BRITISH COLUMBIA INSTITUTE OF TECHNOLOGY

ROV TEAM 2010

Project: Ninja Pig

Team Members

Mechanical Engineering Diploma
(Class of 2010)

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Nick Mayr
Guido Worthmann
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Mechatronics Diploma
(Class of 2010)

Darren Kelly
Nathan Kingston

Sponsor
Mr. Taco Niet

Advisor
Dr. Edward Thompson

TEAM NINJA-PIG

The team that was selected for the ROV competition featured eight students enrolled in the mechanical engineering technology and mechatronics technology program at British Columbia Institute of Technology and has been assisted by faculty mentor, Taco Niet.

Six of the students have been in charge of the frame and tooling for the ROV, while the other two students (from the mechatronics program) have taken charge of the control systems and electronics for the ROV.

TEAM MEMBERS

James Anderson – Mechanical Engineering

Nick Mayr – Mechanical Engineering

Guido Worthmann – Mechanical Engineering

Brenda Le – Mechanical Engineering

Will Yee – Mechanical Engineering

Darren Kelly – Mechatronics

Nathan Kingston – Mechatronics

MENTOR & SPONSOR

Taco Niet – Program Head, Bachelor of Mechanical Engineering

ABSTRACT

This report summarizes the design and construction of a Remotely Operated Vehicle (ROV) named ‘Ninja Pig’. In February of 2010, this project was commenced and sponsored by Taco Niet of the British Columbia Institute of Technology (BCIT). The objective of the project was to complete mission tasks as outlined by the Marine Advanced Technology Education Center (MATE) 2010 international ROV competition.

To perform the task of designing and constructing a suitable ROV, three teams were formed. They are Framing and Propulsion, Tooling, and Control Systems. The Framing and Propulsion team was responsible for designing and building a platform from which tools could be mounted. The Tooling team was responsible for the design, selection and manufacturing of tools required to perform collection and measurement tasks. The Control Systems team was responsible for designing and building the systems for controlling the ROV.

Multiple concepts were generated and subjected to design evaluations. Upon review two were deemed most feasible and of these, the one initially dubbed the Orca II was chosen for full scale design and manufacture. Suitable tooling options were designed and a control system was created to suitably control the entire system.

The project yielded multiple prototypes, one of which attended and qualified at the 2010 MATE Pacific Northwest ROV Challenge. A final ROV is in production and scheduled for completion on June 4, 2010 and will be ready for the international competition in Hawaii.

Concepts, schematics and additional information regarding the competition background and the ROV can be found throughout this report.

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PHOTOS OF ROV

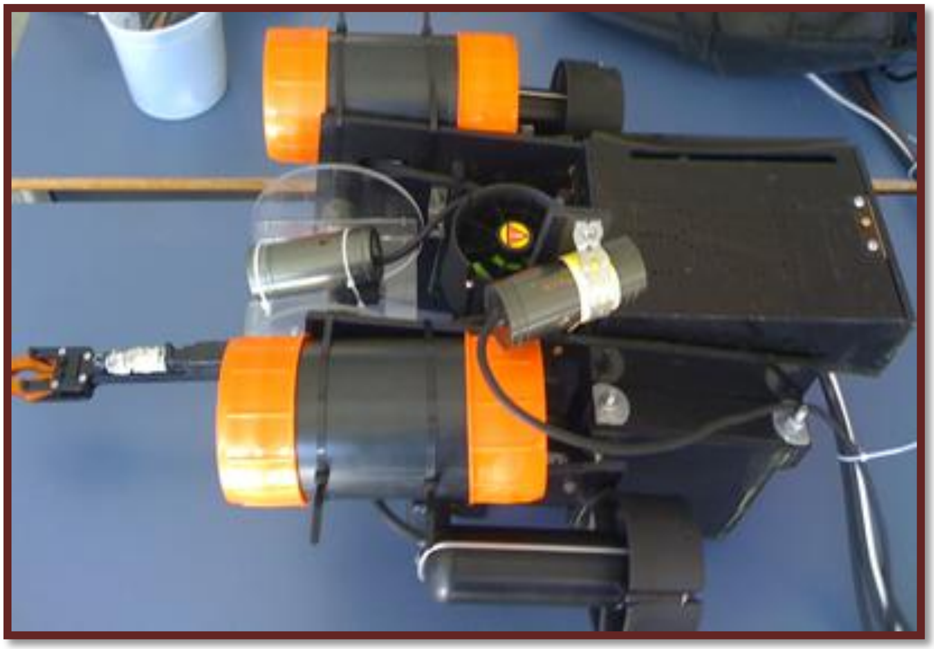

FIGURE 1 - TOP VIEW OF THE ROV

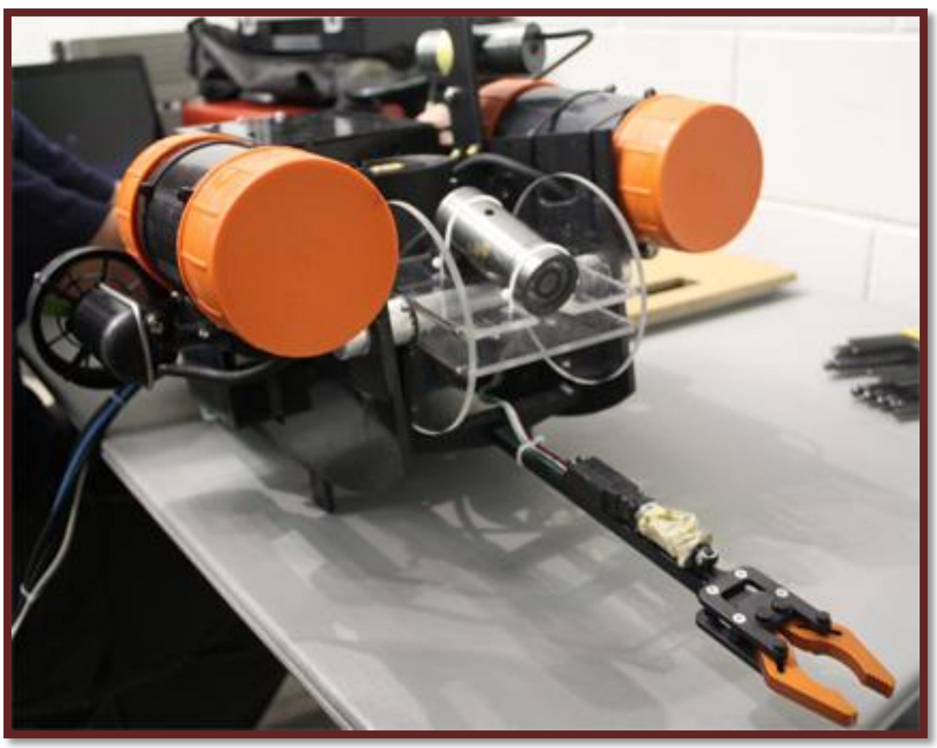

FIGURE 2 - FRONT VIEW OF ROV DEATAILING TOOLING

BUDGET AND EXPENSES

Table 1 below is a comprehensive list of the ROV expenses. Labour is not included in the budget as all the labour has been completed by students and such labour is free.

TABLE 1 - ROV BUDGET

Component	Quantity	Cost per unit ($)	Total Cost ($)
Aluminum	all	nil	$50.00
Fasteners	all	nil	$20.00
Firgelli L-12 Actuator	1	$132.00	$132.00
Traxxas 2075 servo	2	$42.00	$84.00
Taxes 2056 servo	1	$40.00	$40.00
Anodizing	all	$50.00	$50.00
Thrusters	3	$500.00	$1,500.00
Cameras	2	$300.00	$600.00
PVC Plastic	all	nil	$80.00
Buoyancy	all	nil	$45.00
HC-12 Processor	1	$140.00	$140.00
Arduino Mega Processor	1	$75.00	$75.00
Motor Driver	3	$35.00	$105.00
Connectors	all	nil	$200.00
IMU	1	$130.00	$130.00
Misc Components	all	nil	$200.00
Total Cost			$3,451.00

The electical schematics for the ROV are shown below. There are diferent schematics for the power system, temperature reading and signal conditioning, seismic reading signal conditioning, frequency to voltage conversion, and amplitude conversion.

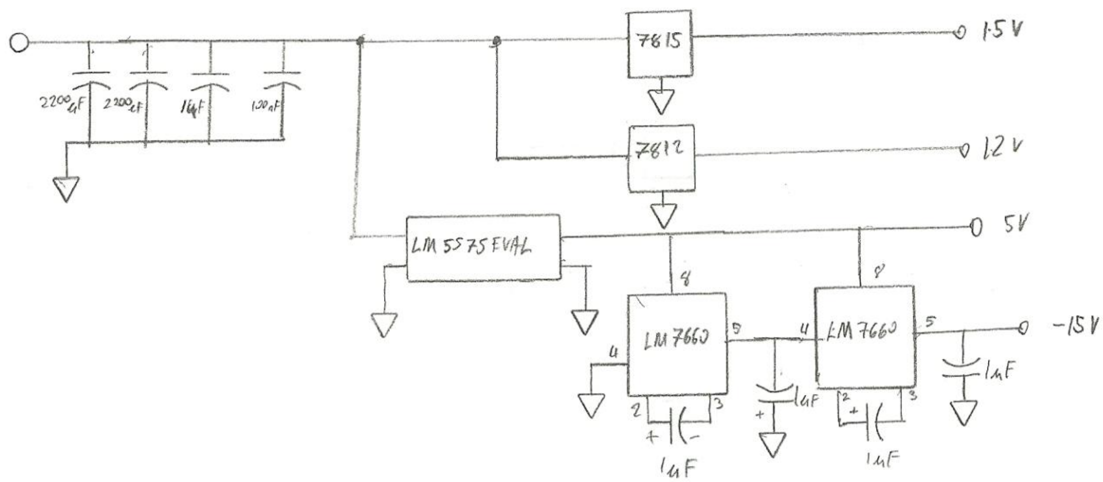

FIGURE 3 - POWER SUPPLY SCHEMATIC

Figure 3 above shows the schematic for all the power supplies onboard the ROV.

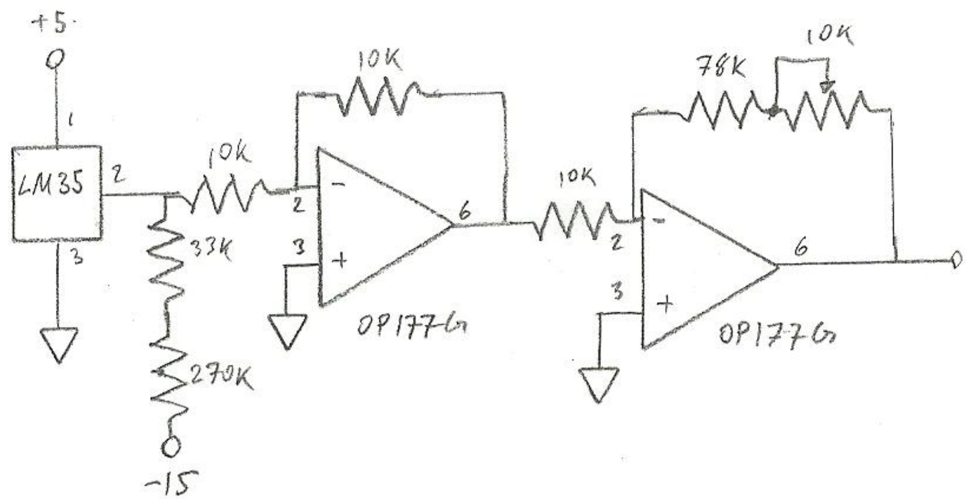

FIGURE 4 - TEMPERATURE READING AND SIGNAL CONDITIONING

Figure 4 above shows the schematic for the temperature measurement system that will be used to accurately measure the temperature at the spires. The resolution of the sensor is 0.2 degrees Celsius.

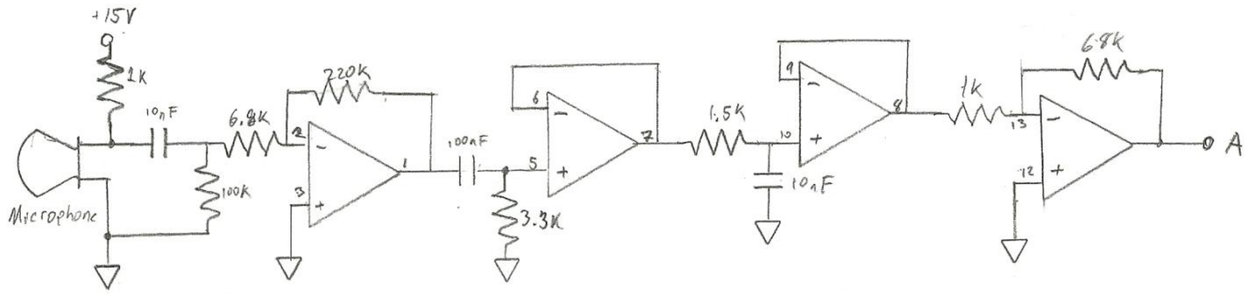

FIGURE 5 - SEISMIC READING SIGNAL CONDITIONING

Figure 5 above shows the schematic for the input into the frequency sensor that will be used to detect and measure the frequencies of the seismic vibrations.

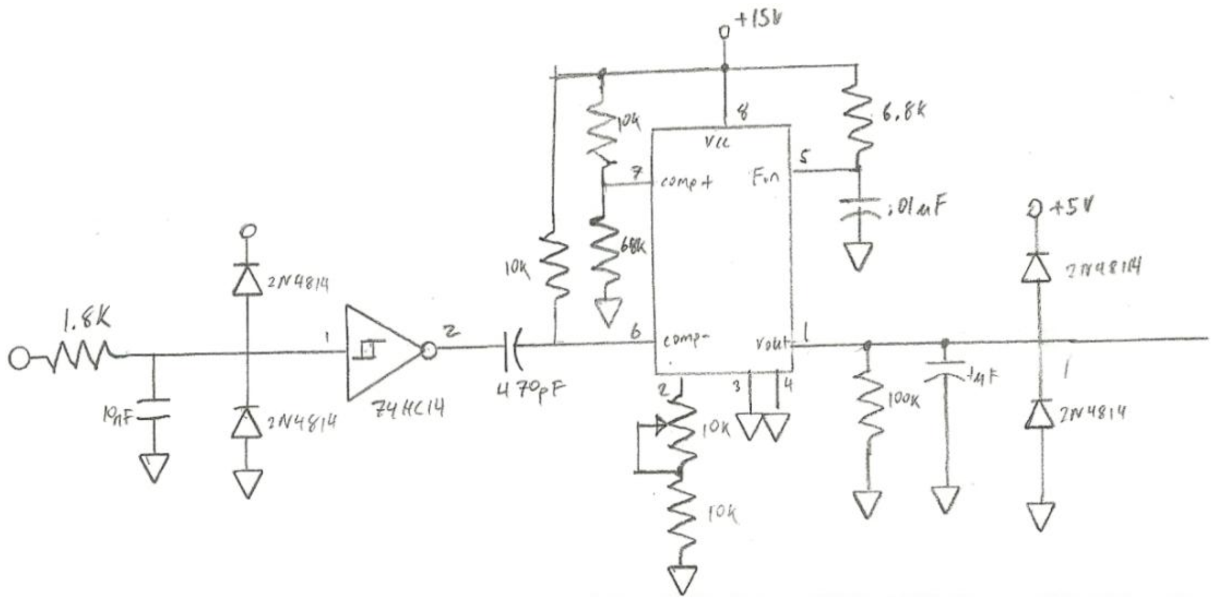

FIGURE 6 - FREQUENCY TO VOLTAGE CONVERSION

Figure 6 above shows the schematic for the frequency to voltage conversion of the frequency sensor. It takes the output from figure 6 and converts is to a voltage. The resolution of the reading is 20 Hz.

(Note the input comes from point ‘A’ on the Seismic Reading signal conditioning circuit)

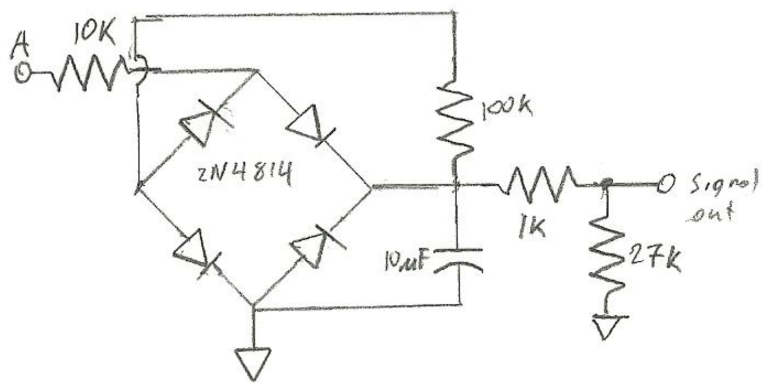

FIGURE 7 - AMPLITUDE CONVERSION

Figure 7 above shows this circuit used to determine where the frequency is being generated.

(Note the input comes from point ‘A’ on the Seismic Reading signal conditioning circuit).

The following section will detail the flow charts that represent the programming of the ROV.

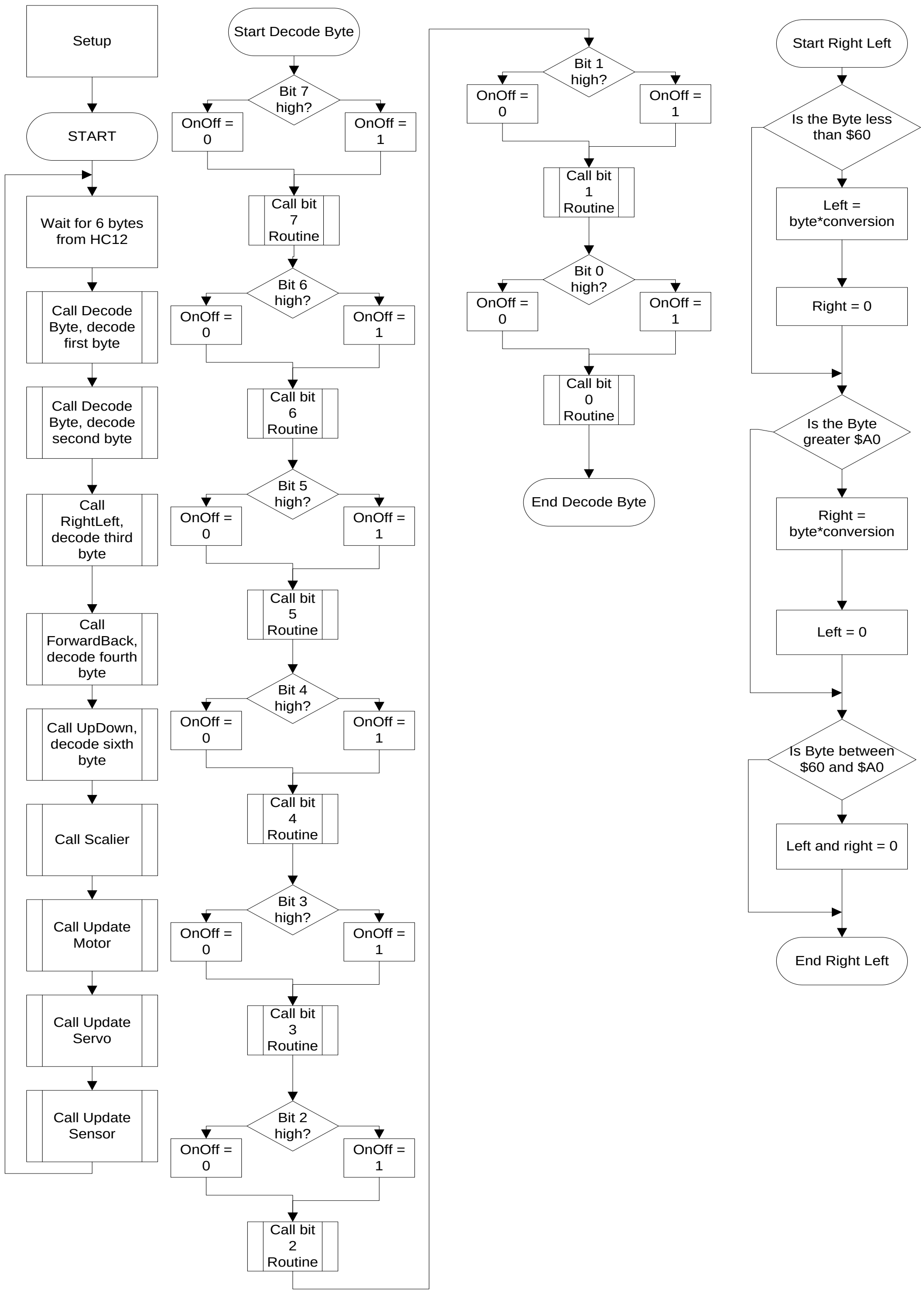

FIGURE 8 - ARDUINO PROGRAM FLOW CHART

Figure 8 above details the structure of the program code for the Arduino processor. This is a high level overview and the sub routines can be found in Appendix A.

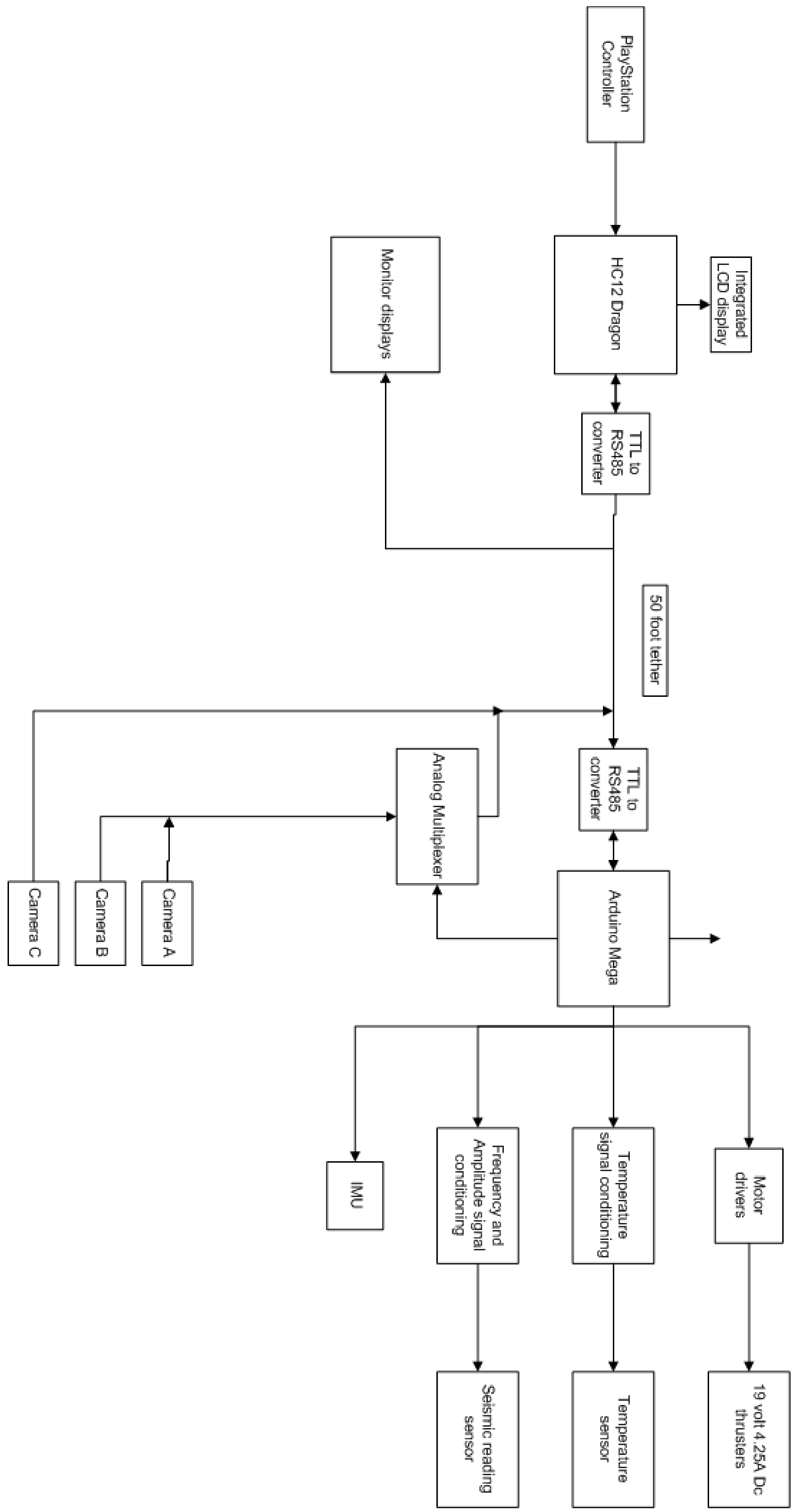

FIGURE 9 - BLOCK DIAGRAM OF THE ENTIRE CONTROL SYSTEM

Figure 9 above is a block diagram of the entire system. This diagram maps out how all the different processes for the ROV tie together to provide a functional control system.

DESIGN RATIONALE

Many different concepts were developed when the team was brainstorming about how to accomplish the objectives of the mission. Attached in Appendix A are a few of the different concepts that were considered but not selected.

The most important parameter in the design of the ROV was for it to be able to complete its missions; therefore, tooling was an important feature.

TOOLING CONCEPTS AND SOLUTIONS

After evaluating many different tooling concepts, the team decided upon the most basic concept that was generated. This involved a fixed arm with a claw at the end that was operated by a linear actuator. The claw would be fixed to a cylinder to be named "the oculus" which would rotate vertically. This concept was chosen because it required less motor integration that the other concepts and would present the least amount of complications due to its basic design.

AGAR RETRIEVAL

The next issue to be considered was how to collect a precise amount of agar and bring it to the surface. One idea to solve this issue was to use an auger to drill the material upwards; however, and the team decided that this idea required too many moving parts and too much complex machining. Another idea to retrieve the agar was to use a syringe to pull the material up; this idea was discarded after doing some testing on the agar itself and realizing that the material was simply too thick for a syringe to be used.

The selected concept involves a cylinder which has barbs on the inside of the exterior membrane and a check valve at the surface of the cylinder. This will attach to the end effecter on the arm and is designed to withdraw 175 ml of agar. This concept still needs a little bit of work before it is ready for competition because of a vacuum seal that is developed when the cylinder is inserted into the agar. This problem is yet to be solved.

FRAME DEVELOPMENT

Many different concepts were developed for the frame. They ranged from simple and blocky to a much more compact sleek design.

The simplest design was the "Vanilla" concept, a proven design used in industry. The problem with this concept is that it is very flat and boxy in appearance and is very un-hydrodynamic. This concept is shown below in Figure 10.

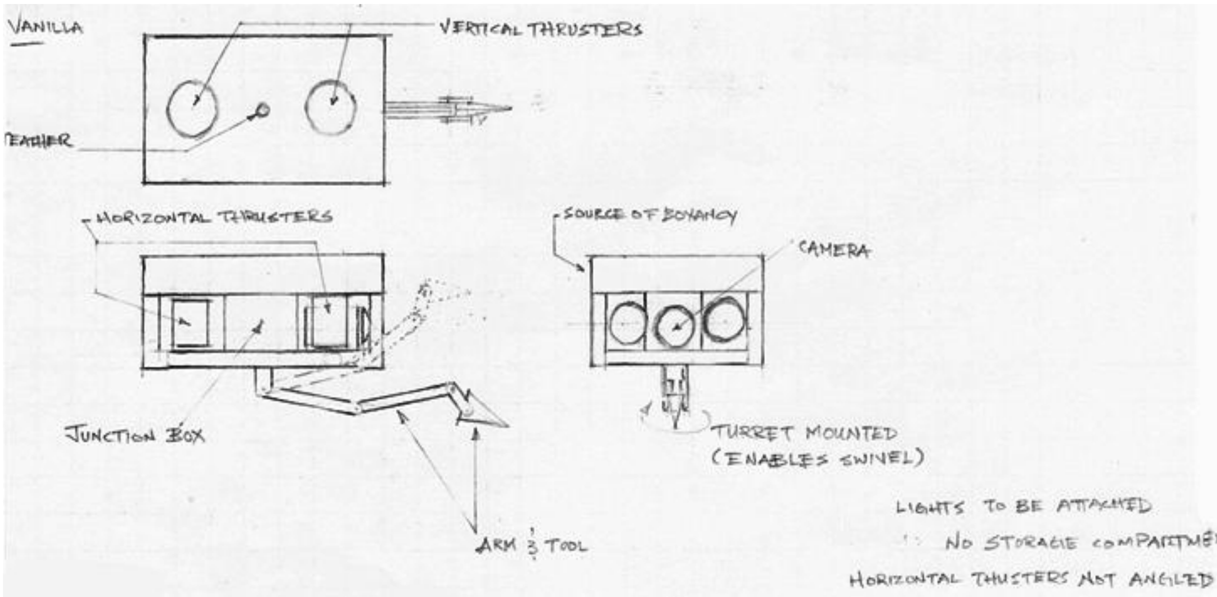

FIGURE 10 - CONCEPTUAL DESIGN OF THE VANILLA CONCEPT

Another concept considered for the frame development was the "Mako" concept. This design was very hydrodynamic and compact. The problems with this concept included difficulty to manufacture, slow vertical acceleration, and drag issues with the vertical cylinder. Figure 11 below shows a concept sketch for Mako.

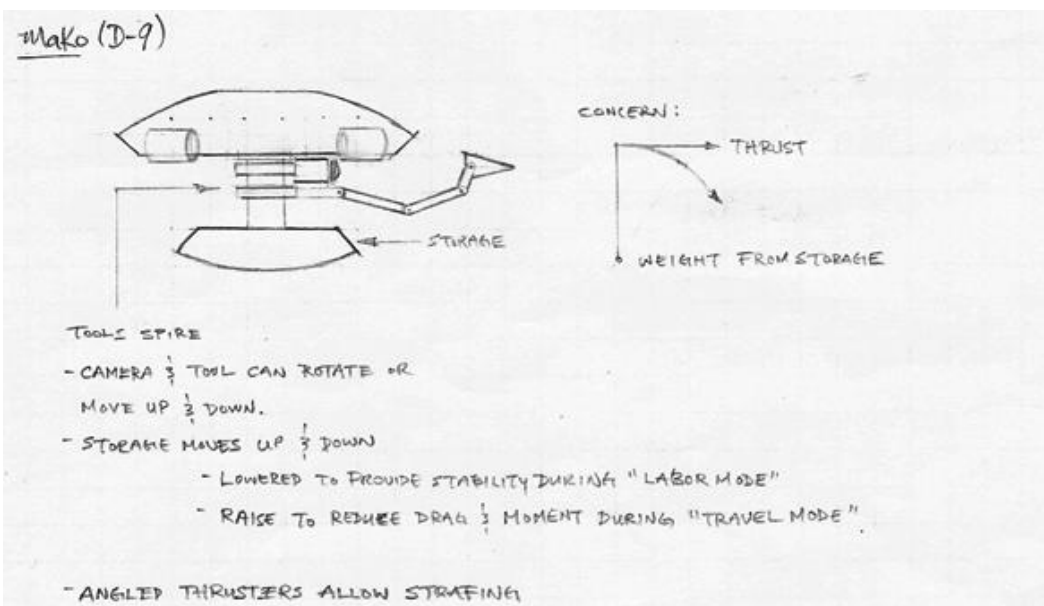

FIGURE 11 - CONCEPTUAL DESIGN OF THE MAKO CONCEPT

The chosen concept was the “Orca 2 revised” concept. This concept is a good compromise between manufacturability, hydrodynamics, manoeuvrability, and function. It features the “oculus” in the front that allows for good manoeuvring of the tooling, three thrusters that provide more than enough drive force, and has a great turning radius. Figure 12 below shows a concept sketch for the “Orca 2 revised.”

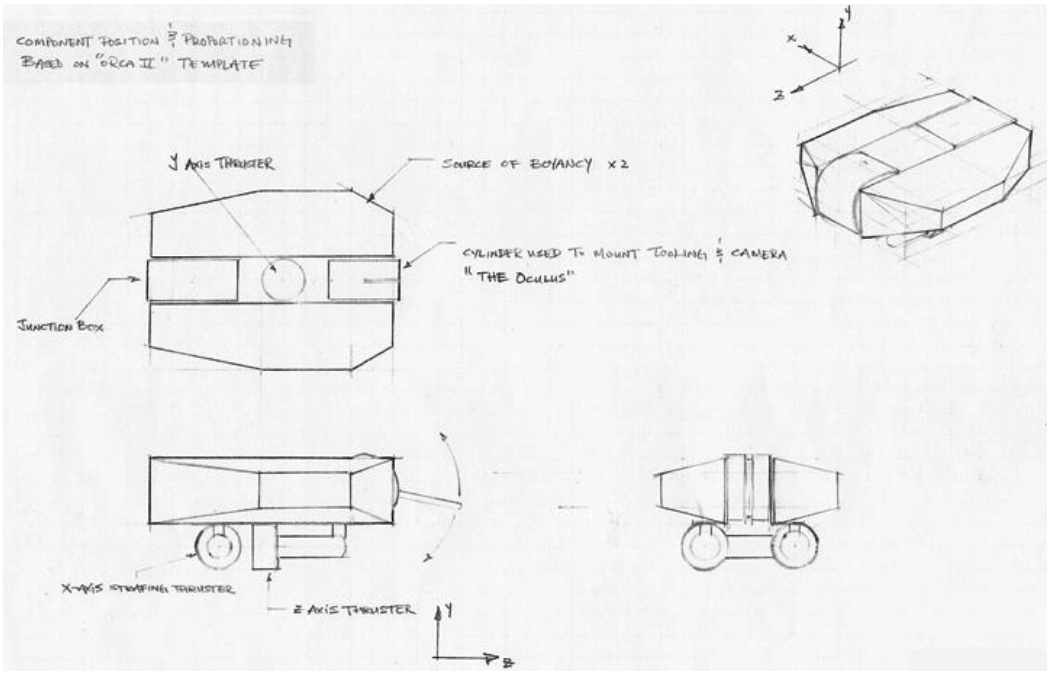

FIGURE 12 - CONCEPTUAL DESIGN OF THE ORCA 2 CONCEPTCHALLENGES

CHALLENGES

Our team experienced several challenges throughout the process of this project. One of the challenges was coordinating group work, tasks and activities among eight different members. This was made more difficult because not all members were in the same program and therefore had different availabilities. There were periods during the development of the project when the group was unable to meet as a whole for weeks at a time; this slowed down production and development as groups were unable to proceed to the next phase of development until all members were able to confer with each other about their decisions.

An example of a difficulty that occurred due to this issue was the selection of the motors. The team in charge of motor selection had decided to use servo motors to rotate the oculus; however, after doing research into the market, it was concluded that there was not much availability of waterproof servos and the group decided that they would try to use stepper motors to accomplish this task instead. Since the tooling group was unable to advise the controls group of this decision, the tooling group was unable to move forward with their decision and upon meeting with the controls group, it was decided that adding in stepper motors would add to the complexity of the control board and was best avoided if at all possible. After this meeting it was decided that non-waterproof servos would be used and the team would waterproof them on their own.

TROUBLESHOOTING TECHNIQUES

The best troubleshooting technique is foresight and the project team tried to anticipate any possible issues before they occurred. One issue that was predicted was the failing of the linear actuator during the qualifying round in Seattle. The linear actuator was manually waterproofed; this waterproofing was not tested at depths beyond 3 feet. It was known that this may become an issue; in preparation for this potential mishap, the team brought a hook-shaped mechanism that could be attached to the arm to accomplish the task of pulling the pin to free the hydrophone. Anticipating this problem was advantageous because before the event, the waterproofing did fail during a test run at a depth of 16 feet.

Not all issues can be thought about beforehand; so far, the ROV team has been both successful at predicting possible errors, and lucky for avoiding unforeseen issues. The best way to avoid issues is to spend lots of time testing out the different components of the ROV and the ROV as a whole. If any unforeseen errors arise during the competition, the team will brainstorm the issue as a group and use the same technique to troubleshoot it as was done previously during the designing process; the only difference will be the time available.

FUTURE IMPROVEMENTS

There are many improvement planned for this project. The entire frame of the ROV is in the process of being rebuilt out of aluminum. This is being done to ensure greater structural strength of the ROV as well as to improve its appearance.

The gripping claw was initially intended to be actuated by a linear actuator; however, since this failed on our qualifying round, the ROV team has decided to go with a more reliable system and will be changing this component to a pneumatic actuator.

The servos that will rotate the oculus and open the storage bin at the rear of the ROV have not yet been installed and this work will have to be done in the coming weeks.

Lastly, the agar collector is yet to be finalized and this will be one of the final changes that will be made to the ROV.

LESSONS LEARNED

In the future, we would improve initial inter-team communications. This would be done through the set up and use of professional communication software such as Microsoft SharePoint; this would enable ideas and updates to be shared quickly in real time. Centralized and real-time communication would improve compatibility of designs and helps teams stay up to date on recent developments in other areas of development without the requirement of exchanging USB sticks or time-consuming face to face meetings. Also loss of information would be minimized, if not eliminated, by using SharePoint because every member would have a copy of all files. This is a lesson that had to be learned the hard when synching files on USB sticks; for example, at one point during the project, the new files were overwritten by old work causing the loss of a day's worth of new work.

Aesthetics is an improvement that should be made the last priority but always kept in mind during the design process so that improving looks is relatively easy. Given that there is a month-long buffer between the final exam week and the Hawaii competition, there will be ample time in the future to improve the visual appearance of the ROV.

An important lesson learned is that when designing in a field like ROVs where team experience and knowledge is minimal, it is important to take the time to make a good design. Then despite having confidence in a single design, one or two alternates should be prepared so that if the first one fails, the alternates would be ready for consideration and further evaluation. Having multiple concepts to test and compare would immediately improve the speed of design and provide an opportunity for multiple team members' ideas to be tried and confirmed systematically rather than merely verbally rejected without adequate consideration.

A hard lesson to learn was that sometimes the design for a component or part must proceed even if it is dependent on unfinished results from another team. For example, a junction had to be designed but its size was dependent on the control system dimensions from the Mechatronics team. Unfortunately dimensions could not be ascertained from Mechatronics. Therefore, following the counsel of our advisor, our team had to arbitrarily decide on a reasonable size. This was crucial to the progression of the design of the ROV.

LOIHI SEAMOUNT

The Loihi Seamount is an undersea volcano, approximately 11 km x 5 km large, located 35 km southeast of the Big Island of Hawaii. Loihi was initially thought to be one of many extinct volcanoes around Hawaii, but a series of earthquakes in 1970 proved Loihi instead to be the youngest active volcano in the area.

In 1996, the island experienced 4,070 earthquakes, prompting scientists to study the volcano in more detail. Funded by the National Oceanic and Atmospheric Administration, Gary Mcmurtry, Francis Sansone, Alexander Malahoff and James Cowen participated in the first incursions into the seamount. They discovered Pele's Pit, a 300 m deep by one kilometre wide pit. Currents created by seawater flowing through the pit create dangerous diving conditions. However, study of the seamount and the pit is necessary in order to determine ecological effects of the volcano and also to monitor the volcano in order to predict future events.

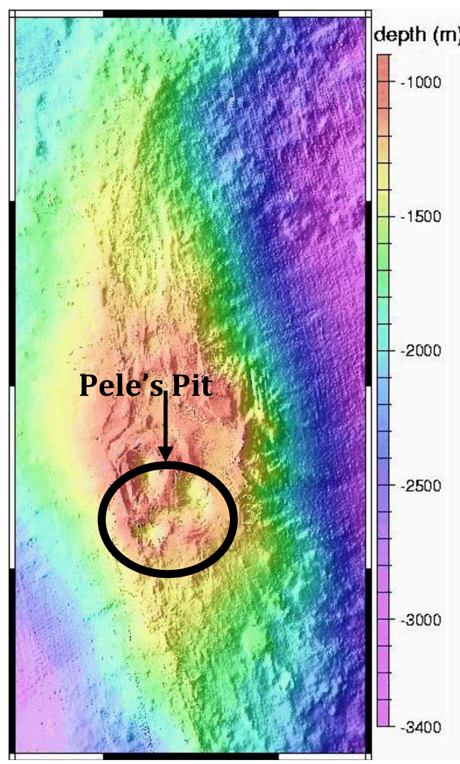

FIGURE 13 - BATHYMETRIC VIEW OF LOIHI

Hawaii Undersea Geological Observatory (HUGO) was built and then deployed on the seamount in order to monitor seismic activity, and provide chemical and visual information about Loihi. The observatory was connected to the surface 34 km via a 40 km long tether. Although HUGO was able to provide valuable data, the tether that transmitted this data flooded twice rendering HUGO inoperable.

Since then, the Hawaii Undersea Research Laboratory (HURL) continues to investigate the seamount. Its resources include the support ship R/V Kaimikai-Kanaloa, an underwater ROV (RCV-150) and two deep-diving submersibles (Pisces V and Pisces IV). With the aid of these underwater craft, HURL is able to collect data, sample organisms, and deploy equipment. At the same time, HURL is also working on repairing HUGO.

Due to the unsafe work conditions around the Loihi Seamount, unmanned ROV's are becoming more ideal for exploration of the seamount as there is no risk posed to human life. The need for ROV's that are equipped to perform tasks such as collecting samples of organisms, geological formations, and measure data such as temperature and frequency while maintaining a size that is capable of manoeuvre through caves and other types of confined spaces.

MATE promotes awareness and provides education to students and professionals about underwater technologies and methodologies used to help better explore, research, and investigate unknown undersea frontiers.

REFLECTIONS ON THE EXPERIENCE

This project has been a great experience for all group members involved. The members have all learned a great deal about teamwork, coordination, and project management. The different phases of the project offered different challenges and rewards. The design process was a lot of fun as all the group members spent a lot of time together bouncing ideas off of each other and finally came to a final design that all members were proud of.

Manufacturing the ROV proved to be a very time consuming endeavour. This phase of the project required the different team members to work a little more independently than the design phase with each member working more to their own strengths and helping each other out as able. The manufacturing phase was very rewarding because when we were finished we had an ROV that was ready for the water. This process is not completed yet as there are several revisions planned for the ROV that will be completed in the coming weeks.

Taking the ROV down to Seattle for the 2010 MATE Pacific Northwest ROV Challenge in order to qualify for the competition in Hawaii was a lot of fun. It was really interesting to see other teams ROVs and to share ideas with other teams about how to accomplish the objectives. Both Nick and James volunteered to help judge for the scout class teams, and they found that to be a very rewarding experience to see the amazing ideas that the young students are thinking up.

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ACKNOWLEDGEMENTS

The BCIT ROV TEAM 2010 would like to thank several people for their assistance with this project.

Thanks to our sponsor Taco Niet for his assistance and support throughout this project, it has been a great assistance to have someone so knowledgeable available to bounce ideas off.

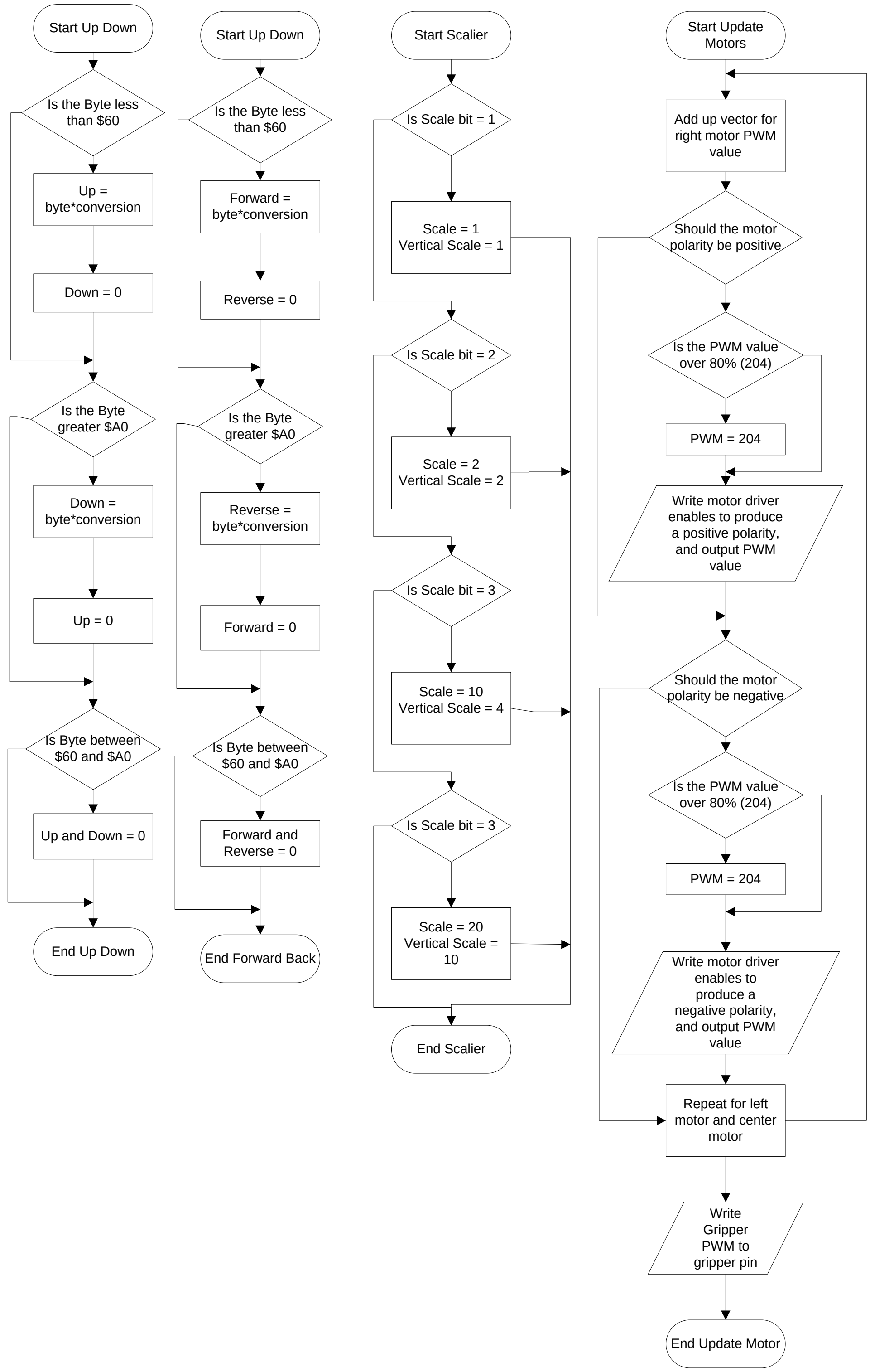
Thanks to Darlene Webb for her assistance with the writing of our technical reports that were written throughout the project, both for the MATE competition and for the course requirements.

Thanks to Dave Lewis and the staff at the BCIT machine shop for allowing us to use the equipment within, advice on different machining practices, and for the donation of most of the aluminum used for the project.

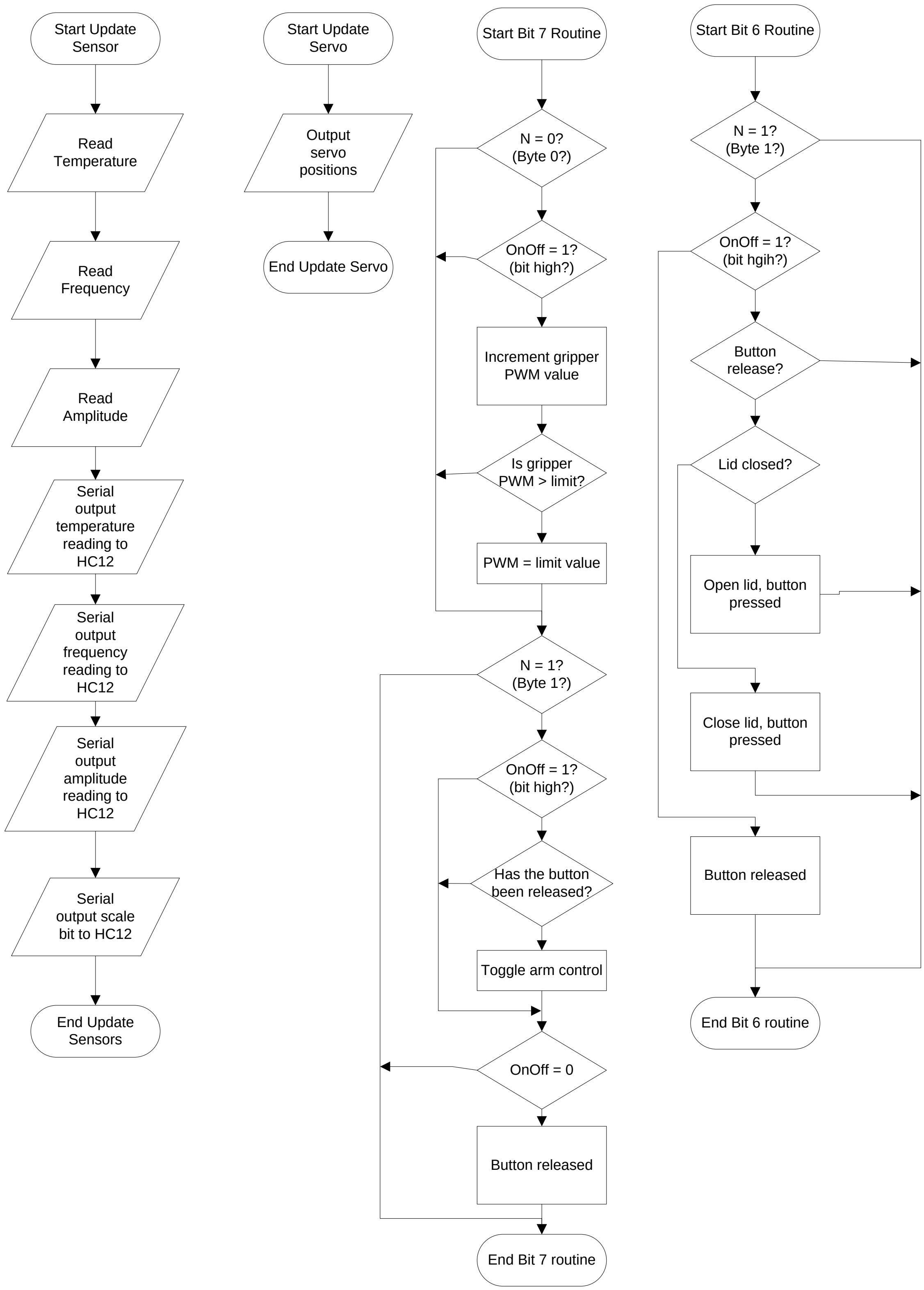
Thanks to Fritz Stahr and all the volunteers who helped put on the 2010 MATE Pacific Northwest ROV Challenge where the ROV was able to qualify for the international competition; this was a fantastic event that was well organized and was a lot of fun.

Last but not least, we would like to thank the MATE Center for providing us with the opportunity to work on this great project; it has been a fantastic learning experience and has given us a memory that will not quickly fade.

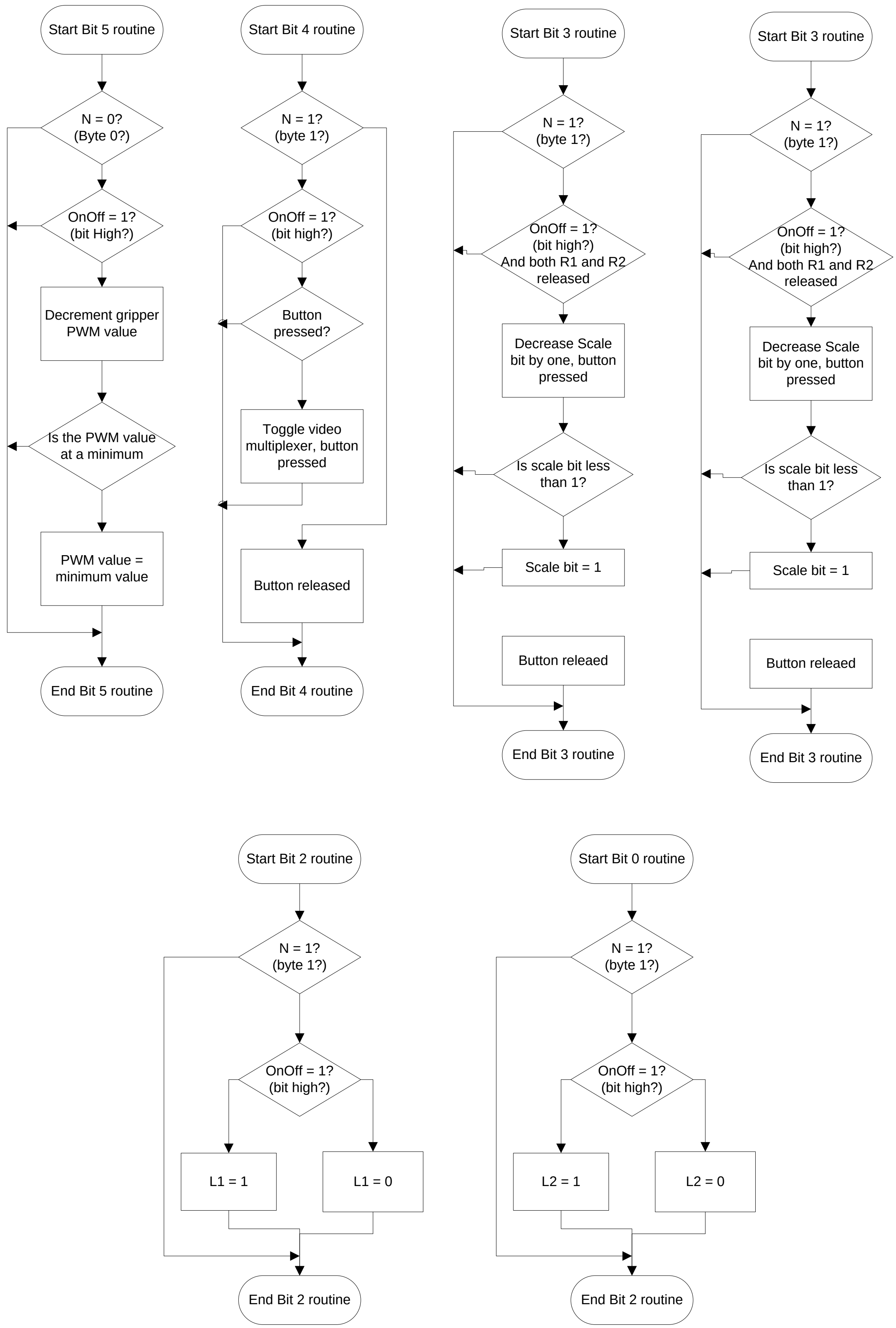
The following flow charts are sub-routines for the arduino processor.



The above flow chart details the processes for controlling the motors.



The above flow chart details the processes used by the sensors mounted on the ROV.



The above flow chart details the process for decoding the control buttons the controller used for the ROV.