University of Waterloo Underwater Technology Team

2008 MATE ROV Competition

Neo I Design

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1. Abstract

The University of Waterloo Underwater Technology Team ((UW)^{2}TT) has developed an underwater remotely operated vehicle whose components are designed to satisfy the goal of a highly controllable and highly intuitive system. The original design featured a unique six-degree-of-freedom control method, a head-motion-controlled pan and tilt camera mechanism, an eight-thruster propulsion scheme and an Industrial Steering Device (ISD) for position communication.

The remotely operated vehicle for the 2008 MATE ROV Competition, named Neo I, is an extensively modified version of the ROV that competed last year. Since the mechanical design was not largely field tested, the team made incremental mechanical improvements, such as the addition of a manipulator, the redesign of the internal chassis and back plate, the creation of a new camera positioning system, and the optimization of the thruster propellers. In addition, the robot now features an additional controller for a new manipulator and temperature probe. The software controlling the system has been redesigned completely, which includes all embedded code, communication protocols and the main controller architecture backend and GUI.

The team members of the University of Waterloo Underwater Technology Team have experienced significant design challenges and team structure changes this year, but many lessons have been learned. The team hopes to continue designing innovative technologies for many years to come.

2. Design Rationale

The University of Waterloo Underwater Technology Team strives for perfection in the areas of innovation and performance. For this reason, the team uses a two-year design cycle. The first year is intended for design, planning, innovation and construction; the second year is used to modify and improve the existing design based on past experience.

The team is currently involved in the second year design stage of the Neo I vehicle which competed in the 2007 MATE ROV Competition. Concurrently, (UW)^{2}TT is partway through the first year design cycle of Neo II, which will compete in the 2009 MATE ROV Competition. The following design rationale includes several details from the original design concepts, as well as philosophies and goals decided upon from the last year of experience and testing.

2.1 Design Concept Overview

During the early design stages of Neo I, the most common phrase that could be heard resonating from the walls of the robotics lab was “highly controllable and highly intuitive”. The origin of the phrase, later to be named the main goal of the vehicle, arose from research that showed how modern ROV’s are still quite bulky and have poor hydrodynamics. This, combined with a limited range of motion and poor control methods such as joysticks, provide the framework for designing Neo I. In the current revision, the team has retained these design philosophies, but has focused on increasing the robustness of the system and ease of serviceability.

For the 2008 MATE ROV Competition, the robot is required to complete three tasks. These tasks are to free an OBS from the seafloor, collect up to three samples of lava, and measure the temperature of hydrothermal vent fluid. Many of the new features of the ROV are tailored towards the completion of these tasks.

2.2 Control System

The motors are controlled using pulse-width modulation (PWM) signals through a board consisting of 8 H-bridges connected to two dedicated processors. The forces and torques that the user applies to the ISD are transformed into linear and rotational movements. A PID feedback control loop incorporating a 3DM-GX1 accelerometer unit is used to correct for unavoidable error produced by the thrusters. A computer feeds raw power values for each motor to the motor control board, thereby controlling the force produced by each thruster.

At the same time, the camera view is projected to the pilot's head mounted display (HMD). The pilot naturally adjusts the force that he or she applies to the ISD, correcting for over or under compensation to the ROV motion.The complex system is very robust and is able to adjust swiftly to changes in the system configuration.

2.2.1 Six-Degree-Of-Freedom Motion Capability

When conceptualizing the Neo IA, (UW)2TT's first vehicle, team members often thought of creating technologies that could evolve into more complex and dynamic systems as time progressed. All components were designed with expandability as an option.

One of these expandable technologies is the six-degree-of-freedom control method. Traditional ROV's are often only able to move with two or three degrees of freedom, which limit their ability to complete complex tasks and to navigate awkward terrains. The members of (UW)^{2}TT conceptualized the idea of a robot that could move and rotate in any direction. Neo I is slightly restricted by the weight and strain caused by the umbilical cable carrying power and communication lines, but despite this, the team has developed suitable control algorithms over the past year. Based on the success in this domain, it is thought that this is a viable control system for other underwater vehicles, particularly where wireless communication through water is possible.

2.2.2 Thrusters

The location and configuration of the thrusters was the most important factor to consider when implementing the six-degree-of-freedom control scheme. The robot must be able to successfully move in all six directions using as few thrusters as possible. The fewest number of thrusters that can be used to attain this goal is six. Adding more thrusters will not increase the controllability of the robot, but it will increase the power.

The design of the robot uses eight thrusters in total. The extra two thrusters provide redundancy should other thrusters fail. Maximum controllability is achieved by varying the direction and magnitude of the forces exerted by the thrusters.

Figure 1: Thrusters

The thrusters themselves were originally designed to handle a large amount of drag that would be caused by the wave and flume tanks. For the 2008 MATE ROV Competition, they have been redesigned to have a stronger focus on speed and power as opposed to controllability in complex environments.

Using elemental blade analysis, the optimal blade pitch was selected based on motor speed torque curve. These results were validated using computational fluid dynamics (CFD). The new propellers should provide more thrust than the previous design. The target thrust value was 10.0N, which has been exceeded.

Another strong design consideration for 2008 is the issue of securing the propellers to the drive shafts of the thruster assemblies. A design flaw caused the propellers to unscrew from the shafts and to come flying off in the water. In order to solve the problem, the blade gap between the blade tip and the shroud is reduced. Also, the blade hub length is reduced to allow for a pair of nuts to be counter-torqued onto the end of the shaft. The nuts should prevent the propellers from falling off again.

2.2.3 ISD

Due to the decision to use a six-degree-of-freedom control method, a device was needed that would allow a pilot to maneuver the robot. Many conventional ROV's use several joysticks and levers for control and operation. These devices are not practical or intuitive for a highly controllable system. The team required a device that would be able to capture forces and torques exerted by the pilot in any direction. These vectors can then be transformed into acceleration and velocity vectors for control algorithms.

The solution to the design problem is a device called an Industrial Steering Device (ISD). The device consists of multiple deflection sensors, that allow the pilot to apply forces and torques in all six degrees of freedom. The data is tranferred to the topside control computer though a RS-232 connection. The ISD is a highly intuitive device because the motion of the pilot's hand directly applied to the motion of the ROV.

Figure 2: Pilot Operating Robot Using ISD

2.2.4 Attitude Sensor

The attitude sensor is used to determine the orientation of the vehicle. In real-life situations, ROV's are often thousands of feet below the sea surface and the pilot cannot see the vehicle. The attitude sensor is used so that the pilot can understand how the robot is oriented. This information can help to determine if the tether is wrapped around the vehicle, or if the vehicle is in a position to perform its task.

The robot uses the MicroStrain 3DM-GX1 model because it is very accurate and has a simple interface. The inertial measurement unit (IMU), along with all of the other sensors located on the robot allow the pilot to easily control and understand the movement of the vehicle.

2.3 Vision System

The camera is one of the most important parts of the robot because it allows for the pilot to view and understand the tasks at hand. In order to navigate, the pilot must have a firm understanding of where he or she wants to go and how to get there. The vision system also helps the pilot to determine obstacles or threats to the robot.

Maintaining the goal of a highly controllable and a highly intuitive robot, the members of $(UW)^2$TT decided to design a camera system that followed the motion of the pilot's head. The system is designed so that the pilot can feel as though he or she is behind the dome of the ROV, traveling through the water *with* the robot.

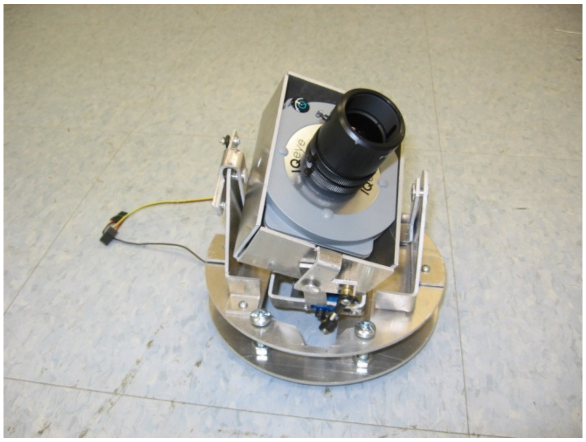


Figure 3: Camera Mounted in Pan and Tilt Mechanism

2.3.1 Camera

The camera used for navigating the underwater ROV is an IQeye 501 Ethernet camera. The IQeye 501 was selected because it has an adjustable iris and a large lens, so should be adept at imaging low visibility environments and providing high resolution images and video feeds.

The decision to use Ethernet as the communication backbone was based on its tolerance for faults and the availability of inexpensive high quality communication equipment. This communication channel allows the team to perform remote monitoring as well, which is extremely useful for expeditions to harsh environments and when reporting finding from expeditions.

2.3.2 Head Mounted Display (HMD) and Head Tracker System

The head mounted display is extremely intuitive for the pilot because it allows for the pilot to see exactly what the robot sees. The idea is that the pilot should feel as though they are moving through the seascape. The robot uses an I-O Display Systems Head Mounted Display which was chosen for it low cost and size.

As the pilot moves their head, the image he or she sees changes with the movement. A MicroStrain inertial measurement unit (IMU) communicates the motion of the pilot's head to the control computer via RS-232. The information is used to control the pan and tilt mechanism which moves the camera and subsequently changes the image. Thus, the image displayed moves in the same direction as the pilot.

The camera feed of the underwater images is overlaid with data regarding the state of the ROV at the topside and sent to the head mounted display. This provides the pilot with a complete picture of the current situation.

2.3.3 Pan and Tilt Mechanism

A pan and tilt mechanism was implemented so that a larger area could be viewed without having the move the entire robot. Moving the camera takes a lot less power than moving the entire robot.

The information from the inertial measurement unit located on the pilot's helmet is used to determine the orientation of the pan and tilt mechanism which controls the movement of the camera. The movements of the pan and tilt brackets are controlled by dedicated servos motors. The tilt bracket is nested within the pan bracket to prevent the camera from brushing against the edges of the dome. This nested device also ensures that the camera lens is kept in the middle of the plastic dome, which prevents image distortion.

2.4 Communication

Communication allows for all of the devices within the ROV to interact with each other to produce careful and controlled movements, to show accurate images, to display status information to the pilot, and much more. Without a solid communication system, all the innovation and thought put into the design of Neo I would be worthless.

The most important feature of the Neo I communication system is the Ethernet data transmission capability. The control computer sends and receives information via two twisted-pair wires to an onboard serial server. The server then handles the communication between the topside control computer, the Ethernet camera, and the RS-232 boards.

2.5 Power

For this year's competition, the team is required to use the battery power supplied by the competition organizers. A 120VAC power connector is permitted for the control electronics at the top. These two systems have been completely isolated from each other at the top, and all power transmitted to the ROV comes through the battery terminals. At the bottom, the robot uses a DC-DC converter to step the 48V down to 24V for the motors. The step down enables the robot to transmit power more efficiently down the umbilical. In addition, all the electronic components are powered through a switching power supply. The supply can deliver -12V, 0V, +5V, +12V and +24V to any system inside the can.

The power is delivered through a bus system at the bottom. Thus, all boards are interchangeable with other boards for testing or debugging purposes.

2.6 Safety

In any system with high currents and voltages, the primary concern must be the safety of the operators and observers. As per competition rules, the robot uses a 40A fuse directly in line with the battery. There are additional fuses on the electronics power and on each motor. For emergency protection, a breaker relay is used for the topside control box. The power to the vehicle is controlled by a push-to-make wireless remote receiver, as well as a push-to-break emergency kill switch. The rationale behind the idea is that any person can activate the main emergency switch. Also, one of several people will designated have access to a wireless key fob that can cut all battery power in the case of an emergency.

2.7 Software

The software architecture is a client-server architecture with a server holding variables. Each client may receive or set variables over a TCP/IP connection. Each client handles one particular task and can be restarted if it fails for any reason. For example, one client speaks to each piece of hardware (sensors & manipulator controller board, motor board, pan & tilt board, inertial measurement unit, and steering device), one control algorithm client responsible for setting the motor values, and a display client for displaying status. The video feed is completed externally to the server for efficiency reasons.

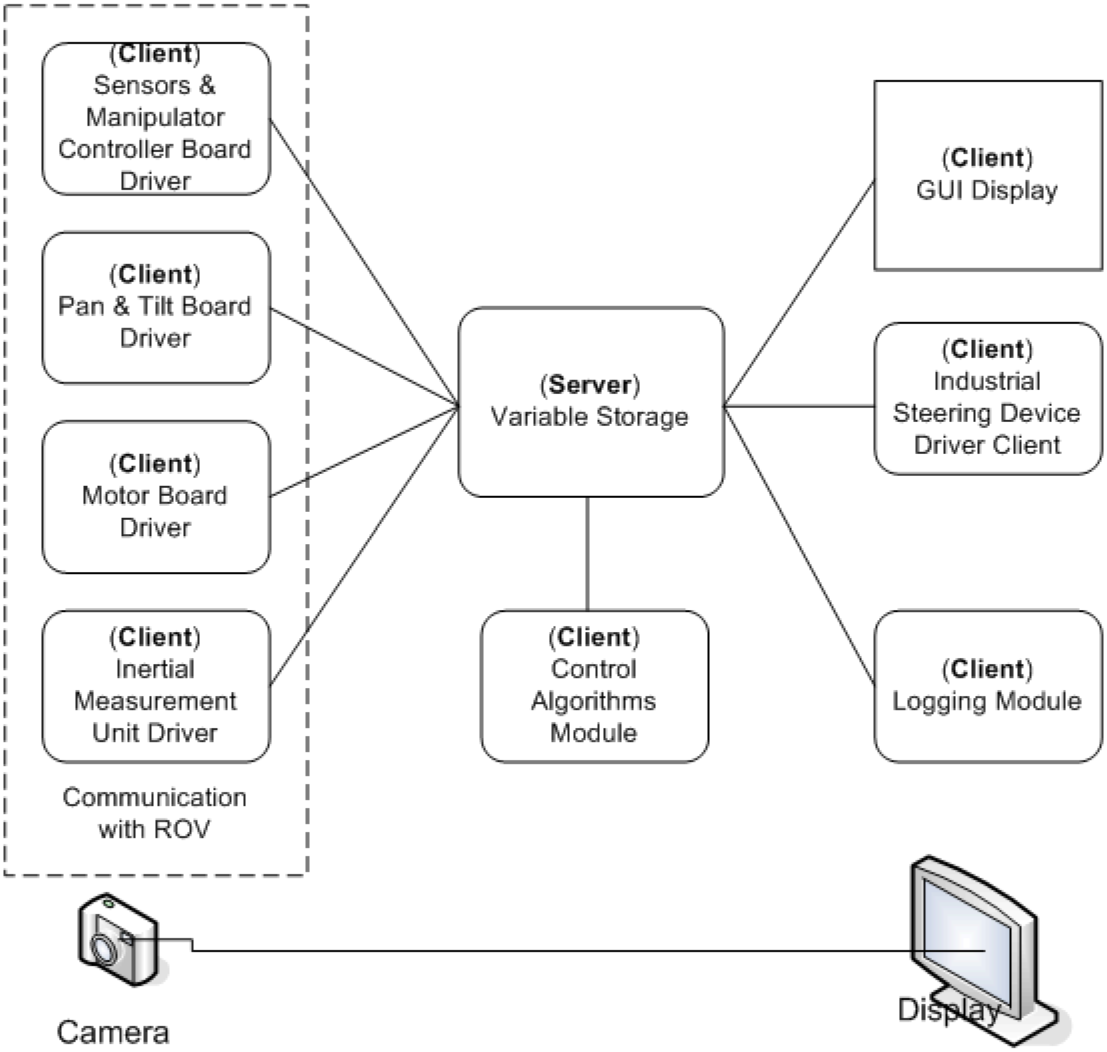


Figure 4: Software Block Diagram

Each of the driver clients that communicate with the ROV sends their data using a custom designed protocol that sends changes to values instead of sending the entire values all the time. This allows for better utilization of the communications channel and for faster response times without sacrificing data accuracy to any significant degree.

2.7.1 High-Level Software Architecture

The main goal for the software system is to achieve maximum fault tolerance while still providing a responsive system. To this end the team designed a modular system that allowed for each piece of the module driver code to run as its own process. The process is able to fail and be restarted without requiring a restart of the entire system. The application core is very small, robust and fast, and as a result, system failures have been minimized.

Another goal for the software system is to de-couple the control algorithms from the user interface and hardware drivers. This allows the control algorithm to run without having to wait for the screen to be refreshed or for a sensor to respond. The control algorithm simply takes the most recent data from the server and adjusts the ROV controllers. The advantage is that in the absence of a pilot at the controls, the ROV maintains its current state, and a pilot's input serves only as stimulus for changing the ROV's position or velocity.

2.7.2 Communication Protocol Design

The streaming protocol used to compress data is designed to be fault tolerant by including error checking to avoid processing bad data. In addition, the protocol is designed to keep communication frames matched to the transmission block size when, which allows for easy recovery from a missing frame. As a result, the main communication protocol is also robust and can tolerate several missing frames of data.

2.7.3 Software User Interface

The graphical user interface is designed to allow the user to view any value he or she wants at any time. Also, critical values, such as temperature, are displayed in graph form so that the user can view the history. History is important because it allows for the user to notice issues early on.

The window consists of three tabbed panes: graphs, values and video. The first pane contains three graphs arranged vertically. A temporary array containing the history of the value is set to advance every time the graph repaints.

The values pane simply contains multiple text fields with corresponding value labels. The refresh rate can be varied. Lastly, the video pane displays the streaming video being sent from the IQeye 510 Ethernet camera. The video can also be viewed via a separate application provided by IQeye.

2.8 Temperature Gauge

The temperature sensing device used is a negative thermal coefficient (NTC) thermistor. A NTC thermistor is a type of resistor where the resistance varies inversely with temperature. A thermistor is an attractive choice because it can be obtained inexpensively, will meet the required accuracy and size specifications and can be purchased in watertight housings. The circuit design for the temperature sensor considers the temperature dependences of the all the components. National Semiconductors LM 234 adjustable current source is used to accurately regulate the amount of current flowing through the thermistor. This current source has an inherent positive temperature drift of 0.33% per degree Celsius. To cancel the temperature dependency, a diode with a negative temperature dependency is added in series with the current source.

The voltage is monitored by a PIC microprocessor at the top of the thermistor. Since the current is fixed and the resistance changes with temperature, the voltage that the PIC sees varies with the inverse of temperature. The current magnitude was chosen to allow temperatures over the range of 0 to 60 degrees Celsius. As a precaution, the sensing circuit is buffered from the PIC microprocessor.

2.9 Manipulator

A claw has been designed to grasp and manipulate objects while underwater. The goals are to keep the manipulator simple in design and to ensure that the claw will not damage the objects it holds. The claw is simply connected to a beam that attaches to the bottom of the robot using a U-beam. In order to open and close the gripper, an actuator is controlled by a waterproof motor which pulls a steel cable.

In order to prevent damaging objects, the claw has been designed to have a tooth-like surface. This design was considered specifically to avoid cutting cables with the gripper. There is also a small tooth on the front of the claw which can function as a scoop when fully opened.

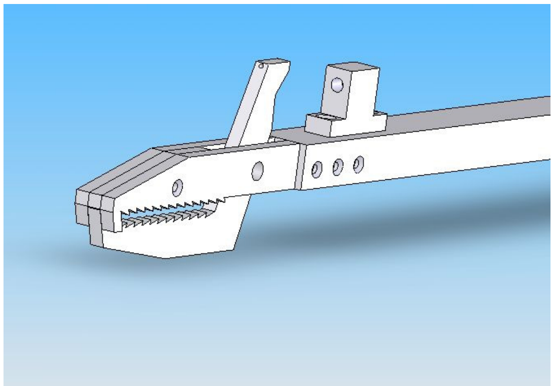


Figure 5: Manipulator

The arm was also designed so that it can be remounted on its side to accomplish different kinds of tasks.

2.10 Body, Frame and Connectors

An assembly containing a housing, a back plate and a clear plastic dome are used to hold the internal electronics that control the vehicle. The pressure vessel can be safely submerged to up to 61 meters (200 feet). The depth rating was determined through finite element analysis (FEA) in ANSYS and analytical calculations in MathCAD. The can was created by rolling an aluminum sheet and machining end flanges.

Due to the high cost of underwater penetrators and connectors, $(UW)^2$TT has designed and built their own connectors. The material used for the penetrators is brass hex stock. The connectors need to be waterproof, and thus two seals are used.

Also, a mold was created in order to pot additional connectors. Each connector takes twenty-four hours to set, and thus scheduling was needed to ensure the body of the robot was ready for competition.

3. Challenges Faced

3.1 Challenge 1: Redesign of Internal Layout and Back Plate

Apart from the initial completion of the design, maintenance is of significant importance. Just as the initial cost of a personal computer is much less than its overall cost of upkeep; the maintenance of the design must also be taken into consideration.

The back plate of the ROV is the main interface between external ROV components and accessories, and the internal electronics. Given that the electronics are concealed underneath a difficult to disassemble enclosure, debugging, repairs and troubleshooting become difficult. Durability is another key aspect of the back plate design. Thru-connections must be firmly strain relieved in order to accommodate the various tensions that will be induced by components and constant reassembly. Amalgamating these two constraints produces another issue: space. Retrofitting of components is required to reduce assembly and redesign costs, while providing an elegant solution.

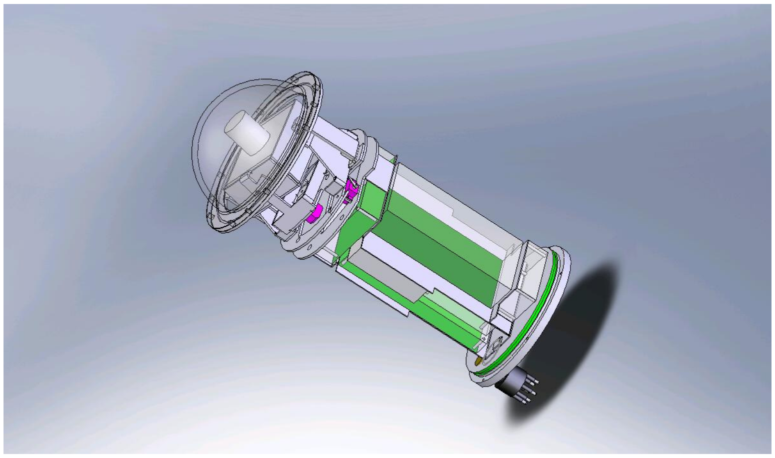


Figure 6: Internals and Back Plate Redesign

The prior three constraints were made apparent in three subsequent design challenges. The initial design rationale was to redesign the back plate to be more durable. In the past, the custom-made brass-epoxy connectors were lacking in the area of strain relief. To solve this problem and to allow for the expansion of other accessories, a new thru-connection and connection strategy needed to be found. As a result, other concepts were implemented into the design.

Of these, accessibility was the next greatest. Prior disassembly of the electronics core required the removal of the ROV frame, so that the electronics core could be removed from the rear of the vehicle. This was a timely task that could possibly destroy chances of repair in emergent situations. In order to solve this problem, the electronics cluster could emerge from the front of the enclosure. However, all of the external connections were at the back of the unit. Thus, extra space in order to have the internals pulled out from the front.

The initial idea was to have a pluggable connector embedded in the enclosure, so that the electronics core need merely be pushed in and rotate-locked. Due to complications and custom connector design, this idea proved to be a great task to complete within the allotted time.

Thus, it was decided that the cables would be connected to the core, and disconnected once the core was removed, also allowed live debugging of internal electronics. This concept required more space, since extra cable needed to be contained within the unit.

Thus, the internal electronics board was redesigned around existing components. This redesign of the internal layout proved to be the mode time consuming part of the project, since every part needed to be precisely molded, and rearranged in a vast regress of combinations. Finally, the design was completed and assembly of the components clarifies whether the design and cooperation with the group proved to be correct.

3.2. Challenge 2: Redesign of Pan and Tilt Mechanism

The pan and tilt mechanism is one feature that makes the $(UW)^2$TT robot unique. The mechanism is able to move an Ethernet-guided camera through the motion of the operators head movements. When the cameraman looks left, the camera moves left. When they look up, so does the camera.

During testing prior to the 2007 MATE ROV Competition, the team found that the edges of the camera were rubbing against the sides of the plastic dome. This slowed the movement of the camera and endangered the internal electrical system from the weakened plastic dome. The challenge presented was to shorten the height of the pan and tilt mechanism, without compromising the movement of the camera.

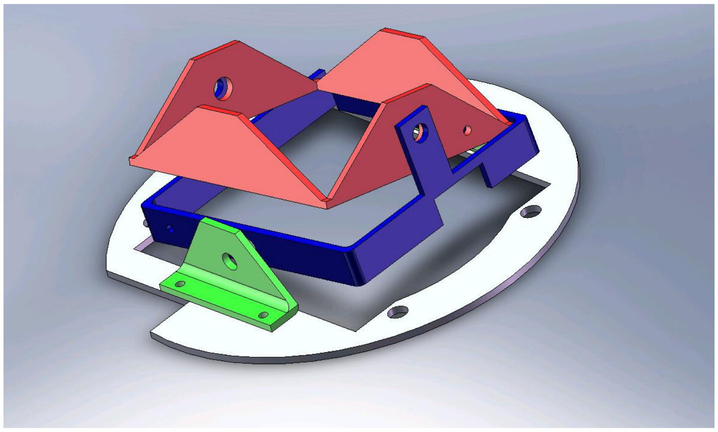


Figure 7: Pan and Tilt Redesign

The previous design from the 2007 Competition featured the pan bracket on the bottom and the tilt bracket resting an inch and a half above. The two movements did not interfere with each other because they did not come into contact. The new idea was to nest the two components. That is, the pan bracket would be widened just enough so that the tilt bracket could move inside of it.

There were several smaller challenges involved in this task. First, the brackets were made in-house using shearing and bending devices. One piece needed to be bent into a rectangle, but our machines did not have the capability for this. The solution to this problem was to make two angled brackets and then epoxy the corners together to make the rectangle.

4. Troubleshooting Techniques

4.1 Embedded Coding and the Value of a Hardware Debugger

One of the large problems associated with programming embedded systems is that when there are logic errors in the code, it can be very difficult to isolate the line of code that is causing the error. Often, one has to rely on turning on or off LEDs to indicate the current execution point which is a very slow and tedious process.

Fortunately, we use the PIC18 and dsPIC series of microcontrollers from Microchip Inc. Using their ICD (In-Circuit-Debugger) and the MPLAB IDE, we are easily able to trace troublesome code, insert breakpoints in key locations and watch important variables and registers. This makes the embedded code development process significantly faster.

As with any tool, there are situations where it is useful to be aware of the limitations of the tool of choice. Using a hardware debugger often means that data loss and broken synchronization do occur if the code being debugged relies heavily on hardware and software interrupts, or the timing of a section of code is particularly strict. This issue plagued the team when developing the embedded code on the motor controller board and cost a significant number of hours of work. This particular situation required the use of the LED indicators in addition to the debugger.

4.2 Using GDB to Debug Software


Figure 8: Software Team Troubleshooting

All of Neo I's control code is written in C and compiled using the GNU compiler toolchain for Linux based systems. For reliability, the code runs a central server connected to driver module code that runs in isolation and uses the TCP/IP network loopback device for inter-process communications. While this architecture is robust and relatively easy to adapt to different system configurations, it can be very complex to debug.

The GNU Debugger, GDB, is very useful in this regard in that it can be attached to processes that are currently being executed to probe for errors. During the process of developing the central server application, several members of the team became intimately acquainted with GDB and various frontends for it.

4.3 Using Serial Terminal and Python to Troubleshoot Communication Issues

The most useful tool used in the software design is the command-line interpreted scripting language Python. It possesses an extensive array of libraries to create serial connections, hook into kernel level drivers and process large quantities of data; all this using a syntax that can be mastered in 30 minutes. If it were not for the relatively slow execution speed, it may have been recommended as the language to write the main application code in.

There were a number of scripts written which tested the limitations of the communications protocols, and assisted with communication debugging. The team used Python to perform the first set of tests on the motor drive board, the pan and tilt board and for calculating the coefficients initially used to control the motor speeds. The reliability of the tool is unprecedented, and it will continue to be used in future software development.

5. Lessons Learned and Skills Gained

The past year has been filled with a lot of change for the University of Waterloo Underwater Technology Team. The previous group leader and founder moved on to graduate studies. As well, our previous mechanical and software leads also moved on to focus on upper year projects and studies. One of the most important lessons learned is the need for continuity of the team. Following the 2007 MATE ROV Competition, a recruitment effort was made, which resulted in the addition two mechanically inclined students and several students skilled in software development. From this group came the team's current Mechanical Lead and Software Lead.

The software situation from the previous year was in a mess. Much of the code was written in C#, which was a language largely not understood by current team members. In addition, the code was poorly documented and difficult to comprehend. Thus, a large amount of existing code had to be disregarded to reprogrammed.

In addition, large delays were produced at time due to the lack of mechanical experience and previous documentation. For example, the plastic dome on the vehicle was broken and there was no existing record of where the item was ordered from. Projects such as the pan and tilt redesign and back plate redesign were behind schedule due to limited experience and skilled workers.

In order to ensure that previous mistakes are not repeated, an online storage space has been created on Assembla.com where all previous designs, code and documentation is stored. Also, records have been created to document where parts are ordered from, and who to contact for reordering. Team leads are also now encouraged to consider who will be following them when they too have moved on, so that new team leads will have previous experience with the team in the future.

New skills have been developed in all team members. These skills vary from modeling designs using 3D modeling software, to programming complex algorithms to control component operation, to leading a group of people to accomplish a common goal. All members of the team hope to continue learning and teaching to ensure that new skills continue to develop.

6. Future Improvements

6.1 Electrical System

In order to make the next ROV, named Neo II, a success, there are many things that can be done to improve the electrical system.

First of all, in order to increase speed, fiber optic cabling could be use instead of a twisted pair for communication. To increase the speed of streaming video, it would be beneficial to implement a video processing board. Currently, the best option appears to implement a video processing board in FPGA.

Already in progress is a controllable lighting system for the ROV. The team decided to simply use dive lights for Neo I, but hopes to use a controllable LED array for Neo II next year.

To better monitor the forces generated by the thrusters, it would be beneficial to redesign the motor controller to include current monitoring and encoder feedback. Also, the electrical housing should be more easily accessible in the future. A possible option could be to have a side window that could be opened if repairs or modifications were needed. This would prefer having to remove the entire housing.

In order to save time and funding, it may be beneficial to the team to aim for a lower depth rating. The current ROV is rated for a depth that is much higher than needed for the MATE ROV Competitions.

6.2 Mechanical System

For the first time this year, a manipulator has been successfully implemented into the ROV design. The gripper could be improved to include several more degrees of freedom. Instead of needing to move the entire robot in order to reach and move an object, an extendible "elbow" could be implemented.

Also, issues involving buoyancy could be improved upon. When the robot lifts a heavy object from the ocean floor, the robot is no longer neutrally buoyant. To compensate for the shift in mass and center of gravity, a variable buoyancy system could be implemented. The system would require that air be sent to the robot through a second umbilical.

Lastly, the amount of viewing area could be increased by using multiple cameras. Because the robot is able to move in multiple directions, it may be useful to have a camera on the front and back of the robot. Perhaps cameras on the bottom on the robot could help the pilot to understand the terrain much better to ensure that all is safe for the robot.

6.3 Software

The software side would also benefit from having the processor located inside of the ROV. This would free up processing time on the computer above and reduce communication latency between the ROV and the computer. The resulting reduced latency would allow the ROV to have a more effective stabilization from the inertial measurement unit.

Another improvement could by making the video processing more efficient. The current video display has a significant delay and consumes a large amount of bandwidth and processor time on the computer.

7. A Scientist or Research Project that Uses ROV's to Study Mid-Oceanic Ridges

From February 19 to May 30, 2003, researchers from the Monterey Bay Aquarium Research Institute explored the Gauymas Basin with the ROV Tiburon in order to investigate the fauna and processes at work in the deep sea outside of Monterey Bay ("Mission"). This article will focus on Leg 2 of their journey, which focused on investigating the differences between high-temperature hydrothermal vents and low-temperature vents. The coordinator for this leg of the expedition is Dr. Debra Stakes and the Mexican collaborator is Alejandro Ortega Osorio ("Leg 2").

The Guaymas Basin was formed from the spreading of the East Pacific Rise which occurred approximately five million years ago. This shift caused a small portion of the earth's crust to drift apart, which formed the Gulf of California. The rise continues to spread, which takes place along continuous ridge segments that are separated by transform faults. One of these short spreading centers is located in the Guaymas Basin. The basin is different from much of the Mid-Ocean Ridge

Figure 9: Guaymas Basin

because of the large layer of sediment made of mud and sand which completely covers the seafloor ("Missions and Objectives").

There are many important features of the Guaymas Basin which are crucial to note. The mineralogy and chemistry of the mineral deposits, vent fluids, and subsurface are unique due to the interaction of high-temperature fluids and the large amount of sediment mentioned above. In addition, petroleum is formed from the large amount of heat without the act of oxidation.

The equipment used in Leg 2 of the expedition included a temperature probe, a water sampler, a Homerpro acoustic marker, push cores, a ISUS/Eh sensor, and two data loggers. The second leg began with the deployment of a thermocouple array at the "Busted Mushroom" site. The Tiburon ROV was able to measure a temperature of three hundred degrees Celsius from a pool beneath the deposit. The crew continued to monitor the temperature of the thermocouple array. In addition, the team watched chimneys - tall columns of solidified minerals on the ocean floor – grow over the next few days. Many other tasks were completed to help the team determine fluid chemistry data, mineral composition, the distribution and characterization of trace and precious metals, the nature of the hydrothermal deposits and more ("Leg 2").

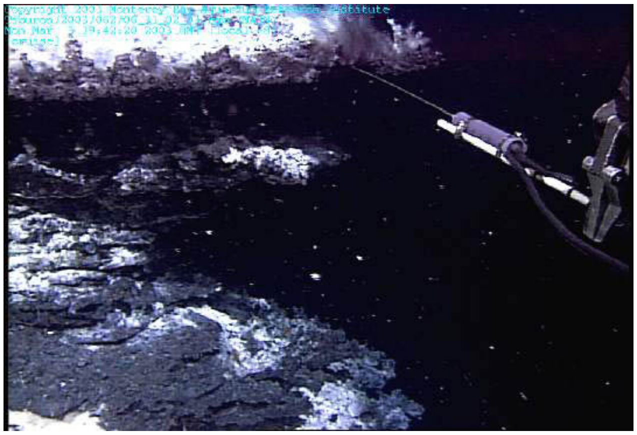


Figure 10: ROV Tiburon Image - Temperature Sensor

In a research paper from the Journal of Environment Microbiology, the team recorded their findings and conclusions. One section explained the nature of the site with respect to temperature. At the Broken Mushroom site, the thermocouple array detected a temperature that was higher than 200 degrees Celsius within six hours. The high temperature indicated that the thermocouple had been surrounded by mineral precipitates and was not in contact with cool seawater any longer (Page, Tivey, Stakes, & Reysenback). Other observations were made that are beyond the scope of this paper. Please see Section 9 for more information.

8. Reflections on the experience

8.1 Team Mentor: Jason Gillham

The 2007/2008 ROV Competition Season for me involved transitioning from my role as team leader into a mentorship position. Having founded the team in 2005 and graduated in 2007, I had a strong interest in seeing the team successfully continue. Over the past two years a strong group of technically minded individuals came together to successfully develop some unique concepts for the University of Waterloo ROV. For a successful transition both this year and in future years a succession plan would be required. To that end it was not one of the more senior and older technically strong members of the team that took over (as is often the case with student teams) but rather a newer and younger member who was charged with leading the team in my absence. By placing younger members in this roll, it gives them time to understand the technical aspects that are required for design while allowing current senior members to focus on technical aspects of the project rather than dealing with daily operations. The goal is to again transition management of the team to a younger member when the current team leader is in their third year, allowing a period of time for the new team lead to adjust to the roll while drawing on the current team lead's experience and allowing the current team lead to utilize technical knowledge she has gained over her years with the team.

With my transition from team lead to mentor, understanding the appropriate level of input from a mentor was one of the challenging aspects of the position. In this roll I focused on not providing a solution but rather directing students towards a potential solution through questioning of their current designs and direction. This approach ensured that they learn and have complete control of technical and administrative decisions. Ultimately it is more important for components to fail and students to learn than having mentors direct the decisions as a means of ensuring success of the system.

8.2 Team Leader: Julianne Kline

The past year has been full of a lot of new experiences for me as I settled into my new role as Team Leader for the University of Waterloo Underwater Technology Team. I found myself having to learn about new systems, politics, funding, and about how to lead a group of extremely intelligent individuals.

Overall, I have learned a lot, from how to create assemblies on SolidWorks, to how to put finances in order, to how to send six people to the other side of the continent. It has been a great year and I am very grateful to have worked with highly motivated and highly intelligent team members. Thank you to everyone who has helped to make Neo I a reality for a second year in a row.

8.3 Electrical Lead: Nick Ford

My experience with the team has been a bit different from that of the others. I was one of original members of the team when it was created three years ago. I have witnessed the first design proposal, assisted with the first iteration of the design, and seen that both the team and robot grow throughout the years.

At the beginning, I initially worked on several smaller boards and was soon surprised to be thrown into the electrical lead position. I found myself having to development management and leadership skills that I did not have at the time. I was able to pick them up along the way and am now fully confident in my abilities in teaching and leading.

Over the last year, I have worked with the other team members on the new software architecture, on some mechanical aspects and of course on tweaking the electronics. I have had the honor of working with a number of great people and I hope to see the ROV project move forward at the same pace as I graduate from the University of Waterloo with a BASc in Electrical Engineering early next year.

8.4 Mechanical Lead: David Mikolajewski

After working a co-op term at Aquatic Sciences Inc. (ASI), a company that provides a number of products and services for water and wastewater applications, I was very eager to apply my new skills to $(UW)^2$TT's

ROV. When I returned from my co-op term, I found a team that was lacking mechanical experience and needed a lot of help in making their robot perfect. I was more than prepared for the task.

Over the past few months, I have learned a lot about improving old systems to work more effectively with other components. I have also gained a new understanding about user usability. Often, we design systems to complete a task, without thinking about how we are going to use the system. I now have a renewed understanding of how robots interact with humans.

8.5 Software Lead: Nathan Buchanan

This has definitely been a learning experience for me. Throughout the past year, I have gained a better understanding of embedded systems and of the electrical design used. However, there are a few areas for improvement that I have noticed.

Due to the co-op work program at the University and the busy schedules of the teammates, a better communication system is needed. This could be done by having all mail sent to the mailing list, instead of e-mails being sent only to the people the information pertains to. We also need to improve on issues such as planning and splitting up work more efficiently. This includes being able to anticipate issues such as exam periods and students relocating due to co-op jobs.

Personally, I feel as I could also improve by specifying how software systems will work or asking for full specifications from team members. I feel that I have micro-managed a bit too much. In addition, in the future I would like to encourage code review so that team members can understand how all parts of the software work.

8.6 First Year Software Engineering Student: Bo Liu

This year has been more of an eye-opener than it is a learning experience for me. I was introduced to many new programming concepts such as multi-threading/processing, RS232, network communication, programming on Linux and more.

I believe that scheduling can be improved. Entire team meetings are held rarely throughout the terms and little is done to follow up on whether tasks are being completed or not. On the software side, regular development sessions helped to solve this issue. Perhaps a concept such as this could be applied to other aspects of the team.

8.7 First Year Software Engineering Student: Alex Amariutei

I have learned quite a bit from working on the $(UW)^2$TT team. I have been able to apply much of the theory that I have learned from my first year of engineering studies at the University of Waterloo. It felt great to be able to contribute concepts that I have learned in class to an application that I actually enjoy.

The rest of the team has been very helpful and I have learned a lot from them. I think that a stronger project plan would be beneficial in the future, so that I and other team members can have a better understanding of the tasks at hand. I also need to follow my own advice and dedicate more time to the project. I would like to be able to help other members in addition to my own personal learning.

I am looking forward to continuing my involvement for next year.

9. References

Leg 2 – Gulf of California Expeidition, February 19 – May 30, 2003 – Mission. Retrieved June 1, 2008, from http://www.mbari.org/expeditions/GOC/Mission/leg2.htm

Mission & Objectives. Retrieved June 1, 2008, from http://www.divediscover.whoi.edu/expedition1/guaymas.html.

Mission – Gulf of California Expedition, February 19 – May 30, 2003. Retreived June 1, 2008 from http://www.mbari.org/expeditions/G)C/mission.htm

Page, A., Tivey, M.K., Stakes, D.S., Reysenback, A. (2008). Temporal and spatial archaeal colonization of hydrothermal vent deposits. *Environmental Microbiology, 10(4), 874-884.*

Stakes, Debra. *March 3, 2003: Leg 2, Day #2 – Gulf of California Expedition, February 19 – May 30, 2003 – Logbook.* Retrieved June 1, 2008 from https://www.mbari.org/expeditions/GOC/logbook/Leg2/Mar3.htm.

10. Acknowledgements

The University of Waterloo Underwater Technology Team would like to thank ANSYS Inc., Electromate/Maxon, Criterion, IQinvision, Jet-Cut Inc., Leoni Inc., MicroStrain, SDP/SI, Space Control, Stratasys, Sunstone Circuits, Systech Corporation, and Assembla.com for their generation product and/or service donations.

The team would also like to thank the ASI Group, OceanWorks, the Waterloo Engineering Endowment Fund (WEEF), the University of Waterloo Engineering Society, and the Dean of Engineering for their generous financial donations.

In addition, the team would like to thank Dr. Melek, Donna Kellendonk, Jason and Kwai of the Engineering Machine Shop and countless others for their support and advice for the team.

From the support of many generous people and companies, the University of Waterloo Underwater Technology Team has been able to make Neo I transfer from drawings to reality. Thank you to everyone who has contributed.

A.1 Appendix One: Budget

Project	Item	Cost	Donation	Cost to Team	Comments
Hydraulic Arm	Materials	$400.00		$300.00	
	Manufacturing	Not Specified	All	$0.00	Donation from Jet-Cut
Backplate and Internal Layout Redesign	Materials	$250.00		$250.00	
	Manufacturing	$300.00		$300.00	
Pan and Tilt Redesign	Materials	$0.00		$0.00	Used Extra Material from Previous Project
	Manufacturing	$0.00		$0.00	Completed by students
Computer Upgrades	Hard Drives	$112.00		$112.00	For running ANSYS
Propellors	Manufacturing and Materials	Not Specified	All	$0.00	Donation from Stratasys
Bouyancy	Weights	$80.00		$80.00	To attain neutral bouyancy
Other	Maintenance/Small Upgrades	$300.00		$300.00	
Competition	Presentation Board	$20.00		$20.00	
	Photos and Photo Album	$20.00		$20.00	
Print Materials	Recruitment Posters - Colour	$10.00		$10.00	
	Sponsorship Brochures - Colour	$20.00		$20.00	
Operation Expenses		$40.00		$40.00	
Travel	Flight - 6 People - Buffalo to San Diego	$3,156	$444.00	$2,712.24	One Member Sponsored
Accomodation	USDC	$1,050	$175.00	$875.00	One Member Sponsored
			Total:	$5,039.24	

Source	**Amount**
EngSoc	$150
OceanWorks	$500
Dean of Engineering	$1,000
ASI	$2,000
WEEF	$5,112.26
Total	$8,762.26

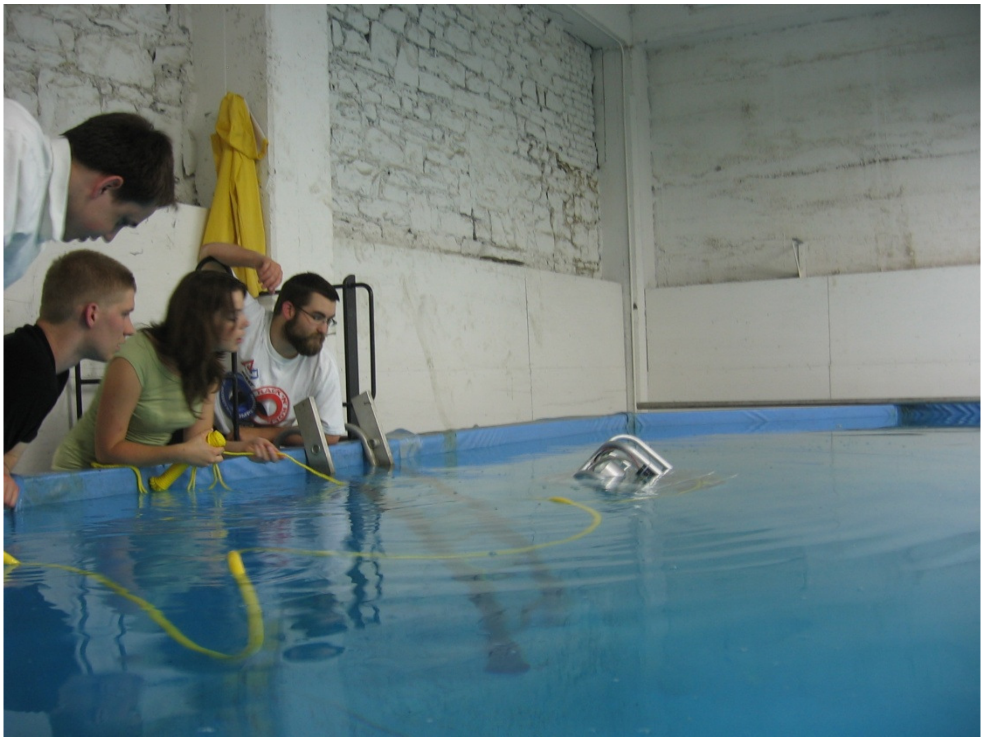
** Note: There is currently $3723.02 remaining in WEEF funding which is being reserved for the cost to manufacture the Neo II robot. WEEF funding cannot be used for operational, travel, competition, or print expenses. The manufacturing of Neo II will begin in September when new students will be arriving on the team.

Source	**Item**
ANSYS	ANSYS FEA Software
Assembla.com	Web Space
Criterion	2 Plastic Domes
Jet-Cut	Jet Water-Cutting
Leoni, Inc.	Cables
Stratasys	$10,000 worth of prototyping

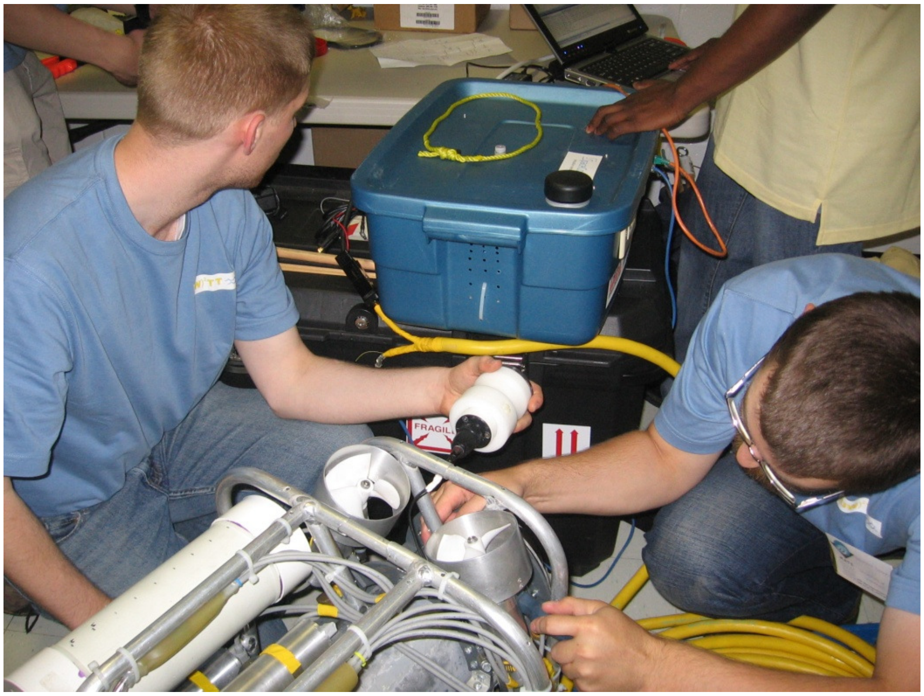
A.2 Appendix Two: Images of Neo I

ROV on Display for Canada Day, 2007

ROV Sitting by the Pool

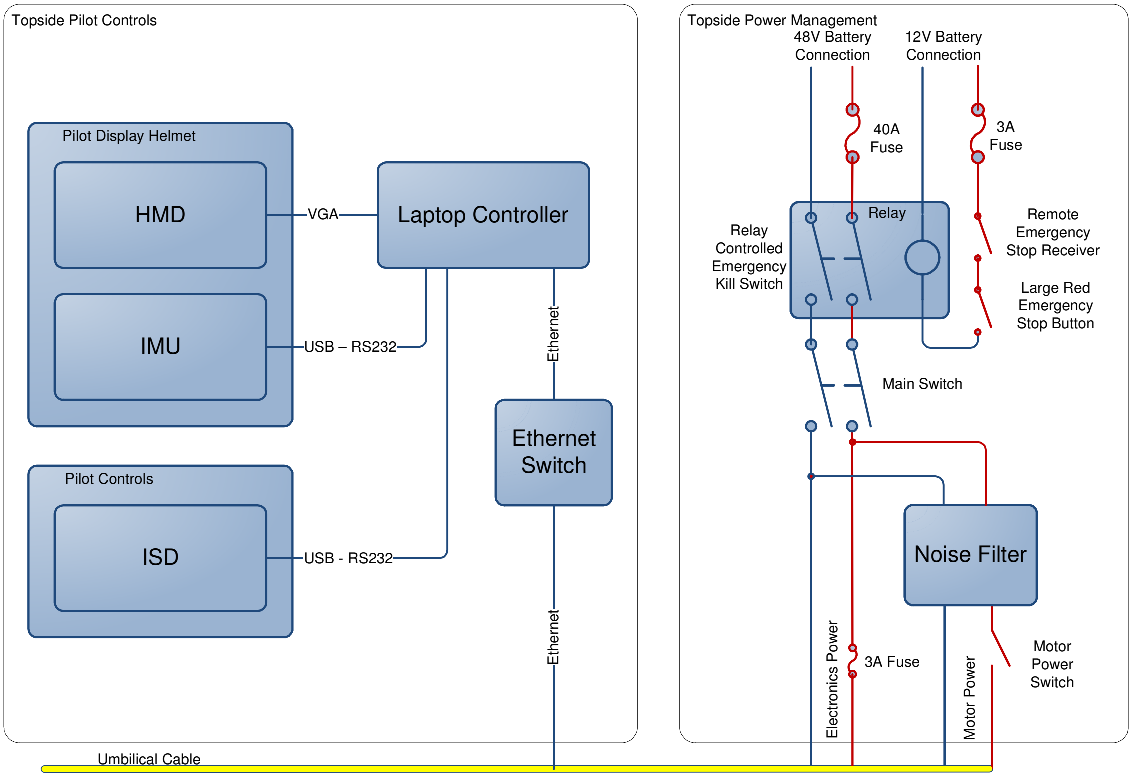


Testing the ROV at ASI



Repairing the ROV, View of ISD and Control Box

A.3 Appendix Three: Electrical Schematics



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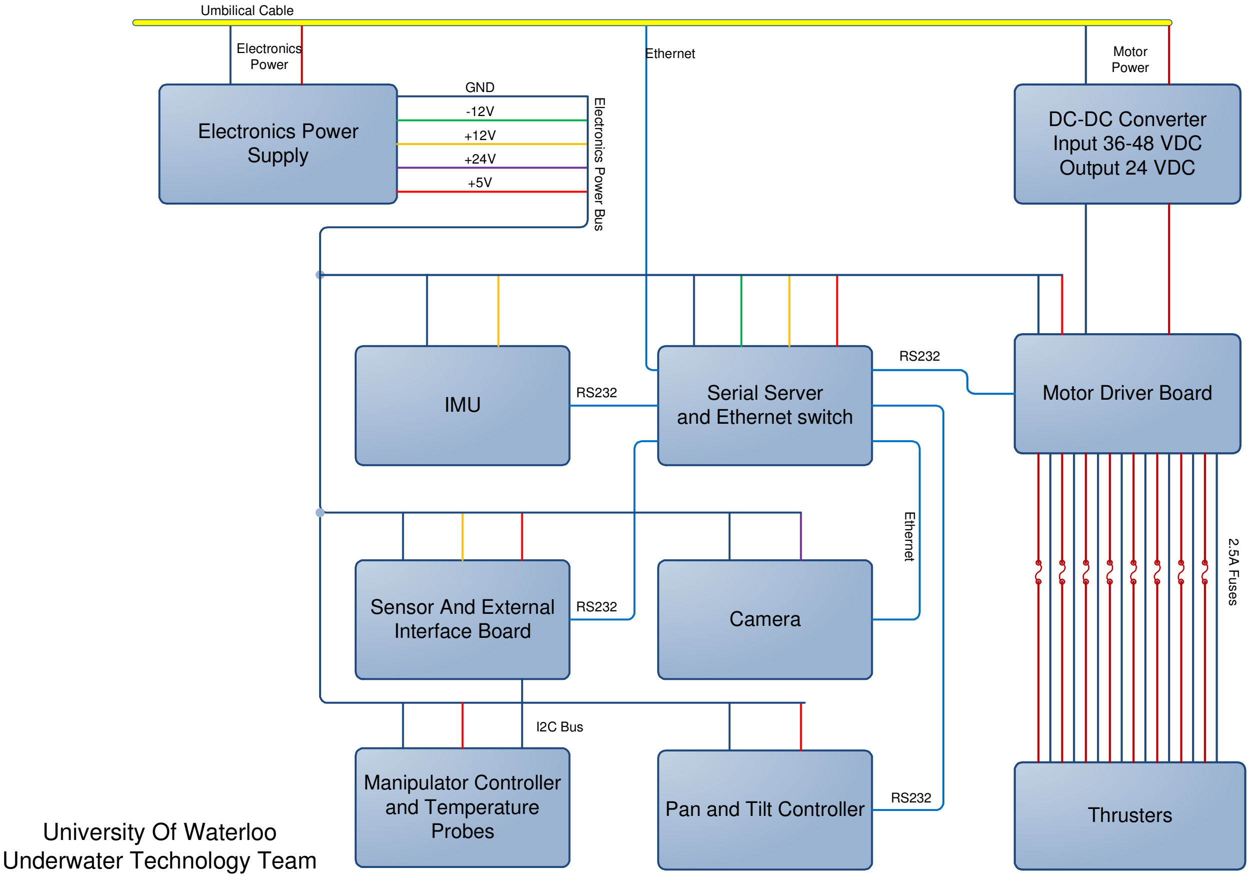
Top Side Wiring Schematic


Umbilical Cable
Electronics Power
Ethernet
Motor Power
Electronics Power Supply
GND
-12V
+12V
+24V
+5V
Electronics Power Bus
DC-DC Converter Input 36-48 VDC Output 24 VDC
IMU
RS232
Serial Server and Ethernet switch
RS232
Motor Driver Board
Ethernet
2.5A Fuses
Sensor And External Interface Board
RS232
Camera
I2C Bus
Manipulator Controller and Temperature Probes
Pan and Tilt Controller
RS232
Thrusters
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