Team Lobos
Monterey Peninsula College Robotics Club

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Figure #1: Team Lobos with Submersibles

Abstract

A Nazi U-boat is cruising the East Coast. Its wartime mission, to deliver a spy carrying a mysterious substance to the Florida Keys. A coast guard cutter patrols these same waters and sights this invader. A chase ensues, the U-boat looks for cover in a mysterious fog bank. Then disaster, as the submarine continues to evade, it collides with an uncharted reef and sinks. Only the captain survives, to find himself washed up on a tropical beach.

Sixty year later, a group of researchers uncovers these events and goes looking for sunken ship. Using side-scan sonar, they locate the wreck, but the bottom rises quickly, and their tow fish is also lost on this uncharted reef. To mark the location for a return trip, a sonic pinger is thrown overboard.

Our mission is to return to Mystery Reef to complete both scientific and recovery missions. We must identify the sunken submarine by returning its bell to the surface. We must also take a length measurement of its hull. We must return both the lost tow fish and pinger to the surface. To identify the mysterious substance the spy was transporting we must return a pure, 500-milliliter, sample to the surface. Lastly, we must take a depth reading and water temperature reading to complete our study of the reef. We designed a pair of submersibles to complete these tasks, one for heavy lifting, one for exploration within the cave system. Team Lobos is looking forward to returning to Mystery Reef.

Introduction

The mission requires that our ROV complete seven tasks in less than thirty minutes. These tasks include taking a depth measurement, a temperature measurement and a length measurement. We also must lift three items to the surface, the U-boat's bell, the lost tow fish and the sonic pinger marking the reef's location. Lastly, we have to obtain a sample of the unknown liquid. This is quite a bit of work to complete in thirty minutes so we decided to construct two submersibles and divide the tasks between them. Our team, the Monterey Peninsula College Robotics Club, elected to call ourselves Team Lobos, after the mascot of our school. Following in this trend, we called our pair of submersibles Romulus (Figure #2) and Remus (Figure #3), after the two legendary brothers raised by a wolf. Romulus would be our workhorse, designed for heavy lifting and power. Remus would be our smaller ROV,

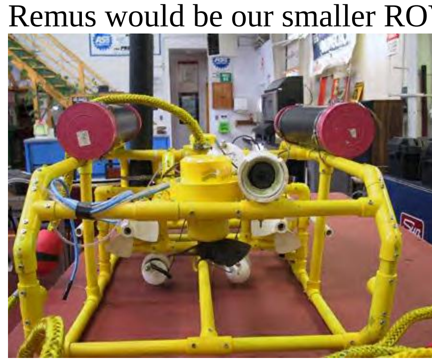


Figure #2: ROV Romulus

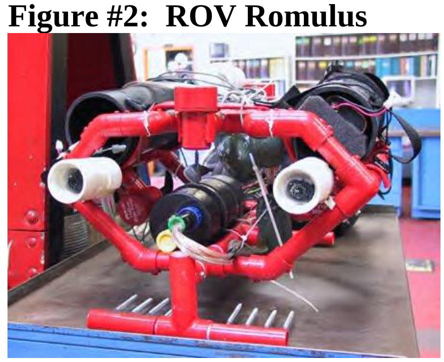


Figure #3: ROV Remus

designed to do the scientific missions and venture inside the wreck and reef. A third vehicle, Sea Wolf (Figure #4), is a radio controlled surface vehicle designed to watch over, and guide, the underwater vehicles from above. With this collection of vehicles, we think we can complete all seven missions in the designated time frame.

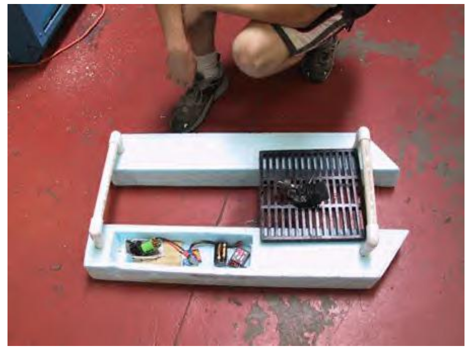


Figure #4: Surface Vehicle Sea Wolf

General Systems

Overall Design

Team Lobos used PVC as construction material. PVC is light, relatively strong, inexpensive and easy to use in ROV construction. It allows for quick repair, and for easy troubleshooting when a design needs a slight, or major, alteration. We also used ABS in construction of our canisters. ABS is similar to PVC, but is positively buoyant. We used it because it is easy to obtain in larger diameters needed for our canisters.

Both submersibles used a standard motor configuration design. Two motors are placed horizontally, to provide forward thrust and allow turning. Two vertical motors are placed in the vertical axis, one near the bow of the ROV, one near the stern. These provide vertical thrust, as well as provide pitch control. Although our motors provide both forward and reverse thrust, motors are designed to deliver more thrust forwards. We oriented our vertical motors to provide maximum thrust for lifting as opposed to descending.

Buoyancy is provided by air enclosed in ABS canisters. Romulus, our larger ROV, needed large air canisters to provide neutral buoyancy. Remus, the smaller ROV, already had three watertight canisters for its power supply and control board. These canisters, even filled with hardware, provided sufficient lift that no extra buoyancy was necessary. Hard buoyancy, such as these canisters, has advantages and disadvantages over foam. Hard buoyancy canisters will not compress at shallow depth as softer foam will. Although high-end flotation, such as syntactic foam, is also incompressible, it is prohibitively expensive. Hard air canisters will collapse under high pressures at great depth, but for the depths we are descending to, it is safe. Team Lobos felt it better than foam for our flotation needs.

To determine the amount of buoyancy needed, each ROV was weighed underwater. Romulus, for example, weighed 7.5 kilograms underwater. Hence we needed 7.5 kilograms of positive buoyancy to compensate. Converting to volume for our equation, we would need 7,500 cubic centimeters of air enclosed in ABS. We calculated the length of both 4-inch (10 cm) diameter ABS pipe, and 3-inch (7.5 cm) diameter ABS pipe needed to achieve that volume of air. We found that we would need 1.6 meters of 3-inch ABS pipe or 1 meter of 4-inch ABS pipe. Team Lobos elected to use one meter of the larger diameter pipe for our flotation needs.

Power Systems

Romulus, our heavy lift submersible, uses three car batteries on the surface to provide approximately 36 volts. Although only rated for 32 volts, the motors we are using should operate at a slightly higher voltage without problems. The voltage increase will increase amperage of each motor slightly, but not enough to burn out the motors. However, amperage for each motor when running at 36 volts becomes problematical. When we first operated our motors underwater, we found that they were severely over-propped. Over-propping a motor is when the rotation of the shaft is significantly slowed due to resistance caused by the propeller pushing water. For our initial power test, we operated the motor at 12 volts, and had 7 amps running through the motor. At 24 volts, amperage increased to 17 amps. At 36 volts, amperage for each motor increased to 28 amps. Since all four motors might be running simultaneously, each motor should be limited to 10 amps to stay within the proscribed 40-amp limit. To control these limits, our team used pulse width modulation to reduce amperages to acceptable levels, while still operating at 36 volts. Pulse width modulation means sending intermittent power through the motor instead of constant power, but at an extremely high rate. Using pulse width modulation, thrust is decreased from that of a constant 36-volt power supply. However, it allows us to control the power more precisely than by using fewer volts. We can control the power curve so that we are always near the 40-amp maximum, giving us the best available thrust.

With a standard motor configuration, often times only two motors will be turning at full speed. Team Lobos is currently working on a computer program to control our pulse width modulation. We are trying to alter the system so if only two motors are running, they are operating at a higher level than if all four are running. Pulse width modulation will be determined by the number of motors running, keeping us at maximum power available whether we are using one, two, or four motors.

We designed Remus with different factors in mind. Remus is our smaller ROV designed to venture into wrecks, reef caves, or other tight enclosures. Since a light, thin tether is needed to facilitate these exploratory missions; we designed Remus with an onboard power supply. There are three watertight canisters attached to Remus. Two of these contain pairs of 6-volt alkaline lantern batteries wired in series. The two canisters are wired in parallel, providing an onboard power supply of 12 volts. The third watertight canister contains the control boards, housing the electronics to control the ROV. Although these canisters add bulk to the hull, we felt that the small, slick, lightweight tether was more important for missions inside tight enclosed spaces. An onboard power supply also allows us to experiment with alternate methods and learn about different design strategies. Team Lobos feels that our two submersibles, with different power supplies, will facilitate this mission and any future missions they undertake.

Motors and Propellers

Power wins contests. That is the belief of Team Lobos. Therefore, we looked for the most powerful motors we could find that would run on 48 Volts and 40 Amps. In the past, bilge pump motors have always served our team well. The biggest benefit of bilge pump motors is that they are built watertight. No waterproofing is needed. The other benefit of bilge pump motors is that under a removable exterior, they have a rotating shaft that turns an impellor. By simply removing the impellor and attaching a propeller to the shaft, we had a working, waterproof motor.

For Romulus, our heavy duty ROV, we chose the Rule™ 3700 GPH (Gallons per Hour) bilge pump motor, the largest, most powerful bilge pump we could find (Figure #5). We removed the outer housing, removed the impeller, and attached a propeller. For a motor of this size, the propellers we found on the market were prohibitively expensive, especially when you have multiple motors. Fortunately the U.S. NAVY donated two Sea Eagle submersibles to our group in 2002. The Sea Eagle's have 3-bladed propellers approximately 15-centimeters in diameter, a perfect size for our bilge pump motors. We removed six of these propellers to be used by our four motors, giving us two spares.

Figure #5: Rule 3700 GPH Bilge Pump with attached propeller

Figure #6: 1100 GPH Bilge Pump with attached propeller

For Remus, our smaller ROV, we chose Rule™ 1100 GPH bilge pump motors (Figure #6). These motors do not have nearly as much thrust as the larger motors, but they are smaller, cheaper and take less power. They also use much smaller propellers, which are commercially available in a number of sizes and shapes. Team Lobos purchased a number of small propellers and did a modified Bollard test to determine which propeller to use. Although motor thrust is the paramount issue of a Bollard test, we also considered the amperage of each motor. Since Remus has limited onboard power, we must take battery life into account. Lower amperage use will give our batteries a longer life. Unfortunately testing problems limited the effectiveness of measuring amperage.

Table #1: Bollard Test Results.

Screw Type	# of Blades	Diameter	Thrust	Voltage	Amperage
Brass	3	80 mm	**1000 grams**	12.66	**8.8**
Robbe	3	60 mm	**750 grams**	12.66	**8.0**
Robbe	3	60 mm	**500 grams**	8.0	**5.0**
Plastic 2317.70	2	70 mm	**900 grams**	12.5	**2.0**
Plastic 2317.60	2	60 mm	**850 grams**	12.5	**8.1**
Plastic 2317.40	2	40 mm	**700 grams**	12.5	**4.6**
Plastic 2317.48	2	48 mm	**800 grams**	12.5	**6.6**
Brass	6	65 mm	**900 grams**	12.6	**8.2**

We believe that the high amperages obtained during many of the tests were due to vibrations and friction problems of our test motors. Our tests were run using older bilge pump motors, not the actual motors that will power the ROV. This was done to minimize damage and wear as propellers were attached to and detached frequently from these test motors. On these test motors, the shafts had been shortened during their previous use. We used 3/16-inch roll pins to attach propellers to the motor shaft, but vibrations due to poor attachments were common. There was insufficient length to give the roll pin the long, straight orientation it needed.

From our Bollard tests, we determined that thrust was fairly similar for most of the larger propellers. Most test propellers provide thrust in the 800 grams to 1000 gram range. Remus, our scientific ROV, will use two plastic 70-mm propellers (model 2317.70, 2 bladed, 70 mm) for our horizontal thrust motors, and two brass 65-mm propellers (6 bladed) propellers for our vertical lift motors. These were the propellers that we could easily obtain. We believe these will provide sufficient thrust and lift for Remus.

Tether

With an onboard power supply, the tether for Remus is very small. It only needs to transfer control signals and scientific data signals between the surface computer and the ROV. Four camera wires must also be incorporated into the tether, but these are small diameter and very flexible. This small, thin, flexible tether should facilitate Remus' ventures into the reef caverns as well, as it is unlikely to become stuck on corners or other points.

Adversely, Romulus, with a surface power supply, has a large, thick tether. It is comprised of eight motor control wires, two per motor. It also contains two air hoses for the suction of liquid task. Four camera wires are also included in the tether for Romulus. Lastly, a strand of CAT5 cable is incorporated for the electronic tools that will be mounted on Romulus.

Control System

The pilot will use a Joystick controller to maneuver each submersible. The joystick controller is comprised of two parts, the throttle bar (Figure 7A) and the flight stick (Figure 7B). This joystick plugs into a standard USB port on the computer.

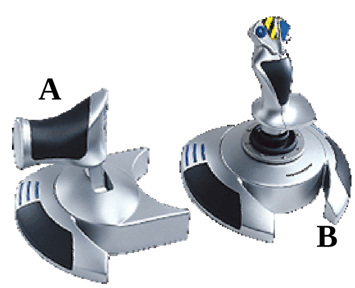


Figure 7: USB Joystick

Although flight characteristics can be modified with a different program, we have our ROV control set up with the throttle bar controlling vertical movement and the flight stick controlling horizontal movement.

The joystick is connected to a laptop, which in turn is connected to a Joystick Interface Box (Figure #8). This Joystick Interface Box interprets signals from the

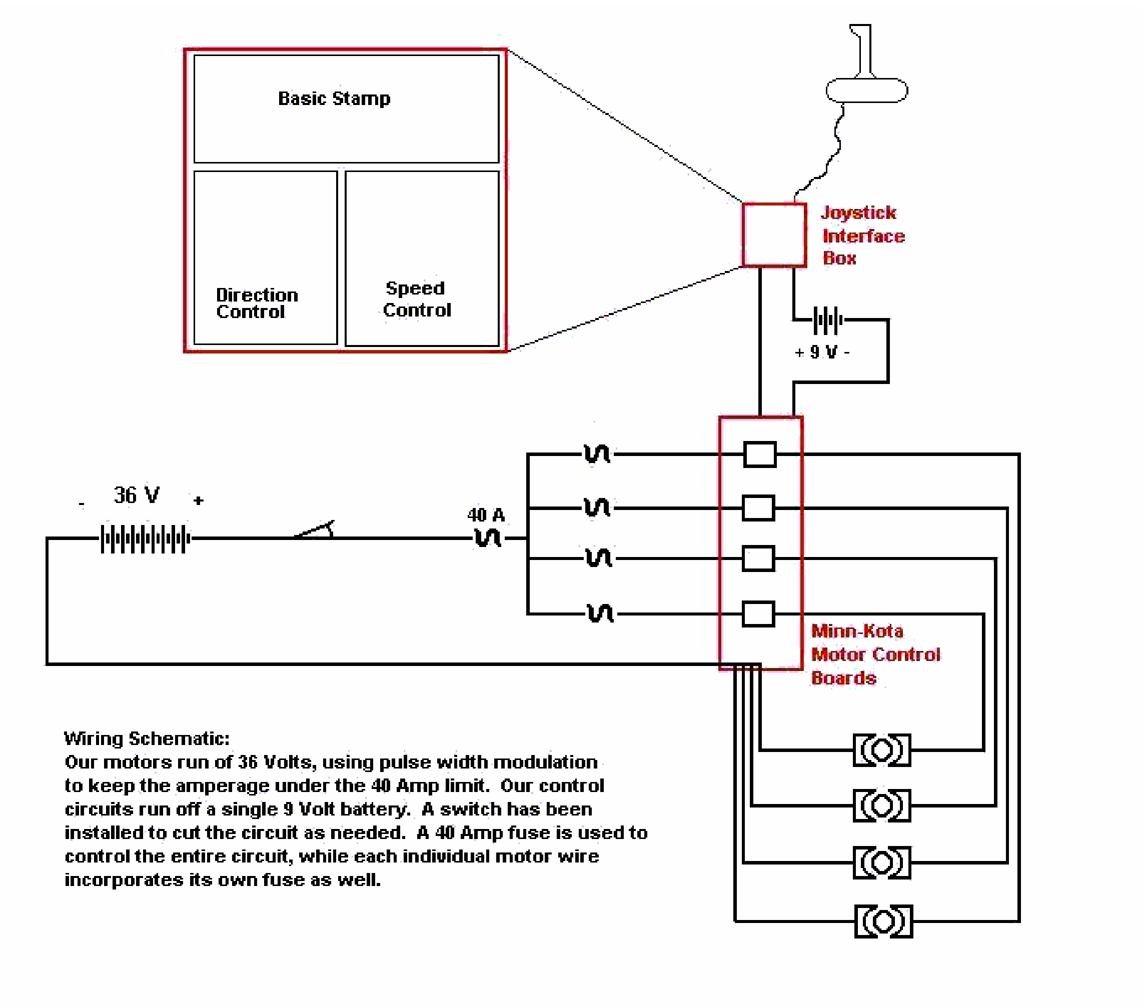
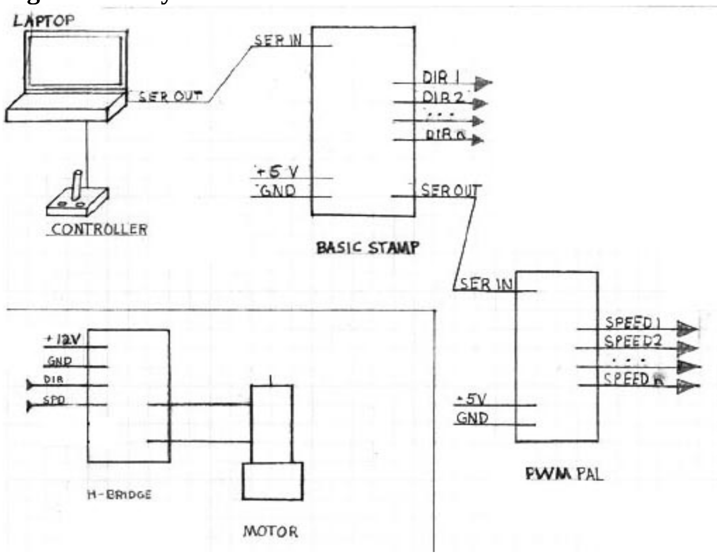


Figure #8: Wiring Diagram of Romulus and Remus

Figure #9: Joystick Interface Box Schematic



joystick and converts those signals into motor commands. There are two basic functions of this system. This system determines direction of motors and it determines speed of motors. The direction of each motor is controlled by an H-bridge. This is a series of four transistors set up to give two paths for the positive charge to go through the motor to ground. One path moves the motor in a forward direction, one path in reverse direction. This allows each motor to move in forward and reverse. The second function of the Joystick Interface Box is to determine speed of the motor. Speed is controlled by pulse width modulation. Intermittent power is sent through the system. A constant stream of power gives full forward thrust. More intermittent pulsing will slow the ROV speed. With these systems, each motor can be given speed and direction commands, and an ROV can be maneuvered through the water.

A computer program coordinates all the of the control commands. This computer program interprets a movement of the joystick into speed and directional commands to each individual motor. The actions of an ROV in response to joystick movement can vary depending on motor placement, or even preference of the pilot. For our submersibles, we have the following joystick control setup. The throttle bar controls vertical movement. The zero point is in throttle center. As the throttle is pushed forward, the ROV descends in the water column. The further forward, the faster the motors turn and the greater the rate of descent. Moving the throttle bar backwards gives the ROV lift. The flight stick controls horizontal movement. Pushing the stick forward moves the ROV forward, pulling back moves the ROV in reverse. Amount of forward or backward movement of the flight stick determines speed. Moving the flight stick to either side turns the ROV in that direction. Amount of stick movement determines the rate of turning.

The final step is converting the low amperage control signals into high amperage to turn the motors. This is done using motor control boards. Motor control boards use the low amperage control signals to modify the higher amperage running from the batteries through the motors. All of these systems, tied together with a computer program, give the ROV pilot an easy to use control system.

Cameras


Figure #10: Ananconda Camera

Each ROV will have a number of onboard cameras. We purchased a number of X-10 Ananconda cameras for our submersibles (Figure #10). These color cameras are small, relatively inexpensive, and come with 19 meters (60 feet) of cable. The only major drawback is that their aperture width is fairly small. We calculated the aperture width of the camera to be approximately 40 degrees in air, less in water. Our team felt that one camera with only a 40-degree field of view might be insufficient to pilot our ROV. We decided that two cameras facing forward, situated on a split screen video monitor would be ideal. A single rear-view camera would be used for reverse movement. Finally, a fourth camera would overlook the payload packages that we would have on each ROV.

Ananconda cameras are not waterproof, so our team had to construct watertight housings for each camera. A PVC coupling was used as the basic housing canister, with a clear plexiglass lens on one end and a PVC end cap on the other end. Once all sections were glued together, we used a Schraeder valve to test the integrity of each seal. A Schraeder valve allows us to use air pressure, either positive pressure or vacuum, to test the seal integrity before submerging it into water. If the housing holds a near vacuum, it should also be watertight.

With four of the waterproof housings, we tried wax as a means of creating pressure resistant canisters. However, problems with hot wax and condensation created severe problems in two of the cameras. Water droplets, formed by steam condensation from the wax melting process, got into the housing. Two cameras ceased working after this process due to water intrusion. The wax was melted out, and the damaged cameras recovered and dried. Fortunately, both cameras were revived, and replaced into new housings without wax. We believe that wax filler can be beneficial to avoid pressure at great depths, but for our purposes, working in shallow depths, the extra protection is not needed.

Navigation

Our cameras allow us to see underwater, but it is also useful to know where the submersible is in the environment. We decided to construct a third vehicle, a surface vehicle, with a wide-angle camera that would look down on the reef from overhead. This vehicle, named Sea Wolf, was designed to park above the reef and visually monitor the two submersibles. This vehicle could also be used to identify measurement or retrieval locations around the reef, and guide our submersibles to them.

We decided to experiment with Sea Wolf and make it a radio-controlled vehicle. Although radio signals travel poorly through water, this vehicle is a surface craft and can easily be controlled via this method. Radio control circuits allow us to have a vehicle without a tether, as Sea Wolf also has an onboard power supply. Remote cameras were also used to keep this vehicle completely wireless. We used X-10 wide eye wireless video cameras for this vehicle. Each of these has a 120 degree aperture width in air. Although less in water, this camera should be able to survey the reef from the surface and assist our submersibles with navigation.

In a deep-sea environment, we would not be able to visually see a submersible at depth, but this system is analogous to a sonar navigation system, where sonar signals sent from the surface bounce off an ROV and structures at the bottom to create a visual picture. Although Romulus and Remus have different sizes and shapes, we also painted them differently to help distinguish them. We hope that this surface navigation vehicle will provide the guidance we need underwater.

Mission Systems

Depth Measurement

It is important to know the depth of any underwater exploration. As depth increases, so does pressure, which can be a major factor in any underwater scientific or exploration mission. To fulfill this mission requirement, we must take a depth reading at a designated point on the U-boats periscope. To determine depth, Team Lobos is using an MSP-600 pressure transducer. This transducer measures pressure, which is proportional to depth. For approximately every 10 meters of depth, the pressure increases by one atmosphere. For our measurement, the water pressure exerted on the transducer is converted into voltage, and this data is sent to a computer on the surface. The computer converts this voltage into a depth measurement. The pressure sensor is located on Remus, our smaller, scientific and exploration ROV.

The data returned to the surface will be displayed on a computer screen. A data point will be plotted every second to give us a transcript of Remus' depth throughout the mission, but we can also mark and save a certain depth at any point of this journey. This will allow us to plot the depth of the periscope marking as specified in the competition, as well as maintain a complete depth record of Remus. Accuracy of the depth measurement is in the range of +/- 1.5 centimeters, well within the stated 5 centimeter range proscribed in the mission objectives.

Temperature Measurement

Located inside one of the caverns of Mystery Reef is a cold spring. One of our tasks is to determine the temperature of water emanating from this cold spring. Since this mission requires us to venture inside the small caverns of the reef, we have mounted our temperature sensor on Remus. We are using a LM35 temperature sensor to take this measurement.

In a similar manner to depth readings, the temperature data returned to the surface will be displayed on a computer monitor. Data points will be plotted and saved every second to give us an accurate temperature profile for the entire trip. However, when Remus inserts the temperature probe into the cold seep, we will be able to mark and save that data point to fulfill the mission requirements. Accuracy of the temperature measurement is in the range of +/- 0.5 degrees centigrade, within the 1.0 degree range proscribed in the mission objectives.

Length Measurement

Our submersibles must determine the length between two points on the U-boat. Length measurements of wrecked ships are a standard investigative procedure used by many underwater archeologists. Length is crucial data that can help identify a wreck's origin, age and identity. To fulfill this mission requirement, we must measure very accurately, within 5 centimeters of the benchmark to receive full points.

Team Lobos came up with two methods of measuring length. The first is to simply pull a measuring tape from one mark to the other and read distance with one of our on board cameras. The second method is to use sound waves to measure distance. Normally, sonar devices bounce a sonic energy signal off a hard surface and note the time it takes the signal to travel out to and back from the intended target. However, two submersibles, both with tethers, give us the ability to send a signal from one ROV to the other, removing any need to bounce a signal, and the inherent problems therein. The methodology for this sound measurement is that both vehicles maneuver so that each one is at a mark. One ROV creates a signal that propagates through the water. Simultaneously, a signal is sent up the tether denoting the start time. The second ROV receives that signal, and sends the ending time up its tether. The signals sent through the tether to a surface computer are traveling at the speed of light, so essentially take no time. The time that the signal takes to travel through the water, from one ROV to the other, is measurable. We must calculate for salinity (density) of the water, as sound travels quicker through a salty medium. But, if we know the travel time of the signal, through a liquid of known density, we can calculate distance very accurately.

There are a few problems that arise from this method. Sound travels well underwater, but a signal will bounce of any hard surface. This is not a problem when working in an open ocean environment, but in a pool environment, the bottom and walls of the pool will reflect the sonar pulse, providing numerous false readings. That is the primary reason we are using two submersibles to take this reading instead of bouncing a signal off the sunken submarine. It would be too difficult to determine which is the true signal amongst all the clutter. With two submersibles involved, the first strong signal received by the receptor ROV should be the direct path signal, not a signal that has bounced off the wall. We believe that the two ROV method should alleviate the problem of bounced sonar signals.

The second problem we found was waterproofing our sound emitter and receptor. Although we can easily waterproof any device inside a canister, the walls of the canisters we experimented with would not adequately transmit a sonic signal. As of this report, we have not found an adequate watertight container. We have tried multiple canisters, even filled with oil, but have not had good sound propagation. Our next attempt will be to waterproof the computer boards, but leave the emitter and transmitter open to the water.

Team Lobos currently has both devices mounted on our submersibles. Using sound to measure length is desirable, but until the problems are worked out of the system, we will rely on the tape measure for determining length.

Tow Fish Retrieval

The side-scan sonar tow fish was lost during the original mission and needs to be recovered. The mission parameters state that the tow fish can be manually pulled to the surface, so this is the primary methodology we adopted. Although simply attaching to the tow fish would not be too difficult, we have incorporated a number of designs to help us retrieve the tow fish with fewer difficulties.

Figure #11: Tow Fish Retrieval Device

The first design is to help connect to the U-bolt. We are using a carabineer to attach to the U-bolt (Figure #11). However, in early experimentation, we found that a carabineer tends to slip sideways off the rounded U-bolt attachment point. To facilitate capture, we used an open carabineer. The carabineer is held open by a small metal wire, allowing the carabineer to slip over the U-bolt without slipping sideways. When the wire is tripped, the carabineer mechanism is already over the U-bolt, and will not slip sideways. This method assures capture, reduces the tension needed to open and close the carabineer, and prevents sideways slippage over the rounded U-bolt. Testing this design showed that it worked remarkably well compared to a closed carabineer system.

Once captured, high-pressure air is used to detach the carabineer attachment from the ROV frame. The carabineer is attached to an ABS end cap, which is simply held onto the ROV by friction. Pumping high-pressure air into the ABS canister overcomes this friction and releases the end cap and attached carabineer. After detachment, the ROV Romulus is free to move away to complete other missions. The detachable carabineer attachment has its own tether, comprised of a pair of air hoses. The first air hose is used to detach the system from the ROV, the second is used to fill a lift bag. Although we could simply pull the tow fish in once we have attached to it, we felt it safer to both the integrity of the tow fish, and to the integrity of the reef, if we lifted the tow fish to the surface, then retrieved it. The second air hose inflates a lift bag, which will bring the tow fish to the surface. It can then be pulled in and successfully recovered.

As a back up system, the sonar pinger recovery device can also be used to recover the tow fish if needed. Our pinger recovery device is designed to retrieve a small chunk of 2-inch PVC. Since both the two fish and pinger are similar in size, we can use the pinger retrieval device to retrieve the tow fish if needed.

Pinger Detection and Retrieval

When the tow fish was lost, a sonic pinger was thrown overboard to mark the location for a future rescue attempt. The pinger is also an expensive piece of equipment that needs to be located and recovered. For this competition, the pinger is a length of 2-inch PVC pipe with end caps, somewhere in the 10 to 20 cm range. It will be creating a noise in the auditory range.

One of the tasks is to find the correct pinger from the bottom of the pool. There will be a number of pinger devices on the bottom, but only one will be emitting noise. It is our responsibility to retrieve the one and only pinger that is active. To accomplish this task, we are using a pair of condenser microphones mounted in watertight housings. The sound is transmitted through the tether to a pair of speakers on the surface. Directionality is difficult to determine, but the active pinger is easily discernable at close distance. Team Lobos plans to use our limited directionality to give us a general area, then examine all pinger devices in that area to determine which one is emitting noise. If necessary, we will separate pingers to assist in our identification.

Once we have located the proper pinger, we are planning on picking it up with 2-inch PVC clamps (Figure #12). PVC clamps are designed to attach to a length of PVC and hold it in place. We use them in a similar manner. Our large ROV, Romulus, has four of these PVC clamps attached to it. The plan is to drive our ROV above the pinger, then descend. With the proper alignment, the clamps will attach to the PVC pinger. We determined that not too much downward force is required to clamp onto the pinger, yet a single clamp is strong enough to stay attached to a length of PVC weighing 1 kilogram. Orientation of the pinger below the ROV might be problematical, but we determined that even if the pinger is 45 degrees off-alignment, the clamp design would still attach to it. To compensate for alignments greater than 45 degrees, we positioned clamps perpendicular to each other. Our capture device should have no problems retrieving the pinger once it is located.

Figure #12: Pinger Retrieval Device

Figure #13: Bell Recovery Device

Bell Recovery

Although it is believed that the sunken U-boat is U-157, that fact needs to be verified. Admiral Doenitz presents each U-boat captain with a ship's bell, engraved with the number of the U-boat, upon embarkation. It is our task to find and recover that bell, verifying that this is U-boat 157. The bell is most likely found inside a small area, so we have designated our smaller ROV, Remus, to retrieve it. We designed a simple spike pick up (Figure #13) to snare the rope attached to the bell. The spikes were placed internally, so as not to snag on any external surfaces. The mission plan is to locate the bell, drop down over, then get our spike through the rope opening. Since accuracy might be a problem, or it might be difficult to spear the small opening with one of our spikes, we attached a row of spikes to Remus.

For our spikes we used long wood screws. The screw surface provides friction that will keep the bell attached to the ROV, even when moving in reverse or at a steep angle. Once one, or two, of our spikes penetrates through the rope loop, we have full confidence that it will not fall off unless our ROV is catastrophically off balance. We can then return the bell to the surface for identification purposes. We have also attached a similar bell retrieval device to Romulus, our heavy lift ROV. If the bell is somewhere Romulus can retrieve it, our heavy lift ROV will do so.

Suction of Unknown Liquid

The Nazi spy was transporting some mysterious liquid to the United States. The barrels containing this mysterious liquid, after 60 years of exposure to the elements, are beginning to leak. It is our task to sample the liquid to determine its chemical composition, and determine whether it represents an environmental hazard to Mystery Reef and the surrounding area. Our task is to recover 500 pure ml, or more, of this substance for analysis. For this competition, the mysterious liquid is a colored liquid denser than water. It will be inside an inflatable bag, inside a canister, and accessed through a length of ½-inch PVC pipe.

The first step our team took was to create a device to suction the liquid. There was discussion regarding pumping the liquid all the way to the surface, but we decided to pump the liquid into a container on the ROV Romulus. A pump at the surface would be used to create a vacuum through an air hose. This hose was attached to a 1-liter Nalgene bottle contained on the submersible. A second air hose runs from the Nalgene bottle to the canister penetration device (Figure #14). The vacuum formed at the pump on the

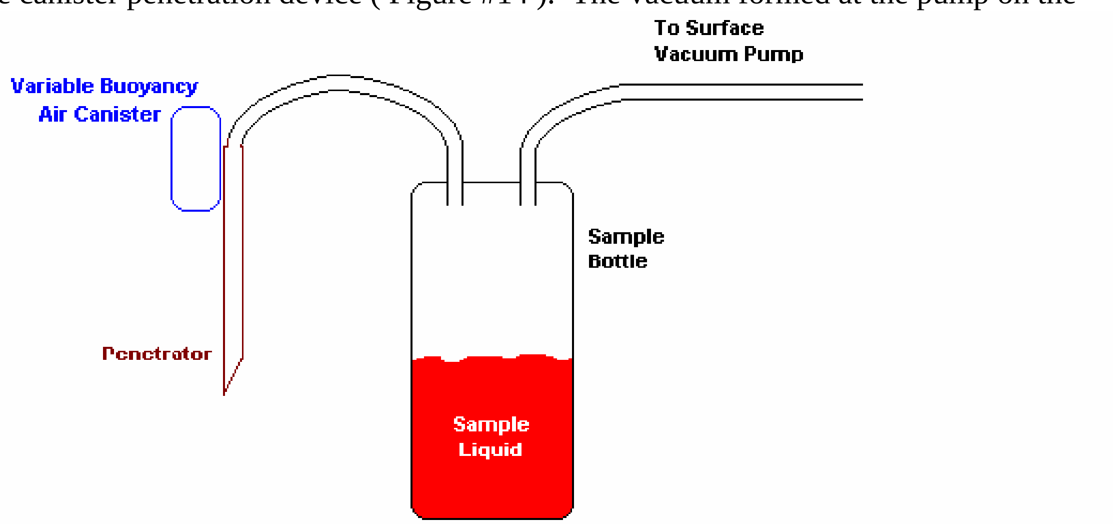


Figure 14 : Suction of Mysterious Liquid
A vacuum pump on the surface creates a vacuum in the sample bottle, which creates suction through the penetrator. Liquid from the barrel is suctioned into the sample bottle to be returned to the surface. A Variable Buoyancy Air Canister lifts the penetrator into and out of the barrel.

surface creates a vacuum in the Nalgene bottle on the ROV. This in turn, creates suction at the end of the penetration device air hose. Liquid is sucked through the penetration device, and deposited into the Nalgene bottle. Gravity keeps the sampled liquid from running up the surface air hose, provided our ROV remains fairly stable underwater. The only concern is that we enter the water with 1 liter of air inside the Nalgene bottle, and return with 500 milliliters, or more, of liquid. This could throw off our buoyancy. We looked at a number of methods to compensate for this buoyancy change, but did not find an acceptable solution. Team Lobos believes that our vertical motors should be more than sufficient to lift this small quantity of lost buoyancy.

The second dilemma we faced was how to get our canister penetration device down into the liquid containers. We needed it to penetrate through a ½-inch opening at the top of the canister. A number of methods were examined, from pneumatic cylinders to ROV movement to deliver the penetration device into the opening. However, our team decided that we would use a variable buoyancy air container to deploy our device. This is simply a vertical length of PVC with an end cap on the top, and open on the bottom. An air hose runs in to this canister. As we pump air into it, it gains positive buoyancy, and lifts the penetration device up. As we allow water pressure to displace the air, the canister loses buoyancy, and drives the penetration device down. It is a fairly simple way to move the penetration device upwards and downwards.

For our penetration device, we used a length of 3/8-inch copper tubing. This was straightened and attached to the variable buoyancy canister. The top end of the copper tube is attached to an air hose that runs to the onboard vacuum canister. A funnel helps guide the penetration device down into the sample container.

Design Conclusions

Team Lobos believes that we have designed ideal components to complete each of the mission tasks. In testing individual mission systems, each component successfully completed its task. The most difficult design factor was to get all of these systems working in conjunction with each other and the submersibles. Just because a component works on the bench, or individually in a test tank, does not mean that it will operate without problems on the ROV. The issue of ROV guidance is paramount to this. All of our designs work well, if we can get them delivered to the proper systems. Trying to determine distance through a two dimensional camera view can be quite difficult. Pilot training is the best solution to this, and we hope that our pilots will be sufficiently experienced to complete the designated tasks. Team Lobos is confident that this will be the case and confident we will be successful in the mission.

Lessons Learned and Future Improvements

Every member of Team Lobos learned valuable lessons during the building of Romulus, Remus and Sea Wolf. Many of our team members had no experience with ROV technology at all, and learned everything from basic sub-sea physics to basic electronics to ROV system integration. Even those members who had participated in last year’s competition had to consider new designs for the new missions. Seven mission tasks provided ample opportunity for new and creative thoughts, and many interesting, and not entirely successful designs were considered. Building our submersibles was a valuable learning experience.

One future improvement that we would make would be to find different cameras. Ananconda cameras are inexpensive and easy to manipulate, but their field of view is insufficient. Our original plan was to have only one camera overlooking all of our mission components. However, to view the entire tool sled area of the ROV, which is only 50 cm or so wide, the camera would have to be placed far above, or far away from the ROV. The aperture width of the cameras was just too small for our needs. Of course we only determined this after we had purchased our cameras and built our ROV. In the future, fewer wide-angle cameras would serve our purposes better.

How ROV's are helping Monterey Bay National Marine Sanctuary

Although the submersibles we built are small, designed to operate in shallow waters only, our team is fortunate to live in the Monterey Bay region where MBARI, the Monterey Bay Aquarium Research Institute, operates some of the best scientific submersibles in the world. Often times, these submersibles operate in the Monterey Bay National Marine Sanctuary.

One of the greatest assets of the Sanctuary's waters is that it provides a deep-water environment only a few miles offshore. The Monterey Canyon reaches depths greater than a mile deep only a few miles offshore. Ships operating submersibles can travel out daily to explore the canyon's deep waters, film creatures at those depths, study water chemistry, and discover new species[1]. In the world today, full of curious scientists, the deep ocean environment is one of the last places new species are being discovered. In just the last few months, a new species of Jellyfish, *Stellamedusa ventana* was discovered in the deep canyon waters as well as in the waters of the Gulf of California[2]. Although seen a few times in previous years, very little was known about this new species of jellyfish. The MBARI ROV Ventana, after which this jellyfish was named, helped to identify and study this seldom seen species. Deep water exploration helped to identify this species unique visual appearance as well as its distribution throughout the ocean. The ability of the unmanned submersibles to study the deep-sea environment on a daily basis is rapidly expanding our knowledge base, not only in the Monterey Bay National Marine Sanctuary, but in all the worlds oceans. An ROV is truly a window, or ventana, to the deep-sea environment.

[1]National Geographic. Blue Refuges: U.S. National Marine Sanctuaries. March. 1998.
[2]http://www.mbari.org/news/news_releases/2004/stellamedusa.html

Conclusion

Team Lobos is very confident in our submersibles. We designed the tool sleds for the specific missions we need to accomplish, but we designed their overall structure with general missions in minds. Romulus, our heavy lift ROV is the workhorse, and with its powerful motors can lift, move or carry whatever is needed. Remus, our scientific ROV, is our exploratory vessel, able to travel into caves, wrecks or wherever the mission takes it. Team Lobos is confident that we can accomplish all the mission tasks. We are looking for a good time in the pool competition. We are also looking forward to having a good time in general.

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