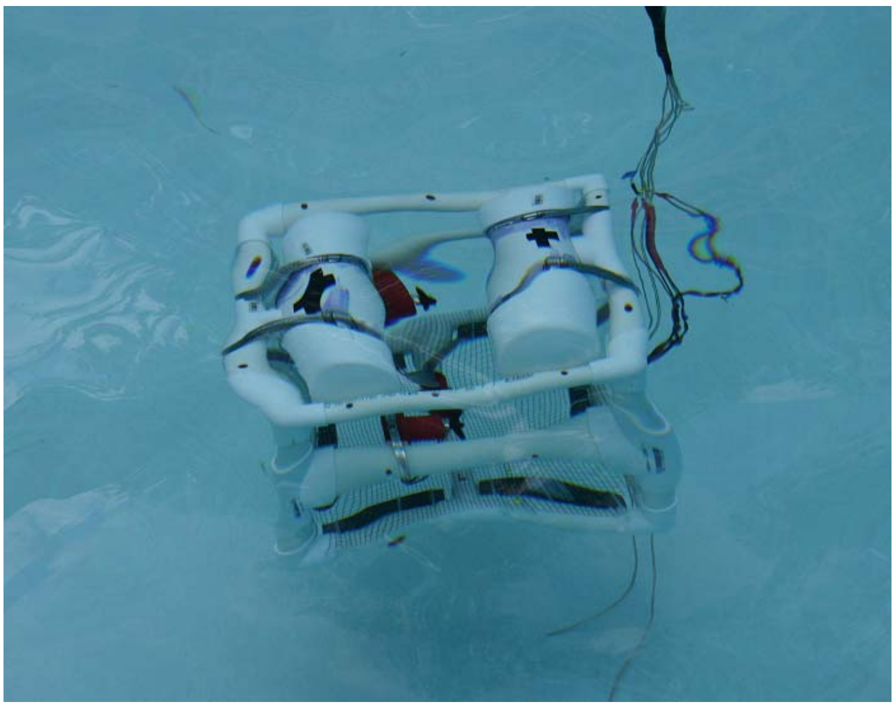
TECHNICAL REPORT ON

PROTEUS

SUBMITTED
TO
THE MARINE ADVANCED TECHNOLOGY
EDUCATION CENTER



BY
LANGLEY HIGH SCHOOL
MAY 27, 2005

TEAM MEMEBERS

ALAN ZHOU
OLIVER PAMER
RON PANDOLFI
DAN PASSMORE
JAMES RALLS
JOSH LIAO

INSTRUCTORS

MS. JEANNE PACKHEISER
MR. TIM CARLSON
MR. CHRIS FARMERIE

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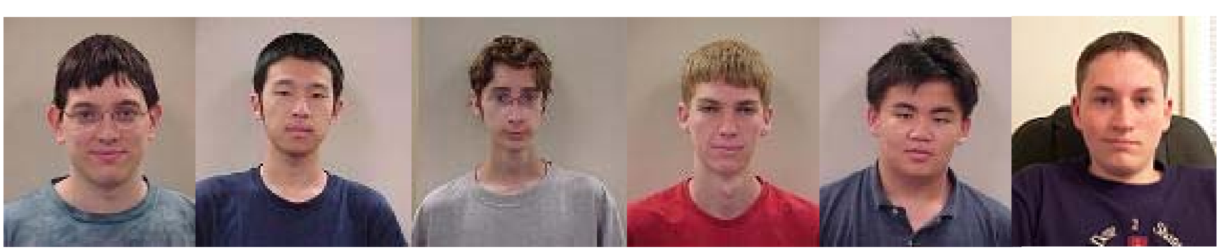


Oliver Palmer	Alan Zhou	Ron Pandolfi	Dan Passmore	Josh Liao	James Ralls
Pilot	Co-Pilot	Engineer	Technician	Technician	Technician

ABSTRACT

This is a comprehensive report on Proteus, a remotely operated underwater vehicle built by Langley High School to successfully fulfill all mission objectives as outlined by the Marine Advanced Technology Education Center for Ranger class craft competition. Proteus has three unique missions to complete: disable the oil flow of a pipeline in the Gulf of Mexico so the region may be converted into an artificial reef, repair a damaged fiber-optics communication cable connecting off-shore oil rigs, and simulate underwater the installation of a modular instrument onboard the Hubble Telescope. Proteus is designed to be agile in maneuverability yet precise in mission execution. Its command crew will be evaluated on the competence and efficiency in performing and completing the individual tasks.

This report will largely focus on the structural design of the vehicle and the craft's ability to conform to specific mission tasks. Accompanying these details will be reviews pertaining to the electrical systems to ensure that the mission objectives may be carried out in an efficient, safe, and controlled manner. Also included are investigations into current uses of remotely operated vehicles and their impact on scientific research, the foundations of which this project is based on.

BACKGROUND

Ron Pandolfi and Dan Passmore

Arguably, the lower depths of the ocean floor are the final frontier for human exploration on earth. The pressures involved near the bottom are enough to crush a human being. Like space, it is a truly inhospitable place for humans. Because we are unable to travel there and study the ocean's depths by ourselves, human engineers build remotely operated vehicles (ROV) to go where they cannot. As we push the technological limit of our abilities, we are able to reach deeper, farther and with less impact than ever before.

An ROV will always have certain functions no matter what it is specifically designed to do. First of all, it must be able to move efficiently through the water. Second, it must have some communication with its controller above the surface of the water. Third, its frame must be durable, light and easy to build. The diversity of motor configurations, communication styles and frame layouts is easily seen when looking at real world ROVs used for research.

Underwater ROVs such as the *Nova Ray* produced by Subsea Systems are made to be modular in order to support many applications. The *Nova Ray* is used to inspect the hulls of ships in port to help with maintenance in dangerous conditions. It is designed with a closed frame, where the internal parts are protected from the water. Open frames are frames where the internal components are not protected by an outer shell. Each design has its advantages and disadvantages. A closed frame can create a more hydrodynamic body that flows through water with less friction. An open body however is easier to service and build, as all the internal components are easily reachable. Closed frame ROVs are generally produced to operate in harsher conditions and be more hydrodynamic.

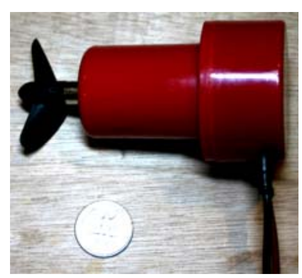
The *Nova Ray* is an ideal example of the way underwater ROVs can be manufactured to serve countless purposes. In addition to hull surveys, the *Nova Ray* can survey the structural integrity of dams, reservoirs, and bridges. The *Nova Ray* can also dive to a depth of 1,000 meters while certified human divers are not permitted to dive below about 58 meters. The resilience of ROVs allows their pilots to investigate using a highly maneuverable system. Such technology will enable explorers, both in the present and future, into crevasses never before explored, and to witness the most fascinating things on the planet.

DESIGN SCHEMATICS

Alan Zhou, Oliver Palmer, and Josh Liao

Proteus is designed to be structurally durable, stable, and robust. A compact rectangular frame renders the vehicle moderately efficient in hydrodynamics but highly stable on three-axis with a well-balanced center of mass. 2.54 cm diameter Schedule-40 PVC was determined to be the preferred material in craft assembly as it is relatively easy to obtain, cheap, and durable. Three-joint ninety-degree PVC corner connectors are used to ensure that the vehicle can endure significant structural stress while preventing the alteration of the frame into a parallelogrammic form. Twenty-eight 6.35-mm holes are drilled into the frame to allow for proper flooding of the interior chambers once the vehicle is partially submerged. To increase the mass and stability, deadweight in the form of six 1.9 cm x 15.2 cm iron pipes are attached to the bottom of the craft, each weighing 225 grams (1.35 kilograms total). To counter the significantly negative buoyancy, two segments of 10.16 cm diameter PVC pipes, each 28.00 cm in length with a mass of approximately 1.81 kilograms and volume of approximately 3.50 cubic meters, mounted perpendicular to the direction of thrust will serve as buoyancy compensators. Each tank has one 9.53 mm hole drilled to allow adjustment of the amount of air and water inside to allow fine-tuning of the vehicle to neutral buoyancy. When equipped with all necessary hardware, Proteus weighss a hefty 3.58 kg.

For thrust, Proteus incorporates three modified Rule 4,200-Lph model 27D bilge pumps. These motors are manufactured waterproof. Originally designed with five 1,900-Lph motors, Proteus' thrusters were upgraded to favor more power as the vehicle was drawing far less than the allocated 25 amps. The primary thrusters are equipped with 4.57 cm diameter R/C boat propellers with 12.70 cm pitch. In water, one of these motors draws maximum amperage of 6.6 and sustained amperage of 6.0, producing a force of approximately 4.5 newtons per thruster. Because only one thruster will be employed for altitude, a 7.87 cm diameter propeller with 11.43 cm pitch is installed to maximize thrust. The amperage of this motor is currently unknown as it is a newly installed component on Proteus,



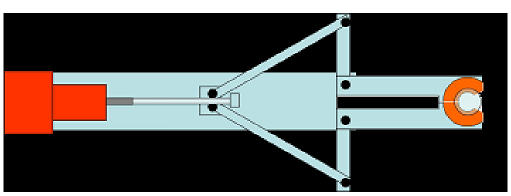
however, estimates of sustained amperage ranges from 6.5 to 6.8.

Proteus is connected to the topside by a simple 12.80 meter tether carrying four pairs of 16-gauge wires for the three primary motors and minimum resistance for the video feed and two pairs of 18-gauge wires supplying power to both the camera and arm mechanism. To keep the tether relatively neutrally buoyant, 2.22-cm wide copper pipe insulation is taped along its length. This continuous strip of insulation is designed to stiffen the line and prevent coiled twists, knots, and entanglement with other underwater objects.

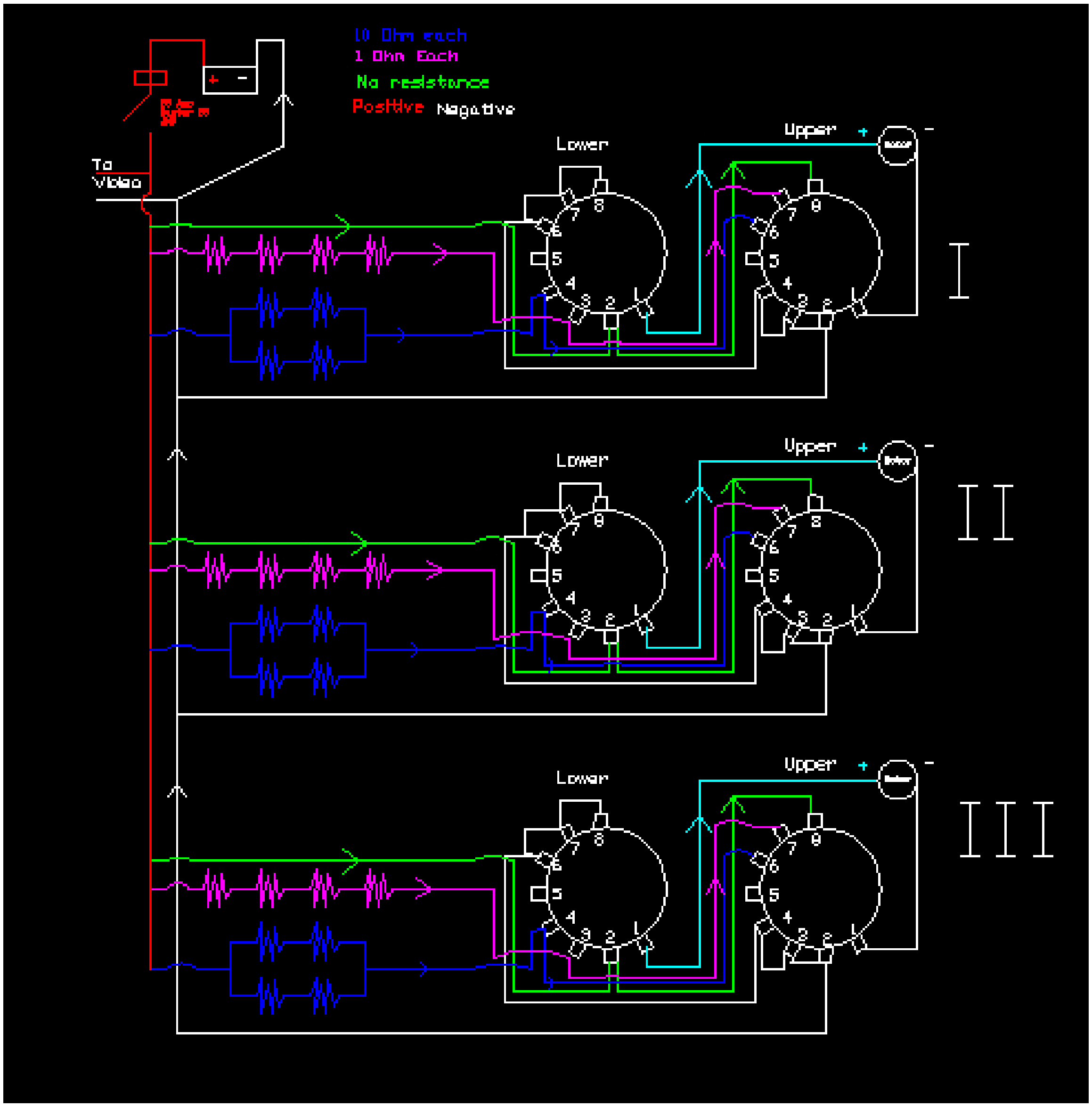
The tether and the vehicle will be attached to the control system through multiple Anderson powerpole connectors. These male-female connectors are soldered to a tether stub on the craft, to both ends of the tether, and to another tether stub on the control system. This eliminates a one-piece tether that is permanently connected to vehicle and control; should technical difficulties arise in the electrical wiring, the problem can be easily isolated and rectified.

Optical equipment on Proteus is provided by a Sony Super HAD CCD camera. This model of color camera was selected because of low amperage draw, high resolution, durability, and a 92-degree, 3.6 mm lens. The camera is mounted within a 3.81 cm diameter PVC, surrounded by copper pipe foam insulation. One O-ring and Plexiglas window are mounted inside a PVC screw-cap on one end and capped and sealed on the rear with hot glue. The purpose of the camera is to provide the pilot with a close-in view of the mechanical arm while providing high-visibility focus on faraway objects.

The mechanical arm is the most important and innovative component of Proteus. The importance of a multifunctional gripping device will enable the craft to engage in many different mission tasks without having to install and uninstall bulky modular accessories. One 4,200-Lph bilge pump is converted into a high-rpm motor with an adapted threaded shaft through cold welding (high strength metal epoxy). The tension on the actuators will control the opening and closing action of the grippers.



ELECTRICAL CIRCUITRY SCHEMATICS

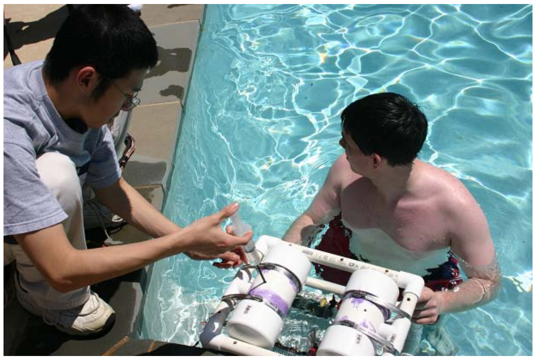


Not shown: arm motor circuitry

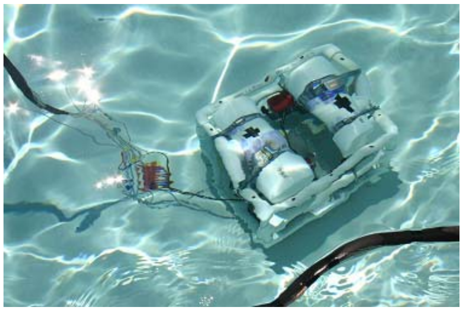
EXPERIMENTAL RESULTS
Ron Pandolfi

Our initial test of the Proteus's systems provided essential information concerning maneuverability, buoyancy, and tether control. Our original design utilized sections of pool noodles 5 cm wide and approximately one meter apart as tether floats. This was problematic, because the pool noodles were too positively buoyant, not flexible, and were large enough to become an obstacle during testing procedures. Also, our initial design entailed the use of pool noodles to provide neutral buoyancy on the Proteus. During initial testing, we found that the pool noodles used on the Proteus compressed significantly less than two meters of water, giving the Proteus less positive buoyancy. Upon further inspection of the pool noodles following our initial tests, we noticed that they had absorbed a significant amount of water as a result of cutting through the outer coating.

We decided to modify the tether by replacing the pool noodles with copper pipe insulation. We used 2.22 cm wide strips of pipe insulation to provide near neutral buoyancy on the tether with 2.5 cm strips near the craft side of the tether to provide slightly positive buoyancy. On the Proteus, we replaced the pool noodles with sections of sealed 10 cm PVC piping to give it consistently neutral buoyancy by inserting 300 ccs of water in each of the containers. A final modification was made to the frame of the Proteus by drilling additional holes in various places along the PVC piping structure. This ensured that air pockets would be released from the Proteus faster and eliminated the risk of air pockets interfering with its level of buoyancy.



During our second major test of the Proteus, we encountered a decrease in thrust from each of our motors, which we attributed to the addition of the large PVC piping segments. We then decided to reevaluate our electrical schematics to find a way to increase thrust. A 1Ω resistor was thereafter removed from the circuitry. The results of this modification were about a 30% increase in thrust from each motor with an increase from 4.2 to 6.6 amps.

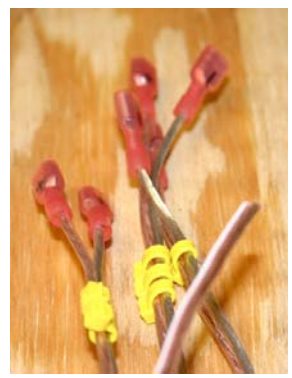


From these trials, we also gained valuable experience in piloting the Proteus as well as controlling the tether. We had evident issues with tether control in during these sessions and have found ways of preventing problems such as allowing the tether to interfere with craft mobility by being more apprehensive in tether management.

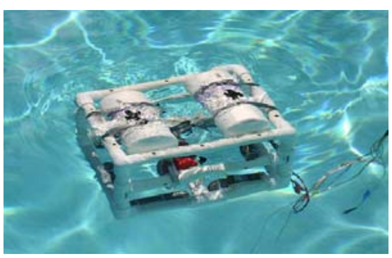
SAFETY AND TROUBLESHOOTING TECHNIQUES

Alan Zhou and Oliver Palmer

The engineering and technical crew of Proteus is sharply aware of the potential dangers and risks of operating electrical equipment near sources of water. On the positive lead from the primary power source is a 25 amp fuse designed to prevent short-circuiting or overheating of wires associated with lead-acid batteries. Power is then connected to a lighted master switch; without turning on this switch, no power runs through any electrical components. A detailed and comprehensive checklist for pre-launch, post-launch, pre-recovery, and post-recovery sequences guarantee that every system is checked and rechecked, and executed in a safe and logical order. Sufficient amounts of baking soda will be nearby to neutralize any acid leaks if the battery is breached.



Throughout the duration of the project, there were numerous electrical anomalies that occurred. By using crimped quick connectors, we discovered it was extraordinarily easy to disassemble the electrical components and quickly seek out the source of the anomaly.



Originally, Proteus used pool noodles for its ballast system. However, through experimentation at depths greater than two meters, the flotation devices compressed and therefore rendered the vehicle negatively buoyant. To correct this problem, rigid-body PVC buoyancy compensators were implemented into the design of the craft.

PROTEUS OPERATIONS CHECKLIST

PRE OPS:
Setup Clock -- MARK
Tools -- STOWED
Work Area -- CLEAR
Monitor -- OFF
Strips -- OFF

PRE OPS VEHICLE:
Top Side Tether -- CONNECTED
Proteus Side Tether -- CONNECTED
Battery -- CONNECTED
300cc Bow Ballast -- FILLED
300cc Stern Ballast – FILLED
300cc Bow Ballast -- PLUGGED
300cc Stern Ballast – PLUGGED

STARTUP:
Strips -- ON
Auxiliary Equipment -- ON
Monitor -- ON
Master Switch -- ON

PRE-LAUNCH ARM THRUSTER:
Open Low-Speed -- CHECK
Open High-Speed -- CHECK
Close Low-Speed -- CHECK
Close High-Speed -- CHECK

PRE-LAUNCH DIAGNOSTICS:
Port thruster – CHECK
Starboard thruster – CHECK
Vertical thruster – CHECK

LAUNCH:
Throttles -- CLOSED
Propeller Area -- CLEAR
Tether Manager -- ON STATION
Proteus -- POOL SIDE
Tether -- CLEAR
Camera -- OPERATIONAL
Arm -- OPERATIONAL
Setup Clock -- STOP
Proteus -- DEPLOYED
Mission Clock -- MARK

POST LAUNCH:
Throttles -- OPEN
Current Draw -- CHECK MAX
Buoyancy Compensation -- HOLDING

MISSION OPS - DIVE:
Arm -- PRESETS
Port Ahead 3/3 -- CHECK
Starboard Ahead 3/3 -- CHECK
Vertical Thruster Dive 3/3 -- CHECK

MISSION OPS - FULL DEPTH:
Thrusters -- TASK MODE
Arm -- TASK MODE

MISSION OPS - SURFACE:
Arm -- PRESETS
Port Ahead 3/3 -- CHECK
Starboard Ahead 3/3 -- CHECK
Vertical Thruster Surface 3/3 – CHECK

PRE-EXTRACTION:
Proteus -- POOL SIDE CONTACT
Throttles -- CLOSED
Tether Manager -- ON STATION

EXTRACTION:
Proteus -- EXTRACTED
Mission Clock -- STOP
Tether Manager -- RTB

POST OPS:
Post Ops Clock -- MARK
Master Switch -- OFF
Top Side Tether -- DISCONNECTED
Proteus Side Tether -- DISCONNECTED
Tether -- STOWED
Battery -- DISCONNECTED
Monitor -- OFF
Strips -- OFF
Auxiliary Equipment -- OFF
Tools -- Stowed
Ballast -- EMPTY
Work Area -- CLEAR
Post Ops Clock -- STOP

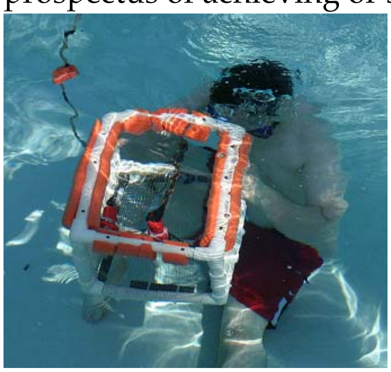
CHALLENGES
Dan Passmore

When it came down to building an ROV for the MATE competition, most of the challenges our team faced did not have to deal with the ROV at all. Our main challenge was getting everyone to communicate and working together on the project.

While we were still in the brainstorming stage of our ROV development, we didn't discuss what we wanted to do. We argued. There were times when people simply would not accept others' ideas because they didn't let the others have a chance to prove if their idea was better. For example, we spent over 30 minutes in a heated argument over how the motors should be laid out on the ROV, and only ended up choosing the motor system we currently use by executive order. It turns out our motor configuration works fine, but it would have been nice with a bit less arguing.

We realized we weren't communicating well, and decided to fix the problem. Some of the more accepting people in our group explained to the others how it was important that everyone had a say in how the ROV was being designed, and that every possible design choice be given a chance. No one is going to be the best at everything, and most of the time, someone other than you is going to have a better idea. Using these principles, by the end of the project, we were working smoothly together.

The project also suffered many time-constrained problems. All of the members of the team were constantly engaged in academic activities, from post-winter break work and pre-AP exam schedules. Not having enough time on the project severely undermined the potential of the project; however, we are still prospectus of achieving or surpassing our goals for the competition.



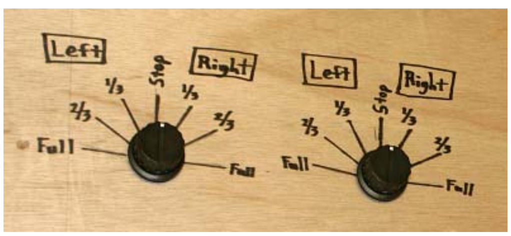
When it comes to specific design problems that we had to overcome, one was picking the right ballast system. We initially had the idea of cutting foam pool noodles and wrapping them around the frame's PVC piping. It was a simple, cheap, and effective technique, until we tried it in the pool. Because the foam is soft, the pressure of the water near the bottom of the pool was compressing the air in the foam and reducing the amount of ballast. This made it take longer for the ROV to surface because the ROV became negatively buoyant near the bottom of the pool. We fixed this problem by attaching solid PVC ballasts that would not compress with the increasing water pressure. They were more difficult to attach, and more difficult to attain neutral buoyancy with, but they provided a more constant buoyancy at different depths.

FUTURE IMPROVEMENTS
Dan Passmore

No competition ROV is absolutely perfect, and ours is no exception. There are a few things with ours that could use a bit of improvement. First of all, our vertical rate of descent and ascent is fairly slow. As our ROV is currently, we are not drawing the maximum amount of amps allowed by the competition. Perhaps if we had added a more powerful motor, we would better utilize the available power and ended up with a faster vertical travel time. After all, less time traveling between the tasks and the surface gives us more time to complete the actual tasks.

Another thing we would like to improve slightly is the tether. We did a good job creating the tether in every aspect except ballast. It has significantly positive buoyancy. Ideally, we would attach solid uncompressible ballasts every half meters or so, much like the ballasts on our actual ROV. This would provide greater consistency in the buoyancy of our tether.

Our electronics work very well on our ROV, but our seven way switches connected to six different parallel loops with different amounts of resistors is a fairly complicated way to achieve different levels of power output. To simplify the design and give the pilot more control, it would have been nice to use solid state controllers. Rather than decreasing the amperage, solid state controllers work by shutting off the connection completely a certain amount of times per second. It increases the power by breaking the circuit fewer times per second and decreases the power by breaking the circuit more times per second. Using these in our circuits would have made things much easier.



CONCLUSION

After six months of design discussion and hard work, Proteus is complete. After careful designing followed by critical testing, we have ironed out the kinks in the ROV. As a result of the problems we have encountered, we now have a better, more functional ROV. Proteus now stays neutrally buoyant consistently and moves quicker through the water while also being easier to control. We are also better prepared for things that might go wrong while we are actually competing. With everything completed, Langley High School is ready put Proteus to the test

ACKNOWLEDGEMENTS

Langley ROV would like to thank the parents, teachers, and support groups for their assistance and expertise in this endeavor to create a project that is ready to compete at nationals in Houston, Texas. Special thanks go out to our instructors as well as:

Dr. Miles R Palmer
Phoenix International
Langley PTSA
Langley Science Department

2003 MATE/MTS ROV Committee Student Competition

Budget/Expense Sheet

Period:

School Name: Langley High School

From: 15-12-04

Instructor/Sponsor: Jeanne Packheiser

To: 27-05-05

Funds

Date	Deposit or Expense	Description	Notes	Amount	Balance
20-12-05	(15.00)	4x 1" PVC, 1x 4" PVC, 30x assorted PVC joints, glue		$15.00	(15.00)
24-12-05	(168.00)	6x Rule 27D 1,100-gph bilge pumps		$168.00	(183.00)
19-01-05	(15.00)	PVC joint: 1"-1"-1"		$15.00	(198.00)
20-01-05	100.00	MATE Intent to Compete funding		$100.00	(98.00)
25-01-05	(45.00)	60x quick-disconnects		$45.00	(143.00)
25-01-05	(6.00)	Solder		$6.00	(149.00)
05-02-05	(6.00)	1.5" propellers		$6.00	(155.00)
06-02-05	(15.00)	7-position switches		$15.00	(170.00)
15-02-05	(150.00)	10-ohm resistors, wiring, tether material		$150.00	(320.00)
20-02-05	(55.00)	Tether conductors (16-gauge)		$55.00	(375.00)
27-02-05	(2.00)	Control switch knobs		$2.00	(377.00)
11-04-05	(34.00)	Tether conductors (18-gauge)		$34.00	(411.00)
11-05-05	(9.00)	Hose clamps		$9.00	(420.00)
17-05-05	(22.00)	3.1" propeller		$22.00	(442.00)
17-05-05	(18.00)	Arm components		$18.00	(460.00)
21-05-05	(18.00)	Camera parts		$18.00	(478.00)
21-05-05	(7.00)	Tether ballast		$7.00	(485.00)
22-05-05	(17.00)	Fuse holder, fuse, master switch		$17.00	(502.00)
23-05-05	(5.00)	Rubber stopper, arm material		$5.00	(507.00)
26-05-05	(74.00)	Camera+adapter		$74.00	(581.00)
				$707.00	$ (581.00)