MAOS ROV Club

Monterey Academy of Oceanographic Sciences
Monterey High School
Monterey, CA, USA

|/\| ***ROV Nereus*** |/\|

Team Members:

Jeffrey Catterlin – 2007 – Club President/Team Captain
James Caress – 2009 – Pilot

Unable to Attend the International Competition:
Ashley Thompson – 2007 – Club Vice-President
Alexander Botkin – 2007 – Club Treasurer
Matthew Hogan – 2007 – Club Secretary

Mentors:

David Caress and Thomas Hoover – MBARI
Geoffrey Von Saltza, Michael Hare, and Ron Woods – MAOS Teachers

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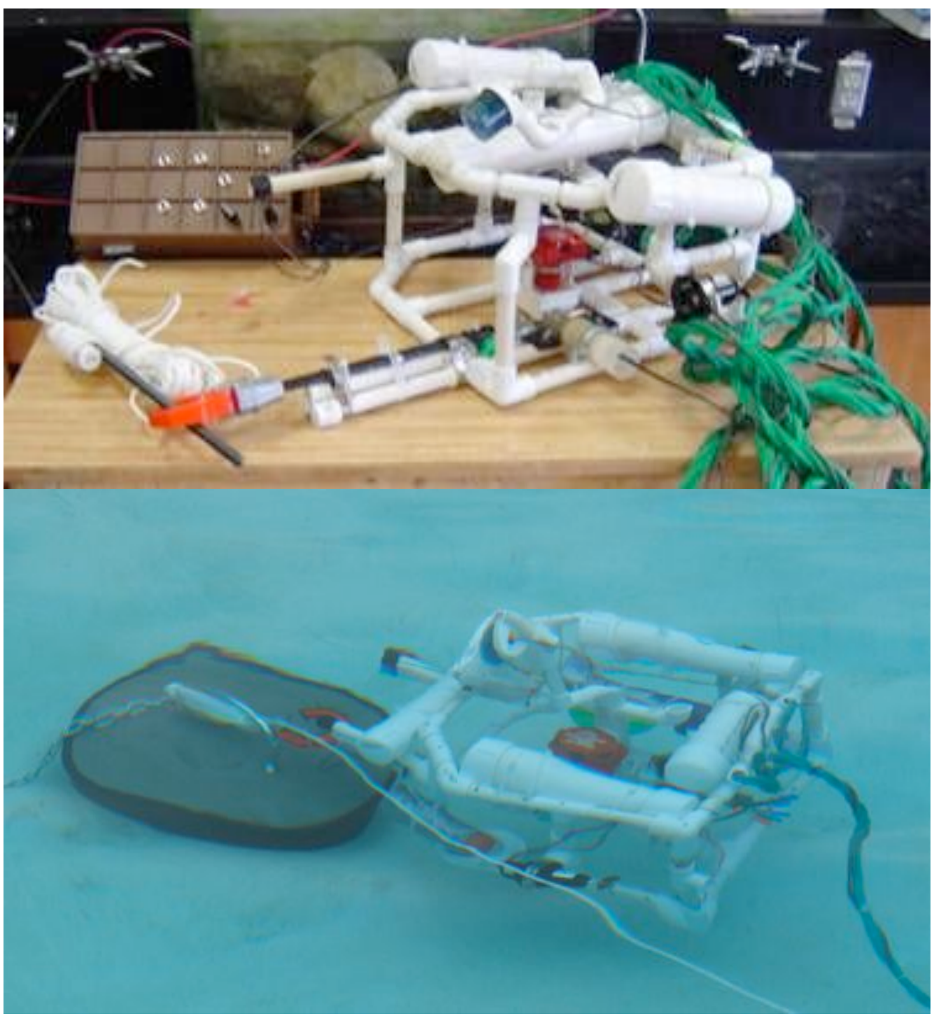
Abstract

The MAOS ROV Club built its most recent vehicle, *Nereus*, to compete in the 2007 MATE ROV competition. The vehicle was designed for the singular purpose of completing three tasks in a simulated near artic environment in celebration of the International Polar Year. Modularity, simplicity, and reliability were all qualities reflected in Nereus' design, which incorporates a relatively versatile frame. The vehicle incorporates four motors for propulsion; two mounted on the left and right side for forward, backward, and rotational movement, one in the center for sideways movement, and one powerful motor for vertical movement. The majority of the components, such as the claw, harpoons, cameras, and lights are mounted in the anterior portion of the vehicle. This allows for efficient coordination between the parts, as well as balancing out some of the weight from the tether and motors. Two cameras provide the pilot with multiple perspectives, providing a more extensive field of view than the narrow, often inadequate view afforded by a single camera. Sealed PVC capsules and large washers create a system of non-compressible buoyancy and ballast that allows the ROV to stay neutral at various depths. The tether is a tightly woven set of wires, allowing for easy maintenance while still maintaining flexibility. A series of toggle switches interface with the vehicle, forming a reliable, simple control system that our team has found to be much more practical than other fancier systems. The team's spirit and unity, combined with the modular systems of *Nereus* should allow for successful completion of this year's tasks.



ROV Nereus on display (top) and in action (bottom).

Design Rational

Name:

Nereus is the name that the 2006 MAOS ROV team successfully submitted to the Woods Hole Oceanographic Institution's "Name the new Hybrid ROV" contest. This name derives from Greek Mythology. Nereus was a wise and gentle sea god with a shape shifting talent.

Design Method:

We designed ROV Nereus incrementally, starting with the frame and then moving on to the other subsystems, incorporating them in to the frame as we completed each. The reasoning behind this method is that having established a basic platform, we would be able to develop concepts in an appropriate context and modify the frame as required. Changing the PVC frame is much simpler and cheaper than modifying the other systems.

Frame:

The frame was the first aspect of our vehicle to be designed and created. After experimenting with differently shaped prototypes constructed by several of the team's members, we decided upon a hexagonal shape. The one disadvantage was that at the time no exact information regarding the competition tasks had been released, so our choice was based solely on ease of use, modification, and mounting. Aesthetics did play a small role in our decision, as all members agreed that a box shaped ROV would not be appropriate. The frame design of the MAOS 2006 vehicle was also considered, but it was determined that due to the irregular shape, buoyancy and ballasting would have been near impossible with our resources. Thus, it was decided that the frame should have a relatively simple shape. The final decision was to use Ashley Thompson's six-sided house shaped design. Similar to the frame used two years prior, the practical skeleton is constructed from half-inch PVC pipe and is compact with numerous crossbars and joints to function as mounting points and increase durability.

Propulsion:

Last year's team encountered several problems with the propulsion system, specifically excessive current draw, difficulty mounting, and inefficient shrouds. MAOS has chosen bilge pumps as our current propulsion for many reasons, most notably the fact that the pumps are pre-waterproofed and are easily available. We attempted to use the bilge pumps, which pump 0.63 liters-per-second [600 gallons-per-hour], as water jets, but discovered that the force produced was insufficient, a problem that could only be remedied only by narrowing the nozzles and increasing the rate of flow. This unfortunately would not fit inside the budget. In addition, jets only propel in one direction, requiring a total of eight bilge pumps to achieve the desired freedom of movement and creating a mass issue (the more massive the vehicle became, the more difficult it would be to propel). The decision was therefore made to convert the bilge pumps to motors fitted with propellers. For the past few years, Monterey High has recycled a set of bronze three bladed propellers that are specially fitted to bilge pump motor shafts. We opted to use these propellers again this year, thereby conserving MAOS's limited budget. Since past teams have been plagued by current draws that exceed the 25-amp power budget, the forward/backward and strafe motors are pumps that draw 4 amps each when equipped with a propeller.

The single up/down motor, a vital part of the system and solely responsible for vertical movement, is actually one of the high energy, high power motors that proved so problematic for the 2006 crew.

The motors were mounted using hose clamps and scraps of PVC. When clamped perpendicular to the motors, these mountings allow the motors to be incorporated into the frame itself.

Lights:

Our light source consists of two generic waterproofed Energizer Eveready flashlights. The casings have been waterproofed using hot-glue and duct-tape; they are 177.8mm in length and 57.8mm in width. Each light is powered by two D batteries. The related voltage is 2.4 and related amps are 0.5. The casing is 60.8 grams without batteries. Since D batteries weigh 165 grams~, the total added weight to our ROV is 781~ grams (2)60.8 + (4)165~ ≈ 781.6~ grams).

▼ Camera ▼

Cameras:

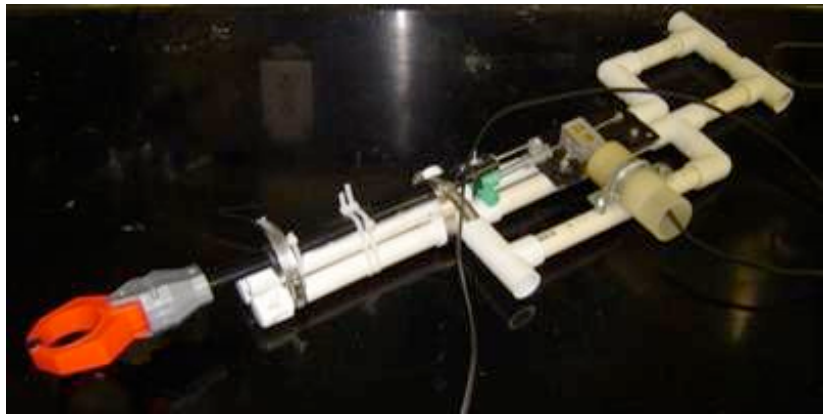
The two color cameras placed on the ROV were created in the Monterey MATE "Learn How to Waterproof a Camera" workshop. In this workshop, a method for waterproofing Videoray cameras was shown and two working cameras were sealed. The two cameras were focused for a range of approximately 30 centimeters using the fine font on a box for reference. The cameras were stripped of their outer housing to leave only the camera and its circuitry, and then they were placed into clear flat-bottomed jars such that no writing was in front of the lens. Epoxy was then poured into the rest of the container to seal off the camera and its circuits. To prevent leakage of epoxy into the camera, the rim of the lens holder was epoxied to the jar, creating the pocket in front. For added aesthetic flair, turquoise blue food coloring was added to the epoxy while it was being prepared; this does not seem to have affected the camera. The cameras have long cables attached to them that end in CAT jacks. The adaptor provided was used, but rather then using transformers to power the cameras, the transformers were taken apart in order to remove the wires that go to the adaptor, allowing for the cameras to be wired through the control box.

◄ Flotation ►

Flotation:

The flotation has been divided among four capped tubes of 2 inch PVC so as to maintain stability and balance in the water. Small weights like washers, bolts, and nuts have been used as ballast to counteract the ROV’s tendency to be front heavy.

Grabber/Payload Tools:



▲ Mechanical Grabber ▲

Having looked at the descriptions of this year's tasks, our team came to the conclusion that a mechanical arm was necessary if we hoped to complete the missions. Building a grabber of any sort has always been a source of frustration for MAOS teams; we have frequently tried and failed to produce a functional mechanism. This year, we were determined to succeed. Many different ideas and possibilities were discussed, concepts ranging from using a motor and gearbox to using a servo. After discussion was held about the practicality of a servo, this design was voted down because it required three wires to operate, one more than the number of tether strands we could afford to allot for the arm. Muscle wire was also discussed, but questions about its efficiency in a cold-water environment were raised since it requires heat to cause it to contract. In the end we went with a motor and a gearbox. A bolt was retrofitted on to the gearbox by means of a hole drilled in the bolt and tapped with a screw to act as a fastening nut. A hex-nut placed on this makeshift shaft, creating the simple worm gear. A screw was attached to the hex-nut's side such that it could transfer the nut's linear motion, opening or closing the grabber. The claw used was harvested from a plastic toy pincher claw purchased at Sharper Image. This claw was modified: the spring and handle were removed and the shaft running from the pincers was fastened to the screw on the hex-nut instead. The gearbox and 3 volt motor originally used were purchased as part of a motorcar set. After testing the grabber out of water, the mechanism seemed to run smoothly and rapidly; however, later field tests revealed a small inconsistency between the gearbox and the worm gear. The arm proved to be too weak and flimsy for our purposes and we were forced to rebuild it.

The first revision made was the replacement of the old motor with a new 12-volt motor. To make this change, we were obligated to waterproof the motor (a task we completed using petroleum and wax within a film canister) and adapting the specially molded gearbox to accommodate the larger shaft. We also made sure that the whole worm gear and claw system was completely straight. This involved the development of an alternative mounting for the grabber.

The original mounting used two PVC tubes zip-tied together to hold the arm out from a T-joint in the frame. The motor was then attached to a different tube, and fitted into the screw. The main problem with this setup was that the two PVC pieces could not lay perfectly straight to each other, and the motor/gearbox were not attached to the same piece of PVC, there by causing the connection to rattle under stress. The claw and gearbox/motor have been remounted onto a module that rather then sticking into one joint on the frame, now is incorporated into the frame. Two bars that force the pincers to fall into a groove have replaced the PVC that previously supported the claw, creating a straight line from the gearbox to the hand. This apparatus is mounted on a plate that is attached by bolts to the same two pipes. This setup increases the rigidity of the mounting as well as the quality of the attachment, and employs bolts instead of zip-ties where possible. The new structure also allows for the new, more powerful motor to be mounted simply by attaching it to a grove in a pipe connected to the base of the mount, and clamping it down with EMT conduit clamps. By using bolts, we have solved the issue of zip-ties interfering with the gears. This second arm has performed very well in preliminary tests, exerting a much greater force than the original mechanism with less current draw.

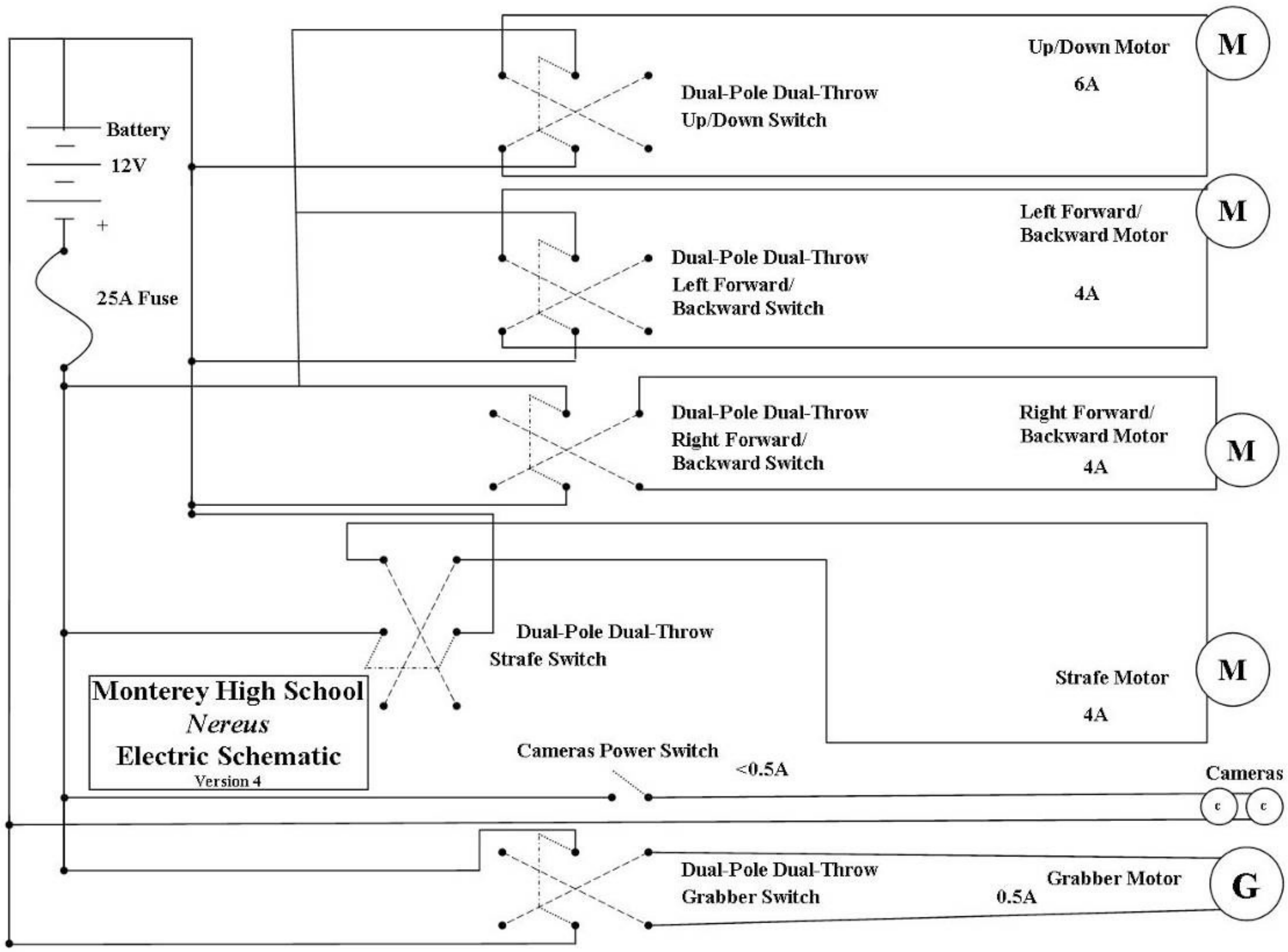
Tether:

The tether was originally designed for the purposes of powering the jet-propelled ROV. Because of this, the tether was created for 8 motors that would use about 2.5 amps each. The length of the tether was calculated for the length needed for the tasks plus some extra room, allowing for future shortening as a consequence of rewiring. This left us in need of a 15-meter long tether. It was calculated using the equation VD = 0.2 x IL x 1.26^(AWG - 10)--sVD being the voltage drop, IL being the current in the load, and AWG being the wire gauge in AWG--that 18 AWG wire should be used. This is because about 1.5 volts are lost in translation, a fairly insignificant quantity considering the benefits gained in flexibility and weight compared to higher gauges which only yield marginally better amounts (1.0 volt for 16 AWG and 0.6 for 14 AWG, only a 50% reduction at significant loss of the others). The number of wires was determined to be 8 pairs for motors and 1 pair for the grabber, creating a tether of 18 x 18 AWG stranded wires. When the motors were adapted to propellers, the number of motors was halved, creating an excess of wires. However, because of the change in the motors, the current draw for them went up to 4 amps. Therefore, rather then converting to 16 AWG wire, thus further increasing costs, wasting time, and still losing flexibility, we chose to double wire the motors. Although more wires translate to a bulkier tether, the 18 AWG wire, purchased as a spool, is extremely flexible, and significantly cheaper. To keep the tether organized, the wires were woven together using 3 groups of 6 wires. This shortened the tether by a small amount, but it provided a significant advantage by keeping all the wires, except for the camera wires to be added later, in one neat package. The camera wire and some insulation used as flotation was added later and secured using zip ties.

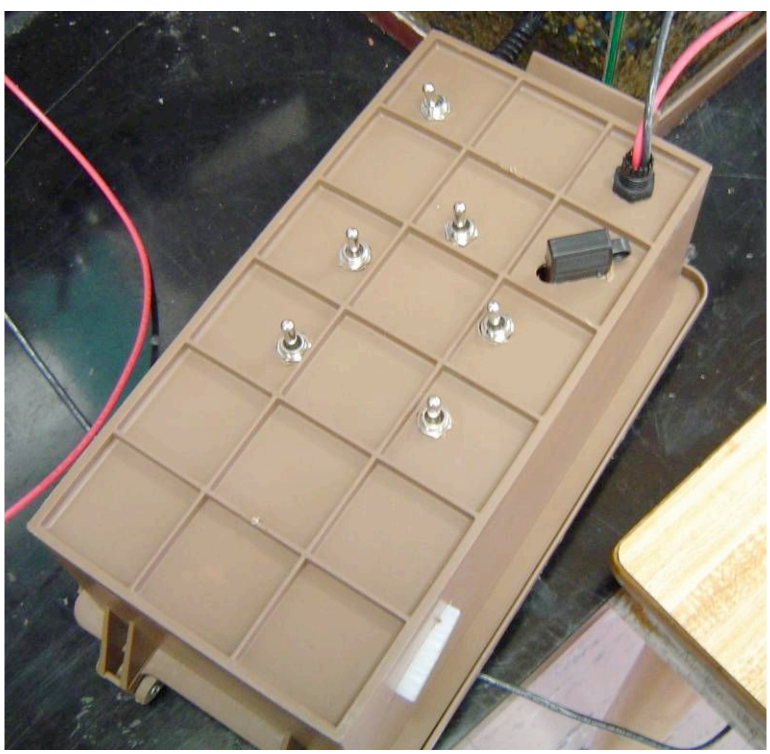
Electrical Control System:

The control box was originally made out of a cheap plastic shoe storage box. The control box uses heavy-duty toggle switches, which have proven to be a reliable control mechanism for our team. The switches used are dual-pole-dual-throw or DPDT switches, with a dual-pole-single-throw (DPST) switch for the camera. The DPDT switches are then wired with an X pattern or in a criss-cross method as to allow direction of flow to be swapped using the switch. The DPST acts as an on-off switch for the cameras, with one pole per camera. The box was hardwired directly to the tether and ROV, which allowed for quick assembly.

In preparation for the international competition, some issues were addressed in the box. One issue of particular concern was the flimsiness of the plastic, and the other was the placement of the switches. Although the international competition is unlikely to be as rainy as the Monterey Regional, the idea of a water-resistant box is still valuable in case of splashing or other complications. An outdoor weatherproof "tool-box" was purchased to address these problems. The box is slightly bigger than the original, but this allowed a better placement of the switches. The switch orientation was fixed by placing the switches in a more comfortable set up that enables allows for our pilot to have faster response time. Additionally, since the box is weatherproof, it has thick plastic to avoid the flimsiness problems as well as water resistance capabilities; because it a toolbox, the case has an easy to access lockable latch and a handle for convenient transport. The actual electric system was designed with conventional circuitry in mind, placing the 25-amp fuse on the positive. The wires originally used in the inside were the same 18 AWG used on the tether, but with the revision of the box these wires have been upgraded to 14 AWG solid wire, thus eliminating the need to double wire within the box and making the attachment to the switches more firm. The joints, which were previously just loose solder and hot glue, now use butt splices, allowing faster replacement. Since the wiring and rewiring became tedious, as labeling both ends takes significant time, the box was revised to contain connectors. Twenty pin ATX connectors were used since each pin is rated to 5 amps, more than the current we pass through the pins, as well as for their unidirectional connection. This means the control box end only needs to be labeled once and the tether/ROV can be separated from the control box to allow easier transport.



▲ Electrical schematic of the ROV control system ▲

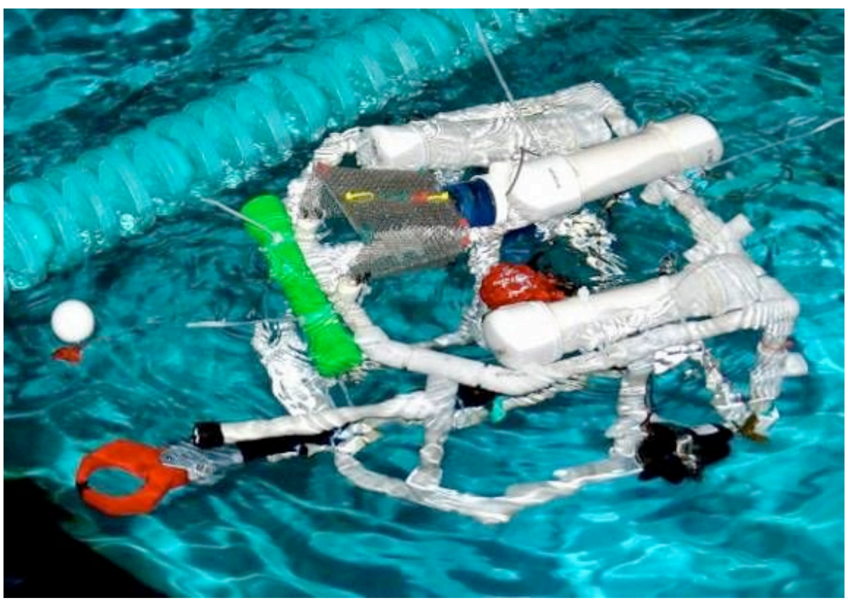


◄
Control Box
In Early
Development
◄

Troubleshooting

Troubleshooting was has always been an inevitable part of the build process as well as operation. By talking out the benefits and disadvantages of different courses of action, the team was able to identify possible problems before they ever evolved. Whenever any design was adopted, the negative consequences were anticipated and a possible solution was found. While all this discussion led to many delays, it was worthwhile in the sense that we were able to prevent many predicaments from happening. A key example is the placement of the motors; when discussion first began on the design chosen for *Nereus*, the problem of fishtailing arose. After debate went back and forth, it was decided that by placing the vertical motor and the lateral motor in the same location, such fishtailing would be mostly counteracted. This was proven true in the early pool tests.

Trial and error is also a key way that our team solved dilemmas. Several of Nereus' systems had flaws that demanded repeated tinkering and constant reassessment. Our control box had to be rebuilt from scratch on at least three occasions; every time we believed the electronics to be bulletproof, some severed wire or dislodged connector would ruin the entire network of circuitry and force us to start over. The trimming of buoyancy and ballast is another process that demanded repeated experimentation on the part of the team's members. One of the most frustrating instances of trial and error for our team was the determination of the cameras' angles. A satisfactory view was achieved only after hours of tweaking and adjusting the positions of our two cameras, and even then the slightest jarring of the vehicle could skew the devices and ruin the perspectives. Finally, learning how to achieve the missions required both practice and troubleshooting (see picture to the left). For this project, patience is more than a virtue: it is a necessity.



▲ Learning to catch a ping pong ball: an exercise in frustration. ▲

Challenges

This year's main technical challenge, as previous years have also experienced, was getting the grabber to function properly. Though there was discussion about changing to a servo this year, a motor with a gearbox was chosen to run the grabber by changing the rotational motion of the bolt turning into linear force on the grabber's main shaft (thus allowing the claw to open and close). However, during several pool practices and out of water tests, the grabber sometimes failed to function correctly. The reasoning among the team was that since no one had bothered to waterproof the motor, the lubricant was getting washed away and thus causing the issues. Although we have tried to address these issues, there is still no guarantee that the mechanical arm will operate as expected during the competition. The complexity of the arm lends itself to innovation and constant revision, making its improvement a major focus of MAOS's design team.

Lessons Learned

We have learned much about the tenuous nature of mechanical arms in the course of this project. After constructing yet another failed arm, we now understand the importance of a precise alignment between the moving parts. If any piece is out of alignment or insufficiently secured, the mechanism will, wobble, give, bend, and get hung up. We have learned that to be successful engineers, attention to detail is essential.

Another gem of knowledge we can take away from this competition is the value of motor shrouds. At the regional competition, we performed at three stations, each involving a line or rope for some purpose. At each station, our lack of protective housings resulted in the various lines becoming tangled in our propellers. Never again will we dismiss shrouds as a luxury; they are clearly a necessity.

Future Improvements

As always, there are aspects of the design and construction of *ROV Nereus* that we believe we can improve upon. Most notable is the lack of practice our pilots had in the water prior to competition day. Last minute modifications and trouble-shooting prevented the team from operating in the water as early as we would have liked. Producing a functional vehicle in a timely fashion is another recurring challenge for MAOS, a tradition that we would like to discontinue. One way to remedy this time crunch is to begin next year's project with a working vehicle. These means that instead of building a new ROV from scratch, we would start with *Nereus* and modify its systems to fit whatever tasks emerge. This strategy would allow our pilots to obtain the practice they need at a very early stage of development.

Although we have increased our range of vision by using two cameras instead of one, some of us still feel that the perspective provided to the pilots is too limited. We would prefer to use a total of three cameras; this is the legal limit permitted under the competition rules. Another improvement that would benefit *Nereus* is the addition of shrouds around the motors. In this year's regional competition, lines frequently became tangled in the propellers. These annoying and debilitating setbacks can be easily prevented if we house the motors and keep the propellers unobstructed.

Culturally Adapting to Life in the Arctic

The Inuits were the native dwelling people in the northern part of North America. They mostly concentrated around central and eastern Canada. We decided to research this particular tribe is because they have lived up in the Artic regions long enough to have adapted to the demands of life at the North Pole. Part of their adaptation to their environment was to become a community-driven people. Marriages and divorces could only take part by the consent of the community. The elders essentially ran the affairs of the Inuit people. Our team needs to take some lessons from the Inuits and work together as a community rather than as individuals.

Inuit hunting at a breathing hole

The Inuits were hunters; using a qajait, or kayak, they would hunt a diverse amount of marine life like fish, seals, polar bears, walruses, and even whales. Their qajait would often be made out of the hides of seals and carried one passenger. A strategy that they would often invoke during the winter was that of the aglu, or breathing hole. By making a gap in the ice, many different marine mammals would come to the hole to surface and get air. When they did this, the Inuits would strike. According to legend, they picked up this particular hunting strategy by observing the polar bear. Some of their key weapons were the harpoon and the knife, which they used while standing at an aglu. Team Nereus' ROV incorporates some of this by the addition of a harpoon to the front of the ROV, which is used to capture "jellyfish" in one of this year's tasks.

Works Cited

"Inuits" Wikipedia Foundation. Edited: 4/1/2007. Visited: 4/2/2007
<http://en.wikipedia.org/wiki/Inuits>

"Inuits" The Pages of Shades. Visited: 4/2/2007
<http://www.angelfire.com/realm/shades/nativeamericans/inuit6.htm

MAOS ROV Club Financial Report

ROV Nereus cost about $570 to build, including the use of an estimated $250 worth of materials and supplies reused from previous years. Our principal revenue sources were selling skewered barbequed beef at school food fairs and contributions from ourselves and our families.

Revenue	Amount
Hardware and materials from previous year	$250.00
Food Fair fundraiser	$200.00
Food Fair fundraiser	$179.00
Member donations	$105.00
Donated purchase	$38.73
Total	**$772.73**

Expenditures	Amount
Various tools - OSH	$10.13
PVC Cement, PVC Joints, PVC, Misc. Hardware	$28.00
Four Motors for ROV	$122.06
SS Hex Nuts, SS RHMS	$18.99
Tether, PVC, Wiring, ect.	$250.00
Toy Grabber	$6.99
Motor and Gearbox for Grabber	$27.89
Cable, Fuses, Misc. Hardware	$40.00
PVC & end caps for flotation	$38.73
Total	**$567.79**

Acknowledgements

The team would first like to thank the mentors who helped us so much. David Caress and Thomas Hoover of MBARI were invaluable guides, MAOS teacher Geoffrey Von Saltza helped coordinate with the school for us and opened up his classroom, and fellow teachers Michael Hare and Ron Woods spent late nights at the school so we could work. There would be no MAOS ROV Club at Monterey High without them. Their continued guidance and gentle prodding helped us to create this year's ROV.

We would like to acknowledge the MAOS ROV Scout team members who helped us braid our tether and made our success possible.

We thank our competitors for coming and giving us a good run for our money. There is a whole lot we can learn from them and just being able to compete against them is an honor. Hopefully we give them a run for their money too.

We thank the MAOS program, and our mentors again, for helping us make it to the international competition, as well as MATE for providing us with this opportunity. We thank MATE and the Monterey Peninsula Foundation for helping to pay for our travel to the competition. This will be a memorable event in our lives.

And most importantly, the ROV Club would like to thank MATE, the judges and everyone else who made the ROV competition possible. Without these people, nothing could have happened. Finally, thank you to Jill Zande, who not only coordinated our regional competition and this international competition, but also enabled us to compete.