Technical Report

Seawolf Robotics Team

2009

Figure 1: The Seawolves' Underwater Rescue Search Utility Lifesaving Apparatus -- U.R.S.U.L.A. at rest

MATE project abstract § Project design and build rationale, electrical schematic, software flow chart, troubleshooting § Team member challenges, value gained § References and acknowledgements § Project sponsors, mentors and donors

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U.R.S.U.L.A.

Underwater Rescue Search Utility Lifesaving Apparatus

Figure 2:
Atlantic wolffish (*Anarhichas lupus*), also known as the **Seawolf**.
Atlantic catfish, **wolf eel** (the common name for its Pacific relative), or **sea cat.**

ROVs: The Next Generation of Submarine Rescue Systems

2009 M.A.T.E.
New England International
ROV Competition

RANGER CLASS

Massachusetts Maritime Academy
Buzzards Bay, Massachusetts
June 24-26, 2009

Seawolf Robotics Team

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REPRESENTATIVES OF: Southern Maine Community College

FACULTY SPONSOR: Dr. Charles Gregory, Professor of Science, Marine Science & Technology, SMCC

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Figure 3: URSULA getting her feet wet.

Figure 4: URSULA going solo.

Project Abstract

A Marine Science Major, Jason Kenosky became interested in the MATE ROV annual competition and approached various SMCC Department heads regarding this endeavor in an effort to generate interest and support, soliciting a project sponsor among the faculty. Dr. Charles Gregory graciously consented to fulfill this role.

Weekly meetings were begun in late January, and were held between classes in one of the Marine Science labs. Economic constraints and the short time frame dictated that the URSULA's final design needed to be fairly uncomplicated, easy to build, and affordable. As this was Southern Maine Community College's first undertaking of designing and constructing an underwater ROV, the design process began by examining small ROV design ideas for usable design ideas. Additionally, team members collaborated outside of the formal meeting structure, discussing ideas with one another and with various faculty / business representatives, depending upon their area of expertise.

As a visual aid, prototype frames were constructed of PVC pipe, boxes, Styrofoam, paperclips, zip ties, duct tape and wire. The overall size of the ROV began as a rough estimate, with the prototype undergoing multiple manipulations before a realistic design was achieved and agreed upon.

URSULA's construction initially took place in a team member's apartment and then eventually relocated to the SMCC Marine Science Shop. Once URSULA was deemed ready for her first water test, David Moore took on the responsibility to make this happen. After several sessions and adjustments, URSULA passed her "swimming test" this May with flying colors.

Profile: Submarine Rescue Organization

Created in 2004 in response to the tragedy of the Russian submarine 'Kursk', ISMERLO is a NATO sponsored, funded, and manned International Submarine Escape and Rescue Liaison Office that is coordinated out of Allied Submarine Command (ASC) headquartered in Norfolk, Virginia. The ISMERLO website [http://www.ismerlo.org] is a place where nations can offer assistance and the Submarine Rescue Authority (SSRA) can chose and coordinate the suitable assets to assist in the event of a submarine incident.

In addition to being a clearinghouse for information, ISMERLO conducts submarine escape-and-rescue simulations.

The most recent exercise took place the 5th of May, 2009. Although no underwater ROV was utilized for this most recent exercise - code name **BOLD MINOTAUR** - efforts were coordinated to rescue a fictitious submarine 'HMS TALISMAN'. Conducted off the UK south coast, resources utilized included the UK Submarine Parachute Assistance Group (SPAG), a UK support vessel, MV SALMOOR, and a UK Frigate, HMS ARGYLL. SPAG, using a C-130 (a 130-seat military transport aircraft built by Lockheed) carried 6 Italians who parachuted onto the datum and offered assistance to the 'survivors'. MV SALMOOR acted as safety vessel and HMS ARGYLL was dispatched with Escape First Reaction Stores, including medical staff, to recover the "survivors" and offer further medical attention.

In 2008 Russia participated for the first time in a NATO-led exercise (code name **BOLD MONARCH**). [http://www.janes.com/news/defence/naval/jni/jni080515_1_n.shtml] Twenty-four (24) nations participated in the exercise which was staged off the coast of Arendal, Norway. During this exercise three (3) submarines - one each from the Netherlands, Norway and Poland – were positioned on the seabed to simulate 'subsunk' casualties.

Figure 5 BOLD MONARCH exercise photo. NSRS (NATO Submarine Rescue System) SRV (manned Submarine Rescue Vehicle).

Figure 6 BOLD MONARCH exercise photo. Italian ADS for POD posting.

Additionally ISMERLO has begun a long term project (**Global Rescue Response Analysis**) to help nations evaluate rescue response scenarios to Air Port and Sea Port combinations around the globe. . Focus of the study will be to look at submarine homeports, operating areas, available rescue systems and response timelines to determine areas of coverage.

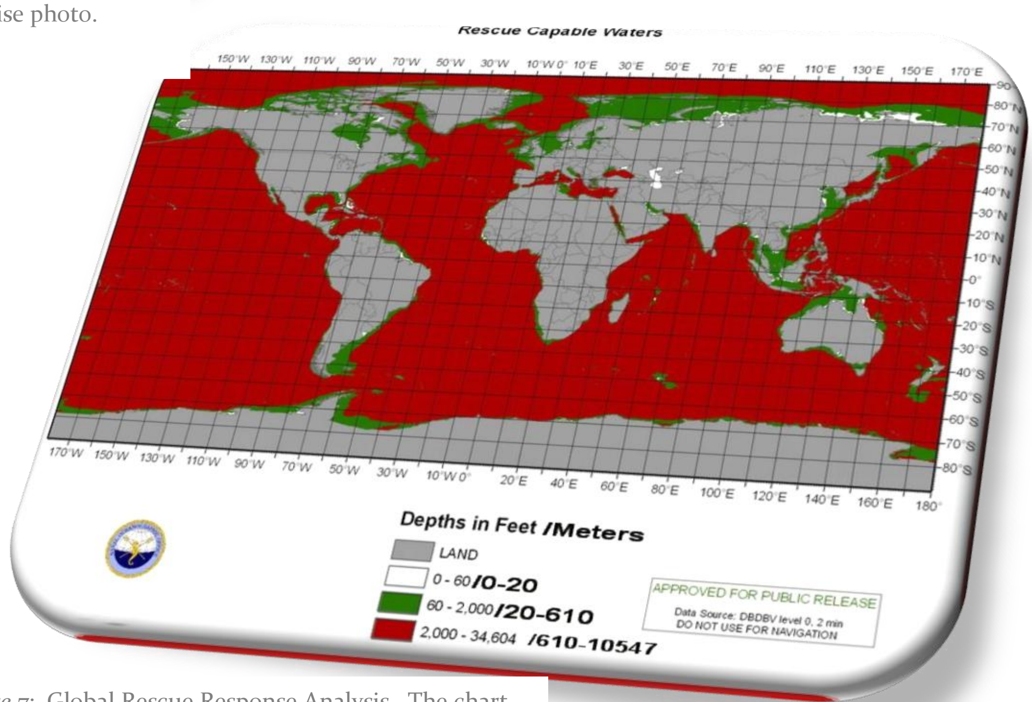


Figure 7: Global Rescue Response Analysis. The chart portrays a general outline of water and depths.

<u>Sources</u>

Images:
www.ismerlo.org website
Information: www.ismerlo.org website; www.janes.com/news/defence/naval/jni/jni080515_1_n.shtml

URSULA's Development

General Description

Excluding the extruding components (camera, tether, adapter, manipulator arm, and skirt), URSULA's frame measures 78.5 cm long x 52 cm wide x 43 cm high.

With the manipulator arm attached, URSULA weighs roughly 11.340 kilograms (25 pounds); without the arm the weight is approximately 8.6183 kilograms (19 pounds).

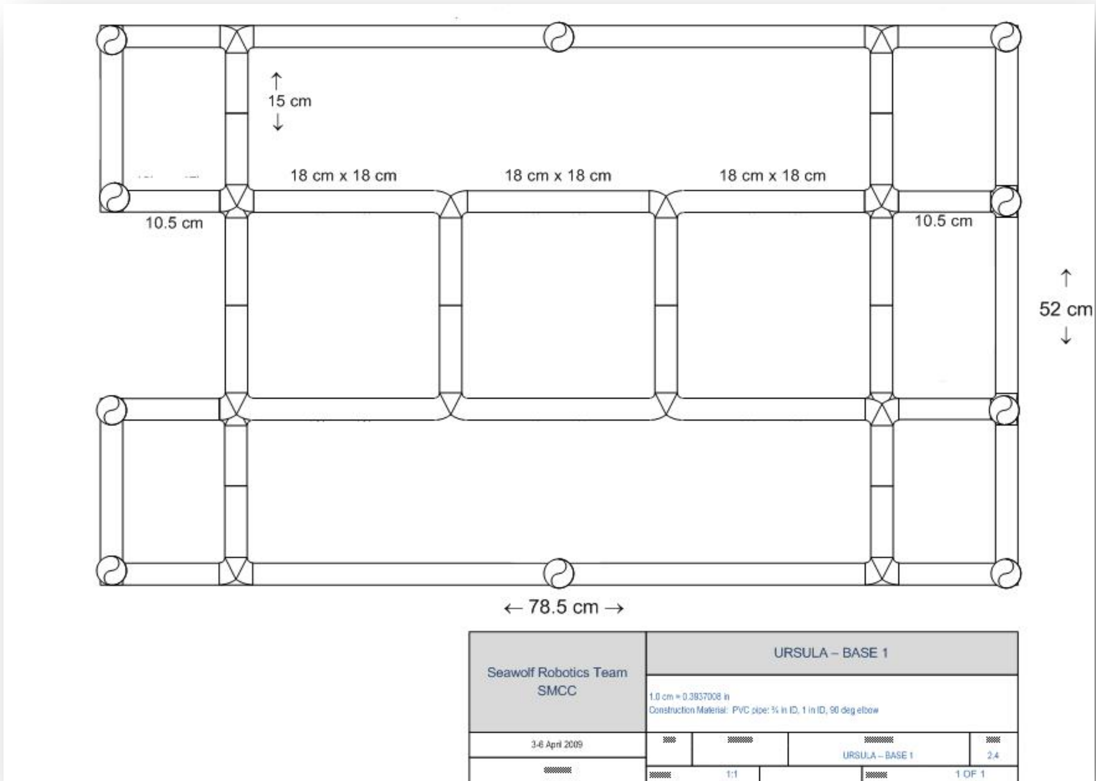


Figure 8: Frame A: Bird's eye view of URSULA's frame that shows the dimensions of the base.

Design Rationale

Structure

Due to its economy of purchase and ease of use, standard PVC pipe was chosen as the primary component for URSULA's main structure. The use of this material allowed for easy assembly of a component of the ROV, examination, and then disassembly for modification. Additionally, as PVC is a light-weight material, it did not require a large amount of flotation to compensate for the weight.

We do not anticipate any negative environmental impact, since URSULA is not intended to be immersed in hot water which would cause the leaching of toxins from the heavy metals used in the creation of PVC.

Thrusters

Bilge pumps were chosen for the thrusters as they were affordable and readily available at marine supply stores. Originally, the plan was to use stock bilge pumps and angle the outflow pipe in the direction the thrust was desired. After discussions with Dr. Chuck Gregory and Brian Tarbox, it was determined that the unmodified bilge pumps would not produce enough thrust to move a smaller ROV that had been previously built by a member of the faculty. Left unmodified, the stock bilge pumps would not be sufficient for URSULA's larger design.

Figure 9: A close up of one of URSULA's thrusters.

To achieve the desired effect, four (4) Sea Sense 1100 GPH Bilge Pumps were modified by removing the exterior housing and impeller from the bilge pumps. Using $^1/_8$" propeller adapters, propellers were then fitted onto the motors' output shaft. The mounting system was fabricated out of 1 ½" to ¾" PVC, utilizing T-adapters, which facilitated easy mounting of the thrusters onto the frame.

Tether

URSULA's donated tether was calculated to be approximately 15.24 meters. The cable is neutrally buoyant in water and contains 9 conductors, which are sufficient to run the thrusters with the current control setup.

The camera cable was fastened to the outside of the tether. Although this added a small amount of weight to the tether, it was easily compensated for with appropriate buoyancy.

Wired to the surface end of the tether is a computer parallel port plug, plugging directly into the control console.

Manipulator Arm and Claw

Various construction materials, ranging from balsa wood to carbon fiber, were considered for the manipulator arm. To minimize weight while maintaining structural integrity, the decision was to construct the arm of 1 in x 2 in square aluminum tubing, which was fabricated under the direction of the SMCC Integrated Manufacturing and Design Department.

Attached to the front of URSULA, the arm was designed to have 3 Degrees of Freedom (DOF), meaning there are three points on the arm that will articulate to give the arm movement:

1) Vertical movement
2) Horizontal movement
3) Rotation of the claw as if turning a doorknob

Each point of articulation was powered by a Traxxas 2075 High Torq Waterproof Servo. Additional waterproofing was obtained by applying an application of an exterior sealant to the Traxxas Servos before mounting them inside the body of each segment of the manipulator arm. Gears mounted on each segment interface with the servos to move each segment. A Phidget Advanced Servo Controller inside the Control Box controls each Traxxas Servo.

The VEX Robotics claw kit attaches to the third segment of the arm and has a dedicated servo to run the open and closing action of the claw.

Camera

URSULA's primary camera is a Lights Camera Action model LCA-7700-CW, reportedly a high quality, consistent performance underwater camera. This waterproof color camera has six (6) internal white LED, equipped with its own 100 foot non-detachable combination power/video cable.

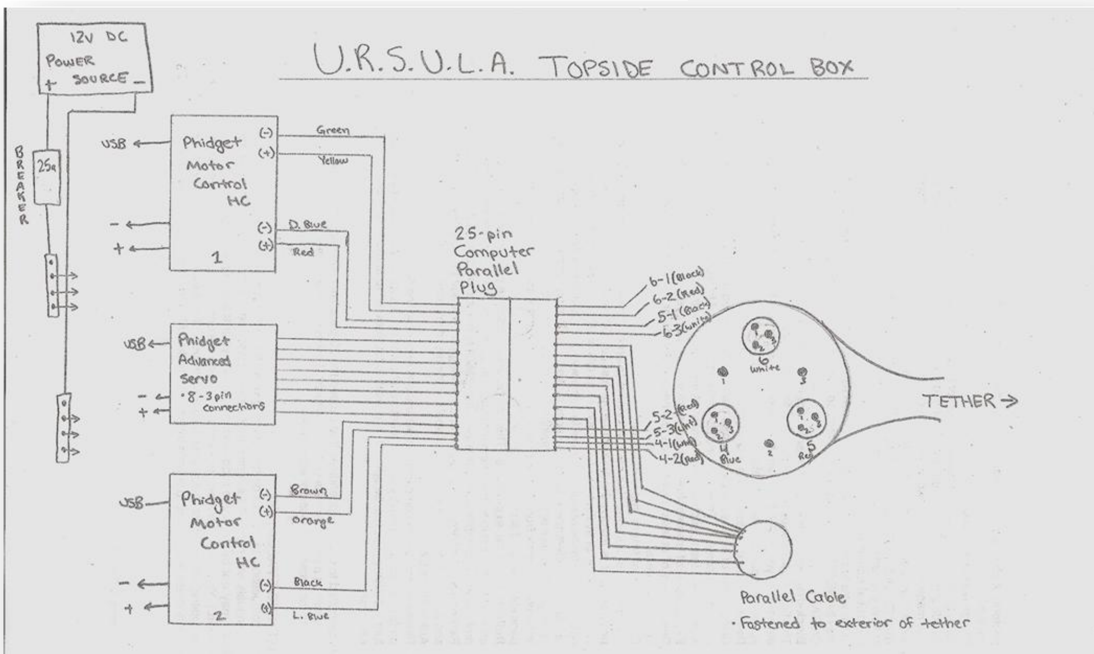
The video will feed directly into our control system.

Wiring/Control Console

The control console is constructed of pine and contains

- three (3) Phidgets (two Phidget Motor Control HC analog controllers, one Phidget Advanced Servo controller)
- one (1) circuit breaker (connected to a car battery)
- electrical power bus bars
- USB hub (connected to a computer)
- parallel port connection for the tether
- analog joystick

Figure 10: Electrical Schematic A: Topside Control Box.



URSULA is controlled using an analog joystick interfaced with custom designed software. Two Phidget Motor Control HC analog controllers run the 4 thruster motors (Sea Sense 1100 GPH Bilge Pumps), which hook into the control program via USB interface.

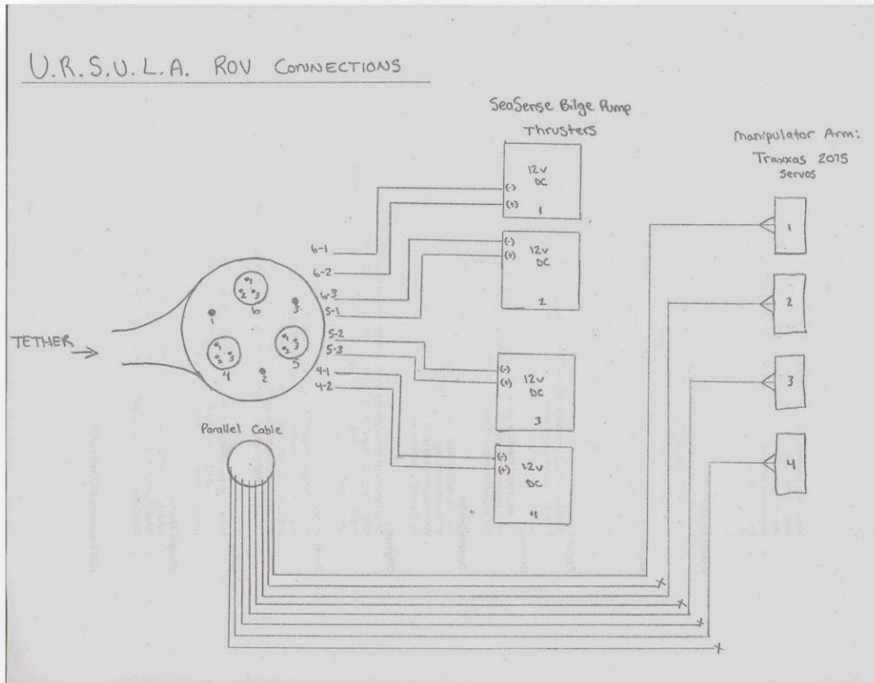
The Phidget controllers allow for bi-directional and acceleration control of each motor. The manipulator arm Traxxas Servos are run from the Phidget Advanced Servo controller, connected via USB interface, and has the capability to run 8 servos.

The computer is responsible for running the software which receives the pilots' input (via the program and the joystick) and passes along that information to the control box via a USB cable.

Each Phidget receives commands from the computer via their own dedicated USB cable (all of them attached to the USB hub). The Phidgets then send signals/power down the tether to the motors.

For this all to work, the battery must be hooked to the breaker (the *big* switch), giving power to the Phidgets, which are hooked up to both the computer (via the USB hub) and the tether. All of the data is captured in real time and only stored temporarily.

Figure 11: Electrical Schematic B: ROV Connections.



URSULA's Software

URSULA's startup procedure:

1. Connect the battery to the breaker
2. Connect the control box to the computer (via USB)
3. Turn on the computer
4. Plug in joystick
5. Flip the breaker to the ON position
6. Run the control program on the computer

URSULA's program was written in C++ language, and includes 600 plus lines of code. The program is compiled into an executable that will run like any other program. Error checking will stop the program if the Phidgets aren't attached AND powered up, or if the joystick isn't connected

Troubleshooting techniques

There were many aspects of our ROV that required troubleshooting.

Propeller Conversion

One of the simplest but most important items that we had difficulties with was the propeller conversion. We began by using different pitch model airplane propellers. These were very effective; however they are designed for high speed and have reduced surface area. The next thing we tried was modifying computer cooling fan blades to fit on our propeller adaptors. The cooling fans had 5-9 blades, which increased the overall surface area on each unit. When testing each propeller in a tank, we found that the airplane prop does go faster, but the computer fan has more pulling power. It was decided that speed can be sacrificed for control. That said, we began to realize how difficult it is to obtain old 120mm computer cooling fans in any condition. The modification process was also difficult as more than one cooling fan had already been modified beyond use.

Electrical Wiring

On this build there were very few problems with electrical wiring. The Phidget controllers are very simple to hook up. As long as the correct wire combinations were kept track of during the build process and marked properly, it was very simple to keep track of all the wires.

Overall

As we went through and designed our system, we tried to keep it as simple as possible, reasoning that the more complicated the system, the more troubleshooting would be needed and thus more time would be needed. Given the very limited amount of time we had to design and build the ROV outside of class, a good amount of due diligence was applied to the design of URSULA.

Technical Challenges

One major technical challenge encountered was the watertight electrical connections where the tether attached to the ROV. The first model we tested involved a 3” rubber pipe with a male slip joint and threaded end cap on each end, with the tether running through the center of one end cap and the wires from the thruster motors running individually through the other end cap. The holes were sealed with 5200 marine sealant. The 5200 failed immediately after hitting the water, primarily because it would not cure properly. This ended further testing of our electronics for that day and prompted us to explore other options for a waterproof connection box.

This project also forced many of us to use skills that we have only been taught in theory (in particular, some of the mathematical problems we have had to overcome). One example that immediately comes to mind is when we tried to formulate an equation to use as a power curve for our motor output. It was the first time that some of us had ever even tried to apply some of the higher level math skills to a real world situation. The process of translation from what we learned in textbooks to true real-world applications weren’t always easy, but nonetheless fun and exciting.

Developing a knowledge base necessary to physically build this ROV was not the only challenge we faced. We all learned a tremendous amount not only about designing and building ROV’s, but what it takes to effectively work on a team and delegate work.

The relatively short time available to work on this project has proven to be a detriment to completing all components of URSULA to our team’s satisfaction. Conversely, these constraints were also forcing us to work more diligently and efficiently in order to complete all our tasks.

Budget

Current expenses to date total $1,038 while monetary donations to date total $730. Estimated travel budget is $945. Anticipated total outlay of cash by end of competition is $1,983.

ITEM	Description	Source Store / Company	D or P	Purchase Price	Market Value	Comments
PVC Pipe	3/4" PVC straight pipe	Portland Plastic Pipe	D			
PVC Fitting	3/4" T-Adapter	Portland Plastic Pipe	D			
PVC Fitting	3/4" 4-Way Adapter	Portland Plastic Pipe	D			
PVC Fitting	90 degree elbow	Portland Plastic Pipe	D			
PVC Fitting	90 degree 3-way adapter	Portland Plastic Pipe	D			
Bilge Pumps	SeaSense 1100 gph bilge pumps	Hamilton Marine	D/P	$57.73		Two pumps were donated, two purchased
PVC Fitting	1-1/2" x 1-1/2" x 3/4" T-Adapter	Lowes	P			Modified for thruster use
Bus Bar	Electrical connector	Hamilton Marine	P	$ 35.68		used to distribute power to electrical components from battery
Prop Adapter	Prop adapter, 1/8" shaft	Ray and Robin's Hobby Shop	P	$ 8.39		used to attach propellers to converted bilge pumps
Phidget AdvancedServo	Phidget USB interface servo controller	Phidgets, Inc.	P	$ 97.89		controls servos on robotic arm
Phidget MotorControl HC	Phidget USB interface motor controller	Phidgets, Inc.	P	$213.81		controls thruster motors
VEX Robotics Claw	VEX Robotics Claw Kit	VEX Robotics	P	$ 27.44		claw for manipulator arm
Traxxas Servos	Traxxas 2075 High Torq Waterproof Servos	Traxxas	P	$ 117.13		R/C Servos to run manipulator arm
Waterproof Camera	LCA 7700-CW Waterproof Camera	Lights, Camera, Action	P	$270	$ 495.00	Discount Price!
Tether	50' Neutrally bouyant tether cable	SOSI	D	$ -	$ 500.00	Donated by Sound Ocean Systems Inc
Propellers	R/C Plane propellers	Ray and Robin's Hobby Shop	P	$ 12.22		Thruster props
Propellers	Computer cooling fan blades	SMCC	D	$ -		Adapted to bilge pumps for thrusters
wood	1" x 12" x 12' pine board for control box	SMCC Building Technology	D	$ -		Used to build electronics control box
Wire	Spools of 16 gague wire	Hamilton Marine	P	$ 16.78		Wire for thruster motors
USB hub	USB 4-1 Hub for computer controllers	Best Buy	P	$ 19.94		Used to connect Phidget controllers to computer
Junction Box	waterproof junction box	Home Depot	P	$ 8.74		Watertight Connection Box for onboard electrical connections
Watertight connector	Watertight connector for attaching tether to waterproof box	Home Depot	P	$ 6.84		creates watertight connection where tether enters waterproof box
Electrical supplies	Shrink tubing, wire connectors, circuit breaker, misc	Boater's World	P	$ 53.60		Misc. electrical components used to wire and connect electrical system
Electrical Supplies	Shrink tubing, waterproof box, wire connectors, electrical tape, misc	West Marine	P	$ 59.15		Wire connectors, box, shrink tubing, misc items used to connect electrical system
Fuse holder	In-line fuse holder, fuses	Napa Auto Parts	P	$ 9.11		In line fuse and spare 25apm fuses for testing
Gears	Pinion gear, spur gear, prop adapter	Ray and Robin's Hobby Shop	P	$23.89		Gears for running manipulator arm
DONATION					$ 200.00	MR & MRS D MOORE
DONATION					$ 530.00	SMCC Senate
				$1,038.34	$ 1,725.00	
				Total Exp	Total Donations	
					$ 730.00	Monetary donations

Person	Lodging @ $10/night June 23, 24, 25	Meal Stipend @ $10/meal, 1 meal June 23	Meal Stipend @ $10/meal, 1 meal June 24	Meal Stipend @ $10/meal, 2 meals June 25	Meal Stipend @ $10/meal, 1 meal June 26	Travel Stipend @ 175 miles one way, $.55/mile	TOTAL TRAVEL BUDGET
Catherine	$ 30	$ 10	$ 10	$ 20	$ 10		$ 80
Chris	$ 30	$ 10	$ 10	$ 20	$ 10		$ 80
Dave	$ 30	$ 10	$ 10	$ 20	$ 10	$ 193	$ 273
Dr G	$ 30	$ 10	$ 10	$ 20	$ 10		$ 80
Emily	$ 30	$ 10	$ 10	$ 20	$ 10	$ 193	$ 273
Jason	$ 30	$ 10	$ 10	$ 20	$ 10		$ 80
Susan	$ 30	$ 10	$ 10	$ 20	$ 10		$ 80
	$ 210	$ 70	$ 70	$ 140	$ 70	$ 385	**$ 945**

Reflections:

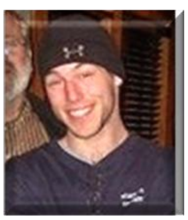
Personal challenges, lessons learned, and skill development.

Catherine C: "As an individual I have been challenged to reach

out to the community and find funding in a short amount of time. It took time and footwork, but there were members in the community that were willing to support our project."

"Some of the skills I learned were: balancing a budget, organizing receipts, and presenting a project to members of the community."

Chris C: "When I heard about a group of students that were attempting to build an ROV for a



competition, and help was needed, I figured 'Hey, why not? It sounded like fun!' Little did I know then that what would start as a passing interest would grow into a passion, and I would grow as a person from pursuing it."

"This experience has taught me many lessons; foremost among them is what a group of dedicated people can undertake when they believe in something. Each and every one of us has a piece of ourselves invested in this project, and it shows in the results. We are doing the near impossible: creating something from nothing, in a *very* limited amount of time, and with a very limited set of resources."

"I am constantly humbled by my team-mates. Their accomplishments, dedication and hard work will never cease to amaze me. Truly, they set a golden standard to follow."

"I think, however, the greatest thing that I have gained in joining this team is a set of friends I will remember the rest for the rest of my life as the first Southern Maine Community College's Seawolf Robotics team."

"*Go Seawolves*!"

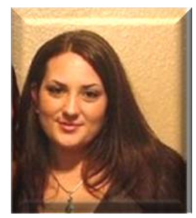
David M: "The ROV building experience has been both thrilling and challenging. I have worked on and built many things, but this is my first experience constructing something robotic, much less a submersible ROV."

"It has been a wonderful challenge learning about all of the components needed to build this type of vehicle: from waterproofing connections and servos to the theory behind designing a robotic arm."

"Originally aiming to participate in the Regional Competition in April, we only had 4 months to fully design, build and test our concept, the time frame, which increased the level of intensity. This also really forced us to focus on completing the stages of development in a timely and organized fashion in order to complete the project on time."

"I have thoroughly enjoyed working with everyone involved on this project as together we learned about the technology and what it takes to effectively work on a team and delegate work."

Emily S: "My biggest challenge

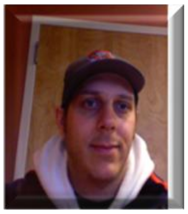


for this project was that I did not know much about the technical aspect. My job was to raise funds, budget, and ask for donations."

"The hardest part was asking for parts / donations from local businesses without knowing much about the vehicle itself. There were a few times that I had to explain that I wasn't sure how parts of the ROV were going to work while still sounding professional."

"I feel that this project has helped me improve my public relations skills. I have also learned quite a bit about the way our ROV works."

Jason Kenosky: **"**My story is a bit different from everyone else's. The ROV project began as a club activity for the Marine Science Society (MSS), a student organization here at SMCC. In the beginning an ROV project was just an idea brought up from one of the club members; something to do for fun. I began



doing research on ROV's and found out about the MATE competition almost a full semester before anyone else, with the exception of Catherine and Emily, even knowing that the project existed. Although there was a good bit of interest initially, eventually people left the project due to either a lack of time or a lack of continuing interest. The team was whittled down to what it is today – everything that this team has accomplished is/was the result of the small hand full of people that are currently involved."

"Personally, going from knowing very little about ROV's to creating something capable of competition within just a few months was a challenge. An additional challenge was finding the time to work on this project in conjunction with other projects and obligations, school related or otherwise."

"This semester has been the proving ground that tested our abilities and ingenuity in accomplishing our goals. I am excited that to have had the opportunity to take part in this project. Regardless of the outcome, the lessons learned, skills gained, and the overall knowledge acquired will be an invaluable asset that will guide me through next year's competition, as well as any future endeavors for school and my career."

Susan K: "One of my several challenges was my initial lack of comprehension of the operational functionality and technical terminology of URSULA."

"Drawing upon my writing experience in other fields, I had volunteered for the role of developing the technical report. After attending my first project meeting in February and listening to the various technical words bandied about in conversations ('ballast', 'propulsion', 'payload') I quickly concluded that I had a good bit of learning to do in the field of underwater ROVs."

"Not being a Marine Science student, another challenge was to build a working rapport with other team members, with whom I felt no commonality other than we are all SMCC students. Adding to this feeling of distance was the perceived disparity of our ages and perceived lack of working project team experience."

"The logistics of balancing project time with schooling and home life were a bit overwhelming at times – chicken pox afflicts the young whether one has time to deal with it or not!"

"Ideally, our team would have benefited from having more time to develop the ROV. Next year should be different."

"I would like to dedicate my time spent on this project to the memory of my late father, Joseph Needham Kinney Jr, QM2 of the USS DIODON SS-349, who passed away one year ago this past February – I know that he would have appreciated the value of this project."

"To the members of the Seawolf Robotics Team, *you have my admiration for the way each of you have admirably risen to the challenge of achieving much within such a short period of time. You have portrayed grit and determination that will carry you forward to success in the future.*"

Future improvements

Planning, Participation, and Communication

This category definitely falls under lessons learned. The consensus of all our team mates is that planning for the 2010 MATE Competition most definitely should begin much earlier than 4 to 6 months before a competition date!

Although by the end of our Spring 2009 Semester several faculty members had already expressed an interest in mentoring future competitors, solicitation of interested participants must commence no later than the 2009 Fall Semester. In addition, a better methodology for interactive communication between participants is needed.

Functionality *vs* Beauty

As this was our first year of competition, we chose to concentrate on functionality over good looks. Once URSULA's functionality is proven during the competition, we will look to improve upon her good looks in 2010.

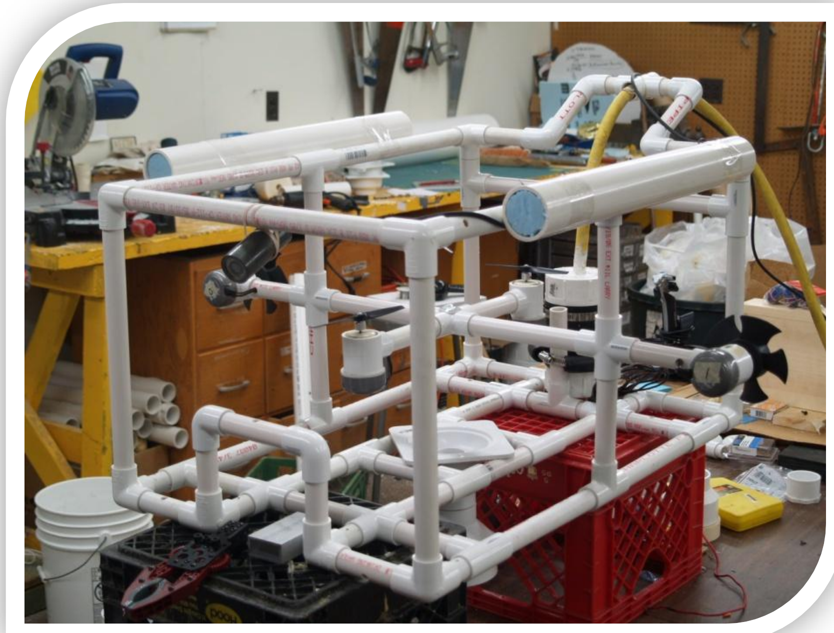


Figure 12: Another view of URSULA in the workshop.

Cameras

Originally we planned for a minimum of 3 cameras, sacrificing quality for quantity. After additional reflection, the decision was made to purchase a quality camera, delaying purchases of additional quality cameras for future ROVs.

Servo Functions

The Phidget Advanced Servo controller was specifically chosen as it allowed for additional servo functions to be added in the future.

The feedback from our entry in the 2009 New England International Competition in conjunction with 2010 MATE Competition requirements will provide the Seawolf Robotics Team with a focus for prioritizing improvements.

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Marine Advanced Technology Education Center, Monterey Peninsula College, 980 Fremont Street, Monterrey, CA 93940 (831) 645-1393 http://www.marinetech.org/home.php

Massachusetts Maritime Academy, 101 Academy Drive. Buzzards Bay, MA 02532 (508) 830-5000 http://www.maritime.edu/

- Site of the MATE New England Regional ROV Competition

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2009 Regional ROV Competition Support web page
http://www.marinetech.org/rov_competition/2009/sponsors.php

2009 Regional ROV Competition Support – Technical Advisory Committee web page
http://www.marinetech.org/rov_competition/2009/tac.php

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(207) 874-1111 http://www.cumberlandcountyymca.org/contact.htm

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(480) 345-0642 http://www.lights-camera-action.net/

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(425) 869-1834 http://www.soundocean.com/

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Glossary

ACM: Association for Computing Machinery

DOF: Degrees of Freedom

ELSS: Emergency Life Support System

GPH: Gallons per Hour

IEEE: Institute of Electrical and Electronics Engineers

LED: Light-emitting Diode

MATE: Marine Advance Technology Education

MSS: Marine Science Society [of SMCC]

PVC pipe: Polyvinyl chloride pipe

ROV: Remotely Operated Vehicle

ROVR: Remotely Operated Rescue Vehicle

SMCC: Southern Maine Community College

URSULA: Underwater Rescue Search Utility Lifesaving Apparatus