Sea tech 4-H Club

Mount Vernon, WA

In Partnership With

Omega Inc.

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Abstract

The Omega ROV is Sea-Tech 4-H Club's entry into the 2011 International ROV Competition, hosted by the Marine Advanced Technology Education (MATE) Center.

A team comprised of four members designed and built a Remotely Operated Vehicle (ROV) capable of performing the mission tasks published by the MATE Center. The design utilizes a versatile aluminum frame to provide support for a variety of systems. Neutral buoyancy and stability underwater are accomplished by a two-part casing. The top half is machined from positively buoyant foam, while the bottom half is machined from aluminum. Two positively buoyant floats provide a strong righting moment. A removable, mission-specific sled is incorporated into the frame to support a set of tools to accomplish the mission. Four high-quality, 19.1 volt thrusters provide vertical and lateral thrust. A pneumatic system operates a manipulator that is used to control or retrieve objects under the water. A set of three cameras provide a comprehensive field of vision. All tooling is controlled by a student-designed electronics system.

The ROV was completely designed and assembled by the team, using student-made custom parts and components, pneumatic systems, sensors, and a limited set of donated parts. The competition theme, "ROVs and the Offshore Oil & Gas Industry" provided an opportunity for the Omega team to experience the challenges of working in a realistic environment and applying real-world challenges to the design and construction of their machine.

Introduction

Sea Tech 4-H Club has been building ROVs for ten years, and has participated in the ROV competition sponsored by the Marine Advanced Technology Education (MATE) Center since 2007. The expertise of the members of Omega Inc., as well as the technical and mechanical resources accumulated from years of experience in underwater technology, has allowed Sea Tech to bring an increasing level of sophistication to the MATE competition every year. The 2011 season brought together a team of four seasoned members who shared not only competition experience, but a passion for creativity and invention.

The team conceived ROV Omega as an adaptable, versatile, and sophisticated machine, capable of performing a variety of difficult tasks. The design is tailored to accomplish several specific missions, which are outlined in a Missions Document[1] published by the MATE Center. Omega Inc. made it their goal to not only perform these mission tasks, but to create innovative designs whose concepts could be applied in the real world. The company has created a machine that exceeds these expectations, and expects to perform exceptionally well on every level at the international competition.

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[1] http://materover.org/rov_competition_files/2011/2011_Mission_Tasks_FINAL.pdf

1. The Team

Stanley Janicki
Company Position: CEO
Competition Role: Pilot

With four years of experience building ROVs in Sea-Tech, Stanley is a task-orientated leader with schedule efficiency as his top priority. Proficient with CAD modeling, he accomplished the goal of creating a detailed, accurate and precise model of the entire ROV. He is currently in the tenth grade as a home-schooled student.

Trevor Uptain
Company Position: Marketing Director
Competition Role: Mission Commander

Trevor has participated in Sea-Tech for eight years. He has worked on six different ROVs, and led a team to a third place Explorer Class victory in the 2009 International MATE ROV competition. With a focus on the competition's engineering logistics, he spearheaded the technical report and worked on a variety of systems on the ROV.

Heather McNeil
Company Position: CFO
Competition Role: Missions Specialist

Heather, 16, is a home-school student and the mentor's daughter. This has given her the opportunity to learn about engineering first hand. She enjoys math and science, as well as their real-world applications. This is her fifth year in Sea-Tech, and her fifth ROV project. Three of those years have been spent participating in the MATE competition.

Eric Coleman
Company Position: Analytics Officer
Competition Role: Tether Manager

2011 is Eric's first year in participation with the Explorer team. An active member with a variety of responsibilities on the team, Eric kept extensive notes on every detail of the Omega design and building process. Eric is a senior in high school and plans on pursuing a degree in Communications.

2. Design Rationale

2.1 Mission Oriented

ROV Omega was designed with the 2011 mission tasks published by the MATE Center in mind. The frame of the machine is versatile, with mounting areas available for additional tooling to be added at any time. In addition to this, a detachable mission sled is included to perform very definite tasks. A variety of removable, replaceable, mission-specific sensors are mounted to the aluminum frame to collect and record data to accomplish the mission. Tooling specific to the competition missions include:

- A pneumofathometer to record depth
- A pneumatically-powered gripper to collect and manipulate objects under the water
- A pneumatically-powered collection system to retrieve and store multiple objects
- A self-contained, motor-driven assembly to cap and seal the wellhead as outlined in task number #2 in the Missions Document
- A set of three cameras for navigation
- A system for collecting and storing water samples

2.2 Design Process

CAD Modeling
Before any construction began, all systems and subsystems were designed in a Computer Aided Design (CAD) modeling program. The team recognized that designing on the computer before construction would greatly increase building efficiency. They made it their goal to design the entire machine and its subsystems in a CAD program.

Figure 1 - A CAD model of the Omega ROV

The company had access to UGS NX6 for mechanical design. This greatly streamlined the building process, and provided the company with the opportunity to have many of the parts for the ROV cut out on a high-precision water jet or a mill. The greater precision of these parts led to increased sophistication, while still providing complete control over the design of the ROV by the company. Although work on these parts were accomplished at a sponsor facility, team members were heavily involved in the process from start to finish. This allowed several members of the company the opportunity to experience real-world work experience, such as programming a CNC mill.

Utilization of the model was very successful, not only in increasing design efficiency, but in allowing each member to add input to and understand every aspect of the vehicle. To date there are over 100 hours of work put into the CAD model by team members, and it contains nearly 1,000 solid bodies and over 200 part files.

Selection of Parts
The team had a combined experience of over 20 years building ROVs. This experience was highly utilized in the solutions the company chose to accomplish the mission tasks. Early on, they chose to build a machine that was technologically sound, yet simplistic in its design to the point where the machine would be extremely reliable and unlikely to fail in any capacity. The technical rationale for the selection of components, as well as the design of the machine, involved a careful planning process and a thorough analysis of every option. This process lent to the stable design of the frame, the reliable outline of the control system, and the selection of the pneumofathometer as a solution for measuring depth. A thorough description of these components are outlined in section *2.3 Mechanical Structure*.

2.3 Mechanical Structure

Frame
The main structure of ROV Omega is a welded frame constructed of 1/4” aluminum. The individual pieces of the frame were cut out on a water jet, then assembled by team members. The work of welding was generously donated by a team sponsor. The frame is specifically designed to accommodate the fairing and the float, as well as to support a variety of subsystems, mission packages, and a set of three cameras. It incorporates a versatile set of mounting holes for potential additions. After welding, the frame was anodized to protect the aluminum by making the surface much harder than natural aluminum. Overall ROV dimensions are 48.5 cm x 66.3 cm x 25.6 cm.

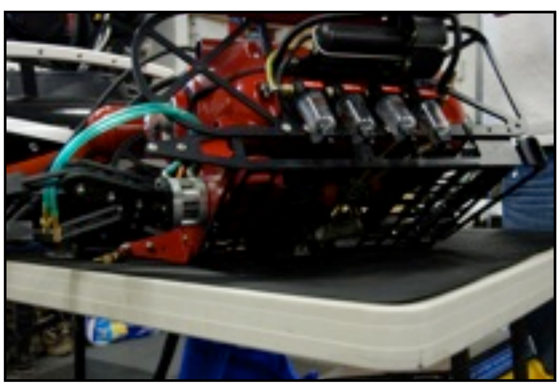

Figure 2 - The underside of the ROV with the mission sled attached

Mission Sled
A process similar to the construction of the frame was used to design and build a mission-specific sled. The sled mounts to the bottom of the frame, and is easily removable through a set of bolts. The sled contains an opening at the rear to secure the ‘biological samples’ as outlined in Task #4 of the mission document. A hinged door controlled by a pneumatic actuator directs the samples into the container. The front of the sled provides a convenient area from which to mount a pneumatically controlled manipulator.

Stability
The body of the ROV consists of a streamlined, two-part float and fairing system which provides structural rigidity in addition to a strong righting moment. The bottom half of the system was machined on a CNC mill from a solid piece of aluminum, which was later anodized. The top half was machined from high-density polyurethane foam. To

compensate for the weight of the frame, the mission sled, and the tooling, two welded aluminum buoyancy tubes were affixed to the top of the machine. The system of stability establishes the entire ROV as a highly maneuverable working platform which is affected very little by the weight of retrieved objects and by unexpected conditions.

Figure 3 - A front view of the machine with the float and fairing in view

2.4 Payload Tooling

The Missions Document published by the MATE Center outlines a set of specific tasks that must be accomplished by the machine. In order to complete these tasks efficiently, a set of tooling was incorporated into ROV Omega which could perform the mission tasks precisely and quickly.

Figure 4 - The pneumatically-controlled manipulator

Manipulator

A versatile claw is affixed to the front of the mission sled within the view of a forward-facing camera. A set of gears transforms the linear motion of the actuator into a horizontal motion. The design utilizes a set of three gears to direct the individual grippers to open in parallel. The claw is operated by a pneumatic actuator, which is controlled from the surface by a valve which strokes the actuator in or out fully. The individual pieces for the claw were machined from aluminum.

Retrieval System

A 3.8 cm tall container is incorporated into the rear of the mission sled to accommodate the ‘benthic organisms’ outlined in Task #4 of the mission document. A hinged door at the rear of the container is controlled by a linear pneumatic actuator, designed to sweep the organisms into the container. The actuator is controlled from the surface.

Figure 5 - The hinged door on the retrieval system

Depth Measurement

The depth of the ROV is measured by a pneumofathometer, an instrument commonly used in diving applications. 0.7cm ID Acrylic tubing is routed from the surface, terminating at the ROV. Pressurized air from an AC-powered pump forces the water out the tube until a constant pressure is achieved. When the machine increases in depth, the pressure inside of the tubing escalates. A pressure gauge translates the amount of pressure to a depth reading.

Figure 6 - The pneumatic control box with the pressure gauge installed

Pneumatic Control Box
The valves and switches utilized for controlling the pneumatic systems, as well as the system for controlling pneumofathometer, are mounted inside of a watertight case manufactured by Pelican. An air compressor connected to the box provides pressurized air to acrylic tubes which are routed to the ROV. The flow of air is controlled by a set of valves, which are operated by toggle switches. Input and output to the pneumatic actuators, as well as the line required for the pneumofathometer, terminate at the face of the control box. The box also houses the pump used for the pneumofathometer.

Wellhead Cap
An important feature of the competition was the construction of a 'wellhead cap', designed to stop the flow of water out of the simulated riser pipe in Task #2, outlined in the Missions Document. This is a simulated solution to a real life tragedy, the capping of the Deep Water Horizon wellhead in the Gulf of Mexico in 2010. The concept of the capping assembly is that it will latch over the well head, then drive a stopper down into the open port to complete the cap. Five tapered pawls on this design help guide and grip the well head. These spring-loaded pawls are pulled down until they latch into a groove, which then allows a ring to drop around the pawls and lock the assembly in place. The ROV releases the assembly, then activates a momentary toggle switch which energizes a 24 VDC motor with a planetary gear box.

Figure 7 - The wellhead cap

The specifications published by the MATE Center require that the assembly be completely self contained and self actuated, meaning the package could not have its own tether. The motor is powered by sixteen AA (1.5volt) batteries, which are wired in series. The planetary gear box drives an ACME screw that threads a rubber stopper into the well head opening, effectively sealing the flow. As this rubber stopper bears down on the well head opening, the pawls bite into the well head, which locks the assembly into place. The pawls, base plate, and rings are made of water jetted aluminum cut directly from the solid geometry of a CAD model. The battery compartment is water-tight, and is constructed of cast acrylic tubing and a machined PVC cap. This compartment acts as a buoyancy float to counter-act the weight of the metal assembly below. The whole device is trimmed for neutral buoyancy. With the majority of weight at the bottom, a strong righting moment is created so that if the ROV loses control of the cap assembly, it will remain upright. The toggle switch that actuates the motor is a double-pole, double-throw, neutral center switch which allows for reversing the motor to remove the well head cap when the mission is completed.

Water Sampling
The ROV is equipped with a system to collect a water sample, as outlined in Task #3 in the Missions Document. A 16 cm stainless steel rod is mounted to an arm attached to the front of the ROV, long enough to reach the center of the water container. Water is pumped from the rod into a container on board the machine. The rod is mounted to an arm protruding from the front of the vehicle and is attached to a hinge. With the ROVs downward motion, the tube swings upward to prevent interference with the claw.

Tooling Alternatives
ROV Omega is equipped with a versatile mission sled, which means that the team is capable of swapping out not only components of the sled, but the sled itself. If alternate tooling is required for future projects, the team is capable of equipping the ROV with a diverse set of instruments. The team built a set of two claws of different sizes which can be added and removed with ease.

Figure 8 - The Seabotix thrusters attached to the machine

2.5 Propulsion System

ROV Omega is outfitted with a set of four Seabotix thrusters made specifically for ROVs. Each thruster outputs 2.2 kg of thrust. The configuration sets up one thruster on either side of the machine for forward and backward thrust and yaw control. The two vertical thrusters produce ascent, descent, and limited pitch control. The thrusters are equipped with a brushed DC motor and housing, end caps, propellers, and kort nozzles, so no modifications were necessary to integrate the thrusters with the system. They are attached to the ROV by a custom-made plate fastened to specifically-designed mounting bars on the frame. This allows for quick removal in the case that repair or modification is necessary.

2.6 Cameras

ROV Omega is equipped with a set of three cameras. A forward facing camera, encased in a watertight housing with a dome, is used for navigation. A second camera is incorporated into the fairing, facing backward for use while navigating in reverse. The third camera is attached to a removable aluminum mount, facing downward with a view of the retrieval system. All cameras provide a comprehensive field of vision, allowing for easy navigation.

2.7 Electrical Control System

Control

The Omega ROV embodies simplicity without compromising function or performance, and a hardware-only approach was selected to control the ROV for this reason. The team has utilized software to control the machine in the past, and this approach has often caused unnecessary problems. The hardware-only approach circumvented this, and would in fact be superfluous on this project. The system utilizes two outsourced motor controllers, which the team custom-interfaced with the system. The controllers were purchased from Dimension Engineering, chosen because they operate at 48 VDC. A potentiometer controls pitch. The controllers utilize 0-5 V analog control signals for the operation of the thrusters. Each controller has two such inputs; S1 controls the speed and direction of two thrusters, and S2 is used to control turning or pitch. The main power input is fused with a 25 amp fuse, as well as a large emergency off switch in the case that a quick shut off is necessary. Each individual output is protected by appropriately rated fuses.

Figure 9 - The control system

The system utilizes a hall-effect joystick sourced from ETI Systems to control the X, Y, and Z axes of the ROV. It is mounted to a small, plastic control box, which is itself connected to the main control case by a cable.

Figure 10 - The control case

Control Case

The entire control system is mounted inside of a pelican rifle case. Two flat panel, glare-resistant monitors are mounted to the inside of the lid of the case. The face plate of the case accommodates an emergency off switch, as well as a set of military-grade

Figure 11 - A team member waterproofing the connectors

bulkhead connectors which connect the control system to the tether and the joystick control box. The system is modular; if one component fails, the entire system will not go down. If a component does fail, replacing it is a quick and simple process.

Connectors

The tether is terminated on both ends with high grade connectors. The surface end of the tether is split into two military-grade connectors. A 12 pin connector supplies power to the ROV. An 8 pin connector supplies camera signals. On the ROV side, the tether is split into a 12 pin Sea-Con connector for power and an 8 pin Sea-Con connector for camera signals. To ensure a watertight connection, the Sea-Con connectors were equipped with underwater cable terminations. This process was performed by the team.

2.8 Safety Features

Safety was an important consideration for the company throughout the design and building process. Several safety features incorporated into the design of the ROV:

- All thrusters are protected by guards and ducts
- Warning labels are placed near any moving parts
- Handles are incorporated into the frame for safe launch and retrieval
- A safety protocol is always followed during the testing of the electronics
- An emergency shutoff switch is incorporated into the electronic controls in case of a system failure

3. Expenditure Summary

The following is a summary of the project expenses. While the company has created a detailed budget sheet, for the sake of space in this report it has been condensed to a price for each category. A more detailed budget sheet can be found in **Appendix A**.

Category:	Total Cost:	Donated Amount:	Company Expenditure:
Cameras	$1,144.12	$0	$1,144.12
Thrusters	$1,817.00	$50.00	$1,767

Category:	Total Cost:	Donated Amount:	Company Expenditure:
Manipulator	$464.35	$350.00	$114.35
Frame, float & fairing	$12,061.62	$12,000	$61.62
Controls	$1,920.67	$217.58	$1,703.09
Tether & connectors	$2,297.70	$0	$2,297.70
Pneumatic systems	$983.22	$0	$983.22
Wellhead cap	$315.84	$120.00	$195.84
Grand Total:	**$21,004.52**	**$12,737.58**	**$8,266.94**

4. Troubleshooting

Troubleshooting is an inevitable process when testing a new design. The team utilized the process of troubleshooting many times throughout the year when the outcome of a design was unplanned. The technique applied to solving the problem was a careful analysis of all the possible reasons the problem might have occurred, followed by a methodical testing to narrow down the problem.

Figure 12 - Testing the ROV in a small tank

An example of this involves video display for the ROV. When the cameras were first connected, the images would not display on a test monitor. To identify the problem, the team made a careful list of all the reasons the images might not be displaying properly. One possible reason was that the monitor was not working correctly. Another was that the cameras itself were not functioning. The third was that there was a bad or reversed connection somewhere in the tether or control system.

The first two problems were the easiest to put on trial. The test monitor was replaced with a second monitor, which did not solve the problem. To test the cameras themselves, the team disconnected one from the system and plugged it directly into the monitor. When a perfect image was displayed on the screen, it was clear that the problem had been narrowed down to a bad connection. A multimeter was used to test all the different points where the camera was connected to the system, and the problem was eventually identified as a reversed signal connection.

This is just one example of successful troubleshooting applied to the Omega ROV. Similar techniques were applied to the system of buoyancy, impaired display on the video feed, and the control system.

5. Challenges Faced

5.1 Team Size

The competition year of 2011 marks the first year that a Sea Tech 4-H club team has consisted of only four members. While the smaller size of the team has several distinct advantages, such as easier coordination for meeting times, it became evident through the year that each member would have to take on a heavier work load than in previous years. This challenge was met with a strict coordination and careful delegation of tasks, which balanced the heavier workload with a thorough knowledge of the tasks that each individual must complete. This strategy met with success when the machine was completed in much faster time than in previous years.

5.2 Suppliers

Although the team carefully compiled a list of the parts needed to build the machine, it was impossible to anticipate the length of time that some suppliers took to ship parts. The company waited months for several orders which were supposed to be delivered in less than two weeks. This caused no end of frustration, and held up productivity on components of the vehicle that should have been completed much sooner. In order to avoid such problems, parts ordered later in the year were purchased locally if possible. If necessity forced the team to order parts online or through a catalog, calls were made to the company to ensure that the product was in stock and would be delivered on time. This method allowed the team to catch up on their schedule and complete the project in time.

6. Lessons Learned

6.1 Connectors

Underwater connectors have caused many problems on machines built by Sea Tech 4-H Club in previous years. Corrosion, leaking, and shorts have plagued the system and prevented the teams from scoring full points on mission tasks. To avoid this problem, the Omega team invested in a set of high-grade underwater connectors manufactured by SeaCon. The company which supplied the connectors, Mecco Inc., offered the team the opportunity to learn to waterproof the connectors themselves. Several company members visited the Mecco facility in Duvall, Washington, and spent time with an industry expert learning how to terminate and waterproof the connectors.

The success of this effort has been tremendous. Not only has the company discovered an excellent supplier and resource, but they have gained an important skill which can be applied in the future. The company plans on utilizing the connector products, as well as the skills gained, in future projects.

6.2 Interpersonal Communications

As with any project of this magnitude, communication between company members was indispensable. In order to complete the project on time, it was apparent that the team's method of communication must be prompt, open, and direct. In order to accomplish this goal, e-mail communications between the team included all members as well as the team mentor. To coordinate meeting times, all team members were contacted not only by e-mail, but by text and phone call. To ensure that each team member knew their responsibilities, a 'To Do' list coupled with assignments was updated every week.

The lesson learned was that these communication methods promoted a strong sense of teamwork, ensuring that every aspect of the project was completed with promptness as well as camaraderie. These methods greatly strengthened the communication skills of each individual member, as well as the company as a whole.

7. Future Improvement

7.1 Mission Sled Modifications

The company considers the incorporation of the mission sled on their machine to be a success. The idea is not a novel one; it was incorporated into the Omega machine after a careful analysis of commercially-produced ROVs. The company strongly believes that, although new and improved technology is important, industry standard exists for a reason. The machine incorporates time-tested ideas without compromising technology, and the addition of the mission sled allowed the company to explore a variety of tooling options without modifying the design of the frame. During practice, however, the team conceived of several improvements that could be made to further increase the usefulness of the mission sled. Since the company plans to continue use of the ROV for further competitions, these modifications will be important to ensure the further success of the vehicle.

The first improvement to be made to the mission sled will be its size. The sled supports a variety of subsystems, and the height of the sled became a factor when trying to incorporate all of this tooling. To accomplish this, a completely new sled will have to be

Figure 13 - A photo of the Omega team

constructed. Fortunately, the sled is easily detachable from the body of the ROV through a set of bolts.

The second improvement to be made will be the areas provided for mounting additional tooling on the sled. Several of the later additions to the ROV required specialized mounting hardware, because very few areas for additions were incorporated into the design of the sled.

The construction of a new mission sled will require some work, but will provide the company with the opportunity to add a diverse amount of tooling to the machine. It is likely that the company will eventually own a set of several sleds which can be swapped out quickly to accomplish various tasks.

7.2 Other Improvements

The company would like to accomplish several other improvements in order to improve the ROVs capability for competition, as well as for its use in a real-world environment. These include: making the machine saltwater capable, adding a hydrophone, creating additional payload tooling, increasing the tether length, and equipping the machine with a higher resolution video feed. These improvements will allow the company to perform a large amount of precise tasks with the machine, as well as to utilize the machine for educational purposes.

8. Teamwork

A project as successful as the Omega ROV could never be completed without the level of teamwork that the company demonstrated throughout the design, building, and testing processes. The small size of the Omega team required a high level of group contribution, as well as an intelligent process to facilitate the planning and creation of the vehicle's technology. The most important contributor to making this team effort a success was the fact that the entire machine was created by the team, with very little input from outside sources and minimal mentor participation. With a high level of competition at the international level, it was important for each team member to possess a thorough knowledge of the workings of the machine. In order to accomplish this, every component of the ROV, including the electrical system, was designed and built by members of the Omega team.

To facilitate the details of the process, it was important that the company develop and implement a detailed schedule to assist in building the vehicle. This schedule was coupled with individual assignments so that there was no overlap in the work done by the team members. The assignments also ensured that each team member was aware of their individual responsibilities, and that no work was left undone. The assignment sheet was updated weekly as tasks were completed. The technical report, an important component of the MATE competition, was created utilizing individual input from each team member's are of expertise. The implementation of the schedule and assignment sheets caused the ROV to be completed in budget and on time, in spite of many obstacles that the team faced throughout the year.

9. ROVs and the Oil Spill

On the morning of April 20, 2010, a large explosion rocked the Deepwater Horizon, a drilling rig stationed in the Gulf of Mexico. Eleven workers were killed, and as the rig sank to ocean floor, a massive oil spill was being let loose.

When well pipes are temporarily abandoned, such as the Deepwater Horizon was about to be, they are plugged with cement. In the primary stage, cement is pushed between the well casings and the sediment layers that have been drilled through. The secondary stage consists of two plugs being cemented in the pipe with drilling fluid between them. In the attempt to plug the Deepwater Horizon well, either the primary or secondary cementing failed, pushing a massive column of natural gas into the well pipe. The gas surged to the surface and exploded the rig.[2]

Figure 13 - The blowout preventer

To prevent leaks should the cementing controls be overwhelmed, the well pipe was fitted with a blowout preventer. The BOP stack is a 450-ton series of valves designed to shear into the pipe and cease the oil flow. When the alarm sounded on the rig, operators initiated the BOP, but it only partially sheared the pipe.[3]

The first attempts to stop the oil spill were put into action by remotely operated underwater vehicles to close the BOP valves on the wellhead. Following, a 280,000 pound containment dome was placed on the wellhead. The oil was to be pumped through this and to a storage vessel on the surface, but when natural gas leaking from the pipe combined with cold water, a formation of methane hydrate crystals occurred which blocked the opening from the dome. Next, efforts were made to pump heavy drilling fluids into the BOP to stem the oil flow, after which cement would be used to plug the well. This also failed.[4]

[2] http://media.nola.com/news_impact/other/oil-cause-050710.pdf

[3] http://www.nola.com/news/gulf-oil-spill/index.ssf/2011/03/blowout_preventer_failure_in_g.html

[4] http://www.nytimes.com/2010/04/27/us/27rig.html, http://www.newsweek.com/2010/05/19/our-eyes-underwater.html

A riser insertion tube was then placed inside the burst pipe. This collected and carried the oil to the surface, where it was stored aboard the drill ship Discoverer Enterprise. On June 16, 2010, a second containment system was connected directly to the BOP which carried oil and gas to the Q4000 service vessel, where it was burned in a clean-burning system.

Figure 14 - Still capture of a video feed from one of the ROVs working on the well

The well was finally plugged on July 15, 2010. The containment cap had been removed and replaced with a better-fitting cap made up of a Flange Transition Spool and a 3 Ram Stack. The riser pipes which carried oil to the ships were turned off so that the full force of the well went into the new cap. That day BP announced that the leak had been stopped when the BOP had closed on the new cap.[5] This mission has brought the use of ROVs into the public spotlight. Without these machines, capping the well would have been impossible. Armed with high-tech video equipment, the ROVs linked the surface operations to the site of the disaster 5,000 feet below in the Gulf of Mexico. Each machine was extremely prepared for their individual missions. BP's Richard Lynch stated, "Everyone watched the ROVs take those six bolts off around the joint and believe it or not we had a tool for every one of those bolts."[6] A disaster of this size required many ROVs, which was necessary in spite of the increased danger of the many tethers being tangled. The spill had a record fourteen ROVs working simultaneously. This was accomplished through extensive storyboarding, where the operations were broken down into a sequence of minute movements. "To people watching the operation, it probably looked like chaos, but every move had been well thought out. Nothing was left to chance, everything was designed for a reason and every movement mapped out in advance . " [7] This statement encompasses the spirit that the Omega team endeavors to bring to the competition.

[5] http://www.huffingtonpost.com/2010/07/15/gulf-oil-spill-stopped-bp_n_647988.html#114862, http://www.telegraph.co.uk/finance/newsbysector/epic/bpdot/7893358/Deepwater-Horizon-oil-spill-stopped-say-BP.html, http://www.foxnews.com/us/2010/07/15/bp-begins-critical-pressure-test-new-cap-oil/

[6] http://www.bp.com/sectiongenericarticle800.do?categoryId=9036600&contentId=7067604

[7] Ibid

10. Reflections

The ROV Omega project has presented a set of unique, offbeat, and rewarding challenges from start to finish. Our team has created a machine capable of performing a diverse range of tasks. It is reliable, highly maneuverable, and very adaptable. With careful planning, we have met every obstacle with intelligent solutions conceived by experience and innovation. The many facets of this project have brought our team closer, forming a group of individuals into a unified team with purpose.

Individual team members have learned to take ownership of various aspects of the project and see them through to completion. As a group, we have discovered that we are capable of accomplishing a project of this magnitude in spite of the challenges. Because of demanding time constraints, we have learned to improvise when the ideal solution was not attainable. We have been challenged on the teamwork, frequently facing differences of opinions. But we have learned to rise above these differences, contributing as a unit to a purpose greater than individual self. No task was insignificant -- each part of the process relied on all of the other parts. The team learned to recognize this fact, as well as gain a strong sense of capability.

The competition missions published by the MATE Center has inspired us to create greater things. Without the technical specifications and thought-provoking ideas published by the MATE Center, many of the innovations on ROV Omega would never have been considered. The wellhead cap, creative solutions for power, depth measurement, and the unique manipulation system are all components that would likely never have been conceived apart from the MATE competition. We believe that the design innovations on ROV Omega will set a new standard at the regional and international levels of competition. The product of experience, the vehicle has built us up as competitors, as designers, and as friends. We are very glad for the experience.

11. Acknowledgements

Omega Inc. would like to recognize the companies, organizations, and individuals who made this project possible. Without their support, ROV Omega would never have been completed:

- Lee McNeil, our team mentor, for your constant expertise and guidance. You have taught us so much, and we would never be who we are today without you.

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- Janicki Industries, for your generous sponsorship of our project through monetary contributions. Your donations of supplies and services were indispensable, most notable the water jetting and milling services, which allowed us to expand our scope of technology.

- Outland Technology, for the donation of our tether.

- Mecco, Inc. for contributing time and expert advice.

- The Skagit County 4-H Office, for your continued support of our endeavors.

12. Appendix

Appendix A: Detailed Budget Sheet

Donations in italics type

Thruster Components / Materials List:						
Item:	**Qty:**	**Item Description:**	**Mfg. P/N:**	**Source:**	**Cost:**	**Total:**
1	4	SeaBotix ROV thrusters	BTD150	SeaBotix	390.00	1560.00
2	6	1/4-20" x 3/4" SS socket cap head screw		Tacoma Screw	0.60	3.60
3	*1*	*Various pieces of water-jetted aluminum*		*Janicki Industries*	*50.00*	*50.00*
4	4	Over Molded, 2 pin, 8amp wet mateable	MCIL-2-FS	Sea-Con	49.95	199.80
5	12	Mounting Screws	LB319	SeaBotix	0.30	3.60
					Total:	**1817.00**

Manipulator Components / Materials List:						
Item:	**Qty:**	**Item Description:**	**Mfg. P/N:**	**Source:**	**Cost:**	**Total:**
1	1	Low profile actuator; 1.5" dia. bore	# FO-171-G	Bimba	69.35	69.35
2	*1*	*Various pieces of water-jetted aluminum*		*Janicki Industries*	*350.00*	*350.00*
3	1	Miscellaneous Stainless Fasteners		Ace Hardware	45.00	45.00
					Total:	**464.35**

Frame, Shell and Mission Tray Components / Materials List:						
Item:	**Qty:**	**Item Description:**	**Mfg. P/N:**	**Source:**	**Cost:**	**Total:**
1	*1*	*Various pieces of water-jetted aluminum*		*Janicki Industries*	*2000.00*	*2000.00*
2	*1*	*TIG welding services @ $100/hr hours*		*Janicki Industries*	*100.00*	*100.00*
3	*1*	*Hydro-static-proof urethane foam; 30#/cu.ft.*		*Janicki Industries*	*150.00*	*150.00*
4	*1*	*5-axis CNC milling; @ $100/hr hours*		*Janicki Industries*	*2075.00*	*2075.00*
5	*1*	*Aluminum Billet: 4" x 10" x 18" aluminum*		*Janicki Industries*	*175.00*	*175.00*
6	*1*	*5-axis CNC milling; @ $600/hr hours*		*Janicki Industries*	*7500.00*	*7500.00*
7	1	Polyethylene 1/2" x 1" x 10"		Tap Plastics	7.95	7.95
8		Miscellaneous Fasteners			53.67	53.67
					Total:	**12061.62**

Controls In Video Monitor Box Components / Materials List:						
Item:	**Qty:**	**Item Description:**	**Mfg. P/N:**	**Source:**	**Cost:**	**Total:**
1	2	Sabertooth Dual 50A 12-48V Motor Driver	2X50HV	Robot Shop	249.99	499.98
2	6	Fuse holder		O-Reilly auto	3.99	23.94
3	*6*	*Glass Fuse*		*Janicki Industries*	*0.10*	*0.60*
4	8	Non polarized capacitors 500uF 100V		Amazon	8.25	66.00
5	3	RCA jacks		Skagit Electronics	5.99	17.97

6	*1*	*Emergency off button switch*		*Janicki Industries*	*39.99*	*39.99*
7	*1*	*Emergency off button yellow ring*		*Janicki Industries*	*1.99*	*1.99*
8	*1*	*Misc Amphenol connectors*		*Janicki Industries*	*175.00*	*175.00*
9	1	Potentiometer	RV24AF-10-40	Jameco	1.29	1.29
10	1	Pelican Case	1750NF	B&H Photo	179.99	179.99
11	2	Aluminum Blank hinge; 3"	1609A43	McMaster-Carr	7.99	15.98
12	1	Stainless Steel Lid stay		McMaster-Carr	57.99	57.99
13	1	Hall-effect Joystick	J30H-XYZ-B	ETI Systems	270.00	270.00
14	2	Flat Screen Monitor: Vizio 19" LCD LED	VM19OXTV	Costco	258.99	517.98
15	2	M5 Knurled Thumb Screw		McMaster-Carr	5.99	11.98
15	1	1" Craft Foam		walmart	19.99	19.99
16	1	Misc fasteners		Ace Hardware	20.00	20.00
					Total:	**1920.67**

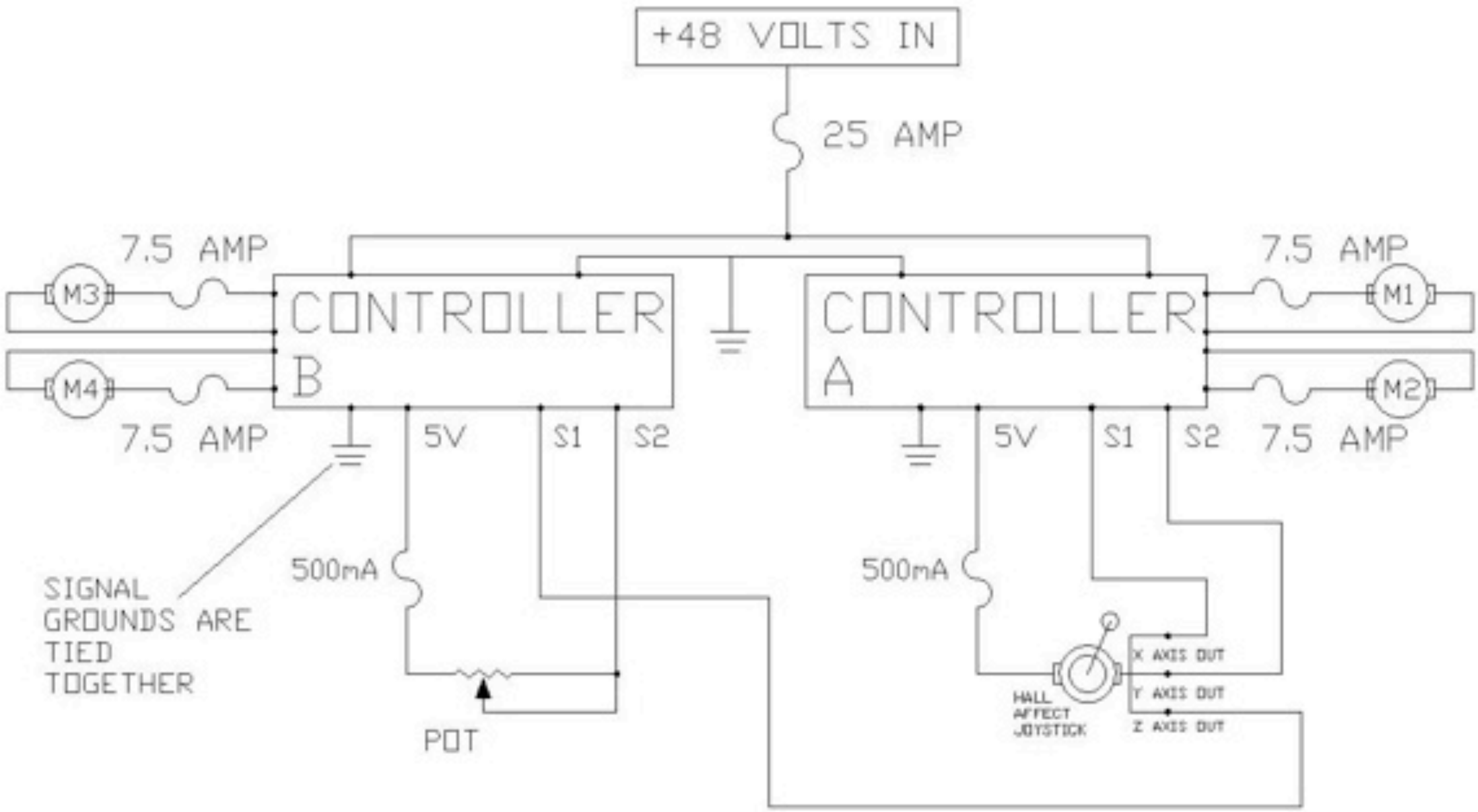
Tether and Connector Components / Materials List:						
Item:	**Qty:**	**Item Description:**	**Mfg. P/N:**	**Source:**	**Cost:**	**Total:**
1	*220*	*Tether*	*C-3400c*	*Outland Tech*	*5.00*	*1,100.00*
2	1	Strain Relief		Del City Electric	3.95	3.95
3	7	Sea Con Connectors:		Mecco		0.00
4		Underwater connection supplies		Mecco	**Total:**	1,150.00
5	100	Nylon over-braid - blue		Buy Heat		0.00
6	500	1/4" O.D. x 1/8" I.D. urethane tubing		Freelin-Wade		0.00
7	5	Shrader valve couplers		Airtronics	7.95	39.75
8	10	#10-32 Barbed fitting		Airtronics	0.40	4.00
					Total:	**2,297.70**

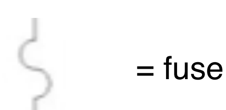
Pneumatics And Pneumofathometer Components / Materials List:						
Item:	**Qty:**	**Item Description:**	**Mfg. P/N:**	**Source:**	**Cost:**	**Total:**
1	15	Brass barb to pipe fitting	11924-1	Airtronics	0.50	7.50
2	9	slip on T fitting	T44-4	Airtronics	0.75	6.75
3	2	1/4 NPT to 1/4 NPT 45 degree fitting		ACE Hardware	2.99	5.98
4	2	1/4 NPT to 1/8 Bushing		ACE Hardware	1.99	3.98
5	4	1/8 NPT to 1/4 Barbed Pipe		ACE Hardware	2.89	11.56
6	4	1/4 Barbed Pipe to 1/8 NPT 90 Degree		ACE Hardware	3.98	15.92
7	2	1/8 NPT to 1/4 Pipe Straight Fitting		ACE Hardware	2.10	4.20
8	1	1/4 NPT to1/4 Pipe 90 Degree Fitting		ACE Hardware	2.99	2.99
9	1	Female to Female Tee 1/8 NPT		ACE Hardware	4.95	4.95
10	1	1/8 NPT Plug		ACE Hardware	1.97	1.97
11	1	1/4 NPT to 1/4 Barbed Pipe		ACE Hardware	1.95	1.95
12	2	1/4 to 1/8 Reducer Bushing		ACE Hardware	1.79	3.58

13	3	Male to Male 1/8 NPT Straight Fitting		ACE Hardware	2.85	8.55
14	1	1/8 to 1/8 NPT Female to Female 90 Degree		ACE Hardware	1.99	1.99
15	2	Intake and Exhaust Screens		McMaster Carr	1.64	3.28
16	4	Pneumatic Filter housing		Home Depot	12.98	51.92
17	1	1/4 NPT Female 4-way plug valve		McMaster Carr	108.95	108.95
18	1	Male to Male 1/8 NPT Stainless Swage Lok		ACE Hardware	4.99	4.99
19	11	1/4 OD Stainless Tubing		ACE Hardware	0.95	10.45
20	18	Brass Barb 10-32 to 1/8 Pipe		Airtronics	8.99	161.82
21	1	Digital Gauge:		McMaster Carr	260.00	260.00
22	1	Vacuum-compressor:		Graingers	249.99	249.99
23	1	Pelican Case	1450NF		49.95	49.95
					Total:	**983.22**

Well Head Cap Components / Materials List:						
Item:	**Qty:**	**Item Description:**	**Mfg. P/N:**	**Source:**	**Cost:**	**Total:**
1	*1*	*Various pieces of water-jetted aluminum*		*Janicki Industries*	*120.00*	*120.00*
2	1	Gear-motor: 32 mm; 24 VDC; 67rpm	IG32-24VDC	SuperDroid	20.50	20.50
3	1	Jaw-to-jaw coupling		Jameco	6.49	6.49
4	16	Duracell AA batteries		Costco	0.59	9.44
5	8	Battery holders		Radio Shack	2.39	19.12
6	8	9V snap connectors	270-0325	Radio Shack	1.29	10.32
7	1	5" dia. x 1" nylon disk		McMaster-Carr	5.00	5.00
8	1	5" O.D. x 1/8" wall cast acrylic tube x 4"		Tap Plastics	12.00	12.00
9	1	5" dia. x 1/2" cast acrylic disk		Tap Plastics	3.00	3.00
10	5	10-32UNF x 5/16"-16UNC stainless keen-		McMaster-Carr	3.95	19.75
11	3	.50" x .25" x .13" o-ring	#90 (35870B)	Ace Hardware	0.95	2.85
12	5	3/8" O.D. x #10 x 1" nylon stand-offs		McMaster-Carr	0.29	1.45
13	5	Springs:		McMaster-Carr	1.29	6.45
14	1	Acme screw nut:		McMaster-Carr	24.95	24.95
15	1	Acme screw thread:		McMaster-Carr	12.95	12.95
16	1	O-ring:		McMaster-Carr	2.59	2.59
17	1	Toggle switch: Panel Seal; DPDT; (ON)-OFF	870-0590	Allied Electronis	13.39	13.39
18	1	Toggle switch: Boot		Allied Electronis	5.59	5.59
19	1	Misc SS Fasteners		Ace Hardware	20.00	20.00
					Total:	**315.84**

Appendix B: Motor Controller Schematic





Appendix C: CAD Model of the Omega Machine