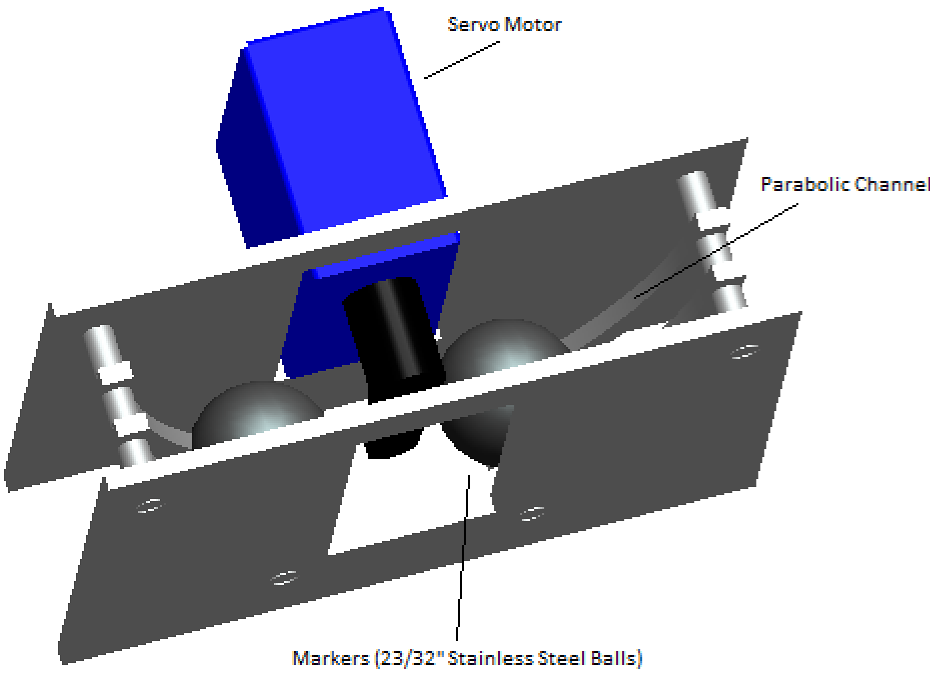


Figure 13: Close-Up View of Marker Dropper

3.6.4 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 a $C0_2$ storage tank, a pressure regulator, solenoid valves, a solenoid actuator, and tubes connecting each solenoid valve to its respective air cylinder/cannon. 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. 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. 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 $C0_2$ storage tank to the valve box. In addition, the accuracy of the launcher mechanism will be controlled by adjusting the length of the barrels and dimensions of the torpedoes.

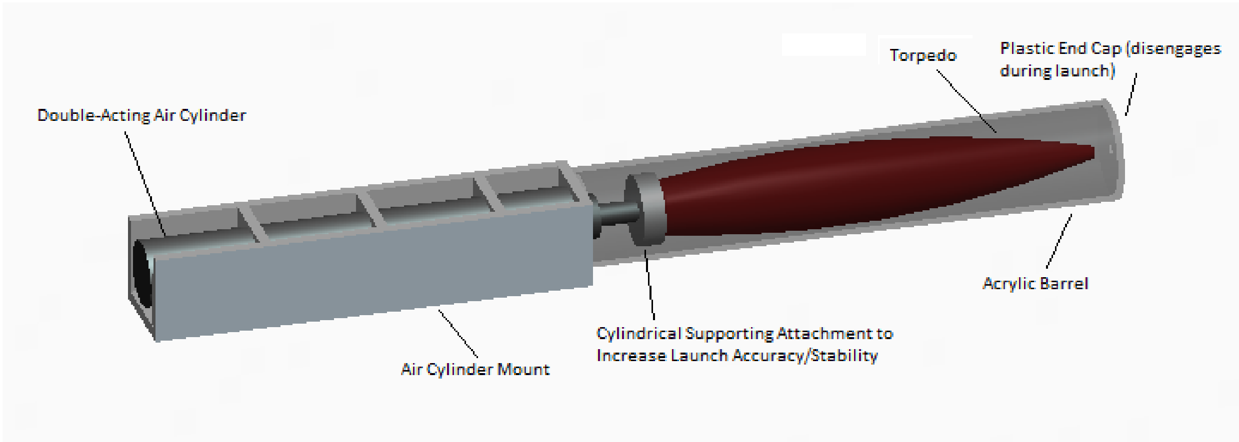


Figure 14: Close-Up View of Torpedo Launcher

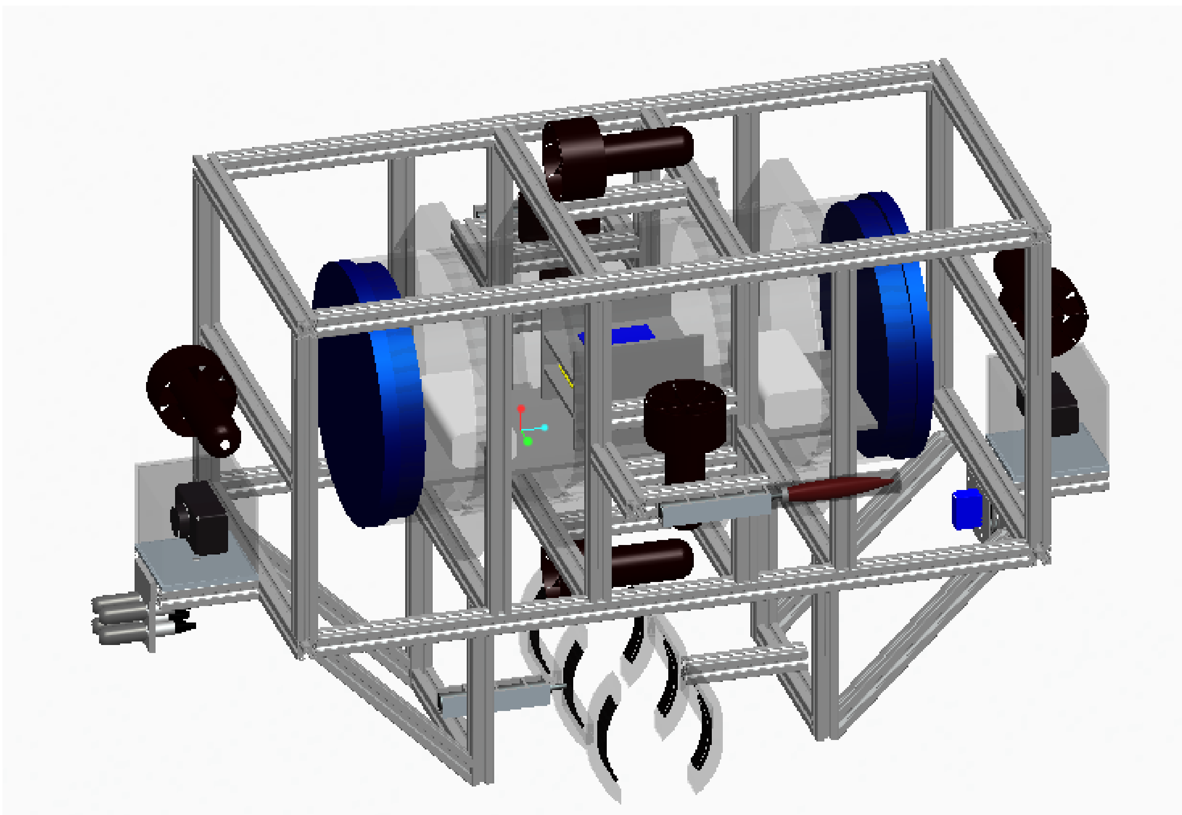


Figure 15: Angled View of Entire Proposed AUV Design

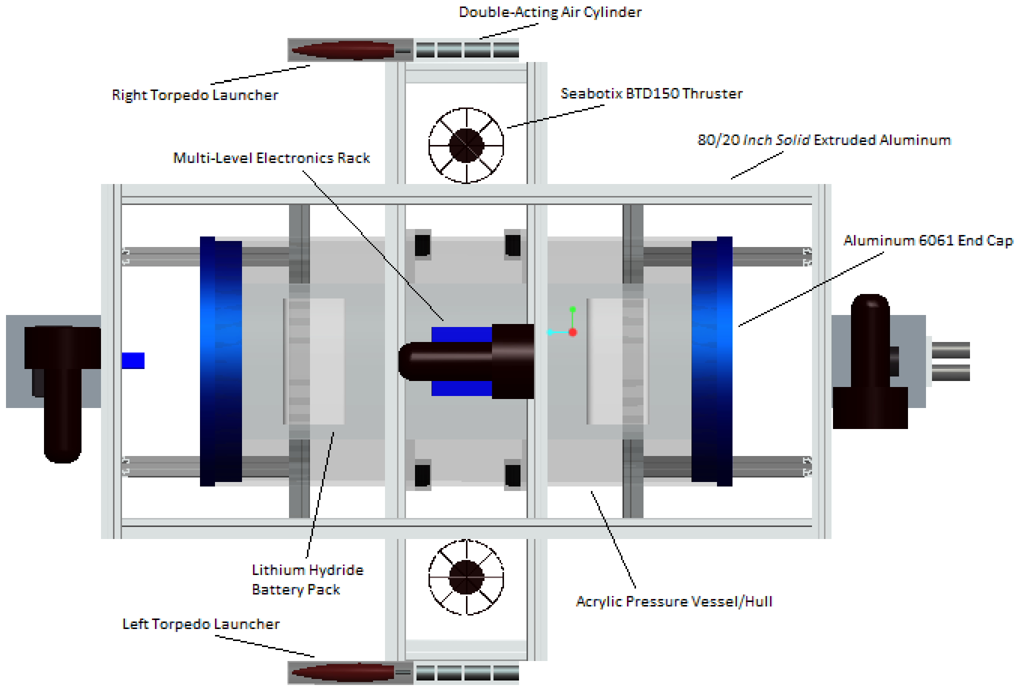


Figure 16: Overhead View of Entire Proposed AUV Design

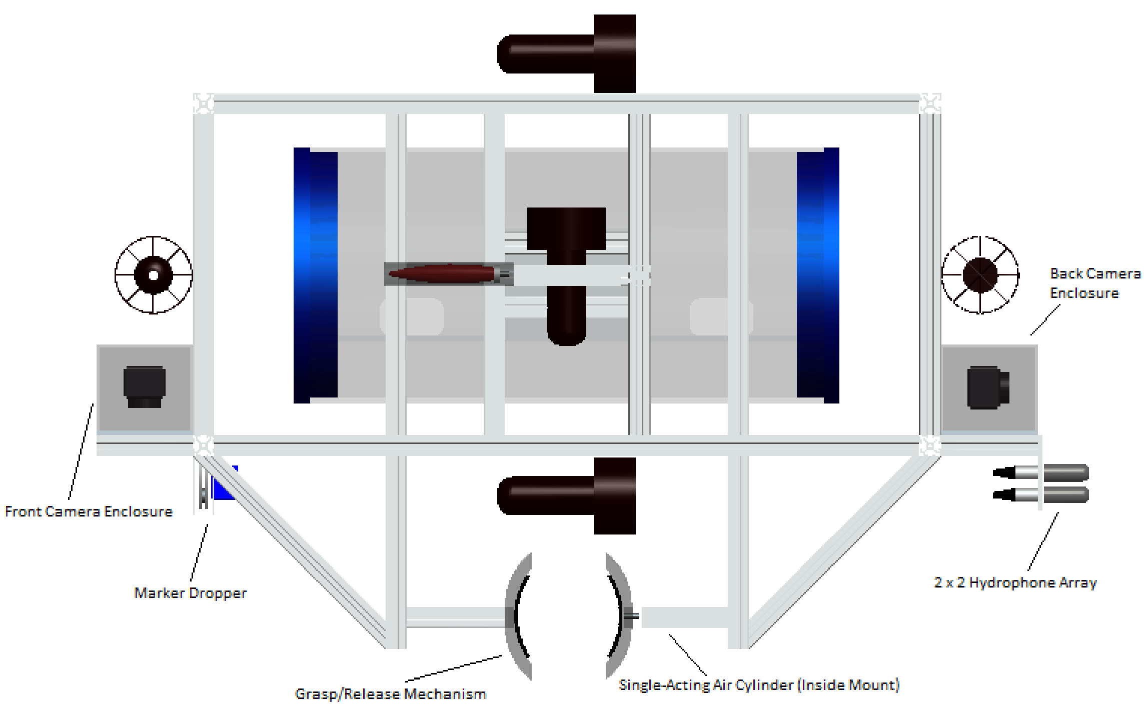


Figure 17: Side View of Entire Proposed AUV Design

4 Statement of Work (SOW)

Problem Definition/Project Management

Objective

The team must design and construct an autonomous underwater vehicle capable of navigating through an obstacle course while completing six specified tasks. These tasks include (1) passing through a designated gate, (2) striking two of three colored buoys in a particular order, (3) dropping two markers into specified bins (there will be four bins and each will have a distinct symbol located on the interior bottom surface), (4) navigating through a box defined by PVC and imaginary boundaries, (5) launching two torpedoes through specified PVC cut-outs (each cut-out will have a distinct size, shape, and color), and (6) detecting and locating an acoustic pinger, grasping a PVC object, surfacing within a specified octagonal region, and then releasing the object. The AUV will need to complete the mission within the allotted 15-minute time frame. Bonus points will be proportionately earned for a lightweight vehicle and rapid completion of the obstacle course. The competition will be held in July 2012, and will be located in San Diego, California at the SSC SD TRANSDEC Facility which houses a large anechoic saltwater reservoir, to be used as the competition arena. The vehicle will be subject to depths of up to 16 ft, and the lateral space will vary throughout the obstacle course region.

Approach

In order to successfully accomplish this task, the design team will distribute the engineering responsibilities in the following categories: hull and frame, grasp/release mechanism, torpedo launchers, stability/depth control (via the integration of the pressure transducer, inertial measurement unit, Arduino Board, BeagleBoard-xM, and thrusters), computer vision and electrical circuit design, and task-specific programming/algorithm derivation. Each team member will be assigned responsibility of the task in which he is most qualified and/or interested. Due to the diverse expertise of our design team, which consists of two computer engineers, one electrical engineer, and three mechanical engineers, this task distribution strategy should prove to yield successful results. Furthermore, milestones will be established over the course of the project in order to ensure that the design team stays on pace to complete the AUV by the deadline, as well as to progressively increase the functionality and capabilities of the AUV in stages.

Phase 1: Complete Each Subsystem/Component of the AUV

4.1 Task 1 – Complete the Hull and Frame of the AUV

4.1.1 Objective

The exact dimensions, attachment methods, and material selection for the hull and frame need to be finalized, and then the foundation of the vehicle must be built. The frame must be able to support the central pressure vessel which will house the electronics, as well as the peripheral subsystems which includes the cameras, hydrophones, pressure transducer, thrusters, grasp/release mechanism, marker dropper, and torpedo launchers. The frame must include two acrylic enclosures in the shape of a box—one for each of the cameras (to be attached on the front and back of the frame)—so that during the testing of the watertight capability of the pressure vessel (and the acrylic camera enclosures), the holes in the end caps can be filled with the attached fittings of the waterproof tubing that will be used to protect the wires as they connect the peripheral sensors, thrusters, and mechanical subsystems to the microcontrollers inside the pressure vessel. Thus, any potential leakage into either of the enclosures via these inlets/outlets will also be able to be tested following their construction. The hull must be completely watertight in order to protect the electronics, and must be designed and implemented to be capable of efficiently dissipating heat away from the lithium hydride battery packs, inertial measurement unit, BeagleBoard-xM, and Arduino board, and into the surrounding saltwater environment. The hull and frame should also be symmetrical and robust to allow for a naturally stable vehicle that is defensible against undesired disturbance forces. Furthermore, the end goal of having the overall density of the AUV be slightly less than saltwater needs to be considered in the design of the hull and frame. Since the hull and frame are the foundation of the AUV, it is of high priority to finalize the intricacies of the design, construct the vision, and test its performance underwater as soon as possible.

4.1.2 Approach

Prior to construction, the dimensions of the hull and frame design will be adjusted according to available products (e.g. available sizes of acrylic tubing for the pressure vessel), as well as to provide attachment locations for each of the peripheral subsystems. Since the design of these attachments will be a function of the dimensions of each of the aforementioned sensors, thrusters, and mechanical subsystems, coordination with, and analysis of these components will be performed so that the result will be clean, simple interfaces between the frame and these peripheral subsystems. In regards to the hull, detailed designs of the custom aluminum end caps will be developed to incorporate the slots for the internal aluminum plate, as well as locations for the fittings on the ends of the wire-protecting, waterproof tubes to permanently attach. Following these detailed additions to the hull and frame designs, the implementation process will begin. During this process, the construction of the frame and hull/pressure vessel will be executed separately, and following successful tests proving the watertight nature of the pressure vessel and individual camera enclosures, the hull will be tightly secured to the center of the frame, and the hull and frame will be considered completed. The following two-stage product development process conveys this approach:

4.1.2.1 Subtask 1.1 – Develop a Pro/Engineer Model of the Finalized Hull and Frame Design

4.1.2.1.1 Objective

Generate a completed 3D model of the detailed hull and frame design to serve as a guide during the building/implementation process, and also to provide valuable dxf and igs files of the custom parts, to be used during the manufacturing process. Each of the custom parts will be verified for their ability to properly attach to adjacent structures or subsystems, as well as for their feasibility of manufacture (i.e. not every part designed on Pro/Engineer can necessarily be physically manufactured with accessible manufacturing tools).

4.1.2.1.2 Approach

All of the pre-assembled components relating to the design of the hull and frame (i.e. thrusters, pressure transducer, cameras, acrylic tube (pressure vessel)) will be purchased. Once these components arrive, they will be physically measured to derive their actual dimensions and design simple, custom attachments to the frame (some of which have already been designed, and would merely require slight changes to their dimensions). The current Pro/Engineer model of the frame and hull will then be modified to include the custom attachments for the peripheral subsystems, as well as to account for the actual dimensions of coupled components (e.g. the aluminum end caps will be modified based on the actual dimensions of the acrylic tube, so that the result will be a tight fit at the ends).

4.1.2.2 Subtask 1.2 – Manufacture and Assemble the Hull and Frame

4.1.2.2.1 Objective

Components for the frame, hull, interior of the pressure vessel, and individual camera enclosures will be manufactured, and the entire frame and hull will be assembled separately. The completed pressure vessel should be completely watertight, and should be able securely supported by custom attachments to the frame.

4.1.2.2.2 Approach

The raw materials will be purchased and brought to the FAMU-FSU College of Engineering machine shop, along with the dxf and igs files for the parts that need to be manufactured. The dxf files will be used to manufacture the respective parts via the high-pressure water jet (e.g. the custom attachments for the external sensors, thrusters, and mechanical subsystems, as well as the acrylic supports), while the igs files will be used to manufacture specific parts (e.g. the aluminum end caps) via the CNC machine. Other parts that simply need to be cut to size (e.g. the 80/20 extruded aluminum bars for the frame) will be carefully cut using a band saw in the machine shop. Upon completion of manufacturing all the components, the frame, hull, individual camera enclosures, and interior of the pressure vessel will be meticulously assembled.

4.1.2.2.3 Test/verification plan

Prior to taking the constructed hull (including the interior of the pressure vessel and the custom end caps), frame, and attached camera enclosures to the FSU Morcom Aquatics Center to test the watertight nature of both the pressure vessel and camera enclosures, a single hole will be drilled and tapped in each of the end caps in order to allow the waterproof tubing (with attached fittings) to connect one of the sealed camera enclosures to the nearest end cap, thus creating a closed system. Caulking and/or Loctite will then be added at these junctures in order to ensure a reliable seal. Thereafter, the hull and frame 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 pressure vessel and frame will be recovered and brought to the surface, where it will be analyzed for any leakage or slippage of the end caps. Once the watertight characteristic of the hull and acrylic camera enclosures has been confirmed, the remaining holes will be drilled and tapped into each of the two custom end caps to allow for the fittings of more waterproof, wire-protecting tubes to connect remaining external sensors, thrusters, and mechanical subsystems to the central hull.

4.1.2.2.4 Outcomes of task

The frame and hull should be built, and the hull and individual camera enclosures should be deemed completely watertight, even with the fittings of the connector tubing attached to the inlets/outlets. Following the completion of this task, the electronics (i.e. lithium hydride battery packs, Arduino Board, BeagleBoard-xM, and IMU) should be able to be attached to the designated racks in the interior of the pressure vessel, and tested underwater without any concern for water leakage and subsequent damage to the electronics.

4.2 Task 2 – Develop the general image processing modules

4.2.1 Objective

Develop the general image processing modules to interpret data from the surrounding environment to determine the desired output functions of the AUV.

4.2.2 Approach

The image processing modules will be divided into three subtasks in order to break down the task into the fundamental elements. Integration of the modules listed below will result in the completion of the general image processing module.

4.2.2.1 Subtask 1 – Develop the pre-processing module

4.2.2.1.1 Objective

Design a module that will prepare images for image processing

4.2.2.1.2 Approach

Use the built-in function in OpenCV to convert images from RGB to HSV color space

4.2.2.1.3 Test/verification plan

The test plan included in the Color Filter module cannot be tested separately and should, therefore, be developed concurrently with the Color Filter module.

4.2.2.1.4 Outcomes of task

- Developed a module that will interface with the cameras to receive color images in RGB (Red Green Blue) format
- Implemented code to convert images in the RGB color space to the HSV (Hue Saturation Value) color space which is less affected by light

4.2.2.2 Subtask 2 – Design the color filter module

4.2.2.2.1 Objective

Design a module that will identify colors in images obtained from the Pre-Processing module and send the information to the appropriate sub-modules

4.2.2.2.2 Approach

Using threshold HSV values, isolate the pixels with a certain color (range). Depending on the camera identifier attached to the image in the Pre-Processing module, this module knows which Color Detection algorithm to use on a certain image. If the image contains the identifier for the front-facing camera, the Color Filter will look for colors (HSV parameter range) used in the front-facing tasks such as Gate, Buoys and Fire-Torpedo-through-Cutouts. Similarly, if the image contains the identifier for the down-facing camera, the Color Filter will isolate colors used in the down-facing tasks such as Path Detection, Drop-Marker-in-Bin and Surface-and-Recover. After determining the color of an object, depending on the camera identifier and color, the information is sent to either Path Detection or Shape Detection.

4.2.2.2.3 Test/verification plan

Create custom images with a specific color as the background which will then be classified and verified. For example, red has a specific HSV range. When the red image is processed, the Pre-Processing module should output the HSV-format image along with a label displaying the HSV range. By verifying the HSV range obtained from the label with the known value, one can verify the correct implementation of the Pre-Processing and Color Filter modules.

4.2.2.2.4 Outcomes of task

- Developed a module to receive images in HSV format from Pre-Processing
- Designed a system that will determine which algorithm to use on each image frame and send color information to the Path Detection, Size Detection and Shape Detection modules

4.3 Task 3 – Develop the navigation system

4.3.1 Objective

The navigation system will be developed, which will yield the AUV capable of navigating through the obstacle course in the proper path (which will lead to the specific obstacles or tasks), without straying off course.

4.3.2 Approach

The navigation system design will be divided into three elemental subtasks in order to ensure a cleaner debugging process. Following the completion of the subtasks listed below, integration of these modules will result in the completion of the navigation system.

4.3.2.1 Subtask 3.1 – Design the Path Detection Module

4.3.2.1.1 Objective

Design a module that will classify the path direction and send relevant information to the Navigation module

4.3.2.1.2 Approach

Using images obtained from the Color Filter, find the edges of the path segments by utilizing the Feature (Canny Edge) Detect and Hough Transform in OpenCV. After isolating the path segment in each image, the direction information is determined using a custom-designed algorithm.

4.3.2.1.3 Test/verification plan

Using the cameras and Color Filter module, training data for various scenarios will be collected. Testing will initially take place in the lab and will later continue in the pool. Direction information will be tested with stub modules that will display the direction information in a custom-designed user interface.

4.3.2.1.4 Outcomes of task

- Designed a system that isolates path segments in each image frame and sends the direction of the path to the Navigation module to guide the vehicle through the obstacle course

4.3.2.2 Subtask 3.2 – Design the Size Detection Module

4.3.2.2.1 Objective

Design a module that determines the size of an object/task in each image frame and uses a scaling factor (obtained by camera calibration) to determine an estimation of the vehicle-to-task distance.

4.3.2.2.2 Approach

Using the dimensions of the actual objects and the dimensions of the objects in the image frame, one can use a scaling factor obtained by experimenting with the camera to determine the estimated distance between the object and the vehicle. The module will receive image frames from the Task Control module and will provide the Navigation module with information regarding the distance from the vehicle to the task/object. Furthermore, a database of images with the various sizes of objects will be used as the "training" data. The module will make use of the training data to determine the distance.

4.3.2.2.3 Test/verification plan

Using the cameras and accurately measured objects that will be part of the obstacle course, the module will be trained to estimate the distance between camera and object. For example, say the system needs to determine the distance from the vehicle to a buoy. Using an equation that relates the radius of a buoy in the image to the vehicle-to-task distance, the performance and accuracy of the module can be tested by performing tests for various vehicle-to-task distances. The module will undergo rigorous testing before implementing it into the overall system.

4.3.2.2.4 Outcomes of task

- A module that determines the relative dimensions of objects/tasks and performs task-to-vehicle distance measurements will have been developed.

4.3.2.3 Subtask 3.3 – Design the Navigation Module

4.3.2.3.1 Objective

Design a module that will provide the Main Controller with instructions to properly navigate the vehicle

4.3.2.3.2 Approach

Using data obtained from the Size Detection module, the special algorithm sends data related to direction and speed to the Main Controller. The data obtained from the Size Detection module will contain information regarding the vehicle-to-task distance and the current task at hand. After the information is processed, the system sends navigation instructions to the Main Controller.

4.3.2.3.3 Test/verification plan

Using Stub modules to simulate input from the Path Detection module and Size Detection module, the output to the Main Controller will be tested for all possible scenarios. Since this module depends on the completion of several other modules, modules should be concurrently designed as much as possible.

4.3.2.3.4 Outcomes of task

- A module that makes decisions regarding the navigation of the vehicle and instructs the Main Controller how to navigate the vehicle will be designed.

4.4 Task 4 – Develop the Task Management System

4.4.1.1 Subtask 4.1 – Design the Shape Detection Module

4.4.1.1.1 Objective

Design a module that will classify the shape of objects to assist in task identification and management

4.4.1.1.2 Approach

Classify the buoys using the Hough Transform (cvHoughCircles); classify the box-passing structure using the Hough Transform (cvHoughCircles) and Polygons approximation (Douglas-Peucker algorithm, cvApproxPoly); classify the drop-in-bin objects using a custom algorithm (Neural Network).

4.4.1.1.3 Test/verification plan

Training data for various scenarios and test environments (lab & pool) will be collected. The algorithms will collect enough training data to obtain a classification accuracy of 80%.

4.4.1.1.4 Outcomes of task

- Developed a system that identifies the buoys, identifies the box-passing task and classifies the 2D images in the drop-in-bin task

4.4.1.2 Subtask 4.2 – Design the Task Control Module

4.4.1.2.1 Objective

Design a module that will provide the Main Controller with instructions to successfully complete the obstacle course

4.4.1.2.2 Approach

Using images from the Shape Detection module, the current task will be determined. This module requires bidirectional data flow since it will keep track of which tasks have been completed. All completed tasks are labeled in the Shape Detection module to narrow down results for the remaining tasks and, therefore, speed up processing time.

4.4.1.2.3 Test/verification plan

Training data for various scenarios and tasks will be collected. The module should have a classification accuracy of at least 80%.

4.4.1.2.4 Outcomes of task

- Designed a module that keeps track of completed tasks and informs the Main Controller of the current task at hand
- Implemented code so that the module assists the Navigation System with the determination of the vehicle-to-task distance

4.5 Task 5 – Control the Mechanical Subsystems

4.5.1 Objectives

The objective of software controls on mechanical subsystems such as the thrusters, grasp/release mechanism, marker dropper, and torpedo launcher is to enable the AUV to perform all the tasks required by the competition. The Thrusters should be programmed so that it can control the AUV’s orientation, depth, speed, and stability. Through software control and communication protocols, the thrusters will be able to dynamically stabilize the vehicle. The dropper should receive a signal from the main control unit which tells the dropper to perform the action. And the dropper then should send confirmation signal to the control unit to confirm the request has been finished. This two way communication protocol also applies to the grabber and the torpedo launcher. The torpedo launcher and the grabber should also by triggered by a signal generated by the main control unit through the software control.

4.5.2 Approach

A divide and conquer principle will be utilized for this task. The team will focus on programming thrusters first so that the vehicle can move underwater. After the thrusters are finished, the team will program dropper, grabber and torpedo launcher concurrently by distributing each component to one or two team members so that we can finish software control on the mechanical systems efficiently.

4.5.2.1 Subtask 5.1 – Develop Software to Control the Thrusters

4.5.2.1.1 Objective

The software program controlling the thrusters should be able to dynamically control all thrusters to adjust the AUV’s speed, orientation, and stability.

4.5.2.1.2 Approach

The program controlling the thrusters will utilize hardware features on the Arduino board which provides 6 PWM (Pulse Width Modulator) outputs for a total of 6 thrusters. Program the PWM will be done on the Arduino board using the Arduino software that can be downloaded from the Arduino website for free. The PWM should be programmed so that it will dynamically adjust the PWM signals for each thruster based on the commands sent from the main control unit.

4.5.2.1.3 Test/verification plan

At first, we will program on one thruster using only one PWM channel. And the main control unit will send commands to the Arduino board to change its speed dynamically. We will write testing programs specifically for the thruster. And the testing program should consider various conditions that may occur during the competitions. After testing the thruster in the lab, we will put the thruster into the water and test how the thruster actually performs in the water. Timing test will be conducted. Since thrusters are very expensive units, we need to be very careful not to break it down during the tests. Therefore, stress test should be performed under the timing requirement of the competition. The purpose of stress test is to make sure the thruster can perform its function during the entire competition. And we have to make sure the thruster will not break down during stress testing. After the program for one thruster is successfully finished and tested, we can easily program other thrusters using the same testing process. Testing programs will be slightly different among propulsion thrusters, orientation control and depth control thrusters. In the end, after all individual thrusters are successfully designed and tested; we will install the thrusters on the vehicle, and test how well the main control unit can control the thrusters. Large amounts of testing must be carefully conducted for this complicated dynamic system.

4.5.2.1.4 Outcomes of task

After all thrusters are successfully programmed, they will provide the AUV with autonomous movement capability. Each thruster will collaborate with others in order to provide stability and control to the AUV. The AUV should be able to use the thrusters to (1) move forward, (2) move backward, (3) adjust the depth, (4) change directions, and (5) stabilize the AUV dynamically.

4.5.2.2 Subtask 5.2 – Develop Software to Control the Grasp/Release Mechanism, Marker Dropper, and Torpedo Launchers

4.5.2.2.1 Objectives

A trigger signal should be sent to each of the three components by the software system in the main control unit. After receiving the signal, the torpedo launchers will fire a torpedo, the marker dropper will drop a marker, and the grasp/release mechanism will grasp or release the item required by the competition.

4.5.2.2.2 Approach

The trigger signal can be achieved by programming the Arduino board through the LED switch. The grabber, dropper and the torpedo launcher can be connected to one of the LEDs on the

Arduino board, since it is easy to program the LEDs. When the LED state goes from off to on, a trigger signal will be sent to the corresponding component. After the required function is successfully completed, and the corresponding LED will be turned off.

4.5.2.2.3 Test/verification plan

Each LED should connect to the correct component. Individual component test will be tested. At first, only the LEDs will be tested. When the main control software sent the command to one of the component, the corresponding LED should light up. Secondly, one component will be connected to its LED, and let the main control unit to send command to the LED and test whether the mechanical functions can be carried out. This testing process will be repeated for all three components. After all three components are individually tested, they will all be connected to their LEDs, and the system should test if they can work correctly with the presence of other components.
The next stage of testing is the real environment testing, which the AUV will be sent into water. We will test if all components can perform their functions correctly underwater.

4.5.2.2.4 Outcomes of task

Accomplishing this task will ensure that the AUV can perform all the mechanical tasks during the competition, as long as the vehicle can move and detect objects correctly.

4.6 Task 6 – Develop the Guidance System

4.6.1 Objective

Design a guidance system capable of interpreting data from various external sensors in regards to the position, orientation, acceleration, and depth of the vehicle, as well as the location of the pinger.

4.6.2 Approach

A guidance system will be developed in four stages. A system will be developed to capture the IMU data, obtain the depth sensor data, detect the dynamics and heading of the AUV and locate the pinger, and interface this data with the main control unit.

4.6.2.1 Subtask 6.1 – Develop a system to capture IMU data

4.6.2.1.1 Objective

Capture IMU measurements and contribute to AUV's internal positional model.

4.6.2.1.2 Approach

Attach the IMU to the Arduino board and measure changes in output.

4.6.2.1.3 Test/verification plan

Move the IMU through the air, measure output then compare output when moved through water.

4.6.2.1.4 Outcomes of task

- IMU reports roll, yaw, and pitch of the Robosub

4.6.2.2 Subtask 6.2 – Design a system to capture depth sensor data

4.6.2.2.1 Objective

Capture vehicle depth and contribute to AUV's internal positional model.

4.6.2.2.2 Approach

Measure changes in the piezoresistive pressure cell due to changes in height.

4.6.2.2.3 Test/verification plan

Measure changes in pressure measurement due to depth sensor descent water and confirm with pressure calculations done by hand, assuming 1000 kg / m^3 density of water.

4.6.2.2.4 Outcomes of task

Depth can be determined up to a maximum resolution of 25mm.

4.6.2.3 Subtask 6.3 – Design a system to capture AUV heading and locate pinger.

4.6.2.3.1 Objective

Capture vehicle heading and contribute to AUV's internal positional model.

4.6.2.3.2 Approach

Measure the frequency response of four hydrophones and use triagulation algorithms to calculate heading. This heading will be sent to the main micro-controller for processing.

4.6.2.3.3 Test / verification plan

Compare the results between the computer vision system and the hydrophone system and confirm accuracy.

4.6.2.3.4 Outcomes of task

- AUV is capable of determining its heading.
- AUV is capable of locating pinger.

4.6.2.4 Subtask 6.4 – Design an interface between the guidance system and the main controller

4.6.2.4.1 Objective

Design an interface to the main controller that contributes to the vehicle's internal positional model.

4.6.2.4.2 Approach

Work with Hang Zhang, who is working on the main controller, to create a standard interface between the two controllers.

4.6.2.4.3 Test / verification plan

Confirm that data sent by the Arduino board is received by the main controller

4.6.2.4.4 Outcomes of task

The positional internal model will be complete and communicated with main controller

4.7 Task 7 – Complete the Pneumatic System/Gas Distribution Network for the AUV

4.7.1 Objective

Select and integrate compatible components for the pneumatic system, which will actuate mechanical motion for the grasp/release mechanism and torpedo launchers.

4.7.2 Approach

The performance history, specifications, and price of the components used in the pneumatic system will be researched. A decision matrix will then be created in order to assist in comparing and ultimately selecting the most suitable pneumatic system components for our design.

4.7.2.1 Subtask 7.1 – Select a Compressed CO_2 tank

4.7.2.1.1 Objective

Choose the appropriate compressed CO_2 tank to be used to store the gas supply for the pneumatic distribution system.

4.7.2.1.2 Approach

Derive an approximate calculation for the amount of CO_2, as well as pressure of CO_2 required for the effective operation of both the grasp/release mechanism and the torpedo launchers. A compressor tank that is capable of containing the specified volume of CO_2 and withstanding an internal pressure at least 50% greater than the estimated target pressure value will be selected. The size, weight, and cost of the remaining selections will serve as the final filter prior to settling upon the optimal compressor tank for the gas distribution network.

4.7.2.2 Subtask 7.2 – Select a Pressure Regulator

4.7.2.2.1 Objective

Choose the appropriate gas pressure regulator that will enable the design team to control the exit pressure of the CO_2 from the compressed CO_2 tank at the suitable pressure for the operation of the grasp/release mechanism and torpedo launchers. CO_2 at this regulated pressure will be relayed to a storage tank containing the solenoid valves, and thus outlets to the grasp/release mechanism and torpedo launchers.

4.7.2.2.2 Approach

Research the quality/reliability, specifications, and price of various air pressure regulators. Ensure that the air pressure regulator selected can be easily attached to both the compressor and CO_2 storage tank, and is capable of effectively reducing the inlet pressure from the compressed CO_2 tank to the controlled, desired pressure required for optimal operation of the grasp/release mechanism and torpedo launchers.

4.7.2.3 Subtask 7.3 – Select a Storage Tank to House the Pressure-Regulated CO_2 and Solenoid Valves

4.7.2.3.1 Objective

Choose a gas storage tank to serve as an intermediate housing location for the pressure-regulated CO_2 prior to its distribution via the solenoid valves to the respective mechanical subsystem (i.e. the grasp/release mechanism or torpedo launchers).

4.7.2.3.2 Approach

Research the performance history, specifications and price of compressed gas storage tanks. The selected tank should have smaller dimensions than the main storage tank, yet allow for the uninterrupted flow of pressure-regulated CO_2 from its compressor to the desired mechanism. The air storage tank will be ensured capable of housing CO_2 at the regulated pressure that is desired for optimal operation of the grasp/release mechanism and torpedo launchers upon distribution. Upon reviewing the possible selections, storage tanks with an insufficient number of outlet attachments for the solenoid valves (i.e. less than four) will be filtered out. The size and weight of the remaining qualified options will be analyzed as the final sieve prior to settling upon the optimal pressure regulator for the CO_2 distribution network.

4.7.2.4 Subtask 7.4 – Select Solenoid Valves and Pressure Lines/Tubing

4.7.2.4.1 Objective

Choose submersible solenoid valves which will allow for the individual, electrically-activated control of the moderate-pressure CO_2 supply from the storage tank to the grasp/release mechanism and each of the two torpedo launchers. Choose tubes which are capable of reliably directing the pressure-regulated CO_2 to its desired mechanism without leakage or severe failure.

4.7.2.4.2 Approach

Research the performance history, specifications, and price of commercial solenoid valves and tubing. Ensure that solenoid valves and tubes are compatible with the outlets of the gas storage tank and are capable of being easily integrated into the main control unit of the AUV, allowing the effective management of the CO_2 distribution to the individual desired subsystem upon command.

4.7.3 Test/verification plan

Each of the above components of the pneumatic system will be physically integrated. Successful integration will demonstrate the compatibility of the components with one another. Upon completion of the test for compatibility, the proper operation of pneumatic system will be verified by measuring the pressure within the system at various locations; the tested locations will be the main compressed CO_2 storage tank, the intermediate storage tank which outlets to the individual solenoid valves, at the outlets of each of the attached solenoid valves. Furthermore, each of the solenoid valves will be directly actuated with an appropriate power source in order to ensure their proper functionality.

4.7.4 Outcomes of task

Each of the storage tanks (i.e. the compressor and intermediate distribution tank) in the CO_2 distribution system shall be capable of storing the required amount of CO_2 at a pressure 50% greater than the nominal gas pressure in each of the respective tanks. In addition, the pneumatic system shall be capable of individual distribution of the required amount of CO_2 in order to generate the desired mechanical dynamics for the grasp/release mechanism and torpedo launchers. The solenoid valves should be on standby for integration with the main control unit, which will serve to provide individual actuation.

4.8 Task 8 – Complete the Grasp/Release Mechanism for the AUV

4.8.1 Objective

The detailed dimensions and material selection for the AUV's grasp/release mechanism will need to be completed, resulting in finalized pro/E renderings and usable dxf, igs, and stl files of these parts. In reference to the 2011 AUVSI RoboSub competition rules, the mechanism must be capable of grabbing and releasing an approximately 3" OD, 3' long PVC pipe. The proper air cylinder actuator and solenoid valves will also be selected for the design. The actuator must provide enough force to grasp and hold the object, and be able to release the object upon command via actuation of a second release valve. This should all be done while providing minimal disruption to the dynamics of the vehicle. The mechanism will be firmly attached to the frame of the AUV.

4.8.2 Approach

The design of the custom components for the Grasp/Release Mechanism will be finalized on pro/E (i.e. slight modifications or additions to the current pro/E model of the design). These parts will then be manufactured in-house at the College of Engineering machine shop using a variety of techniques.

4.8.2.1 Subtask 8.1 – Develop a Pro/Engineer model of the finalized Grasp/Release Mechanism Design

4.8.2.1.1 Objective

Pro/Engineer will be the source for all CAD drawings. These drawings will be crucial for manufacturing, as well as for the economics of the project. Early detection of problems can surface during the design phase before manufacturing takes place, allowing any possible failures during the construction/assembly phase to be avoided, and time and money to be saved. Once the design is finalized in Pro/Engineer, the manufacturing process will begin.

4.8.2.1.2 Approach

Once the dimensions of the object to be grasped and released for this year's RoboSub competition, the exact physical dimensions of the c-shaped arms can then be created. However, prior to this notification, the arms will be designed according to the specifications from last year's competition. The selected single-acting air cylinder will also be purchased and physically measured to ensure that the dimensions of the air cylinder mount and tapped hole in the center of the middle (of the three) c-shaped arm, which will connect to the threaded piston, will be exact. A pro/E simulation of the mechanical system will then be conducted to ensure proper dynamics. Then, dxf, igs, and stl files of each of the custom parts will be created to be used for manufacture via the water jet cutter, CNC machine, and 3D printer (if needed), with the assistance of the machine shop staff.

4.8.2.2 Subtask 8.2 – Manufacture and Assemble the Grasp/Release Mechanism

4.8.2.2.1 Objective

Use the files obtained from the Pro/Engineer renderings to aid in the manufacture of each of the individual components of the grasp/release mechanism, and then assemble each part to form the completed, operational grasp/release mechanism. The mechanical subsystem must consistently provide the proper mechanical output when compressed air is directly introduced into, or released from the single-acting air cylinder.

4.8.2.2.2 Approach

The College of Engineering machine shop has many resources to use for manufacturing each component. The dxf, igs, or stl files extracted from the Pro/Engineer model of the device will be used for autonomous manufacturing machines. This will result in the production of very precise parts, to then be assembled into a meticulously clean overall design.

4.8.3 Test/verification plan

Upon completion of the manufacturing and assembly process, the grasp/release mechanism will be integrated with the frame of the AUV and the pneumatic system. The frame will provide custom attachments and support for the device. Testing will be conducted with a 3" OD, 3' long PVC pipe (unless the disclosed dimensions for this year's competition surprisingly differ). Fine tuning of the pressure system in the actuator can be performed in order to obtain the proper regulated incoming CO_2 pressure. After testing the mechanics of the device in air, tests will then be conducted at the FSU Morcom Aquatics Center in order to ensure proper functionality underwater (e.g. the desired output force will be different underwater than in air).

4.8.4 Outcome of task

Upon successfully completing the above tests, a properly-functioning grasp/release mechanism should rest, and be placed on standby for integration with the gas distribution system, where the solenoid valve actuation will be automated.

4.9 Task 9 – Complete the Torpedo launcher for the AUV

4.9.1 Objective

Develop dimensions for the components of the torpedo launcher based on required specifications as well as desired capabilities. Allow for the precise manufacturing and assemble of the torpedo launcher

4.9.2 Approach

Research the dimensions for the pre-manufactured components of the torpedo launcher (air cylinder and cannon). Select an air cylinder and compatible cannon for the for the launcher mechanism. Use the dimensions of the selected pre-manufactured components to develop dimensions for the torpedo.

4.9.2.1 Subtask 9.1 – Develop a Pro/Engineer Model of the finalized Torpedo Launcher Design

4.9.2.1.1 Objective

Generate a completed 3D model of the detailed torpedo launcher design to serve as a guide during the building/implementation process, and also to provide valuable dxf, igs, and stl files of the custom parts, to be used during the manufacturing process. Each of the custom parts will be verified for their ability to properly attach to adjacent structures or subsystems, as well as for their ability to be manufactured with the tools available in the in-house machine shops.

4.9.2.1.2 Approach

The pre-manufactured components for the torpedo design will be purchased, and their actual critical dimensions will be documented. The detailed design and dimensions of the custom supports/brackets for the two double-acting air cylinders, the torpedoes, and the end cap of the acrylic barrels surrounding each torpedo will be based on these physical measurements to ensure proper connections during the manufacturing or implementation phase. Furthermore, each of the two identical torpedoes will be designed to be hydrodynamic in shape, have a maximum diameter slightly less than the inside diameter of the surrounding barrel (i.e. acrylic tube), and maintain a density either equal to, or slightly greater than that of saltwater in order to ensure a controlled, relatively horizontal flight pattern upon launch. Since the torpedo design will likely be unable to be manufactured via the tools in the in-house machine shops, an stl file will be created via the finalized Pro/Engineer model, and they will be manufactured using the 3D printer—adjusting the accuracy of the system in order to obtain the desired material density of the torpedoes

4.9.2.2 Subtask 9.2 – Manufacture and Assemble the Torpedo Launcher

4.9.2.2.1 Objective

Manufacture each of the custom components for the two identical torpedo launchers using the dxf, igs, and stl files obtained from the finalized component designs, and assemble the constructed torpedo launchers. The completed torpedo launchers should be able to propel the torpedoes accurately, consistently, and to a distance of at least 10 ft in an underwater environment via the direct introduction of compressed CO_2 into each of the double-acting air cylinders. The torpedo launchers should also be able to securely append to the frame via the custom attachments.

4.9.2.2.2 Approach

An aluminum sheet of the desired thickness will be purchased and brought to the FAMU-FSU College of Engineering machine shop, along with the dxf and igs files for the parts that need to be manufactured. The dxf files will be used to manufacture the respective parts via the high-pressure water jet (e.g. the aluminum supporting structure for each of the two double-acting air cylinders), while the igs files will be used to manufacture specific parts (e.g. the custom-designed end caps for the acrylic cannons) via the CNC machine. The stl file for the finalized torpedo design will uploaded to the 3D printer, which will mold the torpedoes from compressed ABS plastic powder to the desired density range. Upon completing the manufacture of all the components for the two torpedo launchers, each of the launchers will be carefully assembled into one unit and tested for proper functionality and desired performance.

4.9.3 Test/verification plan

Each of the above components of the torpedo launchers will be physically integrated. Successful integration will demonstrate the compatibility of the components with one another. Upon completion of the test for compatibility, the proper operation of the launcher mechanisms will be verified by attaching the torpedo launchers to the pneumatic system, placing the integrated subsystem underwater at the FSU Morcom Aquatics Center, and directly actuating the opening of the respective solenoid valves via an external power supply. Pressure-regulated, compressed CO_2 will be independently distributed into each of the corresponding air cylinders, thus launching the torpedoes. The flight characteristics (i.e. distance, accuracy, and trajectory) will be observed. Several trials will be performed, and at various pressures. Upon determining that each of the torpedo launchers provides acceptable consistency, accuracy, and launch speed, the integrated subsystem will be removed from the test site and placed on standby integration with the main control unit, which will serve to provide individual actuation.

4.9.4 Outcomes of task

The torpedo launcher shall be capable of independently firing each torpedo via the direct actuation of each of the respective solenoid valves, using the barrel guide the initial trajectory of the torpedo. In addition the launch speed of the torpedo should be capable of being easily adjusted via the adaptation of the regulated pressure of the incoming compressed CO_2 in the event that the launch speed is deemed “unsafe” during the preparation stages of the competition.

Phase 2: Integration of Each Subsystem/Component of the AUV

Upon completion of each of the individual subsystems/components of the AUV, a four-stage integration process will begin. The four stages of integration will enable a progressive increase in the functionality and capabilities of the AUV, and are as follows:

Stage 1: Add custom attachments to the frame in order to enable easy attachment of the external subsystems/components.

Stage 2: Add thrusters, sensors (i.e. pressure transducer, hydrophones, and inertial measurement unit), and control units (i.e. BeagleBoard-xM and Arduino board) in order to enable general maneuverability, depth control, and stability control.

Stage 3: Attach the mechanical subsystems (i.e. marker dropper, grasp/release mechanism, and torpedo launchers) to both the gas distribution system and the frame in order to enable the vehicle to perform specific tasks.

Stage 4: Add computer vision and cameras to complete the autonomy of the device.

This four-stage approach will yield the fully-functional end product that is ready for testing as a complete system.

Phase 3: End-Product Testing

Following the completed integration of each subsystem/component of the AUV into a single unit, the completed AUV will be taken to the FSU Morcom Aquatics Center, where the competition obstacle course will be replicated in pieces. The completed AUV will attempt each of the tasks from the simulated underwater environment, and any electrical, computer, or mechanical issues will be resolved at this point. Fine tuning of thresholds and task-to-task transition will likely be the focus of this phase. Upon conclusion of this phase, the AUV should be considered ready for competition. Calibration of the sensors to the actual competition environment will take place on site of the competition during the practice time in order to ensure precise operation of the vehicle where it counts.

Phase 4: End-Product Documentation

A 3D Pro/Engineer model of entire system (non-exploded and exploded views), a Pro/Engineer drawing of each of the components of the vehicle, and the complete bill of materials used to construct the device will be provided. In addition, an organized document containing accurate values of the Pro/Engineer-derived mass, density, inertia, and relative center of mass measurements of the system will be provided. In regards to documentation related to the electrical/computer engineering aspects of the system, a hard copy of all the codes used to program the device will be provided with comments for easy readability. Furthermore, an excel file demonstrating the budget analysis (i.e. breakdown of total expenditures, savings, etc.) for the entire project will be provided for review.

5 Risk Assessment

5.1 Administrative Risks

5.1.1 Over or under estimation of Budget

A wrong estimation of the team's budget can cause problems in the design process. The budget can be either underestimated or overestimated. If the budget is underestimated, the team will have to seek sponsorship during the design process in order to purchase necessary components or equipment. This can add a lot of overhead to the team during the design. If the budget is overestimated, it may lead to unnecessary waste of resources. Therefore, it is very important for our team to carefully estimate the budget. In order to accurately estimate the team's budget, we need to carefully design each component of the vehicle at the beginning, make a conscious choice of what component we need to purchase and have a backup plan (or contingency plan) if that choice does not work. And if the budget happened to be underestimated, our team will seek additional sponsorship as soon as possible so that it will minimize the delay of our process.

5.1.2 Team member availability

All our team members will collaborate with each other closely. The design progress and decision making process from each team member must be well documented. So that if any team member is not available (due to sickness or other issues), other team members could take over the work without causing any delay to the entire team's design process. The goal of this enforcement is to help the team stay on the timeline as much as possible.

5.1.3 Team member dedication

Successful completion of this project requires 100% dedication by all team members. If a team member reduces does not dedicate himself to his portion of the project, that portion will suffer and may result in an incomplete Robosub that cannot compete.

5.2 Hull/Frame

5.2.1 Vehicle density greater or less than optimal target density

If it is discovered that after completion of the AUV, the vehicle's density is too far above or below the optimal target density, additional material of either greater or less density than the target system density will be symmetrically added at either side of the bottom of the AUV. These two regions will be reserved for this addition in the case the density of the AUV needs to be tuned upon completion of the vehicle.

5.2.2 Electronics overheat due to insufficient heat dissipation system

Another possible risk to the successful completion of the project is that the electronics overheat due to the heat transfer rate from the lithium hydride battery packs, Arduino Board, and BeagleBoard-xM to the surrounding water (via conduction through the aluminum plate and aluminum end caps) being insufficient. While not expected to be an issue, if this proves to be the case, a battery-powered fan will be installed inside the pressure vessel 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. This, however, would also reduce the efficiency of the heat transfer into the external environment via conduction, and would only serve to displace localized heat.

5.3 Computer Vision

5.3.1 Synchronization and Timing Issues

The Navigation and Task Control modules play a vital role in the functioning of the Computer Vision part of the AUV. Since these modules depend on input from several sub modules of the Computer Vision system, synchronization and timing issues may arise later on in the design process.

5.3.2 Incongruences between Independent Subsystem Functionality and Integrated System Functionality

Unit testing of sub modules does not guarantee the proper functionality of the Computer Vision system when all sub modules are integrated into a single system. The system should therefore be tested as more sub-modules progressively become available. This will ensure that the system maintains functionality as components are designed and implemented.

5.3.3 Issues with Camera Locations

Issues may also occur with camera positioning and mounting; however, the versatile frame design should enable modifications in the camera locations to be made relatively easily.

5.4 Main controller and mechanical control subsystem

5.4.1 Hardware failure

There is a high risk that possible hardware failure will occur during the design process of the AUV. For example, during the tests, thrusters maybe burned due to overheat. Electronic devices may be damaged if the pressure vessel is not water tight. Electronic devices may also be damaged if the heat is not efficiently carried away. Other mechanical parts maybe broke down by accident. During the design process, we have to be very careful in order to minimize possible hardware failure or accidents which lead to hardware break down. In case of a hardware failure, our team needs to identify the sources of the problem as soon as possible, reconsider our design strategy if possible, and get the hardware component fixed or replaced. We may find that some hardware design at the initial stage may not work at all after we start to implement them. This possible situation could be avoided if we choose to design every major hardware component carefully, and consult our technical advisors as much as possible.

5.4.2 Software failure

Due to the complexity of the software programming in this project, there is a high risk of software failure. Program written for a subsystem may not function properly at all. For example, a lack of understanding the background knowledge of the hydrophones may lead us to a very difficult situation on programming the hydrophones to calculate the location of a pinger. It is highly possible that the software may contain many bugs that are very difficult to debug, and these bugs can eventually lead to the software failure of the system. There is also a risk that even though a single program runs perfectly well for its subsystem, however, when the program is running at the same time with other programs, the software system may fail. Therefore, to avoid possible software failure, a very clearly and detailed software structure must be needed. Software design documentation must also be done during the design process.

5.5 Guidance System

5.5.1 Communication or Algorithm Failure

The guidance system is a critical system that augments the data provided by the computer vision system to determine the AUV's position at any time while in the water. Correct combination of this system depends on communication between the two modules as well as algorithmic combination of them in the main controller. Additionally, if one of these modules fails then the system will fail to obtain a correct heading and will not be able to complete some tasks.

5.5.2 Inaccurate Pinger Detection Readings

Furthermore, the hydrophone readings of the surrounds could be inaccurate depending on the location of the pinger. If one of the hydrophones fails, then the pinger triangulation system will not work.

5.6 Pneumatic Gas Distribution System

5.6.1 Solenoid valve actuation and gas line failure

The greatest threat to the proper operation of both the grasp/release mechanism and torpedo launchers is the failure of the solenoid valves to open and close when electrically actuated. This malfunctioning would result in the inability for these mechanical subsystems to perform the required related tasks, thus resulting in a loss of points during the competition. The valves will be thoroughly tested at depths of 17 ft at the FSU Morcom Aquatics Center during the third stage of the integration/assembly phase, in order to ensure the reliability of this actuation. Furthermore, the integrity of the gas lines will be tested by introducing compressed CO_2 at 100 psi, and verifying no leakage or detachment.

5.7 Torpedo Launchers

5.7.1 Torpedoes deemed unsafe due to launch speed/force

The most important design criterion to consider in the design of the subsystem is the safety of the mechanism; the potential force at which the torpedo can be launched has a wide range. According to the competition committee, the torpedoes should not be capable of causing bodily harm upon impact, and if it is deemed that the current torpedoes are launched at an unsafe speed, an adjustment will be made. The launch speed of the torpedo will be controlled by adjusting the nominal output of the pressure regulator which will be attached to the main CO_2 storage tank.

6 Qualifications and Responsibilities of Project Team

Task	Assignment	Skills and Knowledge
Hull/Frame + Stability/Depth Control	Eric Sloan	Mechanical Systems, Dynamic Systems, Thermal Fluids, Mechatronic Systems, Proficient in C Programming
Object Grasp/Release Mechanism + Gas Distribution System	Tra Hunter	Mechanical Systems, Dynamic Systems, Thermal Fluids, Mechatronic Systems
Torpedo Launchers + Gas Distribution System	Kashief Moody	Mechanical Systems, Dynamic Systems, Thermal Fluids, Mechatronic Systems
Main controller + power	Hang Zhang	Proficient in C/C++ Programming, Familiarity with the BeagleBoard and Linux Operating Systems.

management system		
Computer vision system	Ryan Kopinsky	Proficient in C Programming; Open CV; programming micro-controllers
Guidance system	Antony Jepson	Proficient in C Programming; previous Program manager experience

7 Schedule

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

8 Budget Estimate

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	Main controller + power management system	$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	$50.00	1	$50.00

	pressure vessel			
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	$230.00	1	$230.00

	through actuated solenoid valves			
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

9 Deliverables

Two major deliverables will be derived during the design and construction of the AUV. These are the AUVSI journal paper and the Detailed Design and Test Review report. The AUVSI journal paper is required by the competition committee, and will include information on all aspects of our design (e.g. those listed in Section 2 and 3), as well as discussion of the concept generation and selection process that our senior design team underwent in the process of determining the resulting AUV design. The Detailed Design and Test Review report will include detailed discussion of each aspect of the design, as well as data and analysis from the testing phase of the project, and our approach to resolving errors or flaws that were encountered.

10 References

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11 Appendix

11.1 Estimation of power consumption in the Intel PC system

Estimation of the power consumption in the Intel PC system:

Component	TDP(Thermal Design Power)
Intel Core i3-2120T 2.6GHz CPU	35W
3GB DDR3 RAM + SSD + Motherboards	15W
Liquid Cooling System	30W[4]
30% Safe range	24W
Total	104W

11.2 Main controller comparisons

Main microcontroller comparisons

	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	< 1,400 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

[4] TDP for water cooling system: Typically 20 - 60W

Hang Zhang

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hz07@my.fsu.edu

Education:

Florida State University, Tallahassee, FL — April 2012
Bachelor of Science, **Computer Engineering**
Overall GPA: 4.0, with Honors, President's list

Experience:

FSU Capstone Senior Design Project, Tallahassee, FL — August 2011 – April 2012

- Design an autonomous unmanned underwater vehicle
- Extensive programming on computer vision, sensor control, and robotic behavior
- Supervise team's budget of $7,000

FSU CS Department, *Teaching Assistant*, Tallahassee, FL — August 2011 – December 2011

- Grade assignments and offer help in Computer Fluency class

FSU Math Department, *Math Tutor*, Tallahassee, FL — August 2011 – December 2011

- Tutor students for various classes such as Calculus I, II, III, and College Algebra

FSU HPMI, *Research Assistant*, Tallahassee, FL — January 2010 – February 2011

- Performed research on carbon nanotube polymer composite reinforced with CNT yarns
- Conducted research on carbon nanotube yarn field emission
- Designed an amplifier circuit for constructing thermal acoustic carbon nanotube speaker
- Conducted electrical, optical and mechanical tests on multiwall carbon nanotube sheets

Organized a Spring Festival Ceremony, *volunteer*, Tallahassee, FL — February 2009

Organized a China earthquake relief, *volunteer*, Tallahassee, FL — May 2008

- Raised a total of $12,000

Patent:

Mei Zhang, Hang Zhang, Ben Wang, Richard Liang, and Chuck Zhang, "Composite Materials Reinforced with Carbon Nanotube Yarns," U.S. Provisional Patent Application No. 61/392,251.

Programming Skills:

C ,C++, Assembly,VHDL, Matlab, JAVA, Extensive Linux programming experience

Honors:

FAMU-FSU NanoCORE Research Fellowship	2010 - 2011
Undergraduate Tuition Waiver for excellence in academy	2007 - 2011
Florida – China Linkage Scholarship	2008 – 2011
Dean's list	2007 – Present
Golden Key International Honor Society	
Phi Eta Sigma Honor Society	

Antony Jepson

Contact Information

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Tallahassee, FL 32302-0933

Mobile: 1.954.247.4089
Email: antonyat@gmail.com

Qualification

A dedicated Computer Engineer that is serving as the lead PM for Team Robosub.

Education

Florida Agricultural and Mechanical University, Tallahassee, FL

Bachelor of Engineering in Computer Engineering (May 2012)

- Full Presidential Scholar with 3.94 GPA

Coursework

C/C++ Programming; Discrete Structures; Differential Equations; Linear Algebra; Electronics; Signal and Linear System Analysis; Microprocessor-Based System design; Circuit Analysis 1, 2; Engineering Mechanics; Calculus 1, 2, 3; Digital Logic Design

Technical Experience

Linux, Mac OSX, Windows (MS-DOS, 95, XP, Vista, 7), PHP, MySQL, Bash Shell Scripting, Networking, HTML, CSS, C, LaTeX, Regular Expressions, Microsoft Office, Open Office

Experience

Microsoft, Redmond, WA

Windows Phone Input PM Intern **5/2011 – 7/2011**

- Delivered a specification outlining the best-in-class hardware keyboard typing experience on future Windows Phones.
- Worked with OEM on my feature and converted their requirements into trackable internal work items.
- Hosted internal prep session within the Input PM team to champion increased awareness about competitor typing experience.

Apple Inc., Cupertino, CA

Applications Q/A Engineering Intern **5/2010 – 8/2010**

- Designed and improved next generation machine restoration tool improving the productivity of manual testers by saving over a thousand work-hours per month
- Developed reporting engine and metric analysis tool for upper-management granting an easier and more efficient overview of machine restoration tool usage and activity results
- Developed package and testcase upload web interface for use by manual testers enabling autonomous operation of the product

Department of Physics, FAMU, Tallahassee, FL

System Administrator **8/2009 – 5/2011**

- Manage five node Apple Xserve cluster.
- Configure and install software (LAPACK, BLACS, Scilab, GNUPlot, MPI, etc.)
- Administer and manage user accounts and security policies

STEM Learning Community, Tallahassee, FL

Peer Mentor / Communication Project member **8/2009 – 5/2010**

- Prepared multimedia presentation showcasing STEM progression
- Mentored over 50 incoming STEM major freshman to develop their communication skillset
- Coordinated website development/purchasing

Honors and Achievements

Competed for Florida A&M University at the Super Computing Conference (Fall 2010)
Presented at Morgan State Innovative STEM Symposium (Spring 2009)
Dean's List (Fall/Spring 2009)
Bernard Hendricks Conference Excellence Award (Spring 2009)
Dean's List (Fall 2008)
Life Gets Better Scholarship (Fall 2008 – present)

RYAN KOPINSKY

501 Blairstone Rd Apt 921 Tallahassee, Florida 32301 **M** (850) 212-5415 **E** ryan.kopinsky@gmail.com

QUALIFICATION

A dedicated Electrical Engineering student determined to design an innovative Computer Vision system for the RoboSub Project

EDUCATION

Florida Agricultural and Mechanical University, Tallahassee, FL
Bachelor of Science in Electrical Engineering 08/2008 - 05/2012
Full Academic Scholarship with a GPA of 3.99 out of 4.00

EXPERIENCE

Center for Intelligent Systems, Control and Robotics, Tallahassee, FL
Research Assistant 06/2011 - Present

- Designed the user interface for the testing and debugging of CISCOR's terrain classification (Computer Vision) algorithm to improve testing efficiency and simplicity for the research team
- Developed software for a Windows Tablet PC to demonstrate the terrain classification interface
- Mentored summer research high school students during the field testing of the terrain classification system

Future Renewable Electric Energy Delivery & Management, Tallahassee, FL
Research Assistant 09/2010 - 05/2011

- Conducted research on the capacity fade of Lithium-ion batteries throughout the cycle life to improve the lifetime of the batteries
- Determined and analyzed the impedance model of the energy storage device
- Performed journal reviews

Suralco L.L.C., Suriname, South America
Power House Intern 05/2009 - 07/2009

- Conducted over 50 tests on the dielectric breakdown voltage of insulating oils of petroleum origin
- Participated in clearance orders in the electrical distribution system
- Performed quality and reliability testing on electrical equipment

TECHNICAL EXPERIENCE

C, ActionScript, NCURSES, Adobe Flex, Windows, Mac OS X, Microsoft Office

HONORS AND ACHIEVEMENTS

- Global Students Union - Vice President Fall 2010/Spring 2011
- Dean's List 2008 - Present
- Alcoa Distinguished Scholar 2008 - Present

ERIC SLOAN
8309 MISTY LAKE CIR, SARASOTA , FL 34241
(941) 228-1133 | es09e@fsu.edu

EDUCATION

FLORIDA STATE UNIVERSITY, *TALLAHASSEE, FL*
Bachelor of Science, Mechanical Engineering, *April 2012*
Minors: Mathematics, Physics
GPA: 3.87

MAJOR- SPECIFIC COURSES

Physics II, Modern Physics, Calculus III, Materials Science and Engineering, Introduction to Mechanical Engineering, Mechanical Engineering Tools, Ordinary Differential Equations, Mechanics and Materials I, Dynamic Systems I, Thermal- Fluids I, Dynamic Systems II, Mechanical Systems I, Mechanics and Materials II, Thermal-Fluids II, Mechanical Systems II, Experimental Fluids/Thermal, Mechatronics I, Engineering Design Methods, Introduction to Electrical Engineering, Engineering Mathematics II, Mechatronics II, Senior Design I

EXPERIENCE

NATIONAL HIGH MAGNETIC FIELD LABORATORY- APPLIED SUPERCONDUCTIVITY CENTER, *TALLAHASSEE, FL*
Laboratory Assistant, *May 2010 – January 2011*

- Mounted and polished heat- treated, strained, pre- tested Nb_3SN wires to be analyzed for variance in crack count, void count, barrier integrity, and several other properties of the material
- Used advanced imaging microscopes including the LEXT laser confocal microscope and the SEM microscope in order to set up matrices of images, enabling them to later be processed using a series of programs, and then converted into stitched images for analysis
- Worked on projects for ITER, which provided valuable pre-tested TARSIS samples from various international production companies for quality comparison
- Developed a new method to create consistent, high-quality, processed stitched images of the wire samples

STRIDE LABORATORY
TALLAHASSEE, FL
Laboratory Assistant, *May 2011 – August 2011*

- Worked on a variety of projects including refining a two degree-of-freedom pendulum, and developing a 3D simulation of a passive dynamic walker to be used as demonstrations in a dynamic systems-related courses
- Performed extensive stiffness and damping testing to assist in the research of a PhD student in the area of efficient bipedal locomotion

INDIVIDUAL SKILLS

- Always willing to take the lead role in a project in order to ensure quality, correctness, and success
- Strong work ethic and passion for both quality and excellence
- Excellent communication and organizational skills
- Ability to work as part of a group, individually, and under pressure situations
- Ability to find solutions to engineering problems, and also create new ideas and designs

TECHNICAL SKILLS

- MathCad
- Pro/Engineer
- MATLAB
- Code Blocks
- Code Warrior (Programming in C)
- ADAMS
- Word
- PowerPoint
- Excel
- Adobe Photoshop

- Embedded/Autonomous Systems
- LEXT Laser Confocal Microscope

PROJECT-RELATED EXPERIENCE

- Programmed a wheeled robot to follow a winding path (IR sensor), navigate between cement walls (ultrasonic sensor), re-identify the outgoing path, avoid and obstacle, reach the end line, and turn around to navigate the obstacle course in the opposite direction, thus completing the continuous cycle.
- Designed and Built a robot capable of detecting IR beacons with various frequencies, shooting a disk projectile toward the target (using a custom-designed shooter mechanism), driving to where the projectile landed (encoders were built from scratch), re-identifying the relative location of the target, and shooting another projectile (at a different speed) toward the target, until the target was hit.

HONORS/ ACTIVITIES

- American Society of Mechanical Engineers (ASME): Spring 2010 – present
- American Institute of Aeronautics and Astronautics (AIAA): Fall 2011 – present
- National Society of Collegiate Scholars (NSCS): Spring 2010 – present
- Tau Beta Pi (Engineering Honor Society): Fall 2010 – present
- Golden Key International Honor Society: Fall 2010 – present
- Pi Tau Sigma (Mechanical Engineering Honor Society): Fall 2010 – present

3517 Dogwood Valley Trl.
Tallahassee, FL 32303

Phone (850)510-9118
E-mail tlh08f@fsu.edu

Tra L. Hunter

Objective

Mechanical Engineering student dedicated to the Mechanical design of the 2012 RoboSub Project.

Education

2005–2008 Tallahassee Community College Tallahassee, FL

Associate in Arts Degree

- Completion of general studies.

2008–2012 Florida State University Tallahassee, FL

Bachelor of Science, Mechanical Engineering

- Anticipated Graduation Spring 2012.

Awards received

Bright Futures Scholarship

Work experience

2011–Present High Performance Magnetics Tallahassee, FL

Shop Assistant/Technician

- Assist with the fabrication and assembly of machinery parts used in a superconducting cable jacketing process.
- Commissioned a Yoder Tube Mill.
- Disassembled a 400MHz superconducting magnet.
- Conducted thermal expansion test on cable stanchion line.

2009–Present National High Magnetic Field Laboratory Tallahassee, FL

Lab Assistant/Technician

- Perform cryogenic fills on twelve super conducting magnets.
- Maintain vacuum pump oil changes and general lab maintenance.

Computer Skills

Pro/Engineer (CAD), Microsoft Excel, Microsoft Word, Microsoft PowerPoint, Mathcad.

U.S. Citizen

References Available Upon Request

Kashief Simon Moody

3737 12 St. NE<>Washington, DC 20017
202-730-6469
KMoodyndc@gmail.com

Qualification: Highly motivated senior studying Mechanical Engineering, eager to offer my current skills and education as a service to the RoboSub team for the development of an exceptional torpedo launcher mechanism.

Education:

Florida A & M University
1728 Martin Luther King Blvd. Tallahassee Fl 32307
August 2005- Present
Major: Mechanical Engineering
Expected graduation date: April 2012

Experience:

Department Of Veteran
June 2011- August 2011
May 2010- August 2010
May 2009- August 2009

811 Vermont Avenue NW Washington, DC 20420
Kurt Knight: Retired
Donald Myers: 202-632-5388
40 Hour Week
Support Assistant

- Created as well updated Excel Spreadsheets (Spreadsheets used in Design Manuals and Facility Design Guides)
- Created as well as updated Power Point presentations
- Reviewed/edited design standards for Design Manuals and Facility Design Guides
- Researched current titles and laws governing DVA facilities, updated staff members on my findings

Department Of Veteran Affairs
May 2008- August 2008

811 Vermont Avenue NW Washington, DC 20420
Dennis Milstein: 202-461-8266
40 Hour Week
Clerk/Support Assistant

- Created and updated Excel Spreadsheets
- Developed a filing system for contract files
- Assisted in the closing out of contracts
- Faxed invoices and other important documents

Blue Skye Construction LLC
May 2007- August 2007

1539 7th St. NE Washington, DC 20001
Bryan Irving: 202-258-0077
40 Hour Week
Construction Technician

- Scrapped, plastered and painted walls
- Installed doors, appliances and locker units
- Sanded wood floors
- Demolition

Temple Law Offices
May 2007- August 2007

1229 15th St. NE Washington, DC 20005
Donald Temple: 202-628-1107
40 Hour Week
Office Clerk

- Greeted clients and created a comfortable environment
- Accepted incoming call
- Typing, filing and xeroxing documents
- Assisted in serving summons and filing documents at the state court building

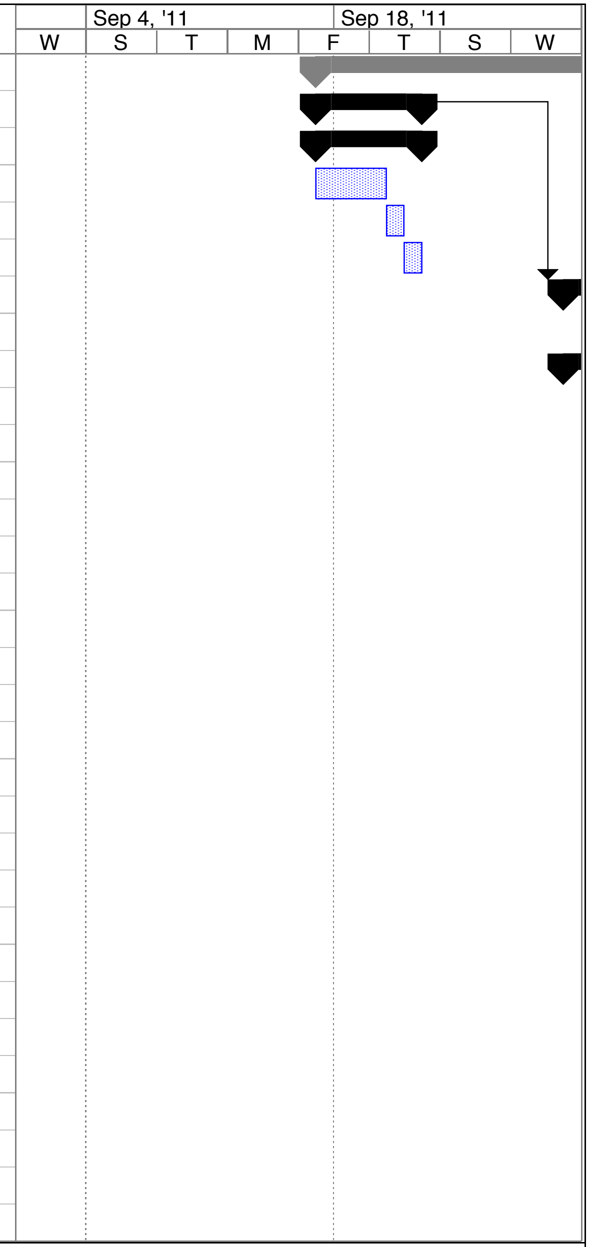
Technical Skills:

- Windows Office Suite (Excel, Power Point, Microsoft word)
- AutoCAD 2011: Software used to design and dimension landscapes, structures, tool etc.
- Pro Engineering: Software used to design and simulate mechanism
- Working Model: Software used to design and simulate mechanism
- Mathcad: Software used to program and solve mathematical algorithms
- Mathlab: Software used to program and solve mathematical algorithms

Extracurricular Activities:

- DC Metro Club, Florida A & M University Chapter
- National Society of Black Engineers (NSBE), Florida A & M / Florida State University Chapter
- Volunteer at Astoria Park Elementary School

ID	Task Name	Start	Finish	Resource Names
0	**robosub**	**Fri 9/16/11**	**Tue 4/24/12**	
1	**1 Ramp-up (Analysis/Synthesis)**	**Fri 9/16/11**	**Thu 9/22/11**	
2	**1.1 Needs Analysis and Specification**	**Fri 9/16/11**	**Thu 9/22/11**	
3	1.1.1 Individual team composition	Fri 9/16/11	Tue 9/20/11	
4	1.1.2 Combine submissions	Tue 9/20/11	Wed 9/21/11	
5	1.1.3 Submit combined needs analysis	Wed 9/21/11	Thu 9/22/11	
6	**2 System Design (Development)**	**Fri 9/30/11**	**Wed 11/30/11**	
7	2.1 Professional engineering assignment	Mon 10/31/11	Mon 10/31/11	
8	**2.2 Project proposal**	**Fri 9/30/11**	**Thu 10/20/11**	
20	2.3 Project management	Thu 10/20/11	Tue 11/29/11	
21	**2.4 Complete the Hull and Frame of the AUV**	**Thu 10/20/11**	**Wed 11/30/11**	
22	2.4.1 Develop a Pro/Engineer Model of the Finalized Hull a	Thu 10/20/11	Wed 11/16/11	
23	2.4.2 Manufacture and Assemble the Hull and Frame	Thu 11/17/11	Wed 11/30/11	
24	**2.5 Develop a computer vision system.**	**Thu 10/20/11**	**Wed 11/30/11**	
25	2.5.1 Develop the pre-processing module	Thu 10/20/11	Wed 11/2/11	
26	2.5.2 Design the color filter module	Thu 11/3/11	Wed 11/9/11	
27	2.5.3 Design the Path Detection Module	Thu 11/10/11	Wed 11/16/11	
28	2.5.4 Design the Size Detection Module	Thu 11/10/11	Wed 11/16/11	
29	2.5.5 Design the Navigation Module	Thu 11/17/11	Wed 11/23/11	
30	2.5.6 Design the Shape Detection Module	Thu 11/17/11	Wed 11/23/11	
31	2.5.7 Design the Task Control Module	Thu 11/24/11	Wed 11/30/11	
32	**2.6 Develop a guidance system**	**Thu 10/20/11**	**Wed 11/30/11**	
33	2.6.1 Develop a system to capture IMU data	Thu 10/20/11	Wed 11/9/11	
34	2.6.2 Design a system to capture depth sensor data	Thu 11/10/11	Wed 11/23/11	
35	2.6.3 Design a system to capture AUV heading and locate	Thu 11/17/11	Wed 11/30/11	
36	**2.7 Develop Software to Control the Thrusters**	**Thu 10/20/11**	**Wed 11/23/11**	
37	2.7.1 Develop Software to Control the Thrusters	Thu 10/20/11	Wed 11/9/11	
38	2.7.2 Develop Software to Control the Grasp/Release Mec	Thu 11/10/11	Wed 11/23/11	
39	**2.8 Complete the Pneumatic System/Gas Distribution Netw**	**Thu 10/20/11**	**Wed 11/30/11**	
40	2.8.1 Select a Compressed CO2 tank	Thu 10/20/11	Wed 11/2/11	
41	2.8.2 Select a Pressure Regulator	Thu 11/3/11	Wed 11/16/11	
42	2.8.3 Select Solenoid Valves and Pressure Lines/Tubing	Thu 11/17/11	Wed 11/30/11	



Project: robosub
Date: Thu 10/20/11

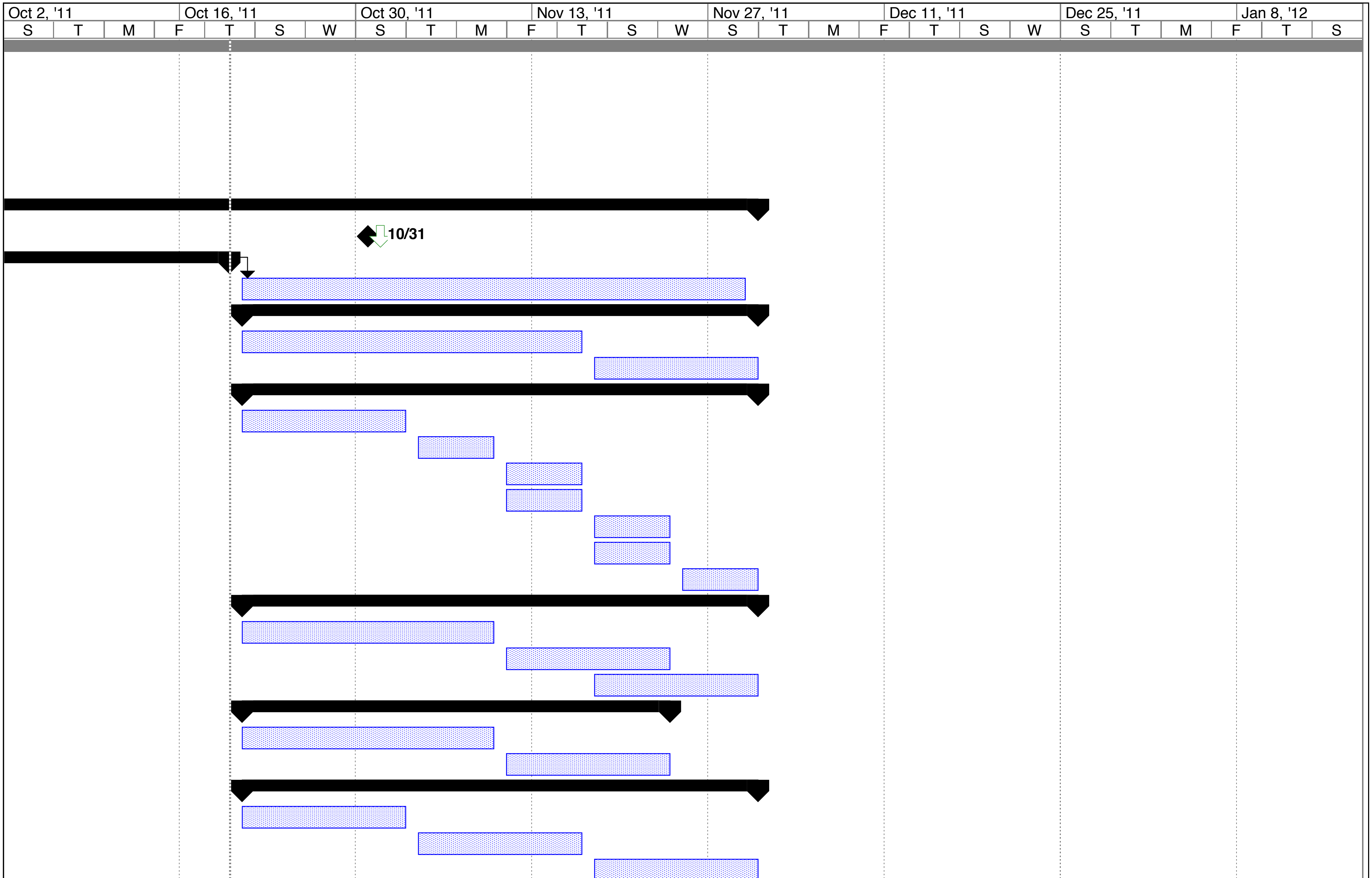
Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

ID	Task Name	Start	Finish	Resource Names
43	**2.9 Complete the Grasp/Release Mechanism for the AUV**	**Thu 10/20/11**	**Wed 11/30/11**	
44	2.9.1 Develop a Pro/Engineer model of the finalized Grasp	Thu 10/20/11	Wed 11/2/11	
45	2.9.2 Manufacture and Assemble the Grasp/Release Mech	Thu 11/3/11	Wed 11/30/11	
46	**2.10 Complete the Torpedo launcher for the AUV**	**Tue 11/1/11**	**Wed 11/23/11**	
47	2.10.1 Develop a Pro/Engineer model of the finalized Torp	Tue 11/1/11	Wed 11/2/11	
48	2.10.2 Manufacture and Assemble the Torpedo Launcher	Thu 11/3/11	Wed 11/23/11	
49	2.11 System Level (Conceptual) Design Review	Thu 11/17/11	Thu 11/17/11	
50	3 System Verification	Wed 11/30/11	Wed 3/28/12	
51	4 Documentation and Review	Wed 11/30/11	Tue 4/24/12	

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

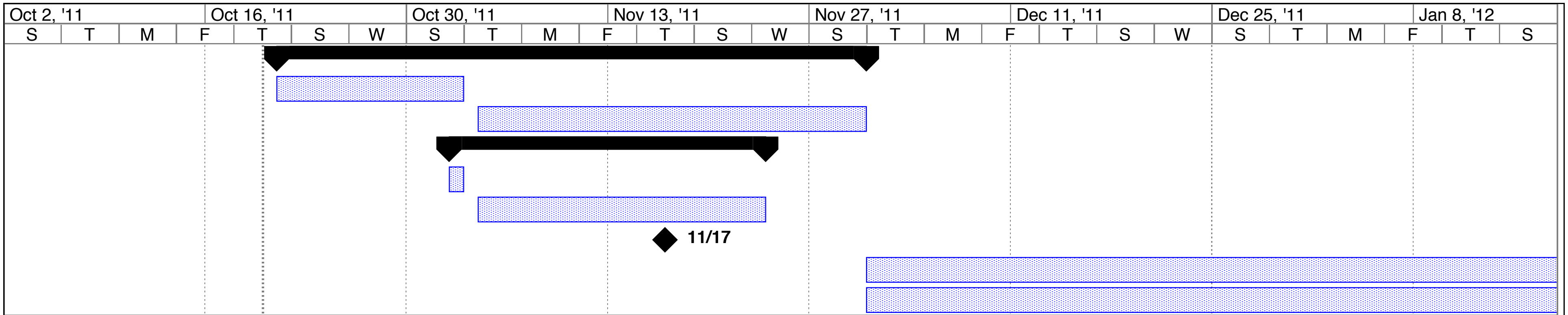
Project: robosub
Date: Thu 10/20/11

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



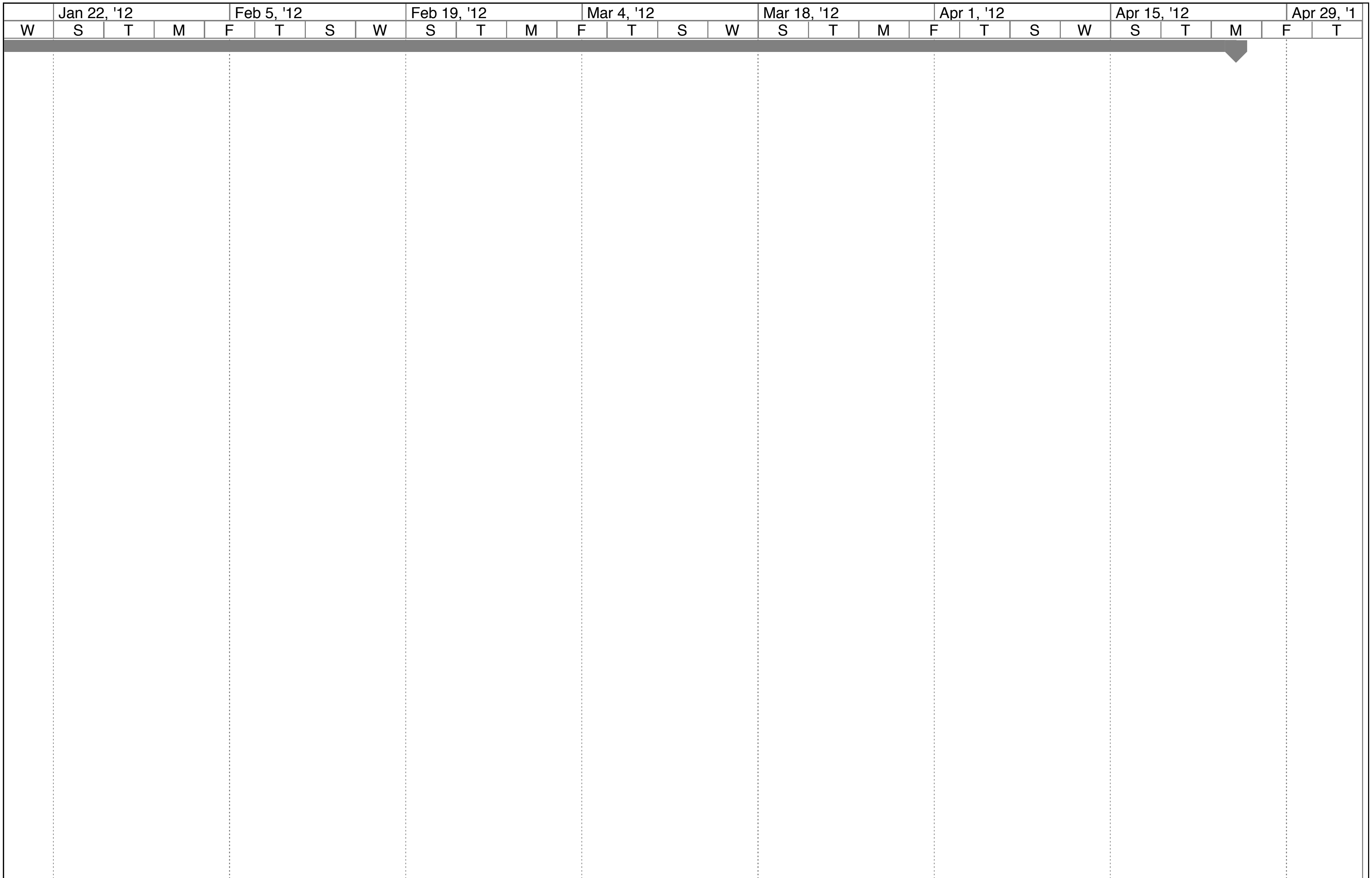
Project: robosub
Date: Thu 10/20/11

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



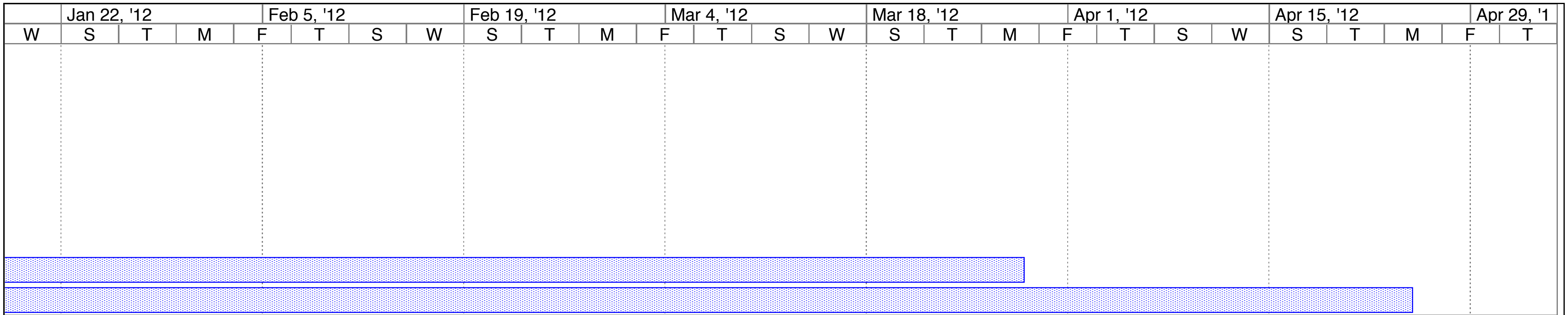
Project: robosub
Date: Thu 10/20/11

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



Project: robosub
Date: Thu 10/20/11

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



Project: robosub
Date: Thu 10/20/11

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