OpenROV Final Project Design Document

OpenROV Team Spring 2021

(Open Source Remotely Operated Vehicle)

Client:

Director of Technology & Laboratories
Iron Range Engineering

Facilitator:

(Spring 2021)

Team Members:

(Project Manager)

(Documentation)

(CAD/Design Lead)

(Programing Lead)

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Abstract

This document states about the team's project called OpenROV. We created a team agreement. The team found a problem statement and went to work after that. We found different ways on how to design this project and chose a version of our liking. The team then went into different documents and design reviews while looking over the various parts we could use. The team found exactly what we needed and found the design for us and started the build stage. With countless meetings, we made some adjustments. COVID-19 made this project a little more difficult with meeting times as we met at the school multiple times to work on the build. The team then completed the build and made adjustments as needed. The final deliverables were given to the client, Jim Boyd, at the end of the semester.

I. Problem Statement

The OpenROV team has been tasked with improving and modifying last semester's Open Source Remotely Operated Vehicle (OpenROV). This ROV is to be used in local bodies of water. The client asked to have these improvements complete and presented by the end of the semester as well as tested in local bodies of water. This project is very open-ended so there isn't a specific design that our client is looking for.

II. Design Objective

OpenROV is a community project that brings different coders and builders together working towards having an ROV that can explore bodies of water everywhere. The objective of this project is to create useful additions to improve the usability of the vehicle. As a team, we have to come up with the improvements we would like to make on this project. We want everything to be user-friendly and so anyone is capable of taking it into the real world and using it to explore.

III. Requirements

The OpenROV team is improving upon last semester's underwater drone. Since our problem is open-ended this semester, here are the things the team has decided to improve:

1. Water-proofing the underwater vehicle
2. Testing the water-proofing
3. Finding a power source
4. Adding lights to help with operation
5. Adding sensors to help in data collection
6. Coming up with ideas to improve the underwater drone that could add value to the system.

IV. Constraints

The constraints of this project are the ROV we already have to work off, the bodies of water, and the amount of money allocated.

The ROV has already been built so when we add features we need to design them as auditions, not as full reworks of the device. It is a challenge to work from a spot where you didn't start and requires creative ideas to accomplish it.

Bodies of water can differ in size, visibility, and currents. Minnesota is also a cold state so the lakes have been frozen over and are only going to be open in the spring. Our budget has limited us from adding any large-scale improvements since batteries are expensive, as well as different sensors and supplies for other mechanisms will add to the total cost. Overall, the team had challenges with these constraints but has worked on them and created a great submarine.

V. Action Plan

For this project, our action plan for completion consisted of fixing our propeller set-up, finding sensors, adding lights, redesigning and printing the camera mount, and a few minor fixes. The propellers for our design both have the same pitch and spin in the same direction. So the way we plan on fixing that is by reprinting one of the props with an inverted pitch and reverse the motor. This will allow the ROV to be pushed straight instead of causing a listing effect or a roll. Next, we plan on finding sensors that will relay the temperature and pH (pH is a scale used to specify the acidity or basicity of an aqueous solution) of the water. We found simple sensors on hundreds of different websites so the real challenge was finding the most cost-effective resource to acquire the sensors from. Next was researching and implementing a lighting system to aid in underwater visibility. After we completed these initial objectives, if time allows, we started on designing a way to determine the depth which is another sensor added to the ROV backplate but is much more in-depth to program and much more expensive than our other sensors. This action plan made the path for us to follow this semester helping us complete our objectives.

VI. Final Deliverables

The final deliverables for our project consist of our required documents and presentation and the ROV implementations and upgrades, if you will. We also have to decide on a power source, in other words, which type or size of battery we would like to implement. We also must conduct an initial test of the ROV, even if it is in a tub of water, to see what we are starting with for handling, visibility, and overall operation. Organizing and finishing up enclosure organization that didn't get accomplished last semester, organizing wires, mounting electronics, and mounting the battery tray. We will also be conducting field tests and taking note of what occurs, whether it be good or bad, and video of the tests. We will put our results and takeaways into a document for future reference and evaluation for these tests.

VII. Timeline

The timeline for our project consists of the full duration of the 2021 spring semester. More in-depth assignment due dates can be found further in the document under project deadlines. We have our facilitator meetings each Thursday during class. In these meetings, we talk with our facilitator to make sure we are keeping on track and making progress. By participating in these meetings it can help keep our team stays organized and efficient. We can use these meetings to share thoughts and ideas about what is the best way to achieve our goals promptly to meet our deadlines.

Design Document

VIII. Project Decision Process

The design process for our team started with making a list of what we would like to implement and bringing the list to our client and asking what his preferences on the list were, and what they thought would have the greatest impact on the ROV. The grapple, sensors, and lights were chosen. As our group changes as time went on we have had to re-evaluate these. Due to our capabilities, we have chosen to implement sensors to collect data throughout an exploration and lights to improve visibility in dark waters. As we continue the project and semester we would like to test the ROV and make changes with what we learn from them.

IX. Design Options

A. Option 1: Grapple

Our original plan was to research, design, and build a grapple or manipulator of sorts to move or pick up objects found on exploration. This would be mounted to the front of the ROV still in view of the camera. This design would require adjustment to the keel weight distribution to allow either tilt forward or counterbalance the tilt due to added weight to the front of the ROV. The grapple would be powered by a servo for each direction of motion (up and down, left and right, in and out, along with the actual grab). Due to changes in team and abilities, we had to veer from this idea and find something more in our range of new abilities.

B. Option 2: Sensors

The second option we'd like to implement would be sensors and lighting to collect water temperature, Ph, GPS, and depth/pressure. This data would be collected and stored on the ROV until the end of exploration. An Arduino would be our brain for the system taking up little room and using little power.

The sensors would be stored on an added piece to the ROV 3d printed and mounted on either the bottom in an enclosure wither just holding the Arduino with the sensors in different locations to get accurate readings for temperature or mounting the enclosure to ensure this. The lighting would be affixed to the exterior of the ROV getting power from the LiPo (Lithium Polymer) battery. This would allow better visibility on cloudy days or murky/dark areas where light doesn't reach as far down.

X. Decision Matrices

Decision matrices have helped us as a team come up with what we will be using for our different electronics and as well as what we will continue with designing in our ROV. A couple of the criteria topics are more of a bias so as a group we all rated them and gave them scores according to how we felt we could do in the specific area the criteria is talking about. Below is the decision matrices that we used to decide what we will be continuing forward with.

	Grapple	Depth Sensor	Temp Sensor	Lights
Capability (3)	1	2	3	5
Cost (1)	1	1	3	4
Enhancement (2)	5	3	2	5
Fabrication (2)	2	3	3	5
Scores	16	19	22	39

Figure 1 - Continuation Decision Matrix

XI. Design Process

Our team was tasked with improving an underwater vessel. We chose designs that we felt will add lots to the ROV and be capable of doing with the tools and resources we have at IRE as well as the limited manpower we now have. Our team prepared to make many changes and improvements but we then had to rework our scope to make realistic changes with our new constraints. Currently, we are in the assembly phase of our improvements and will continue to the test phase.

XII. Modern Tool Usage

We used 3D printers as well as arduinos for this project. There were a lot of Solidworks parts we designed and printed that we added to our ROV to fix little problems with the last semester's design. We used the Arduino to add sensors and lights to the ROV which gave it more functionality. We also are using modern communication tools such as discord, zoom, and other online means. For synchronization, google drive to share documents, presentations, and files. By doing this we were able to work on items simultaneously with each other.

XIII. Future Work

For our future work, we will be adding the temperature sensor and the GPS system to the ROV and securing the components and the weight of the ballast. If there was to be another continuation, possible things that could be added would be a grapple device. The grapple device could have many different styles or functions and be able to perform different tasks underwater.

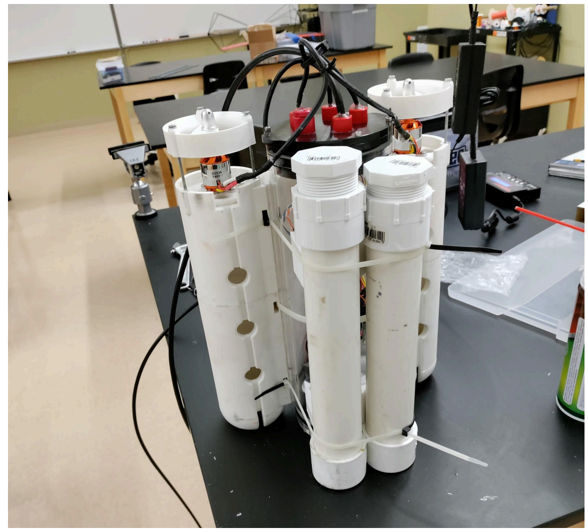


Figure 2: Weight System

XIV. Final Design Description

For the final design of our project, we successfully fixed the issues with the previous ROV. We fixed the rear propeller and the camera mount and developed a better weight system for buoyancy. We also added lights for better visibility and did the necessary research and acquired parts for a temperature sensor and GPS system.

We then tested our system and concluded that the ballast needs to be more secured internally to keep the pellets from moving inside. We developed a plan to keep them from moving with sharp motions.

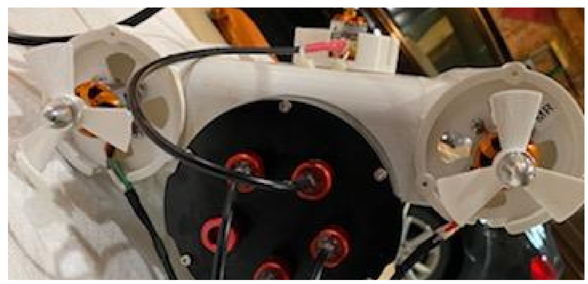


Figure 3: Rear Propellers

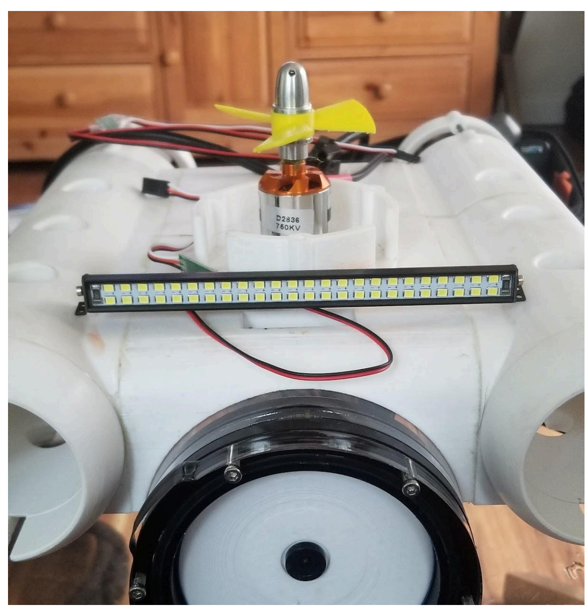


Figure 4: Lightbar

XV. Testing and Validation

The testing we were able to conduct was a real-world scenario, in Silver lake located near the Virginia campus. We operated the motors and checked for functionality between the camera, remote control, and communications buoy. After these tests, we were able to confirm that the vessel would be ready for longer and deeper explorations in other aquarius bodies. Taking the ROV on its maiden voyage allowed us to take note of issues and remedy them if possible with the remainder of the semester we had. With what we have changed and improved. We are confident that we have produced a product that can be used as intended and with satisfactory reliability and performance.

Figure 5: First Full System Test

XVI. Overview of Final Deliverables

The Final Deliverables for this project are an improved version of the ROV, not a completely redesigned ROV but improvements implemented and revisions tested. A completed bill of materials, all necessary documentation, scoping document, design document, and final document. Along with these documents presentations correlating to each. And finally the delivery of these to our client.

XVII. Conclusion

Overall, the team was able to learn what they were looking for out of the project. The team produced a build for the vessel improvements. The team had a couple of designs to start from and continued with the project. The team had multiple parts moving at once such as printing, sanding, electronics setup, and wiring, along with soldering, and camera insertion, and alignment. The team went on to do multiple presentations and concluded the project with this final report. This project went along but not without some bumps along the path, all in all, it was completed and a great learning experience.

XVIII. Project Deadlines

Team Agreement - January 28th
Scoping Presentation - February 10th
Scoping Document - February 15th
Design Presentation - April 1st
Design Document - April 5th
Final Presentation - May 3rd
Final Document - May 10th
Final Build Turn In - May 12th

Appendix I: Research

Led Light Bar

Description of Topic:

1/10 scale led light bars are usually used for scale remote control cars, we are modifying one to be used underwater and illuminate dark areas while operating the ROV. Powered by our LiPo (Lithium Polymer) battery.

Drawings/Sketches/Images:

Applicable Equations:

N/A

Application to Project:

Mounted to the exterior of the ROV to help with visibility in dark and/or murky areas while conducting an exploration.

Research Information Found on Topic:

These LED bars are very bright while using very little power, being led they also are more reliable and longer-lasting while also being easily wired, unlike an incandescent light which would have a much lower efficiency and lifespan. Although this model isn’t waterproof from the factory with some cheap modifications it can be and still be a fraction of the price of a fully waterproof one.

Interaction with other "Systems/Sub-systems/Components/Concepts" in the Project:

Will be a part of our battery-powered electronics system.

Sources

https://www.amazon.com/Mirthobby-Traxxas-Rustler-Crawler-Wrangler/dp/B08GGQBNT6/ref=sr_1_45?dchild=1&keywords=rc%2Blight%2Bbar&qid=1619027155&sr=8-45&th=1

Ballast

Description of Topic:

The ROV needs a ballast in order to sink and stay underwater. Without it the ROV is much too buoyant causing it to sit at the surface of the water.

Drawings/Sketches/Images:

Applicable Equations:

Archimedes Principle Fb= -pgV

Buoyant Force = - fluid density x acceleration of gravity x fluid Volume

Application to Project:

It is applied to our project in the two tubes attached to the bottom of the ROV which is filled with steel/copper bbs as our weight.

Research Information Found on Topic:

Ballast can be applied in many ways, the simplest being our method of just added weight to the object, a variable weight ballast can also be used that lets water in to reach the desired buoyancy for the depth goal. The simple method is less ideal for it is set once the ROV is in use, it can be changed by the operator if brought back to land to do so. A ballast tank would be adjustable by the remote allowing sinking or floating by allowing water in the tanks then pumping air back in to allow float. This would be much more complicated and hard to keep in operation, but none the less much more technical and controllable.

Interaction with other "Systems/Sub-systems/Components/Concepts" in the Project:

Attached to the ROV allowing the whole system to submerge and be used as deigned.

Sources:

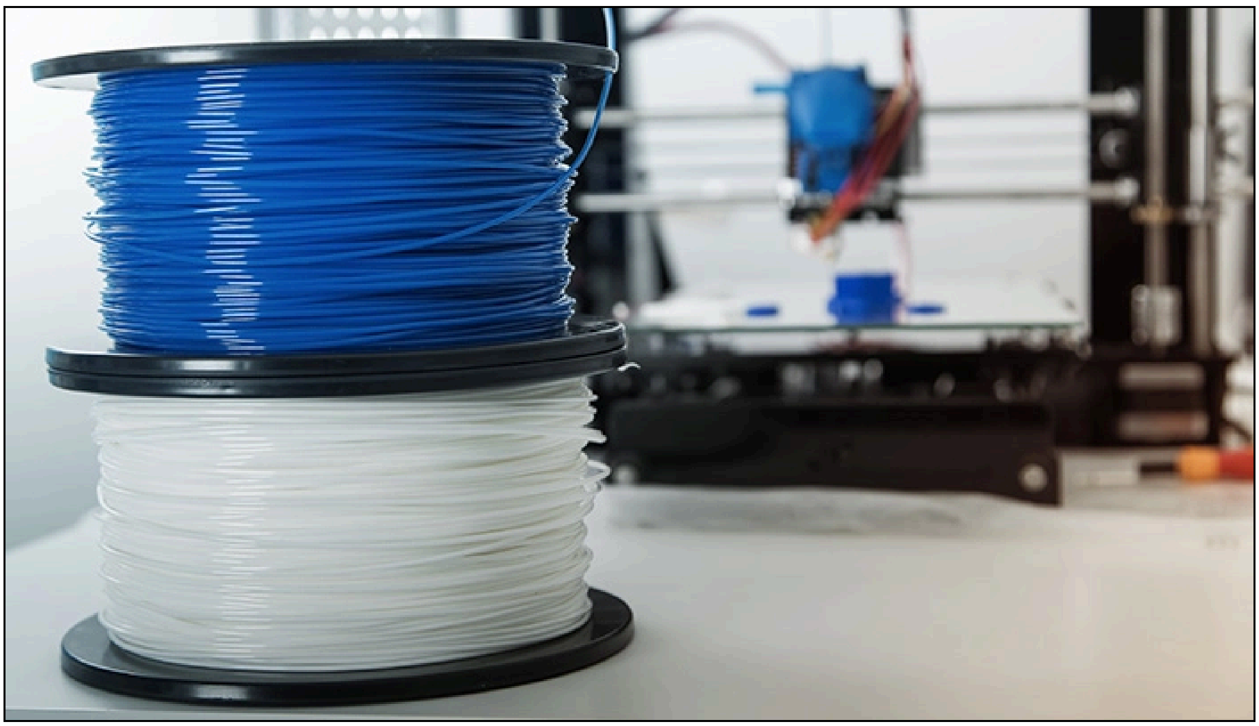
https://en.wikipedia.org/wiki/Ballast
https://science.howstuffworks.com/transport/engines-equipment/submarine1.htm

PLA (Poly Lactic Acid)

Description of Topic:

For the project, the team selected PLA printable material for the printers. This material was compared to others and we saw roughly the same things from each including the pores, sturdiness, and connecting of the parts once printed. They all were very similar, while this one was cheaper than the rest, but also slightly more workable with how the project could be molded with these parts.

Drawings/Sketches/Images:



Application to Project:

With this project being mainly 3D printable parts, this has the biggest contribution to the project than the rest. This is the shell and also the propellers of the design we chose and we saw it deemed very important to this design. This 3D printable material had to be sturdy enough and be able to hold together well and be accurately fitted as it needs to be waterproofed.

Research Information Found on Topic:

https://www.sciencedirect.com/science/article/pii/S2214785318301858

We looked into its properties and saw how it could be incorporated into the project. This article described how and what PLA is and helped us grasp a better understanding of why this would be a good fit for our project, like being environmentally friendly and safe to use.

Amazon

This link is the 3D printable PLA we used in our project. It is durable, does not make the printer overheat, and runs smooth prints. We were happy with this as the parts came in as durable as they were.

Interaction with other "Systems/Sub-systems/Components/Concepts" in the Project:

This is incorporated with everything in this project as this is the base of the project. Without the 3D printers, we could not have chosen this design and would have gone in a different direction of the project, like our first option with acrylic.

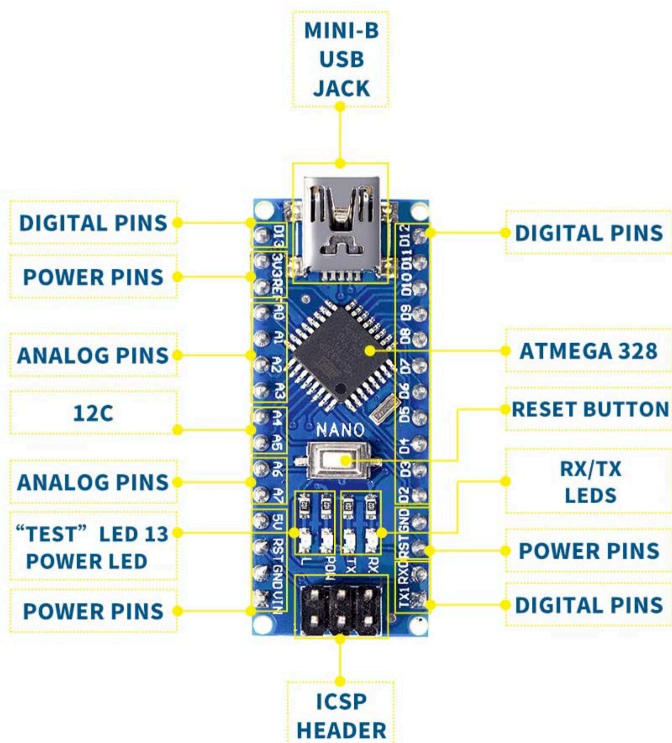
Sources: https://www.sciencedirect.com/science/article/pii/S2214785318301858

Arduino Nano

Description of Topic:

The Arduino Nano` is a small flash drive-sized microcontroller that can be programmed to control electronics or collect and short-term store data from externally wired sensors.

Drawings/Sketches/Images:



Applicable Equations:

N/A

Application to Project:

Used to collect and store data imputed from sensors such as temp, GPS, and depth. Also could be used to turn lights on and off when needed with a photocell or ambient light sensor.

Research Information Found on Topic:

The Arduino can be programmed for each of these sensors and decode it to data we can understand, a voltage change in the photocell or temperature sensor can be translated to lumens of light and degrees Fahrenheit or Celcius.

Interaction with other "Systems/Sub-systems/Components/Concepts" in the Project:
Our battery-powered electronics system.
Sources:
https://www.amazon.com/REXQualis-Board-ATmega328P-Compatible-Arduino/dp/B07WK4VG58/ref=sr_1_2_sspa?dchild=1&keywords=arduino+nano&qid=1620012954&sr=8-2-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUFMMFlTSzhYUU9HMkMmZW5jcnlwdGVkSWQ9QTAxMjg0ODcySk5XSkk4M0FNRjZBJmVuY3J5cHRlZEFkSWQ9QTA3MjczMzU3RU1RTjFCUlgzQUomd2lkZ2V0TmFtZT1zcF9hdGYmYWN0aW9uPWNsaWNrUmVkaXJlY3QmZG9Ob3RMb2dDbGljaz10cnVl

LiPo Battery

Description of Topic:
LiPo or lithium polymer batteries are used to power our ROV, they are varying from 1 to 6+ cells ranging in capacity, discharge rate, and size.
Drawings/Sketches/Images:

Applicable Equations:
N/A

Application to Project:
Used to power our electronics in the ROV including camera, motors, and wireless control system.
Research Information Found on Topic:
For our system, we used a 3cell battery giving roughly 12vdc fully charged. The higher the MAH (milliamp hour) rating the larger the capacity of the battery as a whole. The C rating refers to the highest discharge rate the battery can safely handle, for only 3 brushless motors a camera, and some lights this value doesn't have to be very great. These batteries are a great option for a vehicle that not only needs to last a long period of time but also has a varying current draw based on how high of an RPM the motors are being run at. A downfall of these batteries is the requirement of a special charger which we have acquired for the project, another issue being mishandling or use can lead to "puffing" or even fire if the cells are punctured or burst. We have gone alone and purchased a lipo safety bag which is fire retardant and will contain this event if it were to occur.
Interaction with other "Systems/Subsystems/Components/Concepts" in the Project:

The electronics system entirely as they all will be powered by this.

Sources:

https://www.thedronegirl.com/2015/02/07/lipo-battery/
https://en.wikipedia.org/wiki/Lithium_polymer_battery#:~:text=A%20lithium%20polymer%20battery%2C%20or,instead%20of%20a%20liquid%20electrolyte.

Appendix II: Bill of Materials

Part name	Link	Quantity	Price per	Total price
Lipo Safety Bag	https://www.amazon.(	1	$13.99	$130.65
Batteries	https://www.amazon.(	1 (pack of 2)	$66.99	
Penetrators	https://bluerobotics.co	2	$4.00	
Light Bar	https://www.amazon.(	1	$16.99	
Light Bar	https://www.amazon.(	1	$13.99	
Light Pods	https://www.amazon.(	1	$14.69	
Items already Owned by the School				
Part Name	**Link (if applicable)**	**Quantity**	**Price per (if applicable)**	**Total Price**
Arduino Nano	https://www.amazon.(	1 (come in a 3 pack)	$15.19	$109.88
Arduino GPS Module	https://www.amazon.(	1	$10.99	
Temp Sensor	https://www.amazon.(	1 (come in a 5 pack)	$11.98	
PLA Filament	https://www.amazon.(	1(only used a small (	$23.73	
LiPo Charger	https://www.amazon.(	1	$47.99	

Appendix III: Team Contract

OpenROV Team Agreement

2021 Spring Semester

Client: SAS
Facilitator:

Communication:
Communication will be carried out through the following forms:

- Email
- Team meetings
- Phone
- Text

Project Scope:
As a team, we are tasked with taking the last semester (Fall 2020) OpenROV project and continue the development of the vehicle. We have to decide what could be implemented to the vehicle to make it more functional during operation for whatever it may be doing.

Deadlines:

- Team Agreement - 1/28/21
- Scoping Document - TBD
- Scoping Presentation - TBD
- Options Document- TBD Middle of semester
- Options Presentation- TBD Middle of semester
- Final Document/prototypes - TBD End of the semester
- Final Presentation- TBD End of the semester

Agreement Objective:
The objective of this team contract is to establish an agreement of project team conduct between all team members and the roles of each team member for the OpenROV Team for the spring of 2021. Team members shall adhere to the highest degree of professional conduct. All

team members are accountable for their actions, learning, and contributions towards the expectations of Iron Range Engineering (IRE).

Expectations:

- Punctuality
- Preparedness/Goal Tracking
- Clear Communication
- Professionalism
- Rule of 1/X
- Meet due dates
- Notify other team members/communicators if you won't be able to make it to a meeting.

Group members are expected to adhere to all Iron Range Engineering expectations as listed in the Professional Responsibilities section in the syllabi under Professionalism on the IRE Wiki web page. Group members are also expected to adhere to Minnesota State Mankato policies; including, but not limited to plagiarism, harassment, and appropriate use of technology and resources.

Effective January 2, 2021 - April 6, 2021

Consequences:

- First Offense
    - Verbal apology, admit to wrong-doing. Also, snacks of the team's choice will be needed.
- Second Offense
    - Meeting with facilitator and choice of the team’s favorite drink on Zoom.
- Third Offense
    - Have a meeting with the instructor to discuss behavior and further repercussions.

Agreement Changes

Agreement subject to change with 3/5 team member approval vote and facilitator approval.

Roles:

The role of each team member is as stated below. These roles do not limit any team member's capabilities or choice of tasks but hold each member accountable for leading an equal part of group work.

-Project Manager-

- Keep the project on task
- Ensure communication is maintained between team members
- Make sure everyone is putting in the same work in every aspect of the project
- Make sure everything is getting turned in on time and the project is keeping its course throughout the semester.

-CAD Lead-Programing Lead -

- Use of Solidworks
- Drawing and Designs
- Program the device for its intended use
- In charge of recording pieces of code used and taken from various sources

Goal Statement:

This project is to be improved and innovated by the student engineers learning about the open-source market with OpenROV's community.

Meetings:

Group meetings: 10 A.M. Monday or 10 A.M. Tuesdays
Group meetings with facilitator: Thursdays During Class (12:00 pm-1:20 pm)

I hereby agree to the terms of this agreement and will abide by its rules in order to ensure a positive experience for everyone involved.

Signatures:

Appendix III: Work Breakdown Structure

Work Breakdown Structure

OpenROV Project Team

<u>Foundations - 50%</u>

1. Research Designs
2. Prototype
    a. Looking for flaws
    b. Materials
3. Waterproofing
    a. Joints
    b. Electronics
    c. Wire passthrough

<u>Internals - 20%</u>

1. Lights
2. Sensors
    a. Programing
3. Manipulator

<u>Build - 30%</u>

1. Actual Build
2. Testing
    a. Open water
3. Revisions