Gonzaga Robotics

# Technical Report

Ranger Class

## Jörmungandr

Submitted by the

**Gonzaga Robotics Team**

**Gonzaga Regional High School**

**St. John's, NL, Canada**

To the

**Marine Advanced Technology Education (MATE) Center**

For the

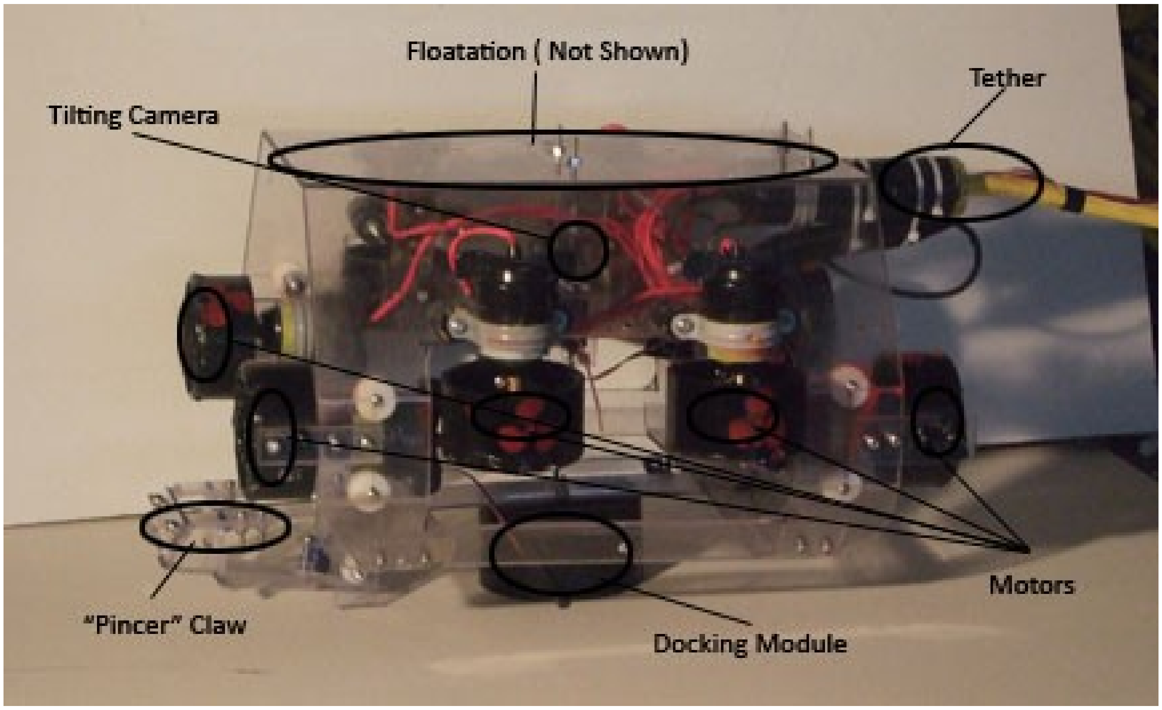
**8th Annual International ROV Competition**

*Advanced Submarine Rescue Systems*

| Team Members | Team Mentor |
|---|---|
| Jason Smith – Grade 12 | Gerry Power – Teacher |
| Greg Harding – Grade 12 | |
| Kyra Ross – Level 1 MUN | |
| Michael Allston – Grade 12 | |
| Tomas Shea – Grade 12 | |
| Mollie Jameson – Grade 10 | |
| Cam Burke – Grade 12 | |
| Matt Hann – Grade 12 | |

## Abstract

This ROV named the Jörmungandr after a Norse sea monster said to be so large it can wrap around the world. We thought this would be an appropriate name because of the relatively large size of our ROV. For this competition the Jörmungandr was built with two ideals in mind: Accuracy and versatility. By building the Jörmungandr out of (3.5mm) lexan it is both durable and manoeuvrable. Our decentralized electronics systems, servo assisted camera, and servo powered claw are all designed and positioned in whatever way possible to increase piloting accuracy . The Jörmungandr was built around a single main tool and because of this that tool had to be very versatile and in the Jörmungandr that was accomplished. The Jörmungandr is limited to 30 meters of depth due to the tether length. The construction of the Jörmungandr involved a variety of materials which includes lexan, stainless steel, PVC and polycarbonate plastics. At approximately 573mm long 550mm wide and 443mm deep with a weight of 8.2kg the name Jörmungandr truly fits this ROV very well. The Jörmungandr has only a single camera which is mounted on a servo powered bracket, this allows the Jörmungandr to locate and land on the escape hatch quickly as well as offer a freedom of range visual encase we run into troubles . The thrusters provide a 10.3 N of thrust each, enabling the Jörmungandr to be quick strong and versatile in movement while keeping it from being to touchy for the finer movements needed.



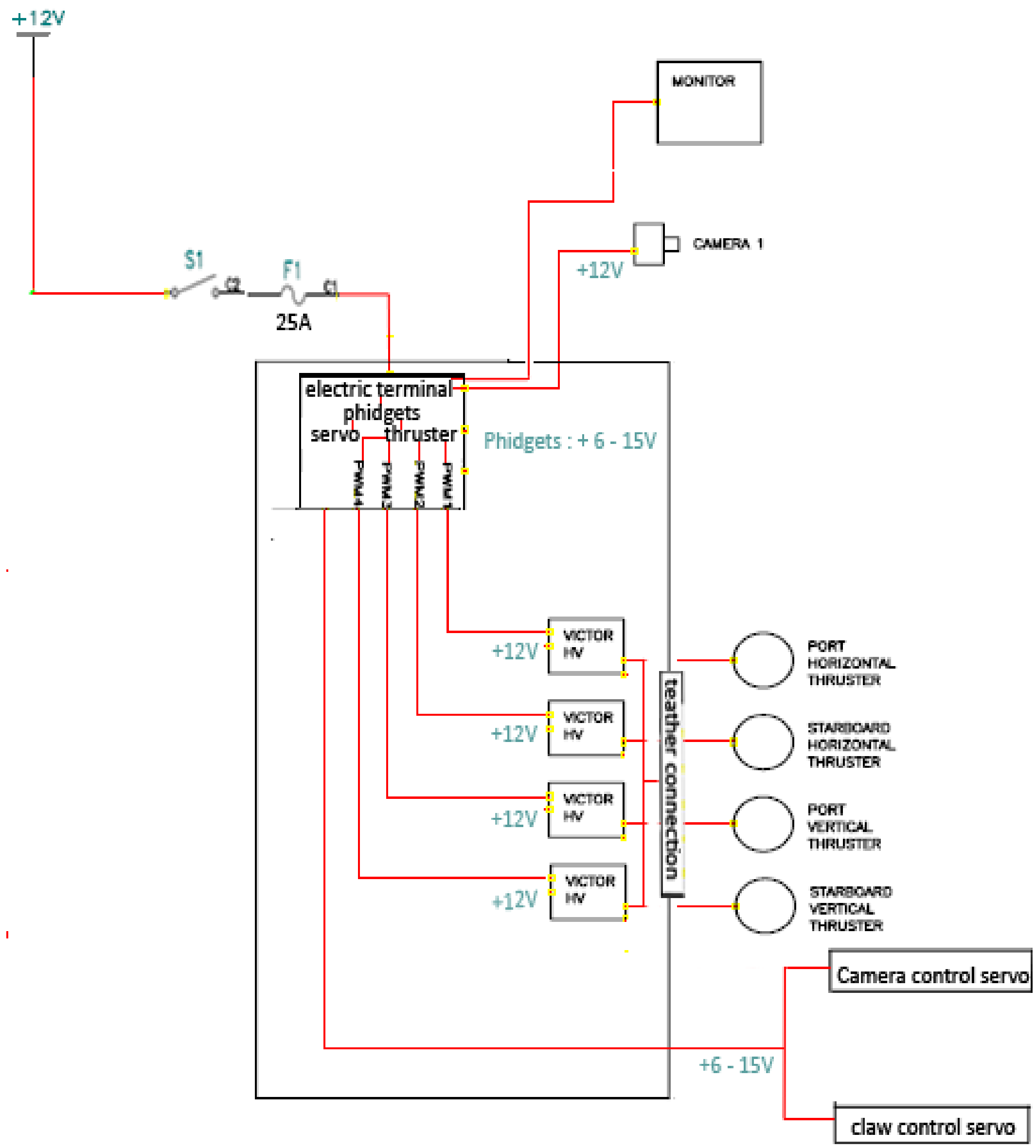
## Table of Contents

## Budget / Expense Chart

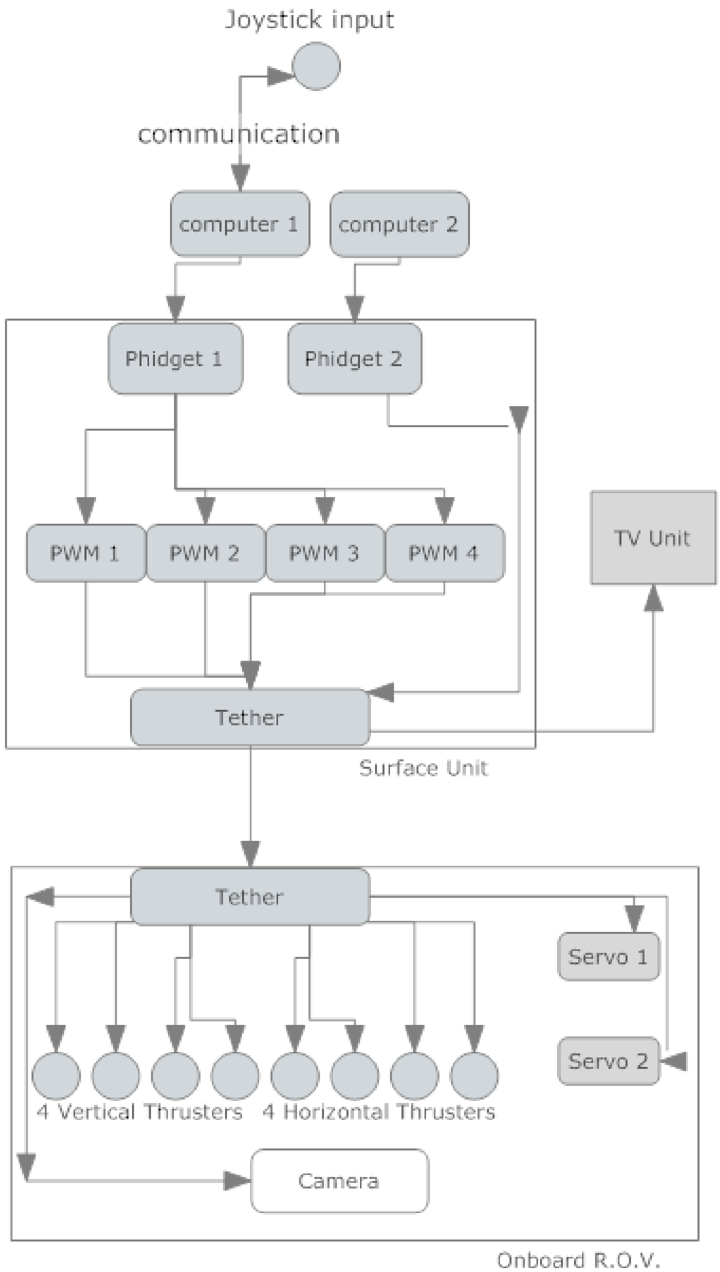
### Gonzaga Robotics Team Budget Chart

| Item Description | Source | Donations | Cost |
|---|---|---|---|
| Tether | Mate (3rd party order) | | $350.00 |
| Lexan sheets | Donavan's industrial | | $265.55 |
| Servos (2) (2 Reserve) | Signal Hobbies | | $240.96 |
| Servo Phidget Controller (2) | Phidgets Inc. | | $107.12 |
| PVC End cap | Home Hardware | | $3.09 |
| Main Camera | Lights Camera action | | $275.00 |
| Heat shrink | Princes Auto | | $38.36 |
| Sealants & o-rings | Canadian Tire | | $175.40 |
| Nuts / Bolts | Fasteners Plus | | $25.00 |
| Mineral oil | Shoppers Drug-mart | | $7.16 |
| Bilge Motors (8) | Gonzaga High School | | (Salvage) |
| Buoyancy Foam | Gonzaga High School | | (Salvage) |
| USB Joystick Controller | Gonzaga High School | | (Salvage) |
| Nuts / Bolts / Screws / Washers | Gonzaga High School | | (Salvage) |
| Travel cost To Boston, MA | Air Canada | | $4,186.00 |
| 2nd Place Regional Mate Competition | Mate Newfoundland | $4,000 | |
| | **Total** | **$4,000** | **$5,673.64** |
| ***Prices Calculated in Canadian Dollars** | | | |
| | **Net Costs** | | **$1,673.64** |

## Electrical Schematic



## R.O.V Flow Diagram




The propulsion of our ROV is controlled by one laptop computer running a Visual Basic program, which interfaces with a USB Joystick for control. The joystick movements are translated into code understood by our speed controllers, which distribute the correct thrust and direction to our R.O.V.

The tools onboard our R.O.V including the Servo Controlled “Pincer” claw, and a servo controlled camera tilt, are controlled by a different computer, and hence a different program. This program, written in VB.NET allows us to view the current voltage running to each Servo motor, Along with its current position in degrees, and its desired position in degrees.

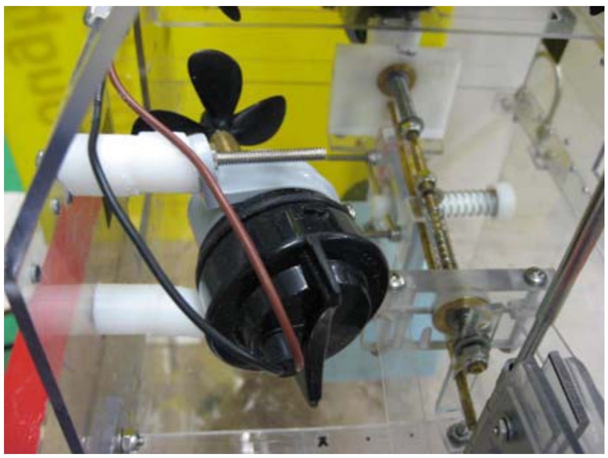
Both of these programs interface with two Phidget Servo interface cards, one for the servo control, one for overall propulsion, these connect VIA USB and are connected directly to the servo-motors and speed controllers. These cards use a 6 - 15VDC Power Supply.

## Design rational

The first piece of our ROV to be constructed was our chassis. Designed to allow high visibility, multiple access points and low water resistance the chassis is highly attuned to accomplishing the mission. The modified octagonal shape gives the thrusters a great control over the movement including the ability to sway. Our chassis was crafted from 3.5mm thick lexan a highly durable and mouldable clear composite plastic. We chose this material for exactly these reasons especially the fact that it is clear, this means we do not have to worry about our chassis impeding the view from our camera allowing any part of the ROV to become a mount point for our tools. To make the chassis we cut lengths of lexan out using a table saw giving us straight cuts to work from, from there we used the table saw again to cut groove lines into the sheet these lines allow the lexan to be bent more easily then otherwise. The lexan is then heated using a bender and moulded into the desired shape using angle blocks to assure accuracy. Three mounting/reinforcing brackets are then added to the base and firmly attached. Finally all sharp edges are then sanded to a smooth round corner to reduce any resistance we could.

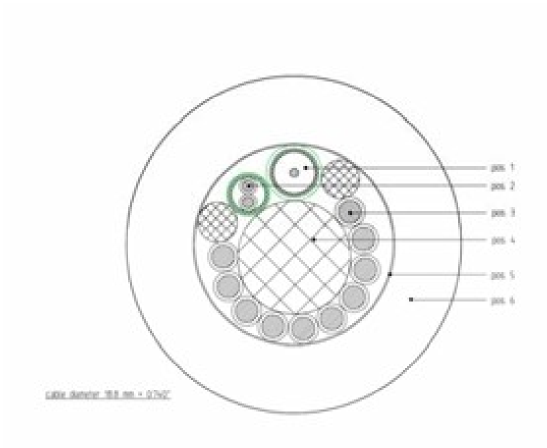
**MOTOR**

Once our chasse was finished we moved on to our propulsion. Eight (8) Johnson Mayfair Marine 1250 GPH sealed bilge pump motors are the basis of the thrusters which provide propulsion to the ROV. They have a maximum current draw of 4 amps (recommended fusing at 4A) when operating at 12 volts DC. Four (4) of the thrusters were placed vertically on both the port and starboard side equally distanced from the center. The 70mm diameter, 30 mm pitch, plastic, four-bladed Grupner™ propellers were the most effective in thrust delivery from our selected bilge pump motors. A battery of Bollard Pull tests were performed with different propeller types at voltage ranges between 13.5V and 6V DC before selecting this propeller. Our experiments found these propellers had worked the best. Once combined the thrusters were attached to the ROV we needed to attach them to the ROV. Using 37.5mm u-clamps and a plastic dowel we attached the motors pointing straight down and straight forward. To base the vertical thrusters straight down we had to cut one side of the spacer dowel to a 35 degree angle.



## Design rational - Continued

### TETHER



Once our thrusters were attached to the ROV we needed to get them linked to the surface. As in previous years we used a neutrally buoyant tether ling .This year we purchased a brand new tether line. The tether for our ROV has been custom designed by the team, to fit our motor and actuator *requirements. It contains five (5) pairs of AWG 18 power wires, one AWG 24 wire, one 75 ohm* coaxial cable and is 45 m in length. A pair of the AWG 18 wires comes from a PWM to each pair of thruster motors. The fifth pair was not used this year due to using servos for our tools. A single AWG 24 wire in the tether is used to power the underwater video camera. Finally a 75 ohm small coaxial cable in the tether carries brilliant video signals to the topside monitor.

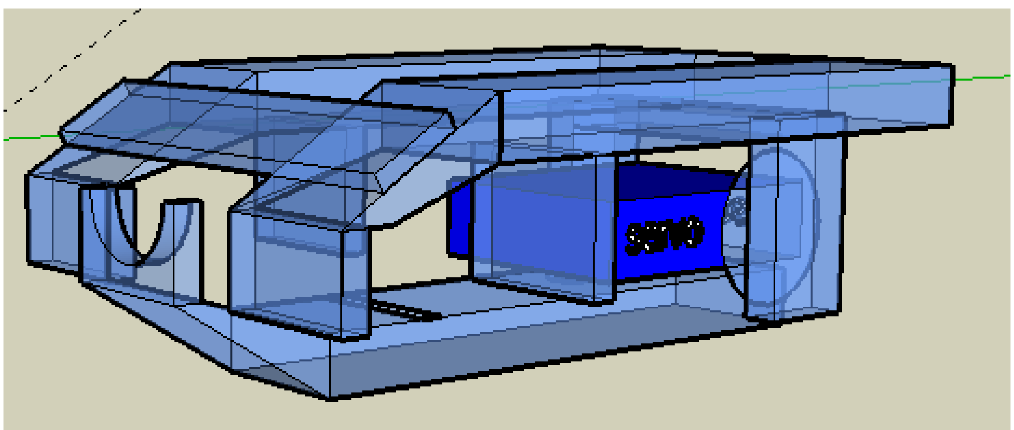
### CAMERA

Our ROV contains only one camera it is a LCA7700C model underwater video camera from Lights Cameras Action® of Mesa Arizona. This camera is contained in a brass housing which is approximately 10 cm long and 3.5 cm in diameter and operates at depths up to 30 m. It has a 3.6 mm lens surrounded by a ring of 6 Infer Red LEDs (a 0.0001 lux low light rating), and 380 TV lines resolution. This camera operates on 12 volts DC, 150 milliamps, and has a 92 degree field of view in air. This camera is attached to a servo (see servo section) which allows it to have a 90 degree vertical view axis making the camera much more versatile and eliminates the need for a secondary camera to see everything we needed to for the tasks.

## Design rational - Continued

**BUOYANCY**

The final task in assembling the body of the ROV was to add buoyancy so that it would not naturally sink in the water and be too heavy for the motors. Our choice for buoyancy was dense durable blue foam that has the buoyancy to lift 70 grams per 2.54 cubic mm. Measured out to be 5 grams negatively buoyant our foam allows slow controlled decent able to not worry about over adjusting. Finally the foam was cut at 45 degree angles to reduce any drag a flat surface might create.




This is a picture of a sub-system (our main claw created using Google sketch-up.)

## Payload description

Our only tool for the Viking IV is a claw mounted on the front of it. Originally we were planning to only use the claw to hold the air hose and the ELSS pods; however we noticed that this one relatively simple tool can complete all of the tasks efficiently and quickly. It is a three pronged claw made completely of Lexan. the top two prongs of the claw are fixed in position and connected at the end with a 45° angle to help hold on to the air hose. In addition there is even more Lexan added just behind the front of the claw to prevent the air hose from moving when held by the claw. The bottom part of the claw is the part that actually moves by the power of a waterproof servo. This bottom piece is curved upwards at a 45° angle to further prevent the air hose from moving as well as to prevent the ELSS pods from sliding off the claw when it is closed. In the tip of the claw is a notch cut out to allow the air hose to sit at a 45degree angle so that it may be inserted in to the port quickly and with ease.

As mentioned earlier the claw can perform all the tasks. Since it has so many modifications to fit the air hose perfectly there is no problem in picking it up and inserting it during the task. If necessary we can even pick it up off the floor of the tank and at odd angles. Since the claw protrudes out from the front of the ROV it can be easily used for opening the air valve and opening the door. When the servo is opened to a 45degree angle the front of the bottom part of the claw is parallel to the floor of the tank, this lets us rotate the hatch in task #2, as well as open it when it is unlocked. The bottom part of the claw was designed with the ELSS pods in mind, so that it can carry them as well with no risk of it being dropped if the claw is closed.

There were many other ideas thrown around for tools on the ROV, some high-tech, some low-tech. A very simple idea that we tried for a while was a simple curved metal rod attached to the front left corner of the ROV. Its purpose was to open the door and flip the air valve in task #3, however we noticed that it was clumsy and in the way as well as the fact that the main claw could complete the task just as well. Another rather high-tech tool idea that didn't get off the prototype stage was a hydraulically powered tool mounted to the bottom of the ROV. It had six metal rods that would extend when the hydraulic pump was activated. The idea was to land on all the ELSS pods in task #2 and pick all of them up at once using the rods, this idea's main flaw was being able to release them in such a way that all of them fit into the hatch at once, or to find a way to release them individually. Again we realized that the main claw could get the job done better and simply went with that instead.

## Challenge Descriptions

Throughout the construction of the ranger class Jörmungandr our group as a whole encountered many obstacles which required a various array of problem solving skills, and creative thinking in order to overcome them.

One of the main problems we faced was our cameras were constantly taking on water during testing; we originally overcame this task by finding a hole in our junction between the wires. This was overcome by using a pressure hose to clear the tether of water and we used epoxy to seal the hole that the wires created. Thinking we overcame this we began testing again to find that we were still taking on water.  We were baffled by this so we began to search again, eventually it was reviled that the O-ring in two of our cameras were damaged from being opened prior to their usage. To solve this we replaced the camera with a brand new one without having it opened and our challenge was overcome.

One of the other main problems we faced was the problem with our servos which were also taking on water. We began to tackle this problem by looking into water proof servos to find out more about them, by doing this we found out the servos we had where water proof up to 3 feet not 4 meters which we were originally told. To over come this we searched the internet for servo water proofing techniques. Upon finding the way to water proof a servo we checked into if it would work and then we water proofed the two servos. After doing these both our servos worked fine.

These are some of the obstacles we face as the Gonzaga robotics team, and through teamwork, and dedication we overcame these obstacles.

## Troubleshooting Techniques

During our Development and testing of the Jörmungandr we encountered many problems. The most notable problem was water proofing the two servos controlling the camera and the claw. When we first tested the Jörmungandr the servos leaked, this was because they were only waterproofed for a depth of 3 feet. We needed a depth of 12 feet for the regional competition, so we researched alternative ways of waterproofing the servo.

One idea that came up included adding an extra camera so that the one we had would not need to move it with the servo. This was rejected because it would cost more than the servo and would not solve the servo problem with our main tool.

Another solution was to buy water proof servos that are rated at a depth of 12 feet and replace the ones on the ROV. We didn't use this solution because it would have been too expensive.

At this point time and money was in short supply, so we decided to water proof the servos ourselves. We researched the materials required and techniques used for water proofing servos. What we used was mineral oil, O-rings, and silicone. What we did was dissembled the servo and applied the silicone to the circuit board and re-constructed it while it was submersed completely in mineral oil. We then coated the outside with the silicone to prevent water from getting in the seams. Finally we added an O-ring to the servo horn. This solution has worked brilliantly because it was cheaper and quicker than our other solutions and is what we are currently using.

## Skills Gained – Technical

Most of the people on the team are currently in there last year of high school and have competed in MATE robotics before. Therefore most of the team was already familiar with the construction and working of an ROV. However this year we used servos on the Jörmungandr, something that none of us had any experience using before.

While constructing the Jörmungandr, we researched servos and how to properly water proof them. This was very beneficial for the team and by the time we had it mounted and installed for both the camera and the claw, we all had a better understanding of their inner workings and potential uses.

We also experimented with the use of a pneumatically powered tool on the bottom of the ROV to pick up the ELSS pods, something that we all had limited experience. We didn't complete the finished tool due to time restraints; however we had a working prototype. There were several things about pneumatics that we had not considered, such as the buoyancy added to the tether from the air line down to the ROV.

The school received a new Dremel 400 series XPR rotary tool this year, a tool that has many unique applications, as we quickly found out. It can have almost any tool configuration for a multitude of small and delicate tasks. One example of how we used it on the Jörmungandr was on the claw, where we rounded the bottom prong to allow the air line to be securely attached.

## Skills Gained – Interpersonal

Through the process of designing creating and testing the Jörmungandr several serious communication processes were witnessed and contributed to by the entire team. Through these experiences the team learned many things about communication and relationships. They learned that the best basis for a good relationship is honesty and communication. This became plainly visible in the design process when opinions were needed. When tool designs were being drawn honest feedback and advice were important in the modification of ideas. In romantic life many team members took this new knowledge and built solid relationships from it. This is just one way that interpersonal lessons learned from this experienced were felt on this team.

## Future improvements

We have many great ideas for improving Jörmungandr, however due to restraints in money and time we can't implement these ideas. One of these ideas was to add a pneumatic tool on the bottom of the ROV, which would allow it to pick up multiple ELSS pods for task 2. This tool had several rods that would extend to the port and starboard of the ROV when turned on. This would hook into the ELSS pods allowing Jörmungandr to carry them over to the hatch, at which point we can turn the tool off and the hooks will retract causing the ELSS pods to fall in. We had a prototype of this tool; however it could not be completed before the competition.

Another plan that we have for future development is replacing the servo that moves the camera with a more advanced one with a 180° rotation. This could allow us to position our tools on the ROV with move space due to the increased line of sight.

We also wanted to fuse the two programs we are using for controlling the ROV. We are currently using two laptops, one to control the motors and one to control the servos that move the camera and claw. If we were to fuse the two programs together, we might not need a co-pilot, or a second laptop.

## Submarine Rescue Systems

**OceanWorks international**

OceanWorks international is a multipurpose company founded in 1986 specializing in underwater and deep sea diving. Serving both military and commercial customers, OceanWorks is a provider for various needs and remains to this day a very reliable company.

Specializing in manned and un-manned sub-sea systems, OceanWorks' service is provided to key marine industries including oil and gas, military, and scientific markets. Product lines include submarine rescue systems, ROV intervention tools, custom subsea equipment, and launch-and-recovery systems.

OceanWorks engineers have extensive design experience using solid modeling and animation, systems engineering, and analysis tools for a wide variety of sub-sea component, including manned and unmanned vehicles to facilitate life support systems.

Everything engineered by OceanWorks is thoroughly tested before released to commercial or military service, and as such, is guaranteed to have top quality. Additionally they offer their facilities to test ROVS, jumpers, etc. as well as offering their technicians for offshore services, making available the expertise that a project may require.

OceanWorks offers a variety of services and products, for a multitude of markets. Including the following:

-ROV tooling

-Atmospheric diving suits

-Submarine rescues

-Burial and recovery equipment

-Cable observation systems

-Control systems

-Flying lead connector

## Submarine Rescue Systems – Continued

-Oil and gas technology

-Renewable energy research

-International military technology and aid

-Submarine telecoms

-Marine salvage and construction

-Scientific/Environmental research

-Project management

-Sub-sea engineering

-Fabrication and testing

-Quality assurance

-Product support

-Sponsorship

OceanWorks International supplies the oil and gas industry with various ROV products, ranging from packages and skids, to components, sub-systems, and offshore support.

**Atmospheric Diving Suit**

OceanWorks developed the ADS (Atmospheric Diving Suit) to provide a new solution to deep sea diving. This suit is used in both commercial and military markets and it has allowed passengers to dive to up to 600 meters without risk of decompression. This allows smaller crew sizes, less extensive training required, and near-unlimited vertical exertion. The 'Hardsuit' brand has been developed since 1986 and over 40 different systems have been delivered internationally. The ADS has assisted in search and salvage, aircraft and weapons recovery, and submarine ventilation and decompression,

## Submarine Rescue Systems – Continued

For military services in multiple countries, including Canada, France, United States, Japan, Turkey, Italy, and Russia. The ADS increases safety for all divers involved; the ADS pilot is not subject to the rigors of saturation diving, a type of diving which involves a long decompression period after the dive work, therefore the auxiliary surface support requirements are greatly reduced.

**Submarine Rescue**

OceanWorks has a range of rescue submarines used for life support and repair, such as Remotely Operated Rescue Vehicles (RORVs) and Submarine Rescue Vehicles (SRVs).

http://www.oceanworks.com/

USA: +1 281 598 3940
Canada: +1 604 415 0088

## Reflections on the experience

In our time with this team we all had various goals but to educate ourselves about the basics was all we originally had in mind but we got far more than we ever could have imagined. We learned everything from the intricacies of the design process to the technique of the building process and the surprising simplicity of the electronic aspects. We learned what mathematical equations can be used for in relations to science, we learned about how far science has come in our lifetime alone and we learned that the building process is a series of small builds working together for the ultimate goal. We guess in reflection we got exactly what we wanted, we just learned more about it then we thought we ever could.


Top (From left to right): Michael Allston, Matt Hann, Jason Smith, Tomas Shea.
Bottom (From left to right): Christopher Burke, Mollie Jameson, Greg Harding.

## Acknowledgements

We thank the following company's, organizations and individuals for the support and time they gave to the Gonzaga robotics team:

The Marine Advanced Technology Education center for there financial support
Gerry Power for his help as our mentor
Tom Donavan for his help as a temporary mentor
Alfonso Diving for there donations of supplies
Clarence Button for his time and assistance in using software and deck crew tips
Dwight House for his help over all, giving us time, facilities and insight

## References

The following are sources where we got our missing information:

- www.marinetech.org for rules, regulations and questions answered from there help site.
- www.youtube.com for the video on how to waterproof the servos
- Dwight House, Clarence button and Gerry Power as points of reference from there experiences
- www.oceanworks.com for there information on there submarine rescue systems
- Gonzaga High School's Robotics information book made from previous years