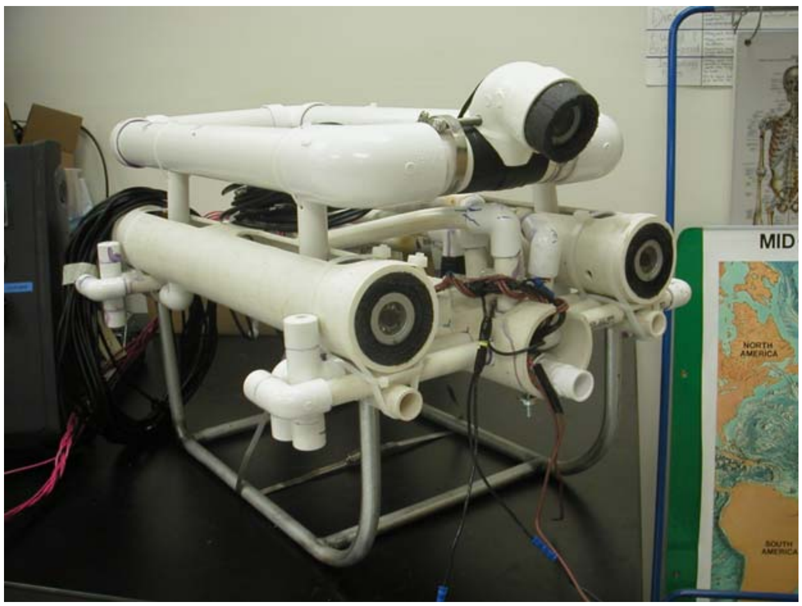
Technical Report

Marine Academy of Technology and Environmental Science
(MATES)
ROV Team

The National MATE ROV Championships 2005



"Megalops" **– "Large-eyed"**

Team Members:

Christopher Meyer 2005, Michael Davis 2005, Jon Gery 2006, Carly Coughlin 2006, Maria DeLeon 2006, Erich Berger 2006, Dakota Goldinger 2007, Christianna Campbell 2007, David Geeter 2007, Alex Lebron 2007, Kyle Boehm 2007, Alan White 2008, Maya Jenkins 2008, Laura Barry 2008.

Mentors:

Tina M. Held, Marine Science Inst., Coach/Facilitator/Mentor
Kurt Berger, Team Mentor

I. Abstract

The goal of Marine Academy of Technology and Environmental Science's participation in the National ROV competition is to create a fully functional ROV. Ideally, the remotely operated vehicle will have the ability to perform specific tasks and overcome obstacles. The Marine Academy of Technology and Environmental Science (MATES) ROV Team is a group of hard working students who have come together with a passion for science and technology. A curiosity about new and innovative robotic technology drove the team forward.

The project has opened a new frontier for the students. Even though this was MATES first year competing, the eager students took on the challenge. The project began in January and throughout the following months the students designed blueprints and constructed a prototype. This model was created with a goal of accomplishing the tasks predetermined by the Marine Advanced Technology Education National ROV Competition.

The MATES ROV Team anticipates utilizing the ROV, *Megalops*, for further uses such as field studies. *Megalops,* will give us the ability to view undisturbed marine environments. The MATES ROV club members are looking forward to applying their knowledge of ROVs and other robotic systems in future studies. The project has inspired the students involved to further their understanding about remote operated vehicles. They hope to expand their career horizons and to create more interest among other students about possible future careers involving remote operated vehicles.

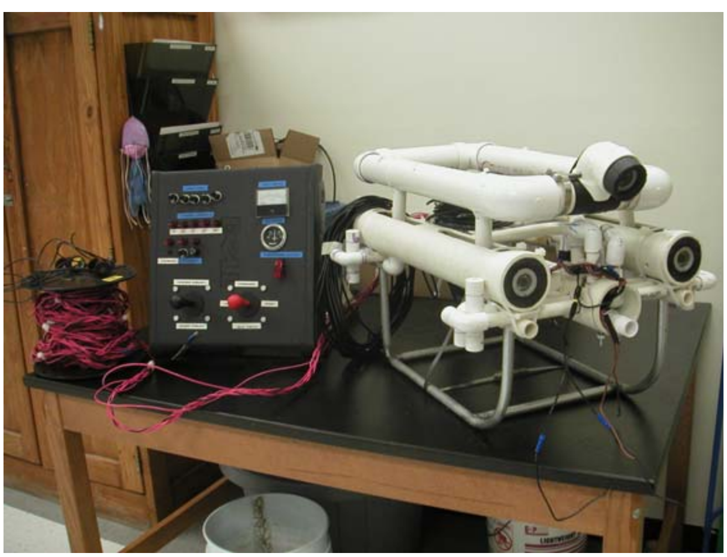


Fig. 1-1: The ROV and Control System

II. Design Rationale

Throughout the design process we kept in mind certain restrictions:

- Ranger Class Criteria and Missions
- Maximum onboard power of 12 volts DC,
- Maximum onboard power of 25 amps
- Conducting competition in chlorinated freshwater
- Maximum of three cameras
- Depth rating of up to 5 meters
- Maximum size of 80 centimeters x 60 centimeters x 60 centimeters
- Complete each mission within 5 minutes

1. Frame

A decision was made to use polyvinyl chloride (PVC) pipes because of their rigid structure and durable strength. We had originally intended to make an entirely metal frame but due to construction complications we altered our plans to mainly use PVC piping. The team constructed an ROV prototype (Fig. 2-1) and we then modified the model to fit our needs, as well as the above design restrictions (Fig. 1-1).

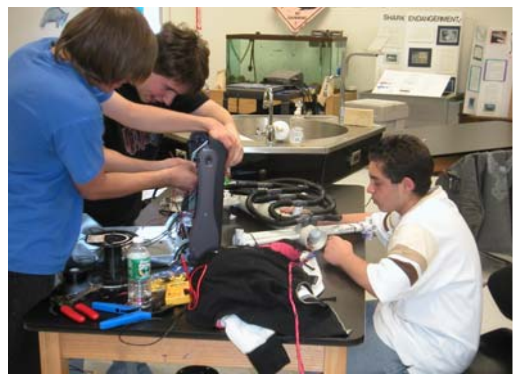


Fig. 2-1: Students constructing *Megalops* in primary phase

2. Propulsion System

Fig. 2-2: Bilge pump system in construction.

Our propulsion system consists of seven bilge pumps (Fig. 2-2) and two DC motors (Fig. 2-8). Three of the bilge pumps are directly used for forward propulsion. The other four contributing bilge pumps, “the power core”, direct water through a connected series of bent PVC pipes to assist in upward, downward, turning thrusts. Two DC motors were installed solely for reverse propulsion. The existing PVC pipes were then given restrictors (Fig. 5-1) to increase the water force propelling *Megalops*.

3. Arms

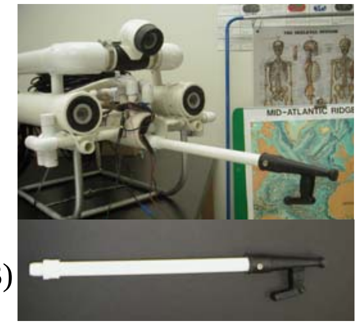


Fig. 2-3: Mission 1 arm

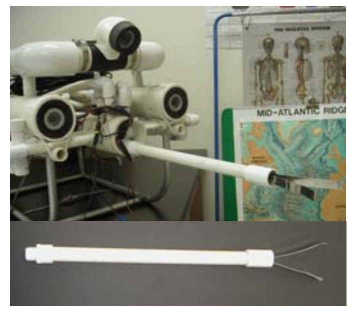


Fig. 2-4: Mission 2 arm

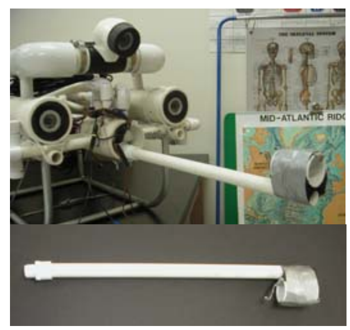


Fig. 2-5: Mission 3 arm

We designed our arms solely with the competition missions in mind. We have created the arm so that we may attach and detach different appendages which are specific to each individual mission. Our first arm (Fig. 2-3) piping attached to a plastic boat hook. The hook has a rigid rubber exterior that will aid in griping the valve that must be closed for mission one. Our second attachable arm (Fig. 2-4) is a 1-inch wide piece of PVC piping. We have attached a strategically bent piece of metal hose clamp that will use a spring action to hold the module in place for the mission. This arm will allow us to easily hold the module as well as detach it for the mission. Our third and final arm attachment (Fig. 2-5) is made of two forked pieces of metal hose clamp that resemble large tweezers. The arm piece will be inserted into the top loop of the module to securely hold it and then easily release it to complete the mission.

4. Bilge Pumps

The team chose bilge pumps (Fig. 2-2) to supply the majority of the thrust power due to numerous advantages. The bilge pumps are conducive to our needs based on high availability, the team’s previous experience with the technology, and usage of ambient water in propulsion. The bilge pumps supply *Megalops* with a great deal of power, while only drawing 3.3 amps at 12 volts of power per bilge. The bilge pumps can cycle 1100 g/h from an ambient source of water. The brand of bilge pump we chose, Rule™, is the first choice of the industry. The Rule™ bilge pumps run longer and stronger than its competitors.

5. Camera Systems

After researching and exploring our camera options we decided to use Atlantis© camera system to provided *Megalops* with "eyes" (Fig. 2-6). We chose the Atlantis© black and white drop camera systems because we had used them in the past. The quad splitter is a valuable tool because it allows us to see several different perspectives of the ROV at one time (Fig. 2-7)

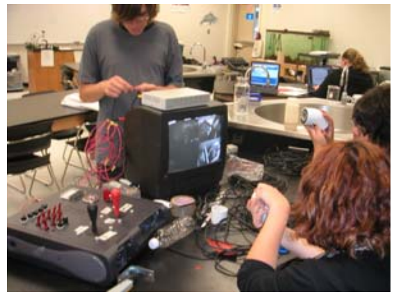


Fig. 2-7: Team members working with camera systems

Fig. 2-6: Atlantis B/W drop cameras

6. Reverse Thrusters

After a handful of trials in our small testing basin (Fig. 4-2), we concluded that it was necessary to have reverse capabilities. We then installed two DC powered thrusters, and positioned them to drive the ROV in reverse.

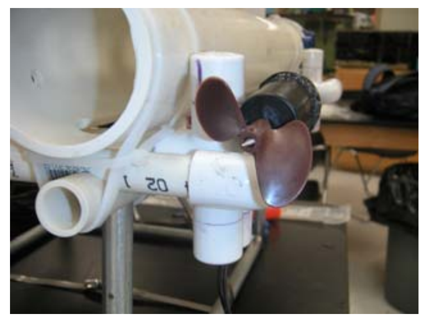


Fig. 2-8: Reverse thrusters

7. Tether

The tether consists of dual-cased 16-gauge wires which are resistant to oil and liquids (Fig. 2-9). The tether consists of several wires and conjoins *Megalops* with the control system and power source. The wires were then braided together to form a single tether. The wires converge in the center of the ROV to form the 50 ft. tether. The seven bilge pumps, two propellers, and three camera systems are intertwined within a single unit. At the end of the tether, it connects to the driving power source (12 volt battery) and the control panel.

Fig. 2-9: View of coiled tether which is approx. 50 feet.

8. Aluminum Conduit Base Frame

Megalops rests on an aluminum base. The aluminum structure was constructed out of half inch conduit piping which aids in base support (Fig. 2-10). Its function is to prevent cutting off the flow of water exiting the directional thrusters and to aid in the overall top to bottom stability. This stabilization helps to keep the ROV elevated which will also aid with buoyancy.

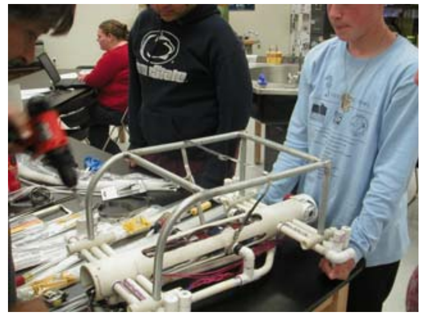


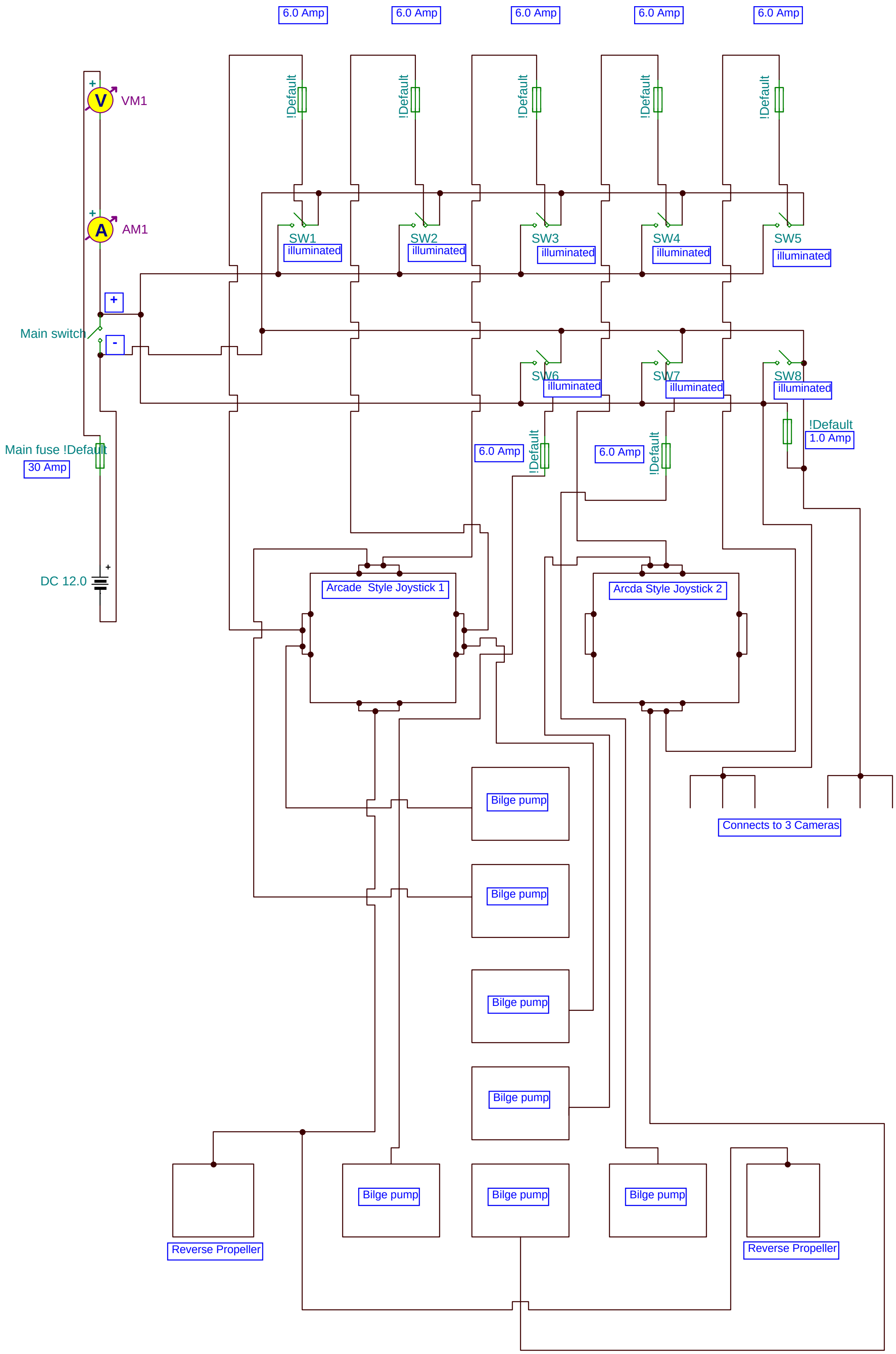
Fig. 2-10: Lower frame installation

1. Power Monitoring

We installed a voltmeter to monitor our power usage throughout our trials (Fig. 2-11) and an amp meter to monitor overall amperage through our missions as not to exceed the competition restrictions of 25 amps. This enabled us to correct ourselves if we ever went over our power budget. The meter was a good detector of any power overages and helped us quickly correct the error, or find a different device, which drew less power, to perform the desired tasks.

Fig. 2-11: Control panel with volt and

III. Electrical Schematic



Electrical Schematic (cont'd)

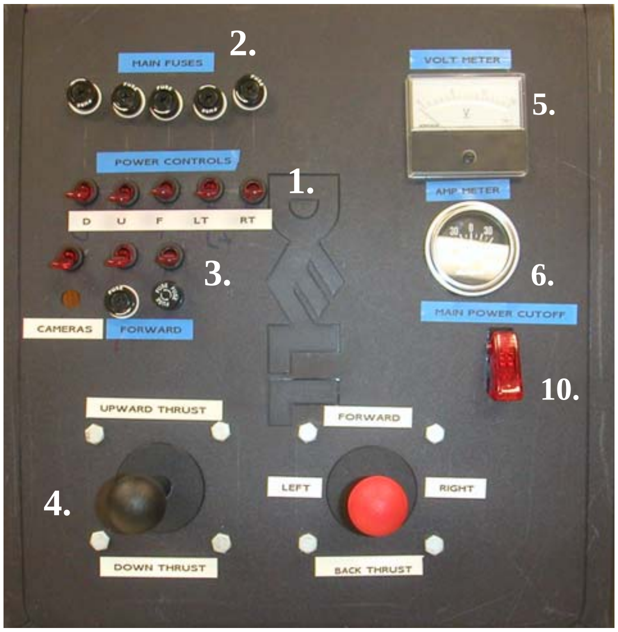


Fig. 3-1: Control Panel with corresponding numbers

Control Panel (Fig. 3-1) Includes:

1. 5 Bilge pump switches
2. 6 amp fuses per bilge pump
3. Two separate extra forward thrusts with individual fuses (6 amp) and camera switch
4. Arcade Joysticks hooked to bilge pump fuses
5. Voltmeter (V)
6. Ampere meter (amp)
7. Main fuse (30 amp), located inside.
8. Battery (12v DC direct current)
9. 1 amp fuse for camera power
10. Main kill switch

Meters and Fuses (safety catches): The control panel is incorporated with a Voltage meter, Ampere meter, a 30amp fuse, a1amp fuse, and seven 6amp fuses that act as safety catches for the protection of our system. The main (30amp) fuse is the first line of defense that blows when a surge greater than 30amps runs through the control panel. Secondly, the 6amp fuses protect the separate bilge pumps from small-scale surges that could damage their individual fuses. Third is our 1amp fuse that protects all three cameras from power overload. The power is monitored by our Voltage and Ampere meters and can be turned on and off by the main kill switch.

Switches*:* The control box features individual switches for each of the bilge pumps; a feature included for saving energy by having only the needed pumps prepared for use at a specific time. Switches 1 through 5 correspond to the original 5 bilge pumps (four directional pumps, one forward pump). Switches 6 and 7 match up to the two additional bilge pumps in the rear of our ROV.

Controls*:* The arcade style joysticks control two separate planes of motion and are thus hooked up to the bilge pumps which control those directions of movement. One joystick controls the up and down movement of the water column, while the other controls the left-right / forward motion. When one of the joysticks is moved, it sends power to the specific bilge pump that corresponds to the specified direction and shuts off a previously engaged directional movement.

Reverse Thrusters: The reverse thrusters stem off of the micro-switch on the bottom base of the joystick. When activated (by moving the joystick in a downward direction), the micro-switch is turned on and transfers power to the reverse thrusters. These thrusters help slow down the vehicle as well as move it in reverse.

Cameras: All three cameras are attached to switch 8 of the control panel. When the switch is activated, the power passes and branches three ways to power each separate camera. These wires terminate at separate DC power plugs. These plugs are connected to the camera adapters which enable the cameras to be powered and give sight to the ROV.

IV. Challenges

- One of the pressing problems was the main body of *Megalops*, which housed the bilge pumps (Fig. 2-2). This body restricted the flow of water into the pump system which decreased the outward flow of water. To solve this problem, we increased the flow of water to the bilge pump by cutting long rectangular slits in the surrounding pipe. This allowed for a larger amount of water to enter the hydro propulsion system, which in turn provided a greater, more powerful outward thrust.
- Another challenge arose from the original metal frame design. Our original intentions were to have the frame constructed of stainless steel or aluminum. Our team had designed blueprints depicting a custom made frame to house *Megalops'* components and stay within the required specifications. We had agreed to work in conjunction with our school's welding program, but some unforeseen problems arose.

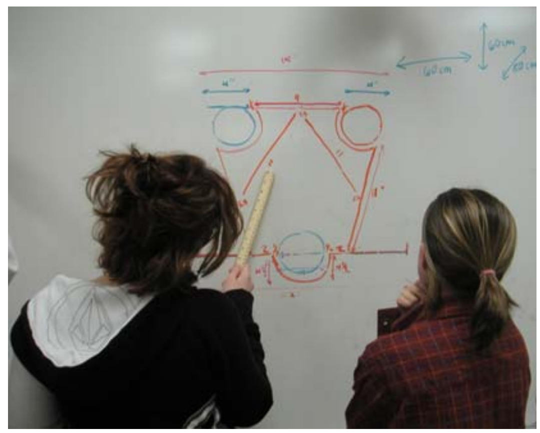


Fig. 4-1: Team members designing initial frame blueprints

Unfortunately, the initial frame prototype that the welding students presented to us was not constructed to scale and the specifications that were determined by the blueprints (Fig. 4-1). It was too unstable to go through the events we would have to complete. It was made out of very thin sheet metal rather than metal piping we had requested. The frame did not have the strength to withstand the physical stresses that it would have to endure in each of the pool missions. These matters were expressed to the welding team with concern in hopes that we would come to an agreement for another design. Unfortunately, it turns out the team could not form the rounded hollows at the top needed to contain the PVC piping ballast we had created. The Welding Department told us that they could make a box frame out of metal. Two weeks later welding gave us the second frame. This frame fit the criteria we needed, but other problems arose while testing the frame. The weight of the metal was too great and our hydro propulsion system did not have enough power to push the weight of the frame.

There was the option of making the frame from PVC piping, but new problems arose. The main obstacle was that the PVC piping would make our ROV weightless considering it is plastic, hollow, and full of air. We had thought that it would push it to the surface regardless of how strong our downward propulsion was (Fig. 4-2). After careful consideration, we opted to go frameless, only using the PVC piping for housing the propulsion system. We already had calculated the weight and ballast of the ROV without the frame, and considering the power of the hydro propulsion system, the haze of problems surrounding the frame issue dissipated. Without a frame, the ROV design was simpler and allowed us to work on the components that were put on hold by the frame.

Fig. 4-2: Trial runs of the ROV in a test basin.

The buoyancy control system, or ballast, was a cause for some problems we encountered in the making *Megalops*. Ballast contributes to the stability of an underwater object, and is one of the most important variables concerning the achievement of neutral buoyancy. When we started to construct the vehicle, buoyancy was not our main focus. We attribute this to the fact that we were awaiting a frame from Welding to work around. But in the later part of the production, we found it necessary to discuss the situation and re-evaluate the problems we now faced. Since we had decided to omit an outer frame, we would have to decipher another way to control the positioning of the ROV in an aquatic environment. Our first design involved two large PVC pipes placed on the top of the ROV to maintain buoyancy. The pipes were too positively buoyant for the thrusters' restricted power and we were unable to attain or maintain neutral buoyancy. Our second attempt at an ideal ballast was a square-shaped, air-filled PVC tube which was slightly smaller then the last tubes we had used before. This tube system compensated for the weight of the unit better, where it was needed, whereby controlling balance more precisely. We also incorporated into the design another tube on both sides of the ROV to house the cameras needed to monitor the underwater challenges. These two tubes would also be a factor in the buoyancy and ballast equation, which we carefully monitored. The pipes were uncapped and filled with foam. The foam housed the cameras and provided more security for them. These two types of pipes combined made our buoyancy perfectly balanced. With the addition of the downward thrusters, *Megalops* would sit neutrally buoyant in the water and would come back to the surface when the upward thrusters were turned on. It was a success.

V. Troubleshooting Techniques

We first encountered problems concerning the hydro propulsion system when we tested the unit in a shallow pool (Fig. 1-2). The directional pipes themselves failed to propel the ROV at an effective rate. So we sprung into action and began brainstorming about how we can improve out ROV. We deduced that the ridged, corrugated tubes connecting the pipes were both too long and created too much resistance to allow enough water pressure to propel the ROV. We tested flexible plastic tubing for the connections, but it was too unstable for the propulsion system. We decided on using custom configured PVC piping (which was manipulated using heat) instead. The PVC piping is smooth and does not cause nearly as much water friction as the original piping. The flow pipes were rearranged until we found the layout which was most energy efficient and balanced (Fig. 5-3).

Fig. 5-1: Resistance caps on directional thrusters

Concerning the directional control pipes themselves, the release outlets were too large and allowed for a drop in pressure. To counteract that problem we placed restrictor caps (Fig. 5-1) on the ends of the PVC piping, which by narrowing the pathway therefore increased the force of water exiting the tubes. This allowed for an efficient water flow throughout the tubes. To ensure maximum water flow, all connected tubing areas were sealed with a waterproof silicone sealer. None of these steps resulted in any changes in electrical use from the original design, which was already under the dictated margin of 25 amps and 13 volts.

Another variable we had discovered was that the main body of the ROV, which housed the bilge pumps, restricted the flow of water to the pump system; which decreased the output flow rate of water. To solve this problem, we increased the flow of water to the bilge pump by cutting holes in the surrounding pipe. This allowed for a larger volume of water to enter the hydro propulsion system. The system was now running with more power.

After more shallow pool tests (Fig. 4-2), we found that all of the directional pipes did not provide the foreword and side to side movement we needed to propel the ROV at a rapid enough rate. In contrast the single, separate bilge pump we had employed for reverse propulsion was quite powerful and moved the unit efficiently. To resolve the problem, steps were taken to modify the ROV so that the front of the unit, where the reverse pump was located, now faced forward (Fig. 5-2). We were successfully in adding more forward power. Essentially, nothing structurally complicated was reworked; simply put, the directional flow pipes were rotated into positions that would be correspond to the new configuration of the anterior designation. This arrangement was tested, and proved capable of driving the ROV, but there still were more adjustments to be made. Being below the electrical usage limitations, we decided upon adding two more foreword facing bilge pumps to further facilitate foreword movement.

Fig. 5-2: Former reverse converted to forward thrust

Keeping in mind the lack of a proper backward propulsion component, we decided to add two DC-run prop thrusters to the vehicle (Fig. 2-8). This would produce the backward motion the unit would need for fine-tuning its position underwater. With the problems concerning the hydro propulsion system worked out, the team moved onto the ballast, and buoyancy control system (5-4).

Fig. 5-4: Air/water-tight PCV ballast for added buoyancy.

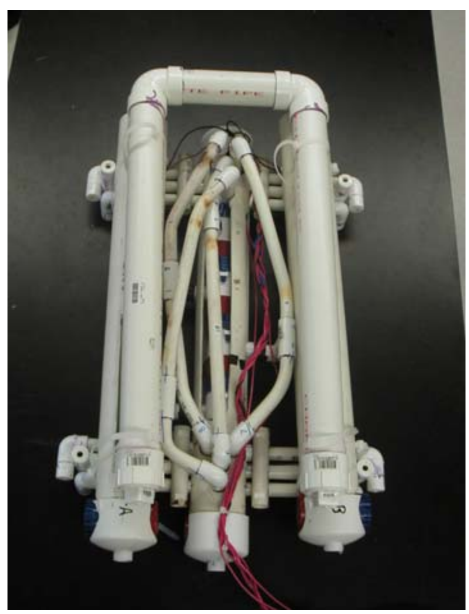


Fig. 5-3: Series of heat manipulated and bent PVC channels utilized to fine tune directional movement

VI. Skills Gain:

1. Students learned how to work with a variety of personalities. Even though there may have been problems between members, the students learned to work professionally and keep feelings aside. In addition students learn how to take constructive criticism. This skill is essential for future careers.

2. Students acquire hands on skills by working with tools and creating an ROV.

3. Students learned how to come up with quick solutions to a problem. They learn how approach problems heads on, and come out successful. As the months passed by, students learned how to utilize all of their resources coming up with new and improve ideas and plans for the ROV. They learned how to think analytically

4. Most importantly the students gained the experience. The project gave students the chance to meet others of similar age and interests. They had the chance to work "hands on" on an underwater robot. The team as a "whole" had a chance of learning completely new subject. The skills gain during the student may open up new career aspects such as marine tech. This project allowed students to focus on their goals. In addition this allowed students to get a taste of teamwork and well help us on future projects.

VII. Future Improvements

- **The Stronger Propulsion System-** Throughout the year, many changes have been made to provide a better propulsion system. After creating different prototypes we finally came to the system most applicable to our needs. In the following years we hope to become more experience in creating a stronger propulsion system by using a minimal amount of power. In addition, we hope to create the propulsion system earlier in the competition year, as to concentrate on other technology to advance our ROV.

- **Multifunctional Arm-** One of the main issues with our team is trying to create a functional arm. Originally members of the team developed a prototype by using servo motors. These servo motors allowed for strength and mobility. The suggested prototype was later dismissed because the idea was too complicated and we felt not necessarily needed to complete each task. Hopefully in the following years, the team hopes to create a better arm. This arm would be versatile and able to carry out many tasks. Hopefully this arm would be able to be used in future competitions and work out in the field.

- **Time Management-** Due to the short amount of time we had to begin the ROV project (January of the school year), our management of time was essential to the efficiency of the developing process. One thing that is critical to the competition is separating the group into two strata, one focused on the technicalities of the ROV and the other for the building/ hands on part of it.

VIII. Budget and Expense Sheet

School Name:		*Marine Academy of Technology and Environmental Science*		From:	1/14/2005
Instructor/ Sponsor:		Tina Held Marine Science Coordinating Senior Instructor		To:	5/27/2005
Date	**Deposit/ Expense**	**Description**	**Notes**	**Amount**	**Balance**
1/14/2005	Expense	3 Robotics text/ Reference Books	Student Reference	$72.50	($72.50)
1/24/2005	Deposit	MATE Trust Fund	Competition Supply Fund	$100.00	$30.86
2/9/2005	Deposit	Donation/Sponsor from the Marine Science Club	Funds for Supplies	$500.00	$530.86
2/15/2005	Donation	Jerry's Marine Service Donation of Parts	5 Bilge pumps and PVC/hoses for Phase I propulsion system	$121.65	$530.86
3/3/2005	Deposit	Donation/Sponsor from the Yankee Stripper Inc	Funds for Supplies	$200.00	$730.86
3/18/2005	Expense	JJ Communications Inc.	Underwater Cameras & Cables + s/h	$634.00	$96.86
3/31/2005	Expense	Jameco Electronics	Robotics arm parts + s/h	$66.00	$30.86
3/31/2005	Expense	Happ Controls Electronics	Robotic arm parts/joysticks + s/h	$39.46	($8.60)
3/31/2005	Expense	Northern Tools & Equipment	Robotic arm brake cables + s/h	$12.67	($21.27)
3/31/2005	Expense	Tower Hobbies	Robotic arm servos + s/h	$87.11	($108.38)
4/20/2005	Expense	Advance Auto Parts	New Amp Meter for Control Panel	$18.95	($127.33)
4/21/2005	Expense	Home Depot	Revise thruster parts	$50.27	($177.60)
4/25/2005	Deposit	MATES/PTSO Organization Donation	Parent Org. demonstration for cameras	$634.00	$456.40
5/5/2005	Donation	Toms River Fitness and Aquatics	Donation of pool time (24 hours at $50 per hour)	$1,200.00	$456.40
5/5/2005	Donation	Ocean County YMCA	Donation of pool time (20 hours at $50 per hour)	$1,000.00	$456.40
5/2/2005	Expense	Ballast parts	Lowes parts	$12.64	$443.76
5/3/2005	Expense	Ballast parts / PVC	Lowes parts	$28.15	$415.61

		& joints & caps			
5/2/2005	Expense	Gas cylinders for butane torch	Melt PVC tubes/ Lowes parts	$16.88	$398.73
5/9/2005	Expense	Replacement & spare fuses (7 amp)	Radio Shack	$1.69	$397.04
5/9/2005	Expense	Spare fuses	Radio Shack	$17.64	$379.40
5/9/2005	Donation	Kurt's Marine Inc.	4 Bilge pumps for Phase II propulsion system & 2 rear propellers	$93.56	$379.40
5/23/2005	Expense	Ballast & Camera Support Parts	Lowes Parts/ Supplies	$40.84	$338.56
5/20/2005	Deposit	OCVTS Board of Education	Airline ticket donation to ROV team	$3,585.76	$3,924.32
5/20/2005	Expense	16 Airline tickets at $224 each	Southwest Airlines to Houston	$3,585	$338.56
5/19/2005	Deposit	MATES/PTSO Organization	Lodging, Shuttle, and Shipping	$2,820	$3,158.56
5/23/2005	Expense	Lodging expenses at competition	2 Hotel rooms at Extended Stay America	$735.92	$2,422.64
5/24/2005	Donation	Camera Maintaining Parts	Ferguson Enterprises Inc.	$14.07	$2,422.64
5/25/2005	Donation	Frame Materials	Home Depot/Kurt's Marine	$54.64	$2,422.64
5/25/2005	Donation	Arm attachment adapter	Lowes 4 1/2" adapters & pipe	$1.82	$2,422.64
5/26/2005	Expense	Update 50 ft tether wire	dual-cased 16 gauge wire	$75.15	$2,347.49*

*The rest of the balance is scheduled to be used while in Texas at the competition. It is to be used for such things as the airport shuttle and for food that is not provided. If any balance remains, the funds will be transposed for startup costs for next year's 2006 competition.

IX. Career Potential

The events of the MATE ROV Competition portray the importance and capabilities of ROV use in various fields of technology. The potential of ROV technology has become recognized more and more by marine, space, and military establishments. They are finding ways in which this growing technology can aid in their lines of work. One organization that is recognizing ROV technology and supports one of the competition's mission themes is the oil drilling industry. The oil drilling industry has established off-shore platforms that are responsible for good portion of our country's crude oil supply, and can utilize the significant aid that ROV technology has to offer.

The oil drilling industry is the driving force of the American economy in that most of our homes, businesses, and automobiles depend on its constant supply. The crude oil that is collected is later rid of its impurities through a process known as refining. In refining, crude oil (petroleum) goes through the process of fractional distillation where impurities are separated using their different boiling points. When the oil is out of its crude state, it can be further refined into gasoline, kerosene, lubricating oil, and petroleum gas. These different products serve fuel, heating, lubricant, and energy for millions of Americans and billions of people in other countries. Having ROV technology incorporated in this huge industry would aid in an efficiency boost to an already important energy source.

Fig. 9-1: Off-shore oil drilling platform

For off-shore drilling stations (Fig. 9-1), ROVs can be utilized to accomplish numerous significant tasks. In a maintenance perspective, remotely operated vehicles may be used to repair any broken/damaged pipes, valves, or hoses under water. Also, necessary inspection needed to keep operations up to code can be done using the submersible cameras equipped on specialized ROVs that will survey the area needed of inspection & will help surface crew in determining what proper measures need to be taken to improve or restore submerged operating systems. With these capabilities being used, it will eliminate human risk factor, and essentially save money to each corporation that embraces the technology. As ROV technology continues to gain attention, those that recognize its potential will help establish a permanent place for ROVs in everyday use.

X. Acknowledgements:

Tina M. Held/ Team Coach and Facilitator

Kurt Berger/ Team Mentor

Ocean County Vocational and Technical School Board of Education

OCVTS Tech/Computer Design

OCVTS Architectural/Engineering Design

OCVTS Welding

Kurt’s Marine Inc.

MATES Parent, Student, and Teacher Organization (PTSO)

Marine Advanced Technology Education (MATE)

MATES Marine Science Club and SCUBA Club

Yankee Stripper Inc.

Divers Two Dive Shop

Toms River Fitness and Aquatics

Ocean County YMCA