S.U.R.E.

Seawolf Underwater Robotics Engineering

Copiah-Lincoln Community College — Wesson, MS

Technical Report

MATE International ROV Competition—Explorer Class

SEAWOLF II

Team Members:

Brandon Boyd (CEO, Design Engineer, Safety Officer, Web Designer), Gordon Tolleson (Vice-President), Jeffery Holifield (Engineer), Will Boyd (CFO), Chelsey Buie (Public Relations), Erica Smith (Public Relations), Cameron Holifield, Will Hill, Steven Sandifer, Cedric Lloyd, Aaron Wicker, Jonathan Nations

Instructors/Mentors:

Dr. Kevin McKone (Physics), Wes Burkett, Bruce Thomas (Drafting & Design), Bo Johnson (Precision Machining), Carey Williamson, Brian Turnage (Electronics)

Abstract

The *SEAWOLF II* is a light duty inspection/observational class ROV constructed specifically for the purpose of taking part in the MATE International ROV competition. Its design, refinement, and construction are the result of the collective imagination, innovation, and effort of the Seawolf Underwater Robotics Engineering (S.U.R.E.) team members. Drawn in SolidWorks and INVENTOR 3D CAD software, the *SEAWOLF II* is designed with an eye toward versatility and adaptability. Its open, triangle frame, aluminum and stainless steel design are an intentionally universal one. With this multipurpose base to build on, the ROV can be more easily tailored to perform specific missions. Adding to this flexibility are several custom designed features. Clear, cast acrylic electronics and camera/lighting housings were created to ensure maximum visibility coupled with minimum reflectivity. The sturdy, light-weight manipulator arm, a custom design based on fundamental concepts, can be utilized for a variety of tasks requiring physical contact with a specific target. Adjustable thruster mounts allow for fine tuning of the craft's propulsion system, consisting of six Seabotix thrusters, to suit changing conditions. Lastly, the *SEAWOLF II*'s power supply, electronics, and control devices were specifically conceptualized and engineered for safety, reliability, and ease of use. The S.U.R.E Seawolves, under the auspices of Co-Lin Community College, are proud to present this ROV as a second entry into the MATE International ROV competition. With its adaptive basic designs, rugged solid construction, the *SEAWOLF II* is an ROV that comes ready to get the job done, whatever that job may be.

The SeaWolves Robotics Team

Brandon Boyd (**CEO**, **Design Engineer**, **Safety Officer**, **Web Designer**), Gordon Tolleson (**Vice-President**), Jeffery Holifield (**Engineer**), Will Boyd (**CFO**), Chelsey Buie (**Public Relations**), Erica Smith (**Public Relations**), Cameron Holifield, Reginald King, Will Hill, Steven Sandifer, Dr. Kevin McKone (**Instructor**), Wes Burkett (**Instructor**), Bruce Thomas (**Instructor**), Bo Johnson (**Instructor**), Carey Williamson (**Instructor),** Brian Turnage (**Instructor**)

Not pictured: Cedric Lloyd, Aaron Wicker, Jonathan Nations

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1. Design rationale

The central focus of SEAWOLF II's design was to allow maneuverability while performing mission tasks. This includes the standard requirements for speed, visibility, and stability, while maintaining a small, compact frame. Based on experiences with missions in the past, it was determined that a frame with minimal drag would be critical to the project's success.

1.1 Structural Frame

The body of SEAWOLF II was designed and tested in INVENTOR and SolidWorks 3D CAD software. It is composed of two main component type groups: the metallic frame and the electronics tubes with end-pieces.

SEAWOLF II's end-pieces are constructed from 1cm 6061 aluminum alloy. Instead of the traditional square shaped design commonly seen in commercial R.O.V.s, SEAWOLF II's end pieces give it a more elegant triangle shape. This shape reduces the amount of upward drag and allows a more even distribution of weight.

Most of the electronics are housed in two clear, acrylic tubes recycled from the previous year's R.O.V. Each tube is sealed with acrylic dome pieces and bolted to the frame. Each tube is 15.2 cm in diameter. The tubes are capped with 15.2 cm acrylic dome pieces and sealed by O-rings. The tubes are connected to each other by an aluminum centerpiece also composed 6061 aluminum alloy. These tubes house two cameras as well as all electronic boards required for operating thrusters, cameras, and payload tools.

The frame is completed by several stainless steel components. These pieces allow for the attachment of the thrusters and manipulator arm. The two pieces running horizontally are screwed into the end pieces, while those running vertically are secured to a stainless piece at the top bearing the SEAWOLF II name.

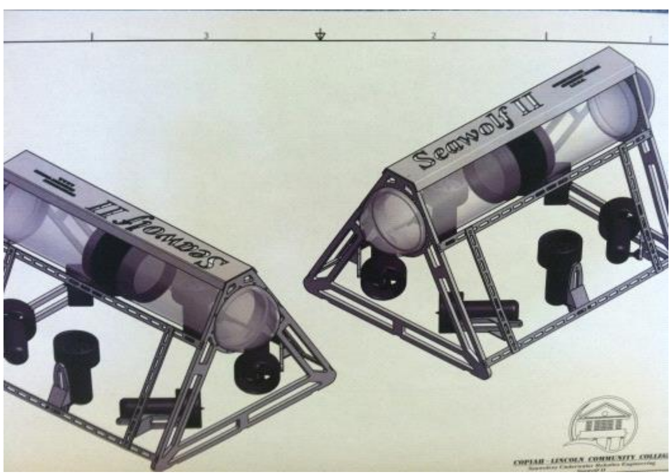


Figure 1: Concept Design

1.2 Thrusters

The SEAWOLF II features 6 Seabotix, 19.1 V DC, 110 W, BTD150 standard thrusters, 4 of which were recycled from last year's ROV. Two thrusters are placed vertically to allow the ROV to ascend and descend. The other four are positioned to allow the ROV a full range of movement in all directions, including a crabbing movement.

1.3 Cameras

The SEAWOLF II is equipped with three Outland Technology color cameras, two of which were recycled from last year.

The two cameras being utilized on board the ROV are 32x32 mm, CCTV Vision Hi-Tech VM38CSHR-B36 open frame color camera. Their color video is based on the matrix 1/3" Sony, it has a resolution of 480, a sensitivity of 0.8 Lux, and a Lens f of 3.6mm/ F of 2.0. Since they were originally designed to serve in surveillance systems, they were placed inside the electronics housing tube. The camera placed at the front of the R.O.V. is placed in a mount, designed and printed by the team that allows it to pan and tilt.

The camera being utilized on the outside is a UWC-325/p. 125 mm long by 40 mm in diameter, this 0.2 kg model is depth rated to 600 m. One of its intended functions was as a manipulator arm camera, so only very minimal adaptation was needed. For the team's purposes it was mounted on the underside of the electronics tube, so that it could provide the ROV's pilot with the best possible view of the manipulator's target.

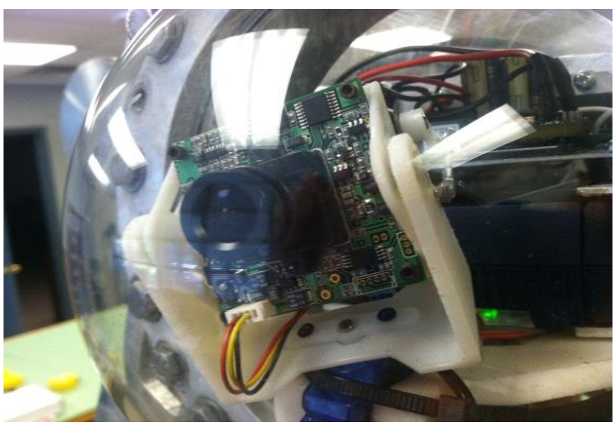


Figure 2: Seawolf II Pan and Tilt Camera

2. Control

The SEAWOLF II's control is based on an "input/output response" principle. Thus all computations are done on the surface. Although not nearly as elegant, it is much simpler and requires less hardware and programming.

2.1 Electronics Board

After a pre-designed ROV control board failed due to design flaws, the SURE team was tasked with designing and building a new electronics system. In the new design, all of the processing for the ROV is done at the surface in LabVIEW running on a laptop. The processing on-board the ROV turned out to be relatively simple, relying on an Arduino MEGA2560 to relay input/output information to the surface. It achieves this communications via the following path; TTL -> RS485 -> Axis Video encoder -> tether/ethernet -> router. The custom designed thruster circuit board for the SEAWOLF II was designed by the team from scratch, and the R.O.V. has two to operate with. Each circuit board has four h-bridge channels, which run the six thrusters and manipulator arm. The result is a simpler to use ROV which is one the strengths of the design.

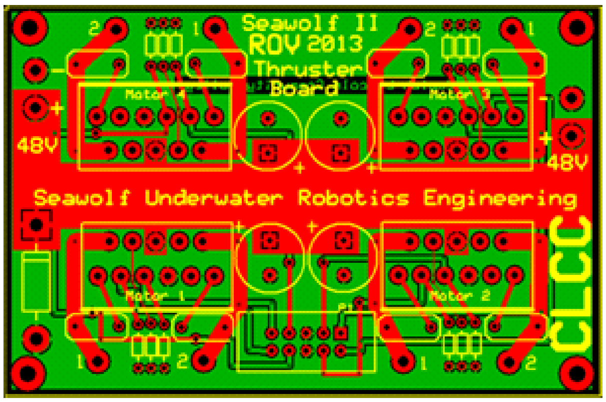


Figure 3: Circuit Board

2.2. Navigation Software and physical control

The SEAWOLF II runs LabVIEW 2012. LabVIEW was chosen due to its popular use as instrument operation software, thereby reducing the need for additional programming and ease of operation. The directions (input) for controlling the SEAWOLF II come from a Logic gaming controller, chosen because of its familiarity with team members. The controller is similar in design to an Xbox controller, with the human user interface being written in LabVIEW. This makes the ROV easy to pilot, almost like playing a video game.

3 Electronics

There are two principle components of the electronic section: the electronic housing and the tether.

3.1 Tether

The Outland tether was recycled from last year’s ROV. It contains a CAT 5 network line and power conductors, carries data and power to and from the ROV, doing its part to ensure the smooth and efficient remote operation of the ROV by the team's pilots.

3.2 Electronic Housing

The electronic housing is a 15.24 cm diameter acrylic tube which houses an Arduino Mega 2650. The Arduino provides pulse width modulation (PWM) and direction signals to the two custom made Seawolf circuit boards. These boards as mentioned above drive the thrusters and manipulator. Power from the surface is sent to a DC to DC converter, also in the electronic housing, which converts the surface 48V to 12V which is then regulated to 9V. The 12V supplies power to the cameras and Axis Q7411 video encoder while the 9V powers the Arduino. All video communications are sent by Ethernet to surface.

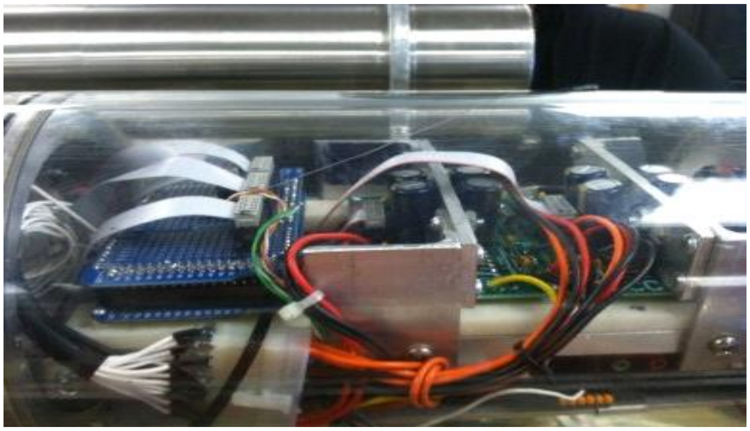


Figure 4: Acrylic Electronic Housing

4. Manipulator

The body of the manipulator arm was designed in Inventor, molded in SolidWorks and then printed out of ABS Plastic. The body was designed to enclose an Inuktun actuator, donated by SeaTrepid. The manipulator's claws were also printed in ABS Plastic, and are approximately 20 mm thick by 130 mm long.

Figure 5: Manipulator arm

5. Challenges

The creation of the SEAWOLF II was a task full of challenges; however, the team succeeded greatly. One of the most difficult challenges was the electronics board. When the original, pre-designed control board failed, the team struggled to settle on an alternative. Eventually, it was decided that the best thing to do would be to would be to design a new system capable of handling the high voltage demands. It was without a doubt a difficult task. It required much thought and work, with tedious attention to details. Eventually suitable boards were created, and it became a key addition to the ROV.

6. Skills Gained

The team learned many lessons by working on the SEAWOLF II. Perhaps the greatest lesson was learning to do multiple jobs. All of the members took an interest in other components of the design, as well as gaining new insight into their respective fields. The team learned a great deal about SolidWorks CAD simulation, and several students participated in a fund-raising effort at Holifield Engineering where they gained experience using the CNC machines. The electronics team members learned very quickly how to design a circuit board when the original board failed.

7. Future improvement

The single best way to improve our ROV would the modification of our manipulator arm. In future the manipulator could be changed to accommodate an elbow joint to allow greater movement of the arm.

8. Safety

When looking at Seawolf II, special precautions were taken to prevent injuries during the manufacturing phase as well as during underwater runs. Many of the uniquely shaped pieces were produced using CNC technologies which can produce a very rough, sharp edge. Just after production, the parts were all sent directly to the machine shop to have the edges debarred. Another very important procedure which is common practice in the machine shop is that all students involved with any of the larger equipment were required to wear safety glasses at all time preventing potential eye injury. All six Seabotix thrusters were outfitted in the factory with a protective shroud over the propellers to prevent bodily injury as well as environmental damage. Regarding electronics, members created a custom heat sink dispersing heat from the controller boards through aluminum stock into the central aluminum hub where it then disperses the heat to the surrounding water. In addition to wiring the required fuse into the tether, the electronics students also programmed in a reset switch accessible from the surface into the Arduino. If for any reason the ROV loses communication during a run, instead of resetting the entire sequence, a button is pressed on screen bringing controls to the pilot in a matter of seconds rather than minutes.

9. Troubleshooting

“Troubleshooting is defined as “to trace and correct faults in a mechanical or electronic system.”

When looking back at this project, we spent most of our time troubleshooting. Sure we spent a good amount of time working on individual parts, but the majority of our time was spent going through simple trial and error. Every piece of Seawolf II has be worked and reworked at some point in the last ten months whether it is in materials or designs.

There is a huge difference between concept designs and working designs. Looking back at various drawings, we have been plagued with unforeseen circumstances that come with any project. A design on paper or in a lab can work perfectly, but it means nothing if it cannot function under real word conditions. We have done virtual testing on every part in SolidWorks and calculation testing by hand time and time again, but no matter the result, there will be a slight difference in the transition to actual testing.

Whether it is the second or fifth variation of a component, we have the desire to make it work better than the last.”

-Brandon Boyd, CEO and Safety Officer

10. Reflection

"Looking back at the creation of Seawolf II from conceptualized drawings to the ending result, members of S.U.R.E. have experienced a long but rewarding learning experience in the field of underwater robotics. For many of the students, this was their first experience with underwater robotics, and even robotics in general.

Thoughts for this project started back in the summer of 2011 when two of the team’s mentors attended an ROV building workshop in California. Armed with this newfound knowledge and the desire to do something never done before in our area, the instructors enlisted a few dedicated students to take on the challenge. These students spent ten months working tirelessly to complete the project. Their end result was Seawolf I, a small, simple ROV.

Moving into its second year of competition, S.U.R.E. was determined to develop a design sure to impress veterans of the field while continually challenging the students. With its varying angles and dimensions, Seawolf II was a force to be reckoned with.

Beginning in late August, three varying design concepts were heavily discussed by all team members. In an attempt to maximize stability and functionality while keeping a unique appearance, our triangular prism design was chosen. Over the next few weeks, we had various supporters donate materials and time to our cause. The design began to take place weeks later once materials were fully tested and finalized. Although we were blessed with generous donors in the area, we realized not everything we need could be donated, so as in all successful businesses we began to raise funds. Although raising monetary funds was our main objective in these instances, it became more apparent that many people were very interested in our project from college professors to high school students. The team setup a demonstration pool with a small ROV at all of our fundraising events. Children and adults alike were given an opportunity to experience the duties of an ROV pilot.

Copiah-Lincoln Community College has proven to be a gracious host for our team as they allowed us to use their facilities across campus including the Precision Machining Shop where many of the pieces of the ROV were created and assembled. Because of the complexity of the project, several components of Seawolf II were fabricated off site at very supportive businesses using CNC and laser cutting technologies. After the main structure of the vessel was constructed, an electrical tube was constructed. After a finalized concept was completed in the Drafting & Design Department, plans would be sent down to the Machine Shop and, in a matter of minutes, students would be manufacturing custom parts. This is the biggest advantage of having a team such as this on a campus as this; various manufacturing practices are all seconds away from each other and many team members can drop everything to assist students of other disciplines.

Our thruster mounts have been the biggest trial and error of the project. Original concepts were sent off to companies willing to use 3D printing technologies for our benefit. A powdered plastic thruster mount was received, but ultimately rejected because of the extreme brittleness of the material. Members then set on aluminum designs that worked extremely well and provided support like no material before with its amazing strength. However, in an effort to reduce weight and increase buoyant forces, the team decided to use a new technology previously unknown to us – 3D printing technology. The mounts were printed in an ABS Plastic which proved to be amazingly strong; not quite as rigid as its aluminum predecessors, but unique and durable in its own way. This technology was also used in other components of the vessel such as custom camera mounts, one of which has been outfitted to pan and tilt for optimum visibility, electronic mounts, and even our custom manipulator. The manipulator is another instance of extensive trial and error involving 3D printing capabilities as well as capabilities of mechanical parts coupled with our generously donated waterproof motor.

All in all, the project was a huge success in that it combined the academic and career tech side of campus and provided so much promotion to the community. Many of the members have put in countless hours outside of the classroom as they learn more about their discipline as well as more about other disciplines in the field. This team has put in a great amount of effort, mental and physical, and even its own fair share of bloodshed over the months. To say we put in a lot of time in this project is a great understatement. We spent any and all accessible free time working on this project over the last ten months and look to have a great showing, but no matter the results of competition, we have learned enough this last year to carry us far in life. We are proud of our ROV – we are proud of Seawolf II."

-Brandon Boyd, CEO and Safety officer

11. Acknowledgments

S.U.R.E would like to recognize the following for their contributions to the efforts of the team.

-Copiah-Lincoln Community College (Co-Lin)

-Co-Lin Career and Technical Division

-Co-Lin Science Division

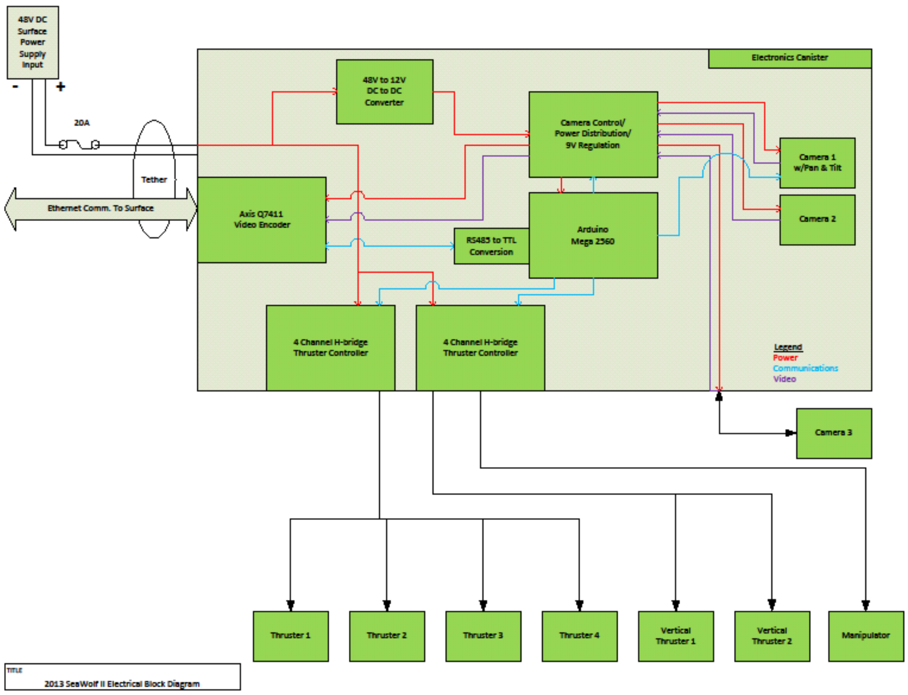
-Co-Lin Foundation

-Brookhill Country Club

-Walt Holifield and Holifield Engineering

-SeaTrepid

Appendix



Seawolf II Electronics Block Diagram

Financial statement (in U.S. Dollars)

Expenditures:

Control Board: 200

T-Shirts: 570.15

Snacks for Fundraising: 89.97

Aluminum for Machining: 134. 02

Travel: 4,500

Grand Total Expense: 5,484.14

Income and Donations:

Income from Fundraising: 490.50

Donation from Holifield Engineering: 2,000

Donation from Co-Lin Foundation: 10,000