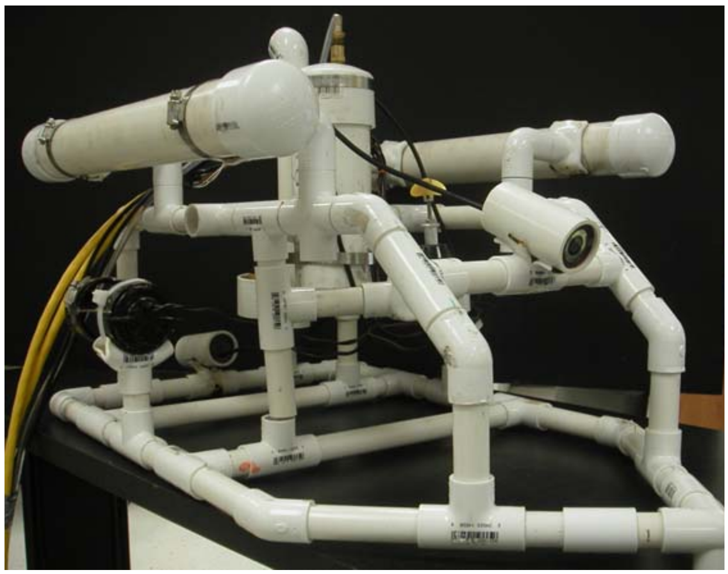
Technical Report

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

The National MATE Center ROV Championships 2006



Aquafox

Team Members:

Maria DeLeon and Connor McBride, 2006; Kyle Boehm, Christianna Campbell, David Geeter, Dakota Goldinger, 2007; Alan White, 2008; Jacob Hershey, Nick Loizos, Brian McWeeney 2009.

Mentors:

Tina M. Held, Marine Science Inst., Coach/Facilitator/Mentor
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I. Abstract

Fig. 1-1: Team members testing ROV for stability, driving ability, and power.

The Marine Academy of Technology and Environmental Science (MATES) team constructed a ROV capable of contending in the 2006 MATE Center ROV competition. Analytical and practical thinking were essential tools in deciding the plan of attack. The team carefully planned the manner in which they were to launch this endeavor. In order to make swift headway into the assemblage, the frame was designed and constructed early. After some frame design modification, the propulsion system was fitted to sit efficiently within frame constraints and provide optimum driving force (Fig. 1-1). The system consists of four marine pumps. Each pump was converted to a submersible drive motor capable of force equivalent to 3800 LPH. Together the motors provide vertical and horizontal movement. In order to successfully complete the predetermined missions, two detachable appendages were customized to be suitable per task. Mission #1 arm is constructed with several metal wire extensions to pull out the pin locking the instrument buoyant. Mission #2 arm is more ornate to match the added complexity of said mission. Since Mission #2 requires releasing a negatively buoyant module, it was a necessity for the ROV to have an adjustable buoyancy system, thus one was created accordingly. The ROV, near to completion, was naturally negatively buoyant. Two sealed ballast tubes were created to counter balance the main weight of the ROV. In order to fine-tune neutral buoyancy, a custom designed buoyancy control system, modeled after a diving bell was produced. The tether, which supplies power and encases the video cables, runs the real-time image monitoring system to the surface. Real-time data and imaging exemplifies the focus of this year's competition, ocean observation (Fig. 1-2).

Fig. 1-2: Team collecting technical information about Rutgers Univ. Ocean Observation system LEO_{15} (see sec. IX)

II. Design Rationale

Throughout the design process we kept in mind certain restrictions:

- Ranger Class Criteria and Missions
- Maximum onboard power of 13 volts DC and 25 amps
- Conducting competition in chlorinated freshwater
- Maximum of three cameras
- Depth rating of up to 5 meters
- Complete each mission within 25 minutes

Frame Design

Fig. 2-1: First frame made from design sketches,

Fig. 2-2: Team members using PVC cement to create a water proof/air tight seal around seam

In building previous ROVs the team has discovered that polyvinyl chloride (PVC) pipes work best due to its rigid structure and durable strength. The team constructed the ROV frame from design sketches. After a proportional size reductions (Fig. 2-1) and seam sealing (Fig. 2-2) the frame ready for further construction.

Height 48cm Length 76.5cm Width 47.5cm

Weight 9.8kg Tether Weight 9.5kg

Propulsion System

Aquafox's propulsion system consists of four powerful motors. The team chose these motors (converted from submersible drive motors) to supply the power due to the numerous advantages these motors contribute. The pumps are conducive to our needs based on high availability, the team's previous experience with the technology, and usage of water in propulsion (Fig. 2-3). The pumps supply Aquafox with a great deal of power, while only drawing 4.0 amps per pump. The impellers were removed and Master Airscrew ® 3mm shaft propeller adapters were then added to each of the four drive motors. Two of the motors use right-handed Octura ® (yellow) plastic glass filled 50mm props with a 2.364 pitch for upward and downward thrust (Fig. 2-5). The remaining two props use right-handed Octura ® (black)

Fig. 2-3: Assembling the props and motors used for propulsion

plastic glass filled 57m props with a 4.256 pitch for forward, backward, right, and left thrust (Fig. 2-4). The team also constructed and added cort nozzles to each lateral (2) thruster to increase the channel flow which increases forward propulsion (Fig. 2-4). These cort nozzles also act as a safety measure; they protect the team from being cut while in the water testing. The pumps were rated at 3800 LPH. There are two pumps situated at the right and left lateral sides of the ROV. These pumps are dedicated to forward and directional movement. Two additional 3800 LPH pumps are positioned in the central region of the ROV. These pumps have been dedicated to vertical movement, and positioned accordingly. These motors combined with the relatively light weight of the ROV, produce a fast moving vehicle.

Fig. 2-4: Thruster with cort nozzles attached for speed and safety concerns, laterally placed motor for forward, reverse, and right and left movement

Fig 2-5: Central thruster used for vertical movement

Mission # 1 Arm

Fig. 2-6: Mission #1 arm, top two images of first appendage, this is used to pick up and insert tele-com connect, bottom image is of second appendage used to open door to the electronics module

Our second arm to open the information port module door and insert the telecommunication link was more difficult to design. The primary section of the arm was to be used to open the door. It was a small metal hook on a metal arm 31cm long. This arm uses the design of the door to its advantage (Fig. 2-6). The upward facing hook will be driven into the mesh, with a small degree of upward movement; the hook would be caught on the wiring. Then with a reversal movement, the door would swing open. The secondary part of the Mission #1 arm is used to pick up the missing link, and replace it into the module.

Mission #2 Arm

a. *b.*

c.

Fig. 2-7: Mission #2 arm. *a*,frontal view of arm, used to catch the pin; *b*, biological species, lamprey, which resembles the design of the arm; *c*, top view of arm, the bottom extension is in place for best camera vision.

Our first appendage is similar in appearance to the mouth of a lamprey (Fig. 2-7). It is 21 cm long section of 2"/5.1cm PVC tubing. At the outward end, the team has created a funnel of metal wires. When the arm is lined up with the key pin, the pin will be directed inward to the end of the metal wires. Once the ROV is directed in reverse, the key will become caught on one of the many wire projections. The key will be drawn out of the chain, and will therefore release the information package buoy. The strength necessary to remove the pin was given to be 1N. The arm was tested with spring scales (Fig. 2-8) for its durability, and the strength necessary to bend the wire projections. It took 8N to begin modifying the structure.

Fig. 2-8: Spring scales used to calculate durability with increasing newtons

Buoyancy System

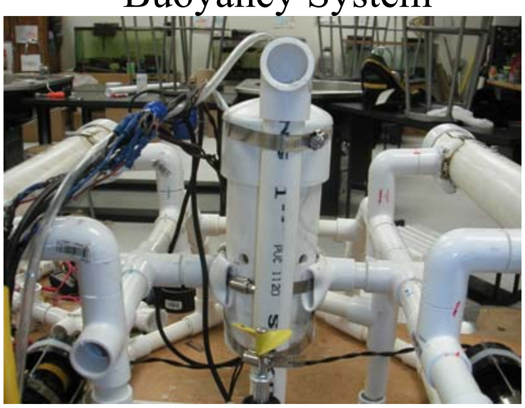


Fig. 2-9: Custom secondary buoyancy system modeled after a diving bell made specifically to compensate for weight of Mission # 1 electronics module.

In order to execute missions the ROV needed an adjustable buoyancy system. The two interacting ballast systems are to compensate for current weight and to find a neutral standing. The primary ballast system is comprised of two watertight 52cm PVC tubes located on the dorsal sides, each providing 9N buoyant force. The ballast tubes are raised from the center of gravity to increase stability in the water (Fig. 2-10). The secondary ballast is a mini re-creation of the diving bell (Fig. 2-9); a customized buoyancy

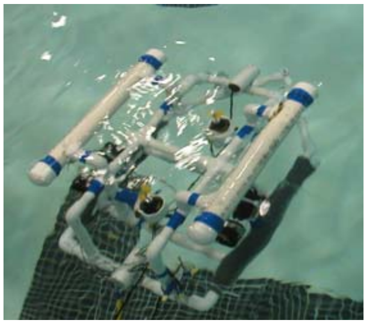


Fig. 2-10: Aquafox before the additional buoyancy system, stable but could not compensate for weight of the electronics module for Mission #1

control system. The bell, which is 24.6cm in height (13.164cm length dedicated to air storage) and 10cm in width, is located in the approximate center of gravity. From the bell, runs tubing that attaches to an air compressor at the surface. The captured air in the bell can be released via a manual pressure valve, in turn returning the ROV close to neutral buoyancy.

Camera Systems

The team's prior experience with black and white cameras prompted them to purchase color cameras. Lights Camera Action ® drop cams were purchased. The color cameras (2) incorporate a highly sensitive color module and 380 TV lines of resolution, to create an excellent image for underwater perspective. These cameras are essential to the successful operation of Aquafox (Fig. 2-11). The camera wires are fed to a quad splitter which then directs the image to the television. The quad splitter is a valuable tool because it allows the team to see several different perspectives of the ROV at one time during the missions at the competition. The team members enjoyed practicing alignment on the cameras, and positioning on Aquafox's frame (2-12).

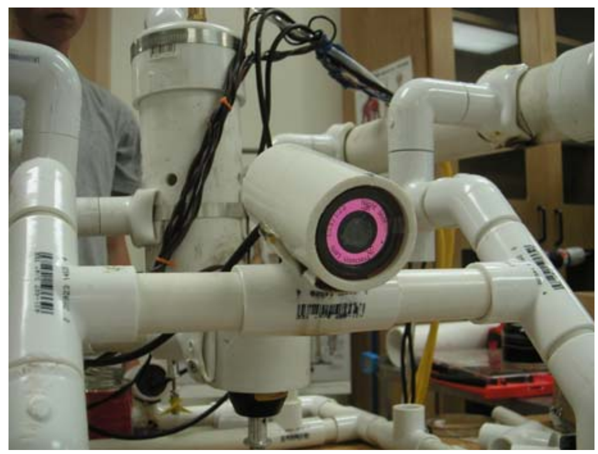


Fig. 2-11: Camera system mounted on the ROV.

Fig. 2-12: Team familiarizing themselves with camera workings

Tether

Fig. 2-13: Tether connected to the ROV via the central point of the bell system. Additionally PVC tube added to house the tether as it exits the vehicle, (see Fig. 2-9).

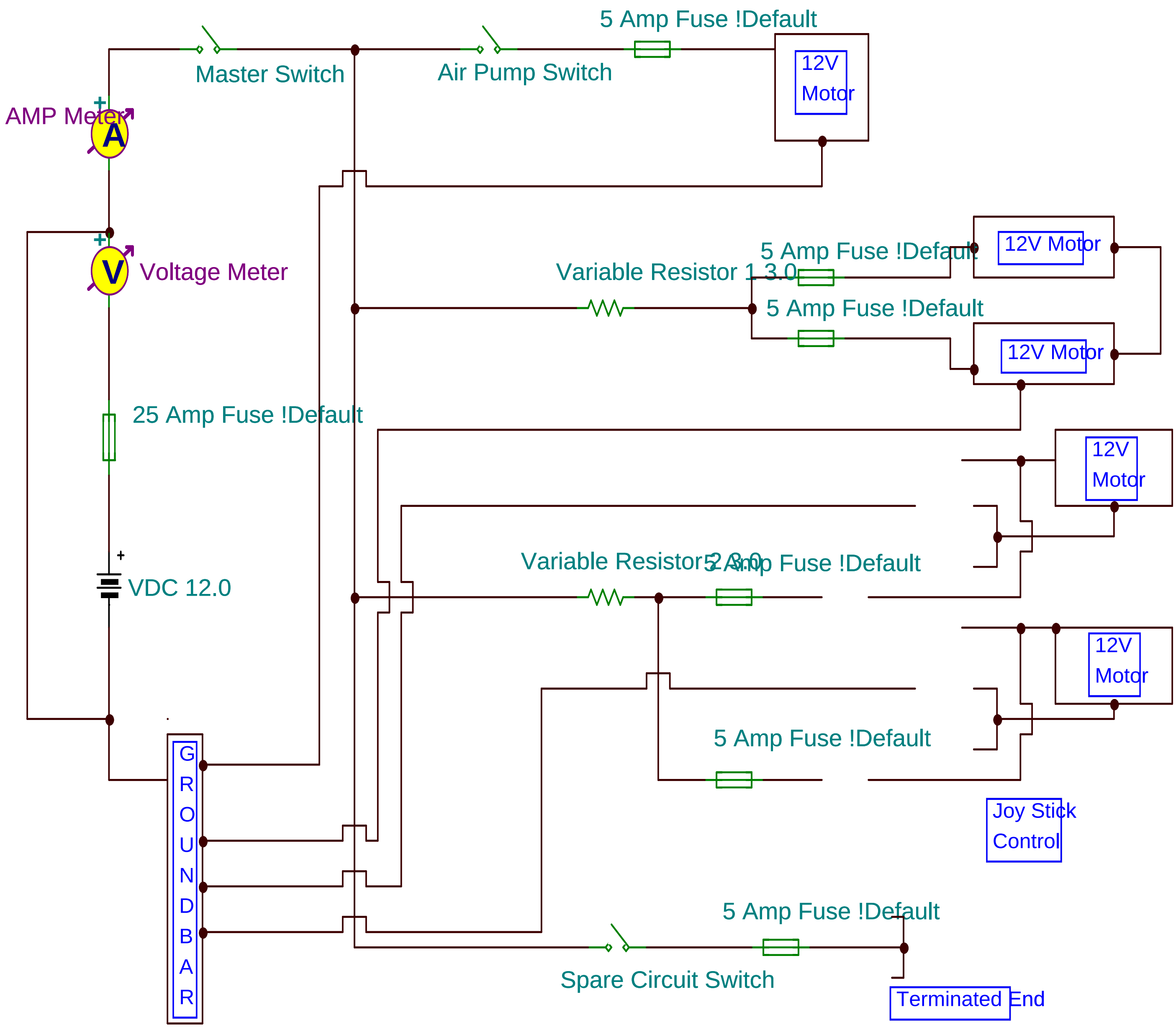
The tether provides the ROV with the power and control via a control box and in turn sends video back to surface for monitoring and recording in real time (Fig. 2-13). There is a total of 15.24m/ 9.5kg tether that accomplishes this task. The tether is, however, not a single unit but is comprised of interacting lines. Encased in the custom sealed tether is two, 8-wire underwater cables. The two cables are equipped with three pairs of 24 gauge wire and one pair of 20 gauge wire. Also included within the tether is the two camera wires that send the real-time feedback to the drivers at the surface, this tool is necessary for ocean observation of ecosystems.

An ammeter was installed to monitor Aquafox's current draw throughout trials and the competition, (Fig. 2-14) so as not to exceed the competition restriction of 25-amps. The meter was an indicator of any current overages and helped us quickly correct any such errors, or find a different device, which drew less current, to perform the desired tasks.

Power Monitoring

Fig. 2-14: Ammeter and volt meter on installed onto the control box of Aquafox in order to monitor power consumption while pool testing, and participating in the competition.

III. Electrical Schematic



Electrical Schematic (cont'd)

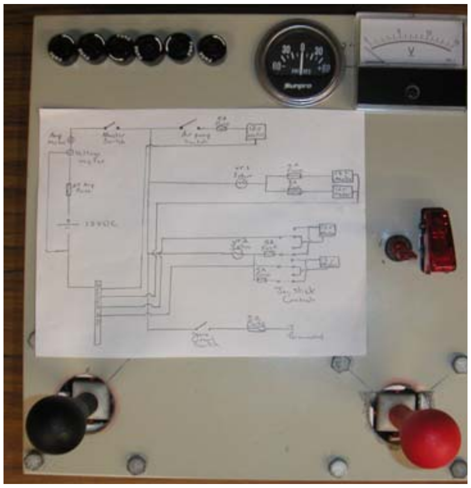


Fig. 3-1: Control box with inlay of electrical schematic

Meters and Fuses (safety catches): The control panel incorporates a voltmeter, ammeter, 25-amp main fuse, and six 5-amp fuses (Fig. 3-1 & Fig. 3-3). The main fuse (25-amp) is the primary over-current device that opens when a current greater than 25-amps runs through the control panel. The 5-amp fuses protect the separate drive motors and would open if an individual motor fails thus isolating it from the rest of the circuit. The power is monitored by our volt and ammeters and the entire controller can be turned on and off by the main kill switch.

Switches*:* The control box features individual 1 through 4 switches for each of the drive motors; a feature that will enable us to disconnect a failed motor. Along with these switches, is a switch for 2 color cameras, and an additional switch to activate our secondary buoyancy device.

Controls*:* The arcade style joysticks control two separate planes of motion and are connected to the individual drive motors which control those directions of movement. Each 8-position joystick engages 2 drive motors (Fig. 3-2). The left joystick controls the 2 portside motors. The right joystick controls the 2 starboard motors. The joysticks are configured as follows:

12 0'clock position: Forward horizontal thrust
6 0'clock position: Reverse horizontal thrust
9 0'clock position: Downward thrust
3 0'clock position: Upward thrust

Simultaneous dual-motor control is accomplished by positioning the control levers in a diagonal orientation. Example; forward and downward thrust is attained at the 10:30 position. Through the use of both joysticks any desired variation of mobility can be attained. The use of 2 rheostats, have been added to connect a series with the joysticks, which allows for control over the amount of overall thrust to each of the motors. This will enable us to have slow stability while maneuvering through each of the missions.

Cameras: The two color cameras are attached to switch 8 of the control panel. When the switch is activated, the power passes and branches two ways to power each separate camera. These wires terminate at a separate DC power plug. These plugs are connected to the camera adapters which enable the cameras to be powered and give sight to the ROV. The camera's video feeds are connected to a quad-splitter, which allows viewing simultaneous screens via a television.

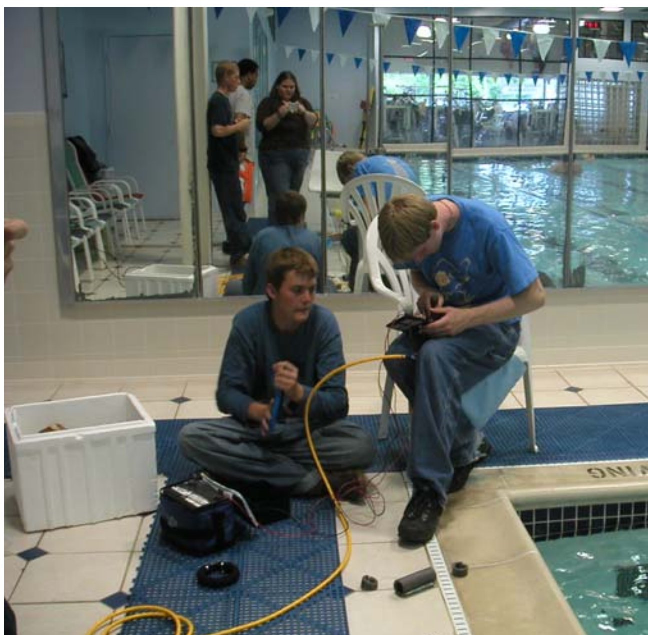


Fig. 3-2: (*above*) Team members working out some electrical "kinks" before pool testing

Fig. 3-3: (*below*) Students working on electrical wiring for Aquafox control box

IV. Challenges

- This year's missions are complex in design, but more believably mirror the tasks that modern ROV technology will face. The number one challenge in constructing this year's ROV, Aquafox, was designing a buoyancy system that could withstand the additional weight of the electronics module for the first mission. The buoyancy control system, or ballast, was a cause for some problems we encountered in the creation of Aquafox. Ballast contributes to the stability of an underwater object, and is one of the most important variables concerning the achievement of neutral buoyancy. The ROV needs to be able to compensate for the additional weight, the electronics module, that she needs to transport to the mission platform, but cannot maintain this level of positive buoyancy after the module is release, or the ROV will fly to the surface. The mission requires a system that can adjust buoyancy so that the ROV returns to neutral buoyancy.

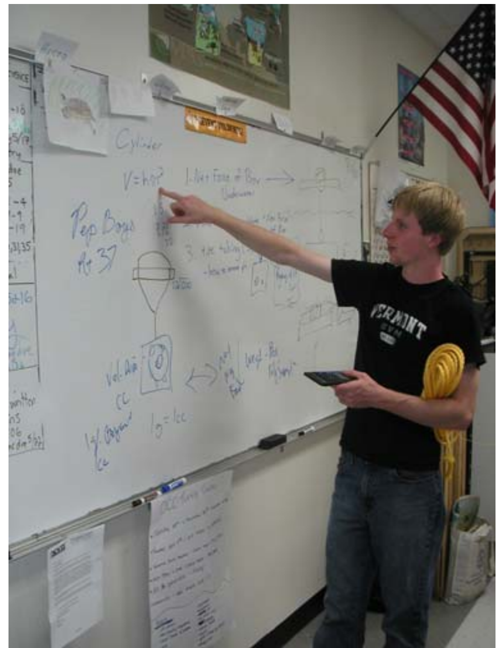


Fig. 4-1: Team member problem solving a buoyancy challenge the team was faced with.

Hence, the team designed a buoyancy control system to compensate for the change in buoyancy when the electronics module is released. In theory, the buoyancy control system works like air in a diving bell or a cup underwater. The team has have constructed a small air chamber inside the ROV itself. The air chamber is connected to a pump at the surface. The chamber has a small row of holes along the midsection to allow water inside, once the air pressure is decreased. The bell uses the air pressure from the compressor at the surface to retain air for additional positive buoyancy, and then using a physical pressure valve at the surface, the pressure can be relieved once the electronics module is released, returning the ROV to neutral buoyancy.

- As with any ROV team, design, construction, and testing sessions need to be scheduled. It becomes difficult to find a time when all the members can attend. Each team member needs to work around ride availability, working, other extracurricular activities, sports, school work, and personal time (Fig. 4-2). Now, to multiply those difficulties by 10, for each team member, and then 100 for the busy schedule of our facilitating coach, and you see wherein the problem lies. The organization of our county-wide school makes this challenge even more difficult. Without provided after school transportation, people needed to make many sacrifices for Aquafox. In resolving this issue, most members sacrificed their time and adjusted their own schedules around ROV sessions. This may sound difficult, but it produced a team of very dedicated workers in the end. Fortunately, the construction of the ROV stayed on schedule and the team continued on, and there were notable improvements with every meeting. In the end, this challenge seems to have been met with well-matched suitor in the team's dedication and belief in Aquafox. Most people would agree that a team with dedicated members works more efficiently to get the job done. In the end, it was all worth it, the comradery of a team and the satisfaction of a job well done (Fig. 4-3).

Fig. 4-2: Busy team member hard at work

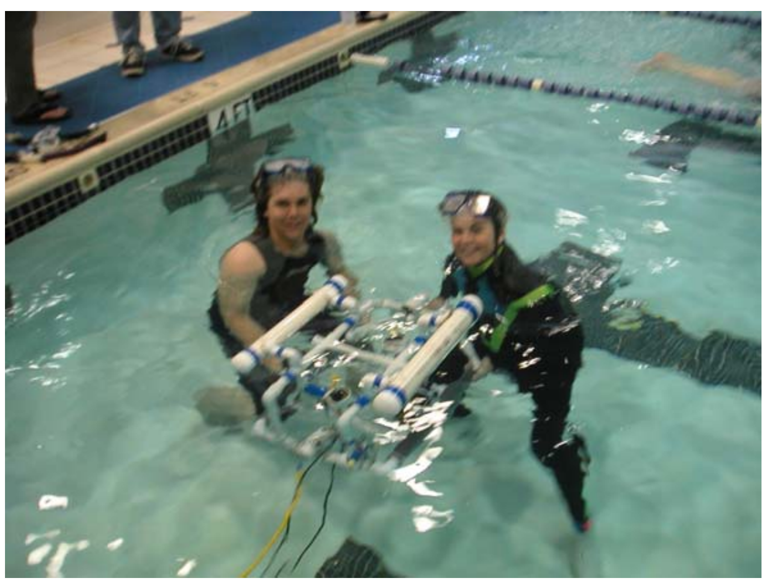


Fig. 4-3: Team members enjoying some time with Aquafox

V. Troubleshooting Techniques

After reviewing the mission set-ups, the team realized that the ROV needed to have an adjustable buoyancy system. The ROV's first mission entails carrying an electronics module, additional 500g (Fig. 5-1), to the mission platform. In order to compensate for this weight, an extra buoyancy system was designed. The "bell" is a small section of 7.62cm wide PVC tubing 13cm in length. It functions as a "cup underwater," in that air is trapped within the tube, which is capped on the top end. The bell is secured at the center of gravity, via bent PVC t-connectors. This custom support system is perfect for the rounded shape of the bell. The air can then be transported down to the mission platform. Once the ROV releases the mission box, the entrapped air will be released, therefore returning the ROV to neutral buoyancy. The air is released because of the natural pressure of air, in that the air underwater will seek the lower pressure of the surface, the container would then be flooded with water. The maximum buoyancy the system has been designed to hold is 600g/600cc (Fig. 5-2); the amount of withheld air can be adjusted to fit the ROV's needs. If it was necessary to add an extra appendage, the 600cc of buoyancy would neutralize the weight of the box and any additional pieces. Secured at the top of the bell is an air tight valve connection. The top of the valve is connected to air tubing which is attached to an air compressor at the surface. The air line will be wrapped around the tether, which originates at the central point of the top of the bell. This air line can be wrapped around the tether in differing intervals in order to help the tether to become more neutral.

Fig. 5-1: Team member using spring scale to calculate the force (N) as well as weight (g) of the electronics module.

Fig. 5-2: Using knowledge of physics and math to compete calculations for size of the 2nd buoyancy system

Volume	=	**$h \pi r^2$**
$600 cm^3$	=	$3.81 cm^2 h \pi$
$600 cm^3$	=	$14.51 cm^2 \pi h$
$600 cm^3$	=	$45.58 cm^2 h$
$\frac{600\ cm^3}{45.58 cm^2}$	=	**13.164 cm** length necessary for PVC tube 3"/ 7.6cm wide

VI. Skills Gained:

- ☑ **Understanding of Engineering:** Students developed a design for the ROV that would suit the competition and given restrictions. The team acquired hands-on skills by working with various tools to successfully create a functioning ROV.

- ☑ **Physics of ROVs**: The team used different calculations to develop specified buoyancy systems and determine the necessary power to complete the assigned tasks. General physics knowledge became essential for ROV construction. This is the reason we go to school, to take what we learn in the classroom and apply it to real-life situations.

- ☑ **Problem Solving:** Students learned how to come up with quick solutions to a problem. They learned how to approach problems head 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.

- ☑ **Analytical Thinking:** The team obtained a skill which always proved to be important in science, analytical thinking. The student members learned how to properly analyze difficult situations they faced in the construction of the ROV.

- ☑ **Professional Attitude:** Students refined their professional attitude which proved important for team morale and an efficient working environment. Students learned how to work with a variety of personalities and take constructive criticism for what it is worth. These skills are essential for future careers and life in the professional world.

- ☑ **Exposure to the World of ROV Technology:** Most importantly the students gained the experience. The project gave students the chance to meet others of similar age and interests. They had a rare chance to develop and build their own underwater ROV, and compete at NASA. The skills gained may open up new career paths such as ROV and other underwater technological occupations.

VIII. Budget and Expense Sheet

Recorded 1/10/2006 through 6/20/06

Date	Donation or Expense	Description	Notes	Amount	Balance
1/25/2006	Donation	OCVTS Foundation Grant	OCVTS Grant	$998.86	$998.86
2/10/2006	Donation	ROV Grade-Marine Grade Foam	Tuckerton Field Station Donation	—	$998.86
3/1/2006	Expense	Mission Construction (parts and fittings)	Mission Construction	$49.46	$949.40
3/8/2006	Expense	Mission Construction (frame fittings)	Frame Construction	$20.53	$928.87
3/9/2006	Expense	Mission Construction (parts and fittings)	Mission Construction	$43.22	$885.65
3/13/2006	Expense	Frame and Propulsion parts	Propulsion	$42.17	$843.48
3/13/2006	Expense	Underwater Color Cameras (2)	Lights Camera Action, LLC	$401.90	$441.58
3/13/2006	Expense/ Donation	100ft ROV Tether Cable	Donation from Ocean Sound System Inc./ Shipping charges	$9.02	$432.56
3/14/2006	Expense	Mission Construction (fitting adapters)	Mission Construction	$11.62	$420.94
3/20/2006	Expense	Tool box and necessary tools	General need and mission construction	$208.80	$212.14
3/22/2006	Expense	Pipe Fittings	Frame and Props	$64.60	$147.54
3/27/2006	Expense	Plexi-glass and fitting	Mission #2	$12.85	$134.69
3/27/2006	Expense	PVC and glass cutting	Service charge	$11.44	$123.25
3/27/2006	Expense	3" PVC Buoyancy	general tools and supplies	$263.73	-$140.48
4/3/2006	Donation	MATES Academy Marine Science/ SCUBA Club	Donation from Club Funds	$500.00	$359.52
4/24/2006	Expense	Electrical parts (fuses and switches)	Purchased from Radio Shack	$84.06	$275.46
4/25/2006	Expense	PVC Fittings for revised Frame	T- Frame PVC parts, Home Depot	$45.57	$229.89
4/26/2006	Expense	Props and prop adapter	Motor prop parts purchased from Jackson Hobby	$12.19	$217.70
4/25/2006	Donation	Parent Donation	Yankee Stripper, Inc.	$150.00	$367.70
4/28/2006	Donation	Toms River Fitness and Aquatics	Pool Time (24 hrs use: $1,200)	—	$367.70

4/28/2006	Donation	Toms River YMCA	Pool Time (20 hrs use: $1,000)	—	$367.70
5/1/2006	Expense	Motor Couplings and adapters	Atlantic Plumbing Supply	$7.76	$359.94
5/6/2006	Expense	Motor Props and prop adapters	Jackson Hobby Shop	$27.29	$332.65
5/10/2006	Expense	Buoyancy System	PVC end caps 2"	$3.69	$328.96
5/17/2006	Expense	Secondary Buoyancy parts	Necessary secondary parts	$77.42	$251.54
5/24/2006	Expense	Motor props (2 back up)	Forward/Reverse black props	$2.65	$248.89
5/24/2006	Expense	Tether materials	Tether parts, Home Depot	$18.77	$230.12
6/1/2006	**Total Summation of Cost : Remnants of Budget**			**$3,067.60**	**$230.12**

VII. Future Improvements

- **Electrical Knowledge:** Last year the team was fortunate enough to have three team members electrically well versed. Following their graduation, and we found ourselves in a bit of trouble. We sought out help from others, and welcomed another mentor to guide us along with these issues. Our goal for future competitions is to truly master the electronic background knowledge to be able to rely on ourselves for guidance.

- **Metal Frame:** Although PVC is strong and durable, it is extremely unlikely that a professional ROV, such as a WHOI or Oceaneering model would be constructed from PVC. PVC seems best for this level of work, but we hope to design and construct a metal frame for next year's competition. By constructing our frame out of metal we will more closely mirror actual ocean observation vessels currently in use by scientist all over the world. The team is looking forward to the new tools and technologies available to them once they move into their new school in the Fall of 2006.

- **Time Management-** Just as in any real-life project, time management is essential. It is important to always keep in mind approaching deadlines, and work to accomplish these goal in due time. As a team we found it most successful to create several small deadlines: i.e. our frame will be sealed by next week, and determine final buoyancy system before first pool session. It was important to the whole team that we work accordingly as not to create tremendous/unnecessary stress for the team members involved.

IX. Ocean Observation Systems: Technology/ Organization/ Career

Fig. 9-1: LEO $_{15}$, Node A, in-shop for routine maintenance. Node B out at sea collecting real-time data

The events of the 2006 MATE ROV Competition portray the importance and capabilities of ROV use in various technological fields. The potential of ROV technology has become recognized more and more by military, space, and environmental establishments that are finding ways in which ROV's can aid in the goals of their organizations. One field of technology that is currently opening its eyes to the added benefit of ROV implementation is the field of Coastal Observation Laboratories. Their significance to the physical and biological assessments of costal waters makes them a valuable asset to environmentalists, oceanographers, and meteorologists. A foreseen increase in efficiency given through the advent of ROV technology will enable various fields of science dependent on costal observation laboratories to progress in research and problem solving.

The Long-term Ecosystem Observatory (LEO) located in southern New Jersey is the first costal observation laboratory ever established. Its creation has globally sparked the growth in these laboratories since 1998, displaying their importance in our costal regions. This year's MATES Team visited the observatory to gain an in-depth look on its functionality and pertinence to the predetermined obstacles of the competition. The system operates using a node (known as LEO_{15}) placed 9 kilometers from the laboratory and 15 meters under the ocean surface. The LEO_{15} provides ocean data such as oxygen and chlorophyll concentrations, light transmission, temperature, salinity, depth and pressure. The data retrieved from LEO_{15} is given in real time through a large communication's cable beneath sediment to the observatory and various scientists/researchers connected to the LEO network. Its existence is essential to the growing field of environmental research, a valuable resource supported by the Marine Academy of Technology and Environmental Science

One issue faced by the Long-term Ecosystem Observatory and the observatories that have followed is the maintenance of the underwater nodes (i.e. LEO_{15}) and the communication cables that connect node to observatory. Currently, hired scuba divers performing multiple tank dives are working on partial maintenance and upkeep of the node/communication efficiency of LEO and other observatories. Their exposure to currents and other elements below the ocean's surface is an unnecessary risk that can be easily solved through the use of remotely operated vehicles. ROV technology enables longer and essentially more efficient missions to optimize system performance. Through the avenue of remotely operated vehicles we not only operate safer and more efficient but save valued time and resources in the process. The challenges faced by our team in this competition represent the arduous obstacles made easy by innovative remotely operated vehicles.

Fig 9-2: Field Station located in Tuckerton, NJ, where the streaming real-time data is channeled. Student team members visited this station and spoke with the designers and active controllers of the LEO_{15} system.

Works Cited

Rose Petrecca: LEO_{15} Specialist

Rutgers University, Institute of Marine and Coastal Sciences:

http://marine.rutgers.edu/mrs/LEO/LEO15.html

Woods Hole Oceanographic Institute: Ocean Observations

http://www.whoi.edu/science/AOPE/dept/OSL/LEO

X. Acknowledgements:

Tina M. Held/ Team Coach and Facilitator

Ocean County Vocational and Technical School Board of Education

OCVTS Tech/Computer Design Class

OCVTS Architectural/Engineering Design

MATES Parent-Teacher-Student Organization (PTSO)

Marine Advanced Technology Education (MATE)

MATES Marine Science Club and SCUBA Club

Yankee Stripper Inc.

Toms River Fitness and Aquatics

Ocean County YMCA

Rutgers University: Tuckerton Field Station

OCVTS Foundation

Sound Ocean Systems, Inc.

Lights Camera Action, Inc.

Octura, Inc.

Master Screw, Inc.