Team MAOS
The Beetle

Technical Report

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Abstract

The MAOS ROV Club has designed and constructed an ROV for the 2009 MATE ROV Competition. This ROV, named *The Beetle* because of its striking resemblance to an insect, has been designed to achieve this year's competition tasks. The mission objectives require vehicles to precisely navigate and accurately manipulate their surroundings in an simulated submarine rescue environment. *The Beetle* is equipped with two strong and reliable manipulator arms to accomplish its tasks, allowing its operators to open doors, transport air hoses and move ELSS pods. A short length of pipe attached to the bottom of the vehicle enables it to lock on to the submarine and dock for the required time.
The control system operates the five propulsion motors using two joysticks. Four video cameras provide the ROV pilot with views from inside, above, and below the vehicle. The ROV design has proven successful in completing all of the tasks in practice and nearly accomplished all objectives during regional competition. The MAOS team's design philosophy of simplicity, reuse of materials from past years, and focus on the competition tasks have resulted in an efficient and competent entry to the competition.

The ferocious face of *The Beetle*!

Design Rational

In designing *The Beetle*, our core philosophy has been to construct the vehicle as a combination of the best subsystems of previous ROVs with a new frame and new tools tailored to meet this year's competition tasks. As a minimally funded, student-led club working out of the back of a biology classroom, we have always found it worthwhile to be frugal in spending and prudent in our use of existing materials. A recycling mentality allowed us to construct rapidly a new vehicle with fully functional tether, propulsion, and control box systems from past years and gave us the time to design and troubleshoot two hydraulic arms, a method of manipulation previously unexplored in our club.

***The Beetle* is a veritable chimera of recycled systems.**

Frame

The frame was the first system we built and served as the foundation and skeleton for all subsequent evolutions. Constructed of half-inch (1.3 cm) polyvinyl chloride tubing (PVC), the frame has a cubical structure, allowing for easy buoyancy adjustment and maneuverability. A system

Does this view make our vehicle look fat?

of crossbars and branches emerge from this basic shape, each the product of a perceived need. When mounting the motors, we offset their integration points to center the propellers; when searching for the right camera angles, we build both adjustable bars and the prominent "horn," the tall crane on which our top view camera is mounted. The frame's dimensions are 53 cm by 37 cm by 30 cm. The almost organic asymmetry of the frame's many intricacies reflects the pragmatism that influenced its growth and the efficiency of the vehicle it supports.

Each system developed for *The Beetle* has been directly integrated into the PVC frame. In tailoring the frame to the needs of the ROV, we have designed parts that are interchangeable and easily replaceable, both of which are convenient when in need of quick modifications. For example, the cameras installed in the frame are bound by hose clamp mountings, with the hose clamps fitted through slits cut perpendicular to the length of the pipes. This clamp-pipe mounting wraps firmly around the cylindrical camera. Two inch-long (2.6 cm) pieces of PVC are placed next to each other inside the hose clamp but underneath the camera, minimizing camera movement within the clamp. This method allowed us a huge amount of freedom when modifying the placement of the engines and repairing them. During the weeks leading up to the competition this was a valuable resource because it meant that we could easily switch out motors that were broken or defective.

When we initially encountered problems with loose PVC joints, one team member developed a serration technique to increase the friction between the pipes and the connectors. By making shallow cuts with PVC cutters at the points of connection, we succeeded in mildly deforming the pipe and forming a better seal. Although serration is an effective method, disconnecting altered pipes has proven difficult (and in some cases nearly impossible) so the technique should be used with discretion.

Docking System

This year's competition requires ROVs to dock on the submarine for 20 seconds, so to complete this task our team attached an ABS pipe connector to the bottom of our vehicle. Our pilot is equipped with a camera specifically for this task, fastened inside of the pipe so he can easily line each pipe up and lock on for the required amount of time.

Submarine dock.

Buoyancy

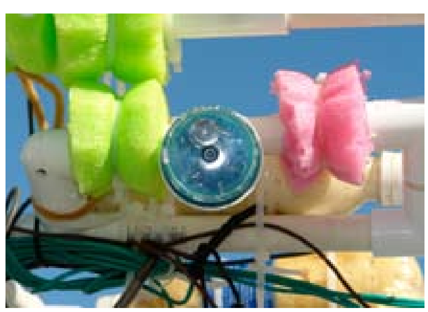
The many plastic and metal components of *The Beetle* make it naturally negatively buoyant. We made buoyancy modules by filling plastic water bottles with triple expanding foam. Because these modules are internally pressurized, they do not crush and change buoyancy during missions to the bottom of pools. Because the weight was focused primarily on the vehicle's anterior and starboard sides (those bearing the predominant weight of *The Beetle's* hydraulic arms), we secured bolts and piles of washers on the forward and port sides as ballast to compensate for the unequal distribution of weight.

The expanding foam prevents compression at depth.

After equipping our vehicle with its full payload, we found that it was approximately 25N negatively buoyant. In order to make our ROV neutrally buoyant, we added five plastic water bottles filled with expandable foam, each approximately 5N positively buoyant, as flotation. We positioned the water bottles so that most of the flotation would be over the front of the ROV, which is the heaviest part of the vehicle.

Cameras

The Beetle sees through four cylindrical cameras that we modified at the MATE camera-waterproofing workshops held this year and in previous years. Each Anaconda Color Camera from X10 Wireless Technology, Inc. came with a sixty foot (18.29 m) cord and draws 0.2 amperes from our battery. To waterproof a camera we removed the lens and circuit board from the housing and positioned it lens down on the bottom of a cylindrical clear plastic case. The specific case was chosen over other types of plastic for its relatively unmarred surface to minimize image distortion. The case was filled with five-minute epoxy after sealing the lens rim with silicone to prevent the epoxy from leaking in and blocking the camera's view. Food coloring was mixed into the epoxy for aesthetic flair. The cameras were attached to *The Beetle* by one of two methods: by screwing a lid onto the plastic case and screwing the lid onto the PVC frame, or by hose-clamping the camera through a slit in a piece of PVC and plugging the PVC into the frame. Both methods of securing the cameras were devised in adherence to our overarching design philosophies of simplicity and modifiability. Simplicity, however, was not a part of deciding on camera placement. We chose the location of *The*



The all-seeing eye.

The tip of the horn.

Beetle's eyes by tedious trial and error. We changed the placement of the cameras numerous times after numerous trial runs on our mission props. The camera locations also changed with the evolution of our ROV. The final camera placements include one camera pointed down for navigating the mating mission; one dedicated to looking at each of our two hydraulic arms, *Robie* and *Gimpy*; and one bird's-eye-view camera of the arms attached to the PVC structure we call *The Beetle's* Horn. Each camera has a focal length of approximately 18 centimeters, but the overhead camera's main area of focus is far enough away that it produces a clear image.

Propulsion

The Beetle is equipped with five 600 gph (2271 Lph) bilge pumps. When used as a bilge pump each motor draws 2.5 A, but we replaced the impellor with bronze boat propeller (German made for an RC craft) and each now draws 4.5 A each. We placed five motors on the vehicle to optimize the amount of thrust and maneuverability when competing against teams with motors that draw more power. We used a spring scale to test our bilge pump motors. We securely taped two parallel bamboo skewers to opposite sides of the motor and taped one shorter skewer piece horizontally to each pair of ends of the two parallel skewers. This created a rectangular arch on both ends of the motor from which to hang the spring scale. We hung the motor on the spring scale, placed it in a deep bucket of water, and ran it in both directions. Following multiple trials of this experiment, we have determined that each modified bilge pump motor, when equipped with a German boat propeller, generates an underwater force of 2 N.

Our primary propulsion system.

We oriented two motors horizontally to maneuver to the left and right. We discovered that having the motors in the center of the vehicle would allow us the largest range of mobility and the least problems when repairing the vehicle. The wiring of our motors allowed us to have one going forward and one going backward at the same time. This meant that we could auto-rotate on a single spot. This ability was very important when we were dropping the ELSS pods into the submarine. We also oriented two motors vertically for maneuvering up and down. The motors were both oriented in the same direction to maximize the amount of thrust when moving up and down. The last motor that was added to the vehicle was the strafe motor. This motor is used in tandem with our vertical and horizontal motors to allow a greater amount of maneuverability.

We also made shrouds for our horizontal motors, both of which extend beyond the confines of the frame, to prevent the airline from tangling in our propellers. These housings were constructed of both metal and plastic fencing and serve merely to protect the propellers; they are not designed to enhance the water flow. Past experiences have taught us that the margin of error inherent in flow-optimizing shrouds far outweighs the potential benefits.

Control Box

A control box with a dual analog joystick system operates *The Beetle*. Unlike the double-pole double-throw switch system, which demands considerable dexterity of the pilot, the joystick system is far more intuitive and allows for complex and responsive maneuvering. The power leads that connect to a battery include a 25-amp fuse. The five propulsion motors draw 4.5 amps each and the four cameras together draw 1 amp, amounting to a maximum draw of 23.5 amps. The bottom of the control box is covered with a transparent, hard plastic covering, permitting inspection of all connections and wires in the system without opening the entire box.

The control box also includes a SPDT switch to enable or disable power to the cameras, which are wired in parallel with the propulsion motors. When turned off, the switch creates a break in the camera circuit, providing an effective safeguard against camera burnout.

A twenty-pin computer connector connects the tether to the control box. As a safety precaution, the 20-gauge wires of the connector are soldered into pairs to create thicker wires of 16-gauge, thus minimizing the chances of their heating up during power-intensive situations. The point of union for each wire pair is wrapped with electrical tape for purposes of both insulation and protection. The ten 16-gauge wires created in this pairing process are adequate to connect to all five propulsion motors, which require two leads each.

Three of the five propulsion motors are wired separately; the two vertical motors are connected in parallel so that both motors activate simultaneously and in the same direction. This circuitry configuration allows each of the five propulsion motors to run independently and to draw its maximum current without its potential being compromised by diversion of power to other motors.

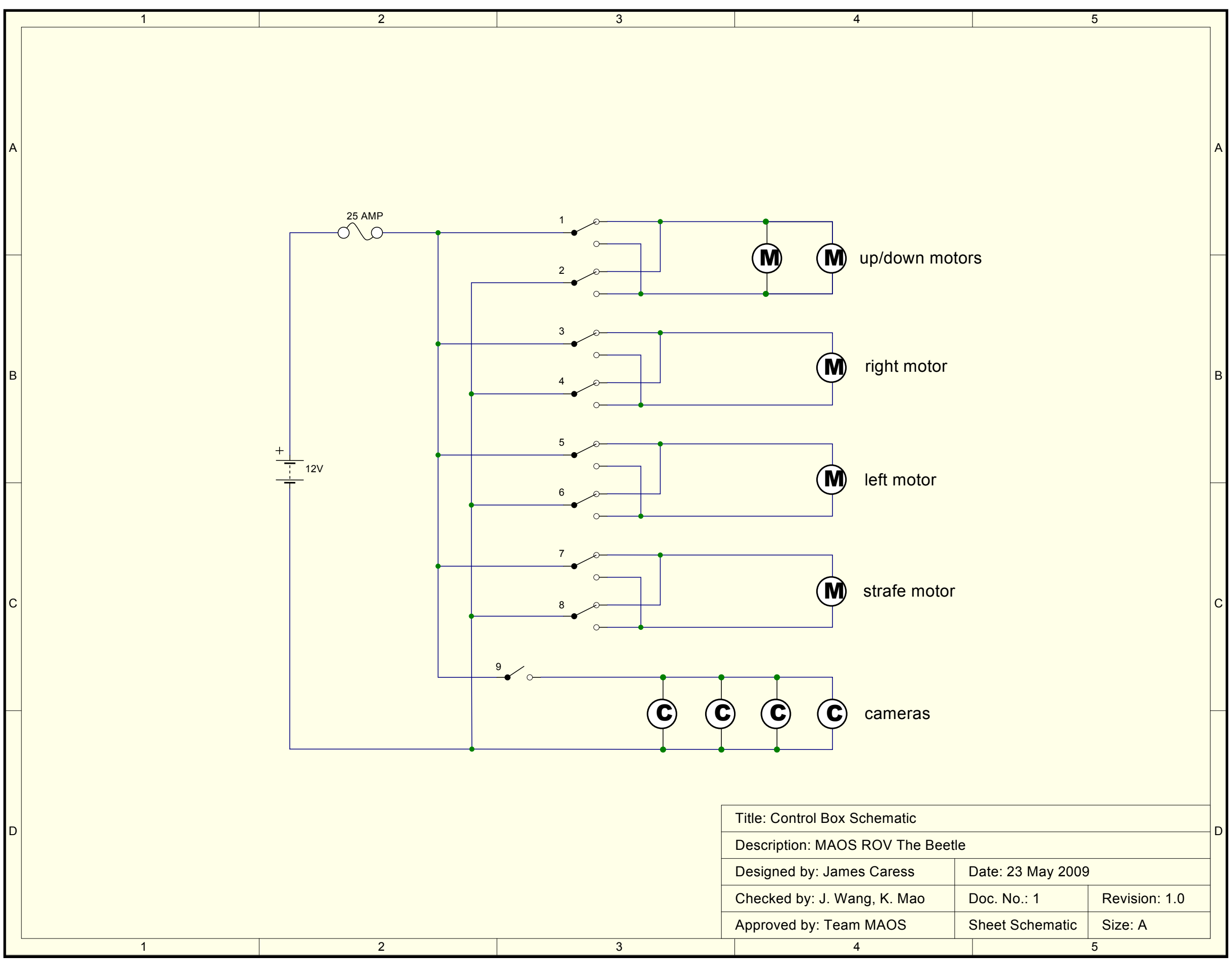
Four SPDT mini-snap action switches are placed around each joystick in a manner such that the button on at least one switch is depressed whenever the joystick moves. The switches, whose internal connections are composed of silver and brass, have two circuit pathways (normally open and normally closed) running through a common ground. Opposing switches—those located on opposite sides of the joystick—are wired in a single parallel circuit to prevent both switches (those wired to the same motor) from activating at the same time. When the joystick moves, it depresses the button on a switch to complete a circuit through which the current runs. By depressing the button on the opposing switch, the current is redirected in the opposite direction, and the motor's direction of propulsion reverses. Because the wiring consists of parallel circuits, the buttons of two adjacent switches may be depressed at the same time, thereby sending currents through two motors without either interfering with the other.

The left joystick controls *The Beetle's* vertical and strafe motors. Moving the joystick to the right, for example, depresses a single switch that causes the strafe motor to propel the vehicle to the right. Likewise, moving the joystick forward activates another switch that causes the vehicle to move directly up. Moving the joystick diagonally activates two circuits and results in a combination of vertical and lateral motion.

The right joystick controls the two side motors, which enable forward, backward, and rotational movement. In designing the orientation of this joystick, however, the team encountered a problem that had not surfaced during the wiring of the left joystick. On the left joystick, activation of a single circuit had been a necessity. On the right joystick such a function was rendered nearly useless due to the inherent orientation of the side motors. In order either to

Our vehicle's control box.

turn or to move *The Beetle* forward and backward with the greatest speed, the pilot must always depress two switches at once. Therefore, the right joystick is rotated 45 degrees, so that when the pilot simply pushes the joystick forward, the switches for both side propulsion motors are activated together—a mechanism quite different from that of the left joystick—and propel the vehicle forward. When the pilot moves the right joystick down, it activates both opposing switches and reverses the polarity of the current in both motors, propelling the vehicle backwards. Should the pilot move the joystick to the right, two switches are yet again depressed: one switch causes the left motor to propel forward, while the other reverses the polarity of the current in the right motor only, turning the vehicle to the right. The 45-degree orientation of the right joystick allows the pilot to generate easily an opposition of forces on either side of the vehicle, permitting rotational movement that is vital to performing the tasks.



Hydraulic Arm Systems

Cutting edge pressure generator.

The Beetle has two hydraulic systems that run from the control end of the tether to the vehicle. Each hydraulic system starts at a 40cc veterinary syringe filled with water. Each syringe has a rubber end from another syringe's plunger silicone-glued to its base, and each plunger has a hole to allow the hydraulic line through and partway into the syringe. The syringes are sealed with generous amounts of silicone sealant to prevent water leakage under high pressure. When each plunger is depressed, pressure is sent down the hydraulic line in our tether to the pistons attached to our ROV's arms. The ultimate goal of the hydraulic pressure is to extend the pistons. These pistons are made by Norgren, and were donated to us from an onion packing plant where they pushed bad onions off a conveyor belt. They max out at 250 PSI (1720 kPa), much higher than our needs. Originally they operated pneumatically, but we converted them to operate hydraulically. Water does not compress as easily as air, so the pistons could be extended with a shorter plunger throw. The hydraulic tubes, being filled with water, were also a neutrally buoyant addition to the tether. These two properties made water much more appropriate for *The Beetle's* tasks than air or oil.

On *Robie*, our main arm, the piston's case is attached to the outside metal casing of the arm. When the piston extends from its casing, it pulls a rod that runs the length of the arm. This rod is attached to a worm gear in the metal grasper casing that pulls two other gears. Each of these gears is attached to one of the grasper's fingers. The hydraulic system works to effectively close and open *Robie*. The mechanism employed by our other and more recently conceived arm, *Gimpy*, differs significantly. On *Gimpy*, the piston attaches directly to the grabber. When the piston extends, it pushes *Gimpy's* lower finger. The rest of the grabber is stationary, so when the plunger is pushed, the grabber closes. The two hydraulic arms are effective for interacting

***Robie* is our primary mandible.**

100% piston powered!

***Gimpy* is used for the airline challenge.**

with the door, air line, hatch, hatch door, pods, and air release valve when *The Beetle* is performing its tasks.

Robie was our team's first hydraulic arm. Originally, the hydraulic design was purely experimental, because we had already created a useable mechanical arm. We adapted *Robie* from a "garden grabber" purchased at Home Depot. The back of the arm was adjusted to fit the size of our ROV. It was attached to PVC pieces so it could be placed on the frame easily. We removed the rivets in the end of the grabber to move each of the grabber's gears back a notch, which made the grabber open wider. The grabber was then reattached to the arm casing using a zip tie – a bolt would have obstructed the rod running down the arm and rendered it unresponsive. We intentionally exaggerated the angle at which *Robie's* claw is bent, enabling our pilot to use the arm – while closed – to turn the hatch and open the air release valve. When open, *Robie* is useful to open the ventilation door. We can even open and close the arm to pick up ELSS pods. In light of the reliability of *Robie*, we abandoned our electrically driven arm and built *Gimpy*.

Gimpy was specifically designed to carry the airline down to the submarine's inlet valve. We angled *Gimpy* parallel to the submarine's inlet valve so that our pilot can easily place and retrieve the airline. *Gimpy's* grasper was originally a set of tongs for carrying beakers used in Monterey High school's chemistry lab; designed to hold glass tubes, it was also well equipped to hold the cylindrical airline. The arm's structural support was constructed from PVC, allowing for quick adjustments between tasks and complete compatibility with our frame, which, if necessary, would have allowed us to change its placement or orientation.

Challenges Faced and the Ways We Conquered Them

As recreational engineers, we understand that the only certainty of a design its inevitable and repeated failure. Even so, the challenges of often-inexplicable electrical and hydraulic failure were a stern test of our collective tenacity and creativity. Both the control system (a throwback to a previous year) and the arm mechanism (a burgeoning system) proved ample stressors in the weeks leading up to our regional competition and their malfunctions required patience and persistence to overcome.

The analog joysticks wired into our control system were a junk heap discovery whose actual age is still unknown. As a consequence, we have no gauge for the condition of the SPDT switches that frame each joystick. This lack of historical reference became troublesome when, at the end of a long and fruitful pool practice, we found our presumably steadfast system had suddenly gone haywire. The left joystick responsible for vertical motion had failed in a peculiar manner; the motors ran without activation of either switch in the circuit and depressing a switch broke the otherwise continuous flow of current. This control inversion was made more vexing by the complete inoperability of one switch and the faint scent of warm rubber ema-

Our pilot Kevin finds an obstacle.

nating from the box. Upon careful investigation, we found the switches themselves were the problem and solved the dilemma by purchasing new SPDT switches to replace the failed ones. Though our box has worked reliably since, we keep a few spare switches on hand just in case.

While none of the hydraulic failures we encountered rivaled the severity of our control box reversal, the frequency of leaks and depressurizations was plenty frustrating. In fact, the hydraulic system's syringe assembly is the most frequently modified segments in our vehicle's makeup. Version 1 had a very rudimentary hose-syringe attachment system, consisting only of a tube shoved over the syringe's end. This system was doomed to fail and we quickly moved to Version 2. V2 had a similar connection, but with zip ties and a wire wrapped tightly around the syringe end. This was, of course, another failure. For V3, we whittled down the syringe end to make it taper backwards. The end was then sanded down to give it a less smooth surface. This version was amazingly successful, but over time, the zip ties and wire loosened and broke, which ushered in V4, a step in a new direction. While at the pool, trying to find a quick fix for two just-broken V3 syringes, we had an epiphany. The plunger had a removable rubber end fitted to preserve seal integrity. We removed the plunger ends, poked holes in them, cut the syringe ends off, and shoved the tube through both holes. We pushed the plunger end to the bottom of the tube, and tested it. V5, our final version, had a silicone sealed plunger end with the tube-through design, and worked magnificently. We developed a fast method for pressurize the entire system in seconds by detaching the tube connector while crimping the tube, then reconnecting a newly full syringe.

In both examples described above, our team tackled the technical problem with a thorough, meticulous examination of the malfunctioning system and copious experimentation with possible solutions. By exploring a variety of options and never achieving complete satisfaction with a solution, we ensured our own preparedness for future failures. Also at our disposal in times of crisis is the experience of seasoned team members whom, in all likelihood, have encountered and resolved similar roadblocks before. As a club with a well-defined legacy—at no time in the past seven years has our team lacked veteran student-engineers—we draw as much on the wisdom of past teams as we do on our own troubleshooting abilities. The control box difficulties we recently encountered pale in comparison to the woes of the 2004 MAOS team, whose sophisticated vehicle and software-integrated controls fried when a team member mixed up the polarity of the battery and plugged in the system backwards. In no year since then has our team made such an error and the mythology of the mistake still travels from generation to generation of our club.

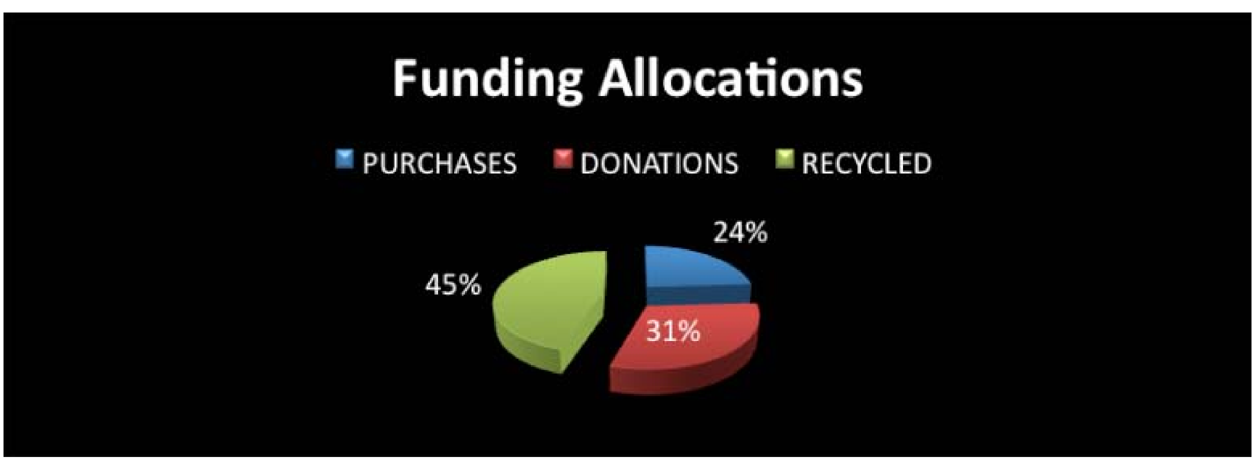
Lessons Learned: The Moral of the Story

Subtle warning label.

Rather unexpectedly considering the mechanical nature of the project, the most resounding lesson we learned while building *The Beetle* is the value of human cooperation and collaboration in creating success. Putting aside our revulsion to such a clichéd and tired realization, we understand the roles that dedication—long days and longer nights of work—and practice—the most time we've ever spent around a pool without swimming—played in our robot's underwater accomplishments. That being said, the project was a rich learning experience for all involved and led to the acquisition of many new technical skills. Several of our members learned how to solder while fixing tether wires, every team member learned how to handle an electric drill, and a few individuals invented new techniques to tackle unexpected problems. When our control box failed two team members learned how it was wired and the physics behind its operation and each time our hydraulics leaked someone invented a new way to seal it. The skills of adaptation are never learned completely, but we've certainly picked up a trick or two.

Budget and Expenses

The MAOS ROV Club raised over $350 in funds by selling food at Monterey High School food fairs. Thanks to previous ROV teams we are able to recycle nearly 50% of our ROV parts from previous years ROVs. Another third of our ROV was built with parts gathered and donated from various sources. This made for a very cost efficient ROV.

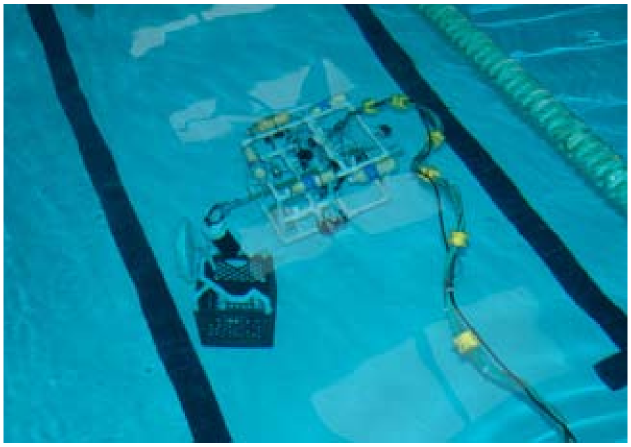


Funding Allocations

Items	Source	Purchases	Donations	Recycled
1.25 cm PVC pip and fittings	Home Depot/previous years' ROV	$23.77		$5.00
7.5 cm abs connector	Home Depot	$1.67		
Actuators (2)	Science classroom		$158.00	
Black bilge motor (3)	Previous year's ROV			$45.00
Blue bilge motor (2)	ROV parent		$30.00	
Bolts (6)	Home Depot	$13.05		
Camera switch	Previous year's ROV			$32.00
Cameras (4)	MATES workshop	$80.00		
Claws (2)	Home Depot/Gargage	$14.98	$12.50	
Control box	Previous year's ROV			$65.98
Hose clamps (7)	Home Depot	$15.33		
Motor props (5)	Previous year's ROV			$18.00
Noodle floats (2)	ROV student		$2.99	
Rubber tubing (2)	ROV instructor		$8.58	
Syringes (15 various sizes 10cc, 20cc, 30cc…)	Vet clinic		$29.50	
Tether wire	Previous year's ROV			$66.09
TV monitors (2)	Previous year's ROV			$120.00
Washers (30)	Home Depot	$9.75		
Water bottle filled with hard foam (5)	Previous year's ROV			$6.46
Wiggle eyes (1 bag)	Michael's		$3.49	
Wire mesh (2 rolls)	Home Depot	$29.96		
Zip ties (1 bag)	Home Depot	$3.00		
Subtotal		$191.51	$245.06	$358.53
Total				$795.10

Future Revisions: Looking Forward

Just as the evolutionary process yields imperfect forms, our work has produced a vehicle that is a work in perpetual progress. With greater resources, we could investigate more extensively the optimal motors and propellers, modify our frame shape, and invest in higher quality cameras. Early in the year, we played with concepts for a variable buoyancy system and even a variable speed system. However, a working vehicle and a looming international competition lead us to view streamlining of the existing vehicle as our highest priority renovation. Based on the comments of engineering judges at our regional competition, we plan to revamp the wet-side wiring of our motors and clean up the wiring within our control box. Having already conducted experiments (previously discussed) to ascertain the exact weight of *The Beetle*, we are now prepared to finely tune buoyancy and weight distribution. The serration method of PVC union ought to be applied to all parts of the frame. The business of ROV maintenance is a hectic endeavor.



A robot's work is never done.

Submarine Rescue Down Under

The submarine rescue system operated and maintained by the Royal Australian Navy from 1995 to 2008 revolved around the remotely operated rescue vehicle Remora, a 16.5-ton vessel that, while robotic, carried a diving bell capable of transporting seven human passengers. Rated to depths of 500m and capable of fighting a 3-knot current, the Remora received electrical information via a fiber optic umbilical cord and required a team of three to operate. The Remora's array of equipment included two hydraulic power units, an underwater telephone, a backup generator, air compressors, and bottled gases. This Australian Submarine Rescue Vehicle (ASRV) boasted twelve ELSS Pods, the supply storage containers on which this year's mock up is based and with which stranded submarine crews can be sustained virtually indefinitely. It was air transportable and required an A-frame launch and recovery system on the deck of its support ship. The Remora's form, like the shape we have given to *The Beetle*, was perfectly aligned with its purpose as a submarine rescue vehicle.

The designers of the Remora adapted the rescue vehicle from a work class ROV commonly used in the offshore industry. The various components of the vehicle were all commercially sourced, a design choice that ensured availability of replacement parts and consistency between the skill set for work in industry and the work experience required to operate Remora. We feel this design rationale follows the same philosophy as our own pragmatism and that the Royal Navy's choice to use available resources validates our own. The originality of the Remora's form shone through its assembly-line makeup just as *The Beetle* retains an identity separate from the vehicles whose systems it has salvaged.

The Remora was a groundbreaking vehicle, melding the deep-sea capabilities of a remotely operated vehicle with the diving bell technology needed to rescue submariners. As one of the first ROVs intended for human passengers, it was also one of the most efficient, performing a simulation in 2006 in which it ran eleven rescue cycles, the number of trips to and from a disabled Collins class submarine required to rescue its entire crew. Though the scenario, Exercise Black Carillon, was artificial, the Remora became the first SRV to demonstrate its capacity for such a large-scale recovery.

Performances like the Black Carillon exercise may praise the Remora's capabilities, but recent accidents have cost the Australian rescue system its certification. Only a few months after the Remora's rescue record, two contractors were trapped in the vehicle when a support cable connecting Remora to a support boat snapped. Stranded on the seafloor at a depth of 130m, the two men waited 12 hours in the vehicle's dive bell. Using the vehicle's remaining cable to lift it to a depth of 15m, rescue divers opened the escape hatch and brought the contractors to the surface. The vehicle itself wasn't recovered until several months later and the incident called into question the Australian rescue system's adherence to safety regulations. Less than two years later, the Royal Navy retired the Remora when a survey of the vehicle revealed that millions of dollars of upgrades would be required to bring the RORV up to par with safety regulations. The survey found the Remora to be in serious disrepair. Citing faulty and obsolete equipment and inadequate training, the report found the Remora fundamentally unfit for service.

While we hope that our vehicle won't fall victim to inadequate maintenance like the Remora, we can identify with the economic difficulties that brought around its retirement. In fact, our express frugality and conservation-minded design reflect a desire to offset monetary shortcomings. Having developed a successful vehicle without an exorbitant price tag, we face the updating of functional systems as opposed to an expensive revamp of commercially bought components. Hopefully, *The Beetle* will soon be setting rescue records of its own without snapping any cables.

Look familiar? *The Beetle* has a docking system similar to the Remora's.

Works Cited

http://www.naval-technology.com/projects/lr5/

http://lubbers-line.blogspot.com/2005/09/aussie-submarine-rescue-system.html

http://www.theaustralian.news.com.au/story/0,25197,24845190-5013871,00.html

http://www.navy.gov.au/Submarine_Rescue_Vehicle

http://www.janes.com/defence/naval_forces/news/jni/jni010219_2_n.shtml

http://www.navy.mil/navydata/cno/n87/usw/issue_9/sub_rescue.html

http://www.idpm.biz/windows/image4.htm

http://www.idpm.biz/downloads/Remora_Fact_Sheet.pdf

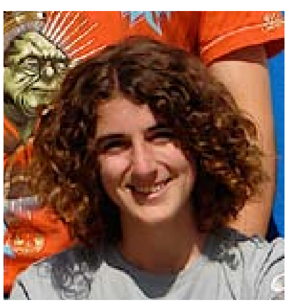
http://www.defence.gov.au/news/navynews/editions/4905/topstories/story15.htm

http://www.defencejobs.gov.au/submariners/technology.aspx

Personal Reflections: Sharing Time

James

In working with this ROV team, my seventh to date, I was treated to a unique and disorienting experience. Whereas my past middle school and high school ROV experiences have been educational in their often-unpleasant group dynamic and the vehicles these teams produced tantalizingly short of competitive, the 2009 MAOS team has proven themselves both dedicated and competent. I express these sentiments from a distance because, for the first time since I began competing at MATE events, my role in the team's success was relatively small. I gave my teammates the benefits of my long involvement in ROV and organized meetings, but they operated the vehicle and built its newest components. For the first time, I was able to enjoy the thrill of a spectator witnessing skill and ingenuity and found it more fun than any of the years in which I piloted a vehicle in competition. This year, I learned how to be a bystander.



Brian

Over the months I've spent helping build *The Beetle*, I've learned things from practical wiring skills to what type of syringe is best to squirt friends (40 cc center spout with a solid plunger), but I think the most important thing I learned is the importance of small details. For example, *The Beetle* was moving very slowly, but out of water our slow motor was rotating at a higher frequency. Why? The propeller attachment had loosened. Small detail. We dropped our ROV in the water, and the camera view was vibrating. Why? A small, overlooked detail: our motor was scraping the side of our propeller housing. We pushed the housing away, and our vehicle started turning right instead of going straight. Why? Yet another small detail: the tether had been attached slightly off-center. Each of these factors contributed greatly to the motion of our vehicle; these keystone parts were much more important than we had believed. I've realized since then that these kinds of small details affect nearly everything - the speakers in my room have a dead bass spot if turned just five degrees off; my driving ability greatly decreases if my seat is just two cm lower; a .09 mm guitar string is unbelievably different from a .1 mm. I now pay much greater attention to these seemingly insignificant differences. *Beetle*, you've made me a perfectionist.

Kelly

After three years of pondering over it, I finally joined the ROV club for the 2008-2009 year. I immediately regretted not having joined this club earlier; I created new friendships, became more knowledgeable about circuits, and experienced fun times with club members. Half of the people in our club this year are people I have recently met through the club; our interactions in the ROV club have made us familiar and friendly toward each other, and we socialize outside of the club as well. Building an ROV made me think outside my normal boundaries and compelled me to work wholeheartedly on a project that I truly enjoyed. I didn't think that I would play a significant part in the creation of the ROV at first, but I learned that everyone's effort was necessary in the perfection of our vehicle.

Katherine

Working on the ROV this year has been a very rewarding experience for me. This year's team was comprised of such intelligent individuals who were receptive to direction and committed to the team. I'm sure every member would agree that this project was an enjoyable and exciting experience, especially when our systems were operating correctly. One particularly exciting achievement for our team was completion of *Robie,* our hydraulic arm, which is our central tool for accomplishing the missions. When our hard work came to fruition it left a good feeling of accomplishment only obtained through dedication and perseverance.

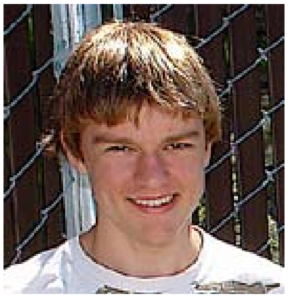
Evan

This year in ROV was very fun. I learned a lot about teamwork and how much work goes into making the machine. Although some of the days could have been shorter, I believe that it was a valuable experience to be a part of the club. The many trials and errs took a very long time to perfect yet we go the best score in the entire United States. Some of the times it seemed that only a few of us showed up to work on the vehicle, but the team still had to work together to finish so I guess it came together in the end.

Kelsey

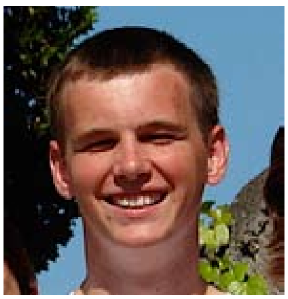
Working on *The Beetle* was an amazing experience that taught me many things. While working on projects before, I had made a plan then followed it pretty strictly. However, when working on this ROV, I learned how to incorporate new ideas as they were thought up and not to insist stubbornly on including every single detail from an original design or concept. I believe that the team's willingness to add, delete, combine, or change components of the ROV in the middle of building it made the vehicle better than any one preliminary design. I also learned, as complete corny as this sounds, how to work with others.

I usually work on projects by myself or, at the most, with one other person; however, while working on this vehicle I was working with a ton of people. I think that it was working on this ROV that I finally understand how much more fun, creative, and rewarding a project can be when you work with other people.



Darin

There are many things I have learned from ROV club. These are the few that I think are the most helpful. First and most important to me is that I learned to make a hydraulic claw. Next I learned that the simpler you make your ROV the less likely it is to break or fail. Finally and probably the funniest is I learned to dremel PVC connecters and fit 2.5 cm pipe through it. So those are I few things I learned in ROV club.



Jack

I had two notable experiences in my time working on *The Beetle*. One was working with my teammate Brian Hardoin building our hydraulic system. The building of the system hit many roadblocks, including leakage difficulties due to pressure and inefficient sealants. These were overcome with modified syringes, silicone sealant, and a re-pressurization system. The other was the competition.

Jonathan

As a first-time member of the ROV Ranger team, I found my experience especially rewarding yet at times challenging. Assigned to work on the control box, I was confronted with what initially appeared an overly complex task. However, with the guidance of teammates I was able to grasp the concept of the system's circuitry, a major accomplishment for myself. Perhaps what impressed me most this year was the ingenuity and diversity of ideas offered by members of the team. As the competition neared, we scrambled to find time to test The Beetle underwater, making small, innovative adjustments after every run to optimize the performance of each system. In retrospect, I see now that the success of our vehicle was ultimately the product of not only our time commitment but also our creativity and resourcefulness in devising solutions to the many problems we encountered. Overall, being a part of the ROV team has been truly a meaningful and worthwhile experience, and I look forward to next year's competition.

Ahmed

In my experience as an ROV Ranger team member, I have learned much about teamwork as well as the design of underwater vehicles. Having participated for only one year, I was confronted with many new aspects of constructing a vehicle. As an operator of the vehicle's arms, I especially found the hydraulic system to be one of the team's greatest achievements. Having advanced from the previous year's scout competition, I was amazed by the complexity of the tether and buoyancy systems. Our buoyancy system required far more management than that of last year; instead of atrial and error method, we measured every facet of the vehicle with a spring scale in order to acquire equal buoyancy on the vehicle. In general, I feel that building a ROV had been a truly rewarding experience.

Kevin

As *The Beetle's* brains, I experienced countless setbacks and breakthroughs right from the driver's seat. The trials and tribulations of designing, building, and piloting our ROV were all experiences that have made me a better prepared engineering student and will undoubtedly aid me in my college career. Designing this ROV has given me mounds of new knowledge about robots and engineering in general and plenty of tips on teamwork. This epic project was the first of its kind in which I have participated. Every aspect of this endeavor—from brainstorming on the drawing board and fine-tuning the PVC frame, to soldering wires and adjusting camera angles—was perpetually filled with a sense of ingenuity and concentration. I enjoyed the energized team atmosphere that exuded from every member of Team MAOS, a collective sense of triumph felt at our first pool practice and upon receiving our Mission Champion and First Place plaques at the regional competition. The culmination of our team's hard work into those two symbolic planks of machined wood was deeply rewarding. Being the pilot of this winning ROV and a member of this winning team is one of my most scintillating achievements.

Acknowledgements

The team would first like to thank the mentors who helped us so much. David Caress of MBARI and Lisa Rike were invaluable guides while MAOS teacher Geoffrey von Saltza helped coordinate with the school for us and opened up his classroom. Their continued guidance and gentle prodding has helped us to create this year's ROV and there would be no MAOS ROV Club without them. Thank you to Michele Hardoin for organizing our trip to Boston. Also, special thanks must also be extended to organizations that have made our journey possible. We thank MAOS for the opportunity to organize a club and field a team. Finally, we would like to thank Jill, Matt, Scott, and all of the other MATE staff and volunteers for coordinating this exciting and unique competition year after year.