EML 4905 Senior Design Project

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MECHANICAL ENGINEERING

URSA MATE ROV
Final Report

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Ethics Statement and Signatures

The work submitted in this B.S. thesis is solely prepared by a team consisting of Nikko Miniello, Joshua Gonzalez, and Brandon O'Neill and it is original. Excerpts from others' work have been clearly identified, their work acknowledged within the text and listed in the list of references. All of the engineering drawings, computer programs, formulations, design work, prototype development and testing reported in this document are also original and prepared by the same team of students.

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1. Introduction

1.1 Problem Statement

With the ever increasing demand for petroleum-based products, reaching further and digging deeper have never been more in need. From maintaining undersea pipelines to conducting experimental science underneath ice and around hot gas vents, there is a specific place for the remote operated vehicle. A major challenge today is keeping people and equipment safe while still being able to conduct required inspections and experimentation. Our aim is to construct a prototype, remotely operated vehicle for use in maintenance and inspection of underwater pipelines; one which has the dual functionality to conduct biological research in icy water conditions.

The M.A.T.E. ROV competition permits a specific framework and rule set with added constraints that will challenge our engineering abilities. With the intention to compete in the Ranger class, we will construct a frame for the ROV, engineer and develop a control system, and test and modify specific instruments used for manipulation and movement of the robotic arm that will be located on the ROV.

Furthering this, we will look to past examples for a basis in technology that is optimal for these conditions. Additionally, examining past designs will also provide us with key insights into what designs and specifications are undesired. From this foundation we will use our own developments and ideas together with proven parts to engineer and construct our vision of what the ROV of the future will be.

1.2 Motivation

Navigating in deep, icy waters more often than not is quite treacherous. Having a ROV that can easily maneuver and display conditions readily on screen would cut down on both costs and human casualties greatly. Our motivation for this MATE ROV project design is to attempt to make difficult operations, that would normally take multiple people and machines to accomplish, simplistic.

1.3 Literature Survey

When attempting a new design it is important to consult with past designs. While the intention of this is to design and construct a unique solution to a problem there will always be areas that have been covered by others. This is why one must first consult different forms of literature and review material before embarking on specific design options. Firstly consulted was the MATE ROV page of past participants. From here we are able to see examples of what has worked previously. Additionally, we are able to see other designs that have failed in certain aspects.

<u>Seawater vs. Brushless Motors</u>

Experiment

Long term solution for using brushless motors. Three different methods were used; silicone mold release spray, silicone conformal coating, and nothing (control). The three methods were dipping into a cup filled with a mixture of tap water and salt. Three DC motors were individually treated and left to sit for several days. After removing them from the solution, the DC motors were washed and wiped to remove any rust that had accumulated on the magnets.

Result

The silicone spray had the most resistance to rust, so it would be seen as excellent water repellent. With regular cleaning and re-coating this method would improve the longevity of your motors. There is also a drop in power when underwater due to short-circuiting effect between coils. So other possible sealant methods would be polyurethane sealant, epoxy, and marine vinyl-ester resin.

Open ROV 2.6

The OpenROV 2.6 encompasses a very simplistic design directed towards one sole purpose, exploration. This design does not utilize any external add-ons or functions; in essence it is an advanced underwater camera with navigation capabilities. The project was started by Eric Stackpole, along with partner David Lang. The idea began when Stackpole and Lang met three years ago and began to discuss exchange their ideas for underwater exploration. From the start the two connected and began to pursue this small idea of theirs that has now evolved into an enormous project. The OpenRov 2.6 uses three brushless motors for its maneuverability. There is one centered at the top to control the lift followed by two in the back to control its propulsion. As a source of energy the ROV uses six C batteries, three on each one of the front extremities. The design was also focused towards having gaming remote controls as the primary source of driving the ROV; however, since all of the programming is all open sourced you can format the programming to your liking or functionality. The advantage to this is it allows people to code their own add-ons that can then be further modified or utilized by others in the community. With the initial launch there was a targeted goal of selling $20,000 surprisingly enough they sold that much within the first two hours. It was at that moment both Stackpole and Lang realized how large of a calling there was across the world interested in joining the exploration movement. At this moment they've currently sold $111,622 worth of ROV's. In order to keep it easy to manipulate the design the two founders are currently not seeking to obtain a patent, at least for now. The unique thing about this project is the global involvement; "OpenROV is an open-source community," Stackpole said. "If the ROV is having some sort of a problem and we can't figure out how to handle it, I can go onto the forums and post, 'Hey, this is a problem I'm having,' and as I sleep, the problem is going across Europe and people who are experts are answering it because they find it interesting. By the time I wake up, it's going to cross the U.S., and by lunch I can have five or six good solutions."

Figure 1 - Literature Survey, ROV 2.6 [OpenROV | Underwater Exploration Robots]

Water Conditions and Propulsion

Thruster design is also an important factor for operating and ROV. In order to choose a proper thruster apparatus one must first take into account the vehicle's drag. The formula for drag is:

$$D = 1/2\sigma A V^2 C_d$$

Typically ROV propulsion systems are divided into 3 categories: electrically driven propeller, hydraulically driven propeller, and finally, the rarer type being ducted jet propulsion. The primary concern of thruster design setup is to maximize thrust capabilities while still minimizing weight. Proper speed considerations are also required since propellers have specific design speed. ROVs are primarily slower craft that require slower operational propellers. For this application where depths are limited, diving speed is not terribly important allowing for the use of slower diving propellers as well.

Robotic Manipulator

When considering what kind of a claw we wanted to use, we first had to consider what functions our claw was going to have. Initially we thought a one degree of freedom robotic claw would suffice; however, we realized that adding a second degree of freedom isn't that much more complicated and drastically improves the range of motion of our claw. The manipulator features a pan/tilt with a robotic claw equipped with rubber tips at the end to improve its grip. The claw we selected is made out of stamped aluminum which makes it fairly lightweight in comparison to the overall weight of the frame. The stamped aluminum is also not a very expensive material as we are trying to keeps our costs as low as possible. The claw will have two servo motors independently attached to control the clasping function and pan/tilt features. Compared to other claws, the one we chose has received a multitude of great reviews online and essentially was the best deal out there. Not only does the claw accomplish the tasks we sought to achieve but it did it with the same specs as most of the other claws we looked at a fraction of the price.

1.4 Survey of Related Standards

Guide to weatherproofing, weather resistance, and IP ratings

Lorex security cameras are given an environmental rating to indicate their suitability for installation in different indoor and outdoor environments. This rating is based on the camera's Ingress Protection (IP) rating. Check the specifications sheet for your camera model to determine the environmental rating.

Contents:

What is an IP rating?

The IP rating tells you how resistant the equipment is to dust and liquids. The IP rating is a simple code that covers a range of international standards for enclosures and electrical equipment.

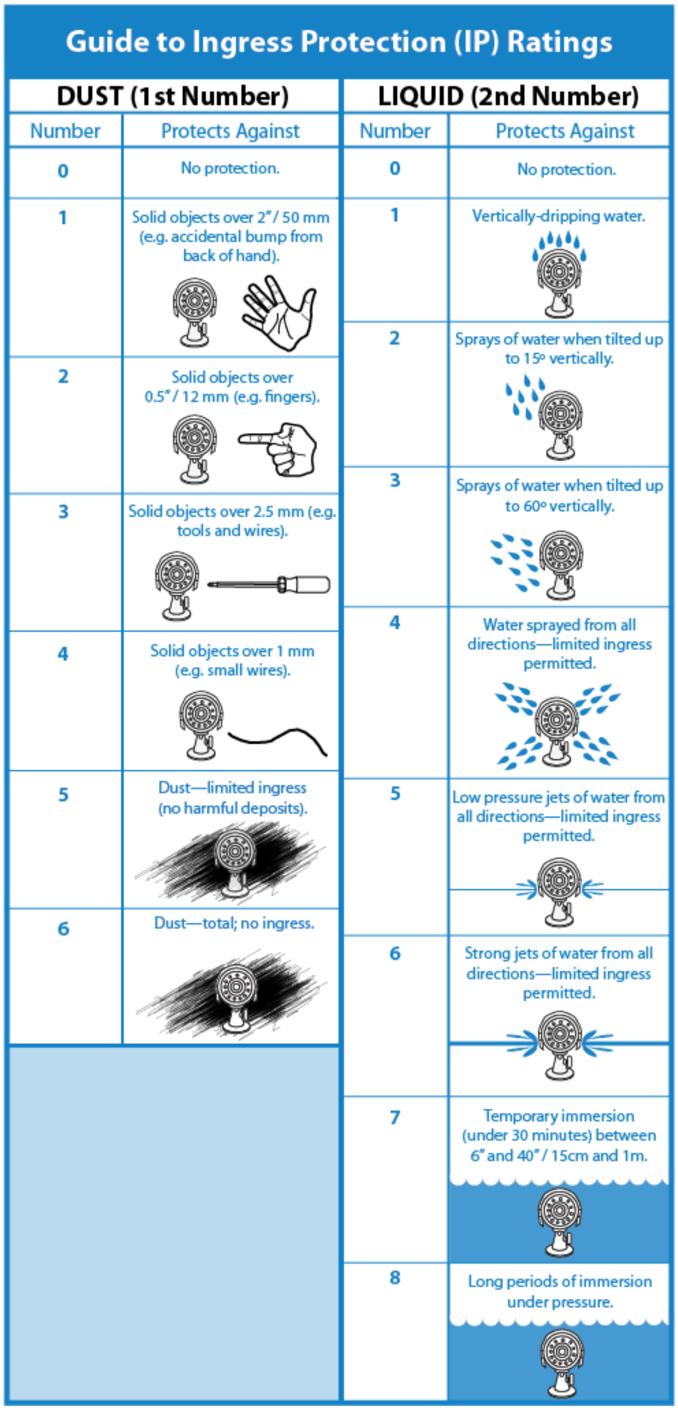
What does the IP rating mean?

IP ratings are given as a two-digit code, such as IP54 and IP65. The first digit represents the level of protection against dust; the second digit represents the level of protection against fluids. The higher the number, the stronger the level of protection.

Figure 2 - Literature Survey, IP Explanation

IP rating codes

The following chart explains each element of an IP rating and provides examples of all possible ratings:



Guide to Ingress Protection (IP) Ratings

DUST (1st Number)		LIQUID (2nd Number)	
Number	Protects Against	Number	Protects Against
0	No protection.	0	No protection.
1	Solid objects over 2"/ 50 mm (e.g. accidental bump from back of hand).	1	Vertically-dripping water.
2	Solid objects over 0.5"/ 12 mm (e.g. fingers).	2	Sprays of water when tilted up to 15º vertically.
3	Solid objects over 2.5 mm (e.g. tools and wires).	3	Sprays of water when tilted up to 60º vertically.
4	Solid objects over 1 mm (e.g. small wires).	4	Water sprayed from all directions—limited ingress permitted.
5	Dust—limited ingress (no harmful deposits).	5	Low pressure jets of water from all directions—limited ingress permitted.
6	Dust—total; no ingress.	6	Strong jets of water from all directions—limited ingress permitted.
		7	Temporary immersion (under 30 minutes) between 6" and 40"/ 15cm and 1m.
		8	Long periods of immersion under pressure.

Figure 3 - Literature Survey, Guide to Ingress Protection Rating

What rating do I need?

CCTV cameras can be broken down into four classifications of environmental resistance. The following table explains the required installation environment for Lorex security cameras:

Classification	IP Rating	Location	Description
Indoor	<44	Indoor	Not intended for submersion in water. Installation in an indoor required.
Weather Resistant	44 - 65	Indoor/ Outdoor under Shelter	Not intended for submersion in water. Installation in a sheltered location required
Weatherproof	66 - 67	Indoor/ Outdoor	Not intended for submersion in water. Installation in a sheltered location recommended.
Submersible	68	Underwater	Full Immersion

NOTE: IP68 submersible cameras are specialized products intended for specific applications (e.g., mounting on a boat). Cameras rated for full submersion will be clearly labelled. Weather resistant and weatherproof cameras are not intended for submersion in water.

1.5 Discussion

Overall in this section we went through various studies that relate with multiple past designs. A brief analysis of the drag in water is discussed as well as a basic analysis of brushless motors in water. Open ROV is also mentioned for one of their simple underwater robotic designs. A brief introduction to the Ingress Protection water proofing coding that we used was also presented.

2. Project Formulation

2.1 Overview

In this section we will be discussing the main objectives, design specifications, main project constraints, as well as our global design focus. We will be designing and building an underwater remotely controlled vehicle that is able to perform successfully within specific environmental conditions while being within competition guidelines and limitations.

2.2 Project Objectives

The main objective in this project is to design and create an underwater remotely controlled vehicle that will swiftly complete the required tasks of the competition in a precise manner. The vehicle will have to complete a variety of tasks some of which are to: be able to visibly inspect pipelines with an accurate image.

2.3 Design Specifications

When designing an ROV one must first consider the operational environment. Factors such as salinity, depth, temperature, visibility, and water dynamics. Salinity is a direct measure of the amount of dissolved salts in the water. While this ROV is expected to operate in only shallow waters one must still take into consideration expected depth and pressures. For each 33 feet of depth water pressure increases by approximately 1 atmosphere. Each compartment that is airtight must maintain that ability at all expected depths. Water conductivity is also an important factor that helps to evaluate water quality conditions used in primarily research related fields.

2.4 Addressing Global Design

When designing any project it is important to take into consideration the scale of global impact and design. Making your project available and easily understood by as many people as possible would be the optimal goal. By having the input voltages/ currents, multi-lingual operating manuals, and a pamphlet indicating the environmental conditions such as temp, salinity, and security of the design, we are able to branch out to many different groups while keeping the content clarity simplistic.

2.5 Constraints and Other Considerations

Some of the obstacles we need to keep into consideration include working in shallow, freezing water conditions. Also we need to keep in mind the difficulty of maneuverability while underwater while keeping all circuitry sealed and out of contact with the water. The competition also entails restrictions to size and power which do not let us exceed a 12 volt power supply and a 25 amp current supply. The vehicle must also be able to maneuver through a 75 cm x 75 cm hole.

3. Design Alternatives

3.1 Overview of Conceptual Designs Developed

In this section, focusing on the proposed designs we examine the proposed designs and narrow them down into the working design. This is an important teamwork oriented brainstorming process that allowed for continual revision of designs as a group in real-time. Each team member brought a different way of thinking and the final design is a reflection of this consolidation of ideas.

All of our designs had similar aspects such as the motors used for propulsion as well as the gripper/ claw that would be used to grab and adjust the necessary objects specified by the competition guidelines. The designs all aim to achieve the same goal which is maneuverability in icy water and the ability to fit into a narrow space. The main differences between each design is with the placement of the motors, fins, and electronic enclosures as well as differing outer frame structures. Some minor features such as lighting and camera placement also change within the design alternatives for the sake of efficiency and balancing.

3.2 Design Alternate 1

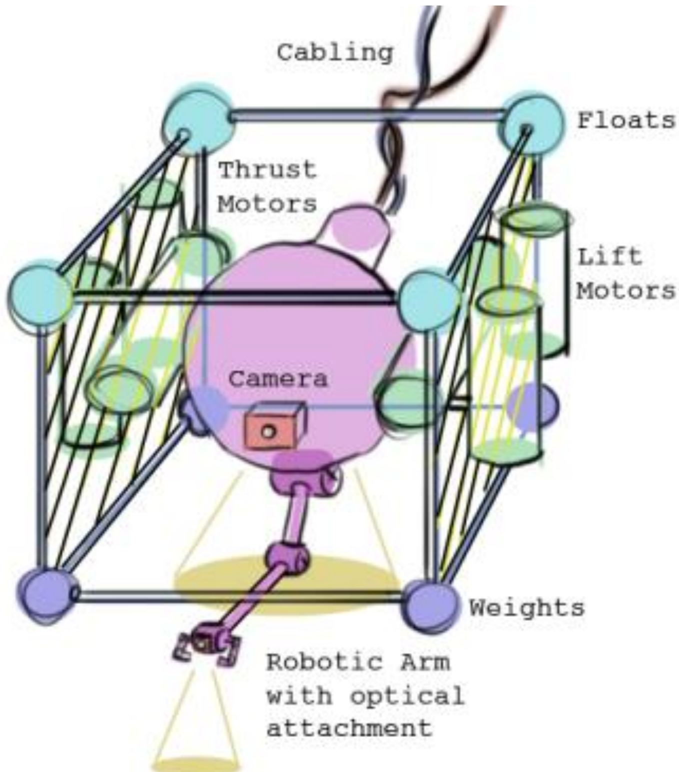


Figure 4 - Conceptual Design, 1

Pictured above is the preliminary design of the ROV. Focusing on 2 forward/reverse thrusters coupled with 4 up/down thrusters situated in a rectangular metal or PVC frame. The frame has a metal grating on it sides to allow for higher structural integrity and easier mounting of propulsion and tools. The thrusters feature reversible propellers to allow for equal operation in opposite directions. In the center is the "brain" of the ROV. Enclosed is all the electronics of the ROV, including its motor control units, telemetry acquisition devices, and camera equipment. Relying on lead shot in the lower parts of the ROV and syntactic foam on the top, the ROV will stay upright and neutrally buoyant in most conditions.

3.3 Design Alternate 2

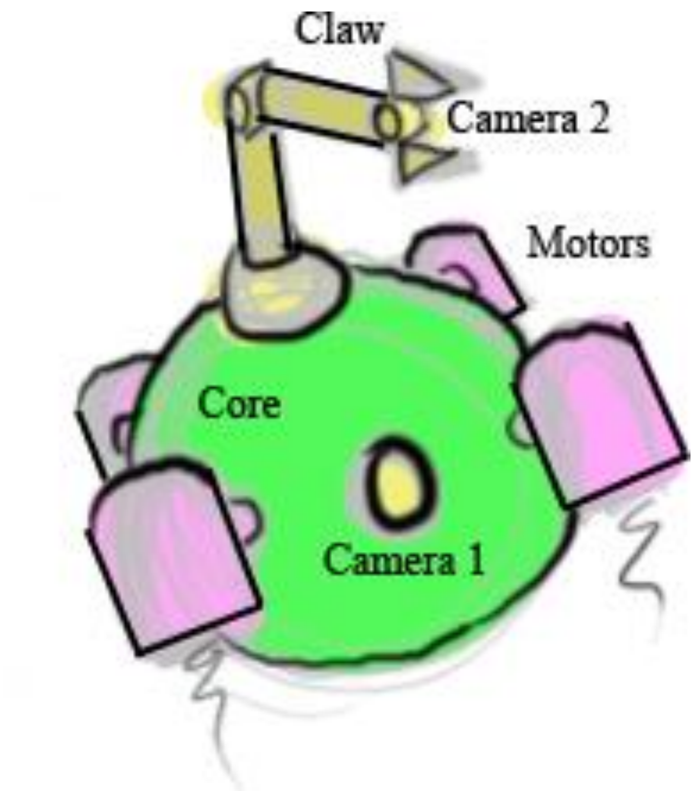


Figure 5 - Conceptual Design 2

Design two of the underwater ROV mimics the structure of a quad-copter. Focusing on 4 main forward/reverse thrusters housed in simple motor enclosures, the thrusters feature reversible propellers to allow for equal operation in opposite directions. In the center is the "brain" of the ROV, which is affixed to each motor enclosure with a small wiring housing tube. Enclosed is all the electronics of the ROV, including its motor control units, telemetry acquisition devices, and camera equipment. Relying on lead shot in the lower parts of the ROV and syntactic foam on the top, the ROV will stay upright and neutrally buoyant in most conditions. With a gyroscopic sensor the ROV will be able to detect, at all times, its yaw, pitch and roll, and potentially self-level so that the plane of action of the ROV is always parallel to the surface plane. This design has the benefit of being able to move in specific lateral directions as well as up and down with minimal driving motors.

3.4 Design Alternate 3

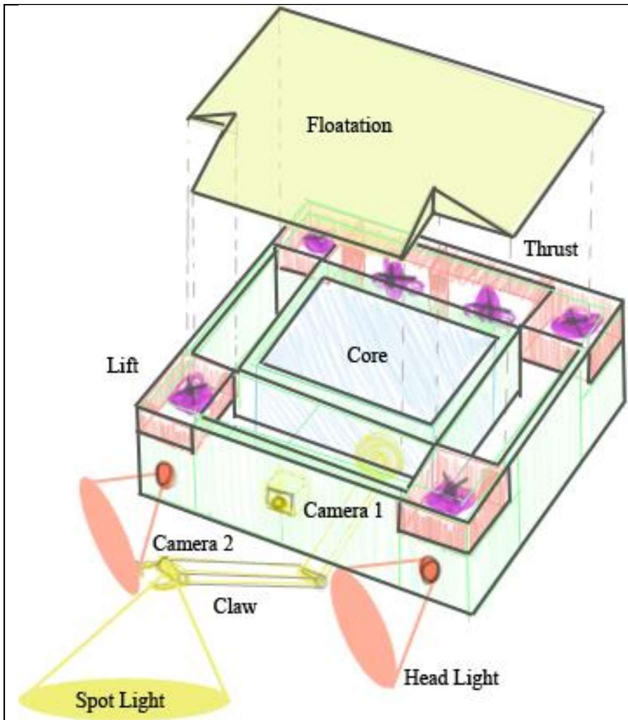


Figure 6 - Conceptual Design, 3

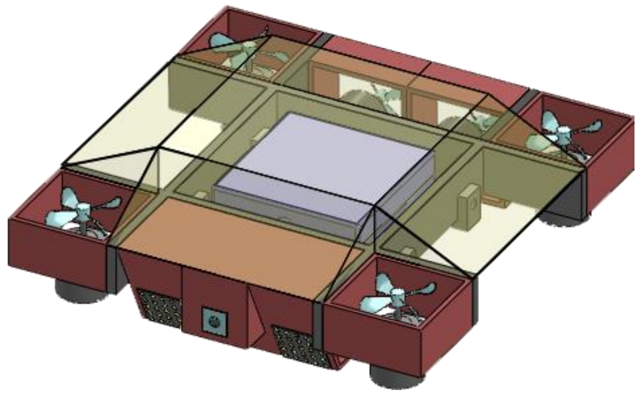


Figure 7 - Conceptual Design, 3 Simulated Model

Pictured above is the most recent design alternative iteration. While similar to some of our design alternates this design allows for a more modular approach to construction, maintenance, and troubleshooting. Centered on a square waterproof housing for the control components and telemetry unit, along with the "brain" of the ROV is a square frame made from aluminum angle. At the four top corners are brushless motors used to control the elevation of the ROV. Slightly more inboard and facing the rear are the two other brushless motors used for forward and reverse propulsion along with yaw capabilities. Additionally, located on the front plane is the main navigational camera. This is a full color wide angle camera that helps for macro scale navigation. Additionally, just under the main camera is a smaller, black and white camera, aimed towards the claw to assist in the finer details of arm manipulation. As with other designs, there will be ballast located on the bottom plane to provide for increased stability, in addition to the floats used along the top plane to ensure that the ROV stays properly oriented through all maneuvers.

3.5 Integration of Global Design Elements

With our current design we have integrated various global design elements. First and foremost is the waterproofing and material selection that allows for differing salinity contents of the water. This allows for operation in more inland countries with only access to freshwater. Additionally, seawater tested materials allow for deployment in harsher environments. Furthering goals of global design, the ROV can be powered, with an appropriate inverter, by various countries' power standards. All documentation will also be provided in multiple languages. Tri-fold operating brochures will be handed out in multiple languages to each participating staff member. We are planning in a future installment to provide a converter for the power source ensuring that URSA can be used regardless of what country you are in.

3.6 Feasibility Assessment

The Marine Advanced Technology Education (MATE) Center is a national partnership of organizations working to improve marine technical education and in this way help to prepare America's future workforce for ocean occupations. The Marine advanced technology education center has been a National Science Foundation (NSF) Advanced Technological Education (ATE) Center of Excellence since 1997. The MATE Competition Network began in 2001 and consists of 24 regional events distributed around the world.

3.7 Proposed Design

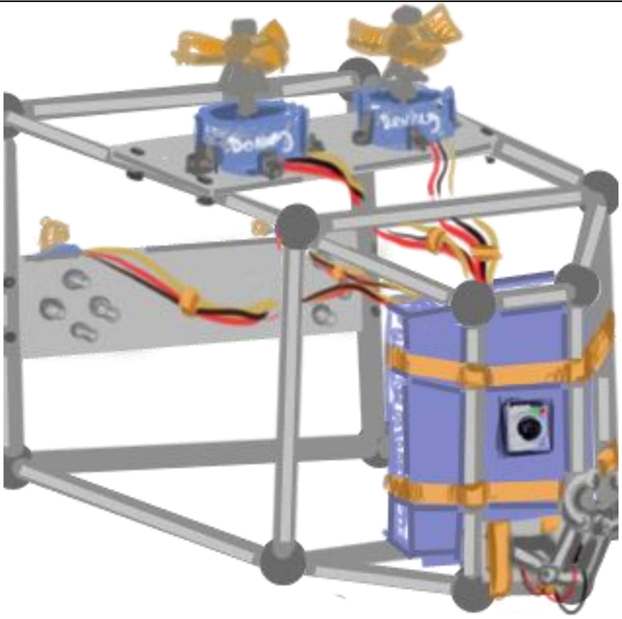


Figure 8 - Proposed Design (Rough without Floats)

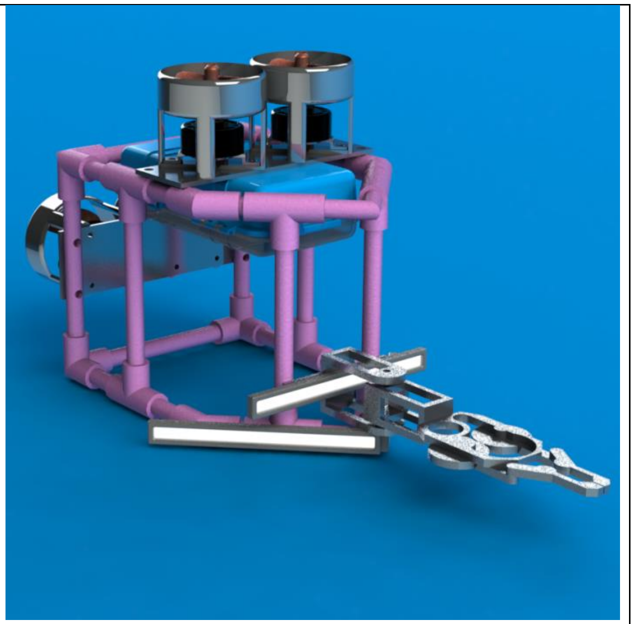


Figure 9 - Proposed Design (Rendered)

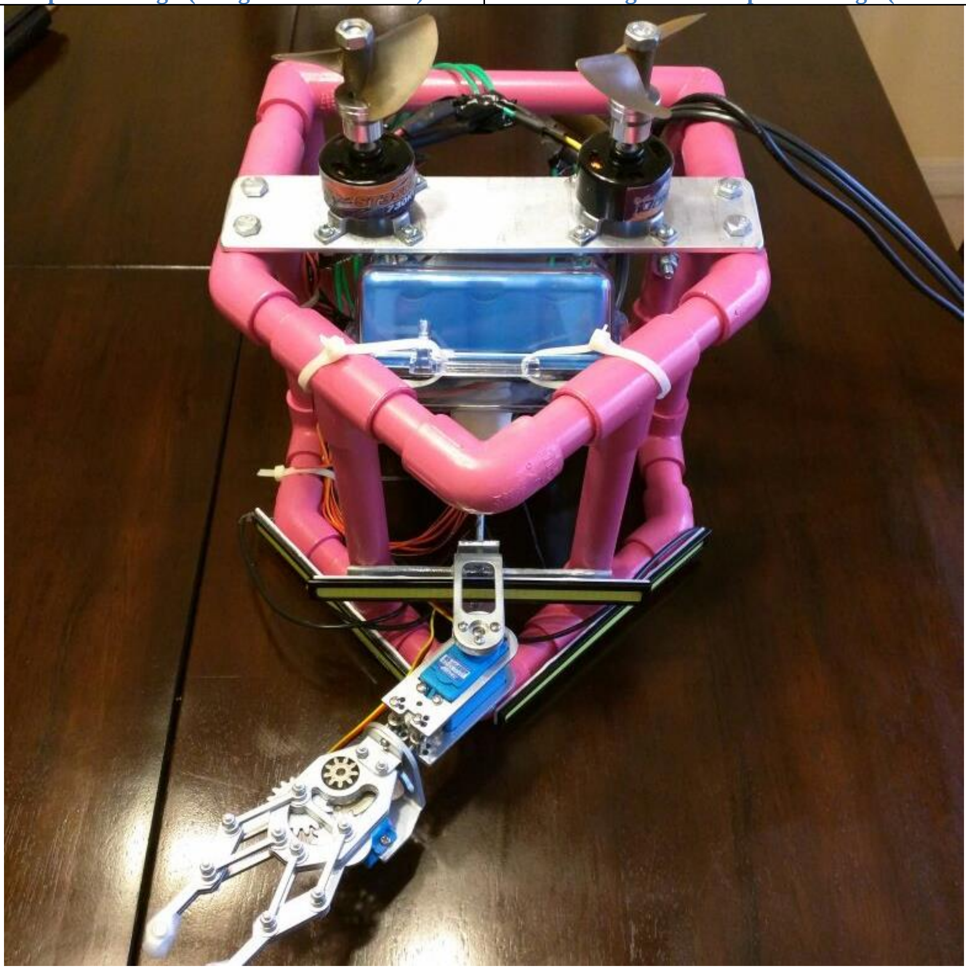


Figure 10 - Proposed Design (Actual)

Pictured previously is the most recent design iteration. While similar to some of our design alternates this design allows for a more solid approach to construction, maintenance, and troubleshooting. The design is centered on a flow-through frame that encapsulates a waterproof dive box for the control components and telemetry unit. At the top sits an aluminum bar with brushless motors affixed, used to control the elevation of the ROV. Mounted on the back in a similar fashion are the two other brushless motors used for forward and reverse propulsion along with yaw capabilities. Additionally, located on the front plane is the main navigational camera. This is a full color wide angle camera that helps for macro scale navigation. The camera is centered in a way to assist the claw in the finer details of arm manipulation. As with other designs, there will be weights located on the bottom plane to provide for increased stability, in addition to the floats used along the top plane to ensure that the ROV stays properly oriented through all maneuvers.

3.8 Discussion

While we started with a spherical waterproof housing where the electronics would be housed, with most of the devices attached directly to the housing, we iterated away from this initial design due to difficulty in obtaining a sufficiently suitable spherical housing. From there, the next iteration was a pod focused design with the motors attached directly to the central pod. Once again, this design was abandoned due to cost and ease of manufacture. Finally, we decided on a more modular rectangular based design with all parts mounted individually. Advantages of this design include cost savings to build and ease of manufacturing and maintenance.

4. Project Management

4.1 Overview

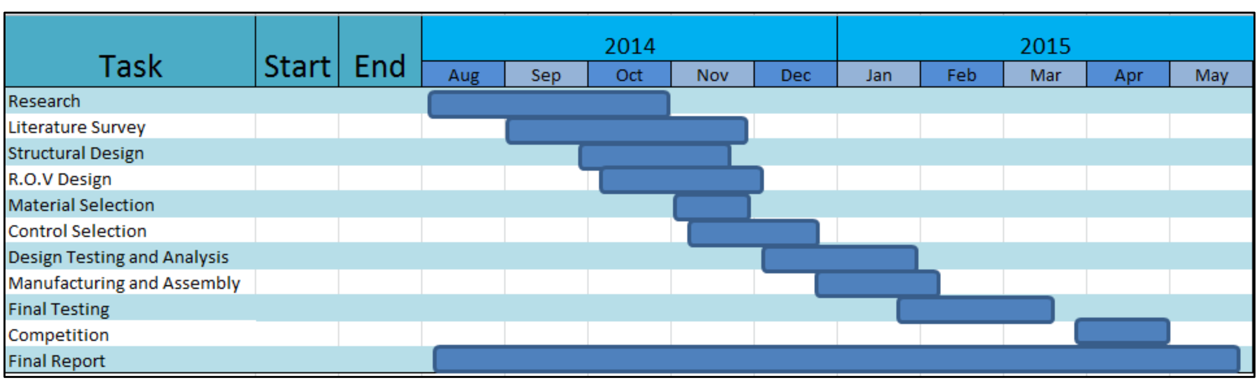
In this section of the report you will be able to see exactly how all the work for the project was delegated amongst the team members. To begin with we split the project itself into individual tasks so that we could equally divide them between all of us. Next we created a Gantt chart to serve as a visual aid for us to keep up with the project due dates and serve as a reminder to stay on pace. Below the Gantt chart is a table that displays what tasks were given to which individual member.

4.2 Breakdown of Work into Specific Tasks

- Research
- Literature Survey
- Structural Design
- ROV Design
- Material Selection
- Control Selection
- Design Testing and Analysis
- Manufacturing and Assembly
- Final Testing
- Competition
- Final Report

4.3 Gantt Chart for the Organization of Work and Timeline

Table 1 - Gantt chart



4.4 Breakdown of Responsibilities among Team Members

Table 2 - Responsibility Breakdown

Topic	*Nikko Miniello*	*Joshua Gonzalez*	*Brandon O'Neill*
Research	**X**	**X**	**X**
Literature Survey	**X**	**X**	**X**
Structural Design	**X**	**XX**	**X**
ROV Design	**X**		**XX**
Material Selection		**XX**	
Control Selection			**XX**
Design Testing and Analysis	**XX**		
Manufacturing and Assembly		**XX**	**X**
Final Testing		**X**	**XX**
Competition	**X**	**X**	**X**
Final Report	**XX**		

A single X indicates work was put in while a double XX indicates that this person contributed the majority to this specific aspect.

4.5 Commercialization of the Final Product

The future goal of this project would be to market to companies that require delicate underwater procedures to be done, such as underwater scavenging, harvesting, or maintenance. Various companies such as NAVSEA, Odyssey Marine Exploration, and Global Marine Exploration would be companies that could benefit from our product development and design. Making the product run as efficiently as possible at a minimal costs is our most prominent consideration.

4.6 Discussion

As you can see in this chapter most of the work we all collaborated on; however, there were some specific tasks individually assigned to team members who we thought were more prominent in that area. At the moment we are not currently seeking a patent on the actual design of our vehicle but are still open to the idea due to the technology we may incorporate. For the future of this product there is a continually growing outreach for underwater remotely operated vehicles to execute tasks ranging from some of the simplest to the more complex.

5. Engineering Design and Analysis

5.1 Overview

Design and analysis of a system are important tasks to accomplish well during any experimental process. In this section a complete analysis will be done of our entire system. The topics of analysis goes as follows: Flow, Stress, Strain, Vibrational, and Displacement, but further analytical iterations may be added when necessary. These following sections will cover our design choices as well as a brief explanation on why our choice was made.

5.2 Kinematic Analysis

The Kinematic Analysis is performed by setting up our frame in a simulated space with an approximate velocity of 20 MPH in the direction of motion. By setting up in this manner we are able to accurately mimic the underwater motion that our system would undergo. The pressure is set to 29 kPa (4.2 psi) which is the pressure of water at 3 meters (9.8 feet). The water is also set to be at ambient temperature.

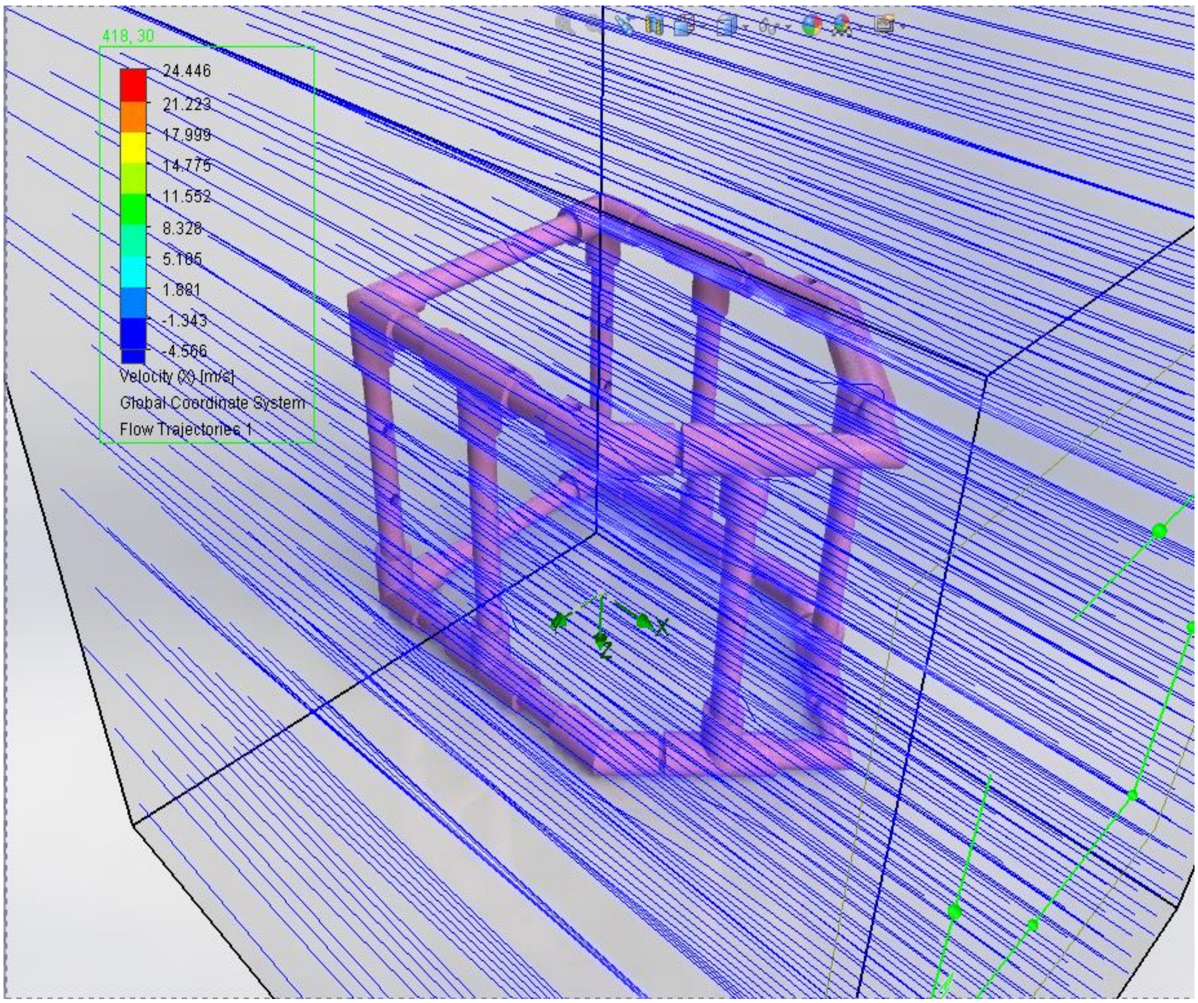


Figure 11 - Flow Analysis, URSA Trajectory Vectors

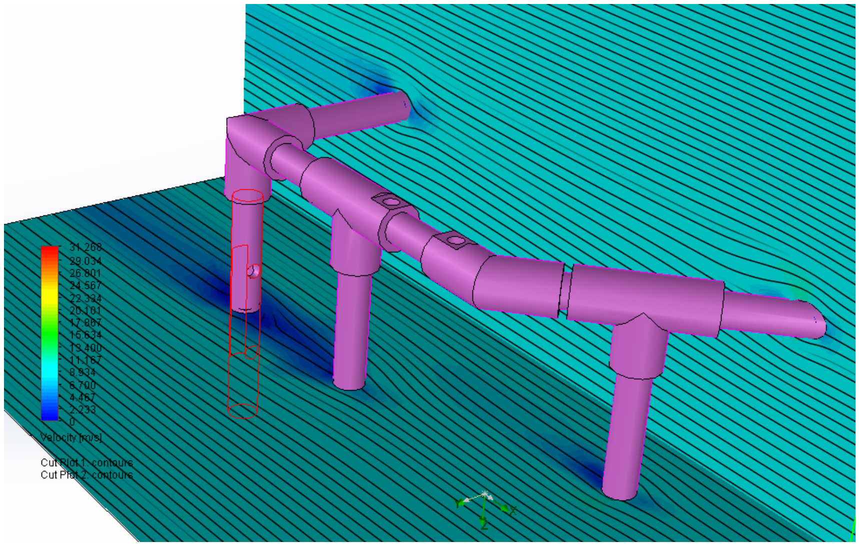


Figure 12 - Flow Analysis, Trajectory Cut Plot

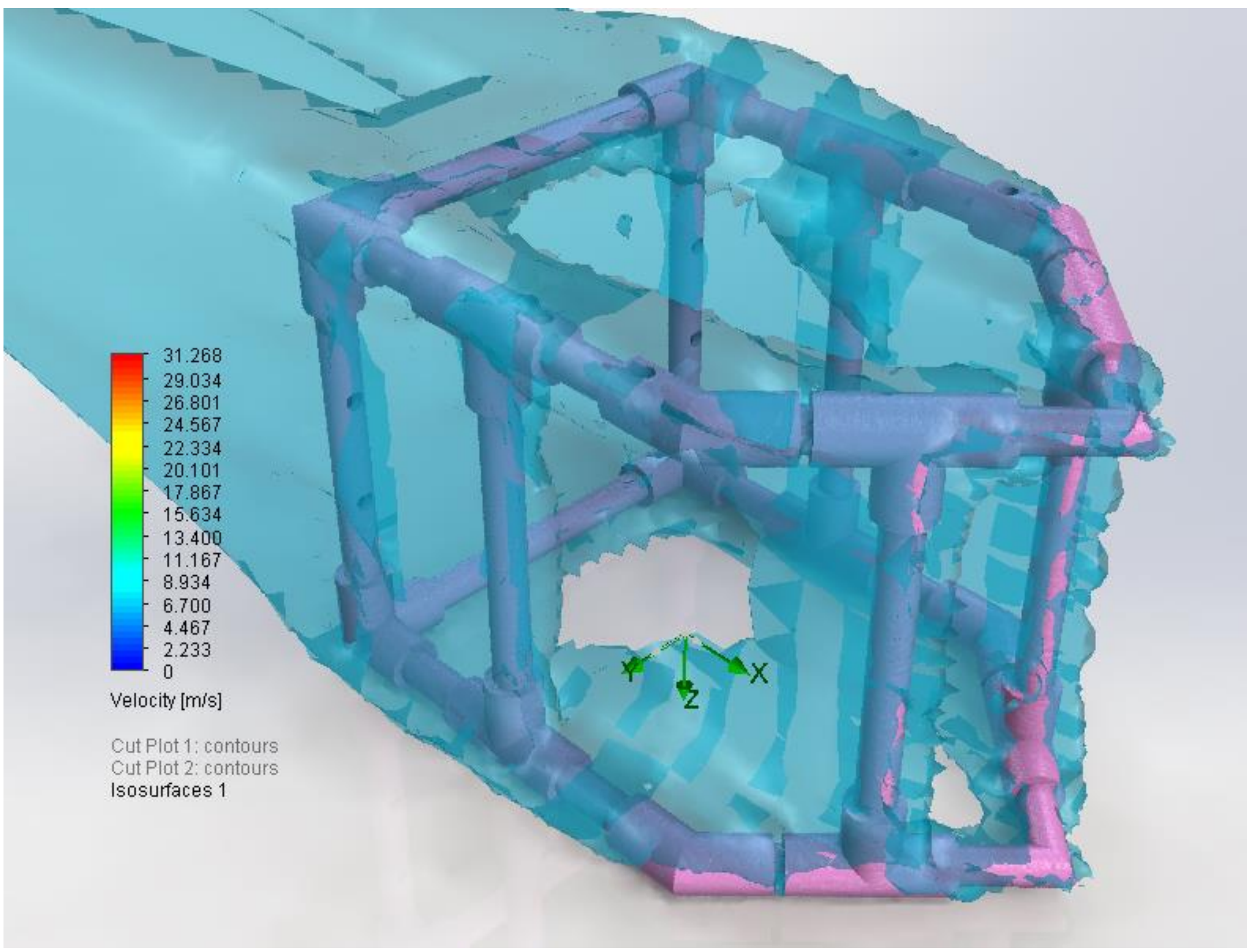


Figure 13 - Flow Analysis, 3D Isosurface Flow

Ambient Conditions

Table 3 - Flow Analysis, Ambient Conditions

Variable	Data	English	SI
Thermodynamic parameters	Static Pressure	4.2 [psi]	29000 [Pa]
	Temperature	68 [F]	293.20 [K]
Velocity parameters	Velocity X	20 [MPH]	9 [m/s]
	Velocity Y	0	
	Velocity Z	0	
Turbulence parameters	Intensity	0.10%	
	Length	0.079 [in]	0.002 [m]

Table 4 - Flow Analysis, Goals

Goals				
Name	**Unit**	**Value**	**Delta**	**Criteria**
SG Normal Force (Y)	[N]	-0.030	0.0278165496	0.0325425218
	[lb-f]	-0.007	0.00625340856	0.00731584931

The goals values come from the upward lift that is generated from the frame having flowing water running through it. As you can see the force is slightly negative which means the object will sink when left alone. The results came out as expected, generating higher pressure zones with a lower velocity around the pipes that come in direct contact with the oncoming flow of the water.

Min/Max Tables

Table 5 - Flow Analysis, Min/ Max Values SI

Name	Minimum	Maximum
Pressure [Pa]	0	188020.87
Temperature [K]	293.16	293.22
Density [kg/m^3]	997.53	997.58
Velocity [m/s]	0	13.993
Velocity (X) [m/s]	-13.220	2.512
Velocity (Y) [m/s]	-9.854	9.852
Velocity (Z) [m/s]	-9.413	9.448
Temperature (Fluid) [K]	293.16	293.22
Vorticity [1/s]	0.257	9603.175
Shear Stress [Pa]	0	159020.87
Relative Pressure [Pa]	0	352567.11

Table 6 - Flow Analysis, Min/ Max Values English

Name	Minimum	Maximum
Pressure [lbf/in^2]	0	27.27012
Temperature [°F]	68.02	68.13
Density [lb/in^3]	0.036039	0.036040
Velocity [in/s]	0	550.92
Velocity (X) [in/s]	-520.45	98.90
Velocity (Y) [in/s]	-387.95	387.89
Velocity (Z) [in/s]	-370.60	371.95
Temperature (Fluid) [°F]	68.02	68.13
Vorticity [1/s]	0.257	9603.175
Shear Stress [lbf/in^2]	0	0.11379
Relative Pressure [lbf/in^2]	0	23.06403

In order to properly obtain the drag coefficient of our simulated model, we first had to remove the back section of the assembly, effectively disjointing the front portion of the assembly in order to get the frontal surface area. By doing this and then using the build in mass evaluation feature of SolidWorks2013, we were able to properly find the surface area of 259.75 square Inches.

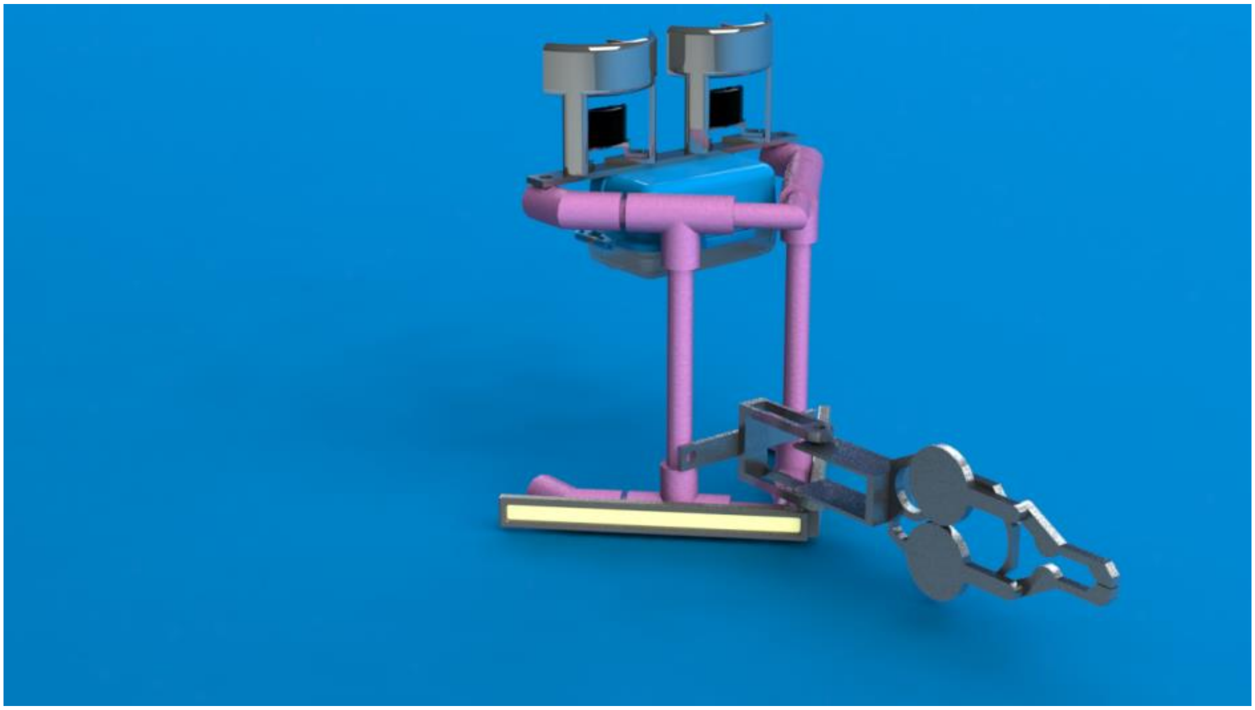


Figure 14 - Flow Analysis, Rendered Assembled Front Section

$$F_D = \frac{1}{2} * \rho * v^2 * C_D * A$$

Equation 1 - Drag Force

$$C_D = \{GG\ Force\ (X)1\} * \frac{2}{1000 * (9^2) * (.17)}$$

$$C_{Davg} = 0.11$$

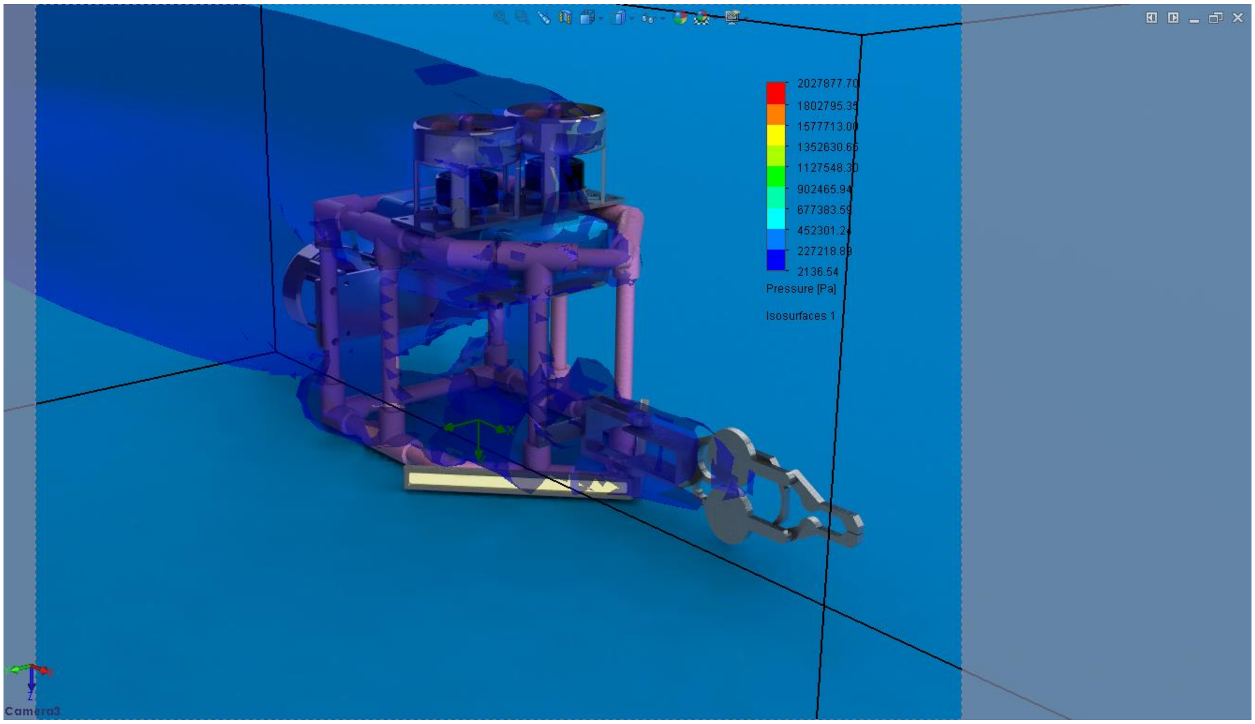


Figure 15 - Flow Analysis, Assembled Isosurface

These figures show the flow of water around the frame and inner pieces of the assembly. As you can see the design is very flow-through and allows for a very small average drag coefficient of 0.11. the claw pointing outwards also assists with breaking the tention of the water in front of the path that the ROV travels. As you can see the water wraps tightly around the claws base and is mainly resisted by the shrouds which are affixed ontop of the frame. Following we have a top and side view of the velocity profiles of the flow in the water. The water is set to be approximately 20 MPH simulating around the expected top speed of our final version of URSA.

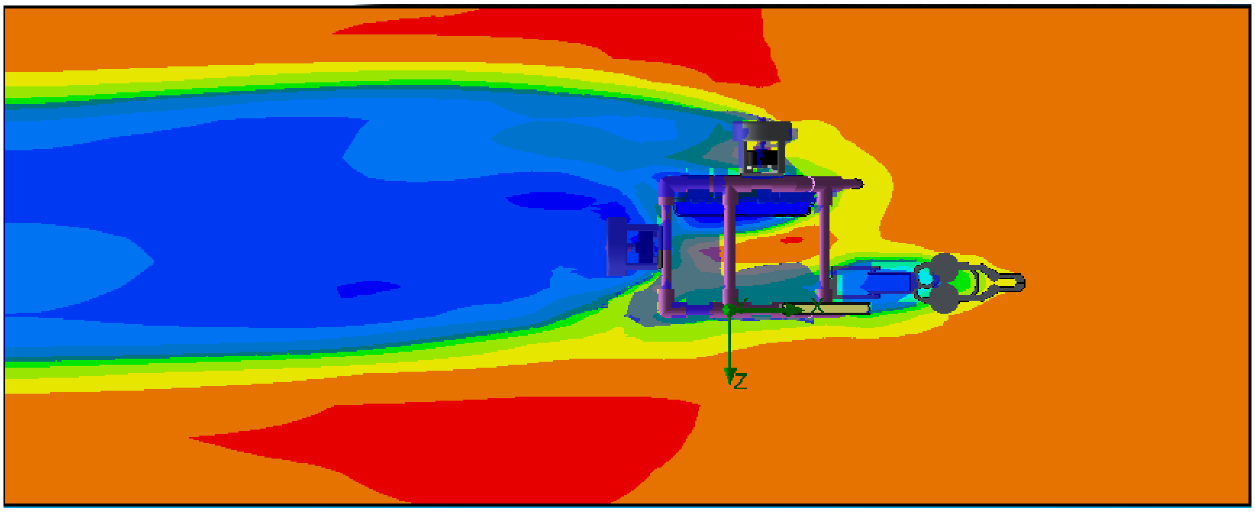


Figure 16 - Flow Analysis, Cut Plot Side View

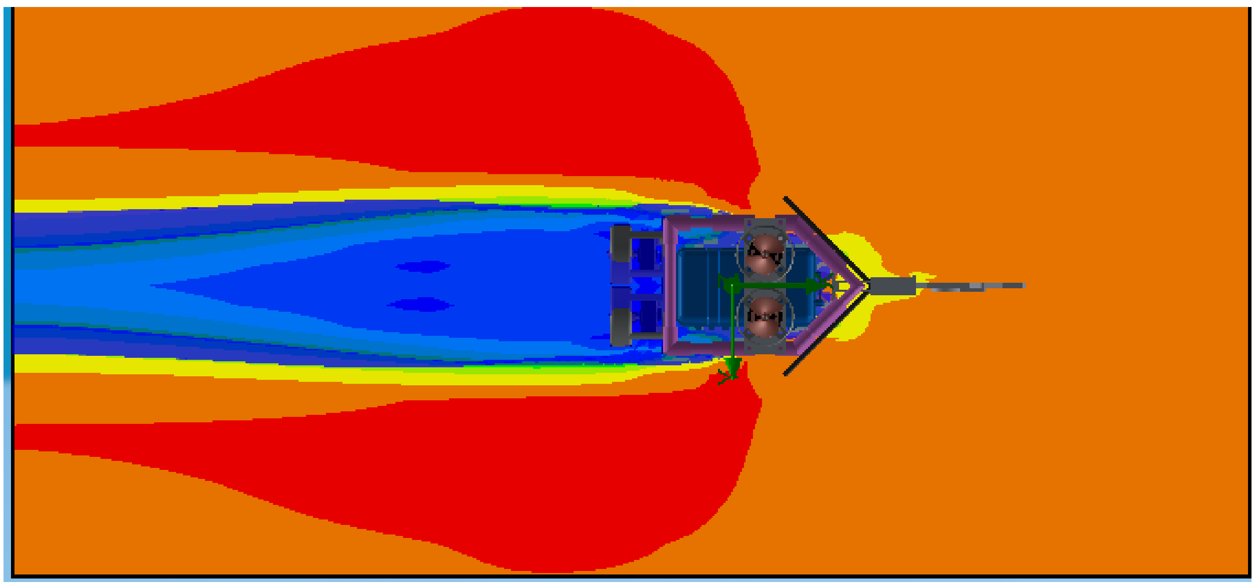


Figure 17 - Flow Analysis, Cut Plot Top View

5.3 Dynamic/ Vibration Analysis of the System

Overview

Due to the high rotational speed of our motors (720kV) a large amount of vibration is produced. The oscillation caused by the motor as well as by the thrust generated by the propeller is observed to be a critical aspect that we need to consider within our design. Ensuring that the system will not fail under vibrational load, as well as ensuring that the systems supports will not come undone during operation are two key factors that we have accounted for in our design.

Pelican Micro 1060

The premise of absorbing or dampening the produced vibrations was accomplished by affixing our electronic components to a, "Thermal Plastic Rubber Liner" that comes standard with the Pelican Micro 1060 series dive box. This in turn doesn't diminish the amount of vibrations produced from the motors, but lessens the impact upon our electronic components.

Aluminum Mounting Bar

The second step we took to limit the amount of vibrations that impact our apparatus was to affix the motors to aluminum mounting bars. Aluminum has relatively good vibrational damping factor as well as a reliable strength to weight ratio; which overall when compared to its cost make for the optimal choice for our specific purpose. We used four ¼ inch bolts per aluminum mounting bar to provide an even and distributed surface fixture to the frame. Each of the bolts were individually coated with a later of LOCTITE® THREADLOCKER BLUE 242® which prevents loosening of metal fasteners caused by vibrations and is removable if necessary. An additional layer of marine grade sealant was also applied to the screw joint itself to prevent any water from washing away the Loctite.

Motor Screws

As stated previously our motors generate a significant amount of vibrational load; the vibration was observed to be sufficient enough to rattle the nuts loose from the screws if left unattended. By using washers and Loctite for each screw holding the motors legs to the surface of the aluminum mounting bar we were able to tightly fashion a secure grip in which prevented the screws from coming undone. Since the propellers are threaded to the collet, it was necessary to apply a liberal coating of Loctite to the threaded surface and to the nut that locks the propeller to the motor shaft.

Discussion

The process of minimalizing the impact of the vibrations on the system is a fundamentally essential design consideration. Limiting the vibrational impacts has both a safety and functionality purpose to it. Our foresight on this aspect of our design has helped to save us a lot of potential headache and concerns.

5.4 Structural Design

Overview

The structural design of our MATE ROV has undergone a multitude of changes as our project progressed. The main fluctuation was between a flow-through square design and a more modular approach that relied on mounting all corresponding components to the main circuit box as well as a flat, mounting, base panel. We settled on the flow-through square design with minor modifications to the front panel because that design had the best fluid dynamics as well as simplicity and ease of construction.

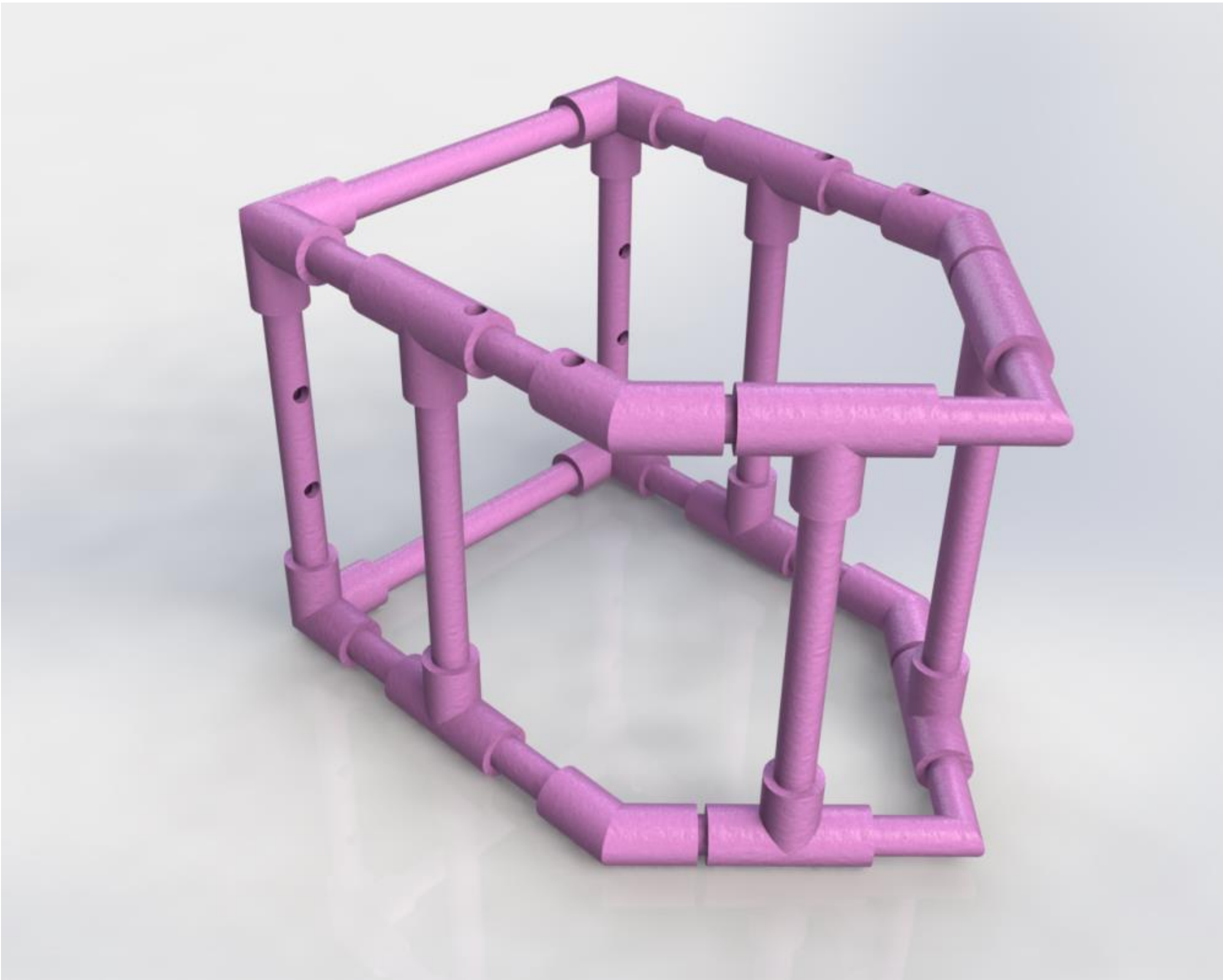


Figure 18 - Structural, Rendered PVC Frame

Water Proofing

Without a doubt the most complex and important design consideration when constructing any underwater apparatus is the water proofing. Since we have multiple electronic devices that need to be housed internally we had to look into specific enclosures that were capable of withstanding water at a specified depth. Ideally we wanted to find something that was rated to IP68, but the cost goes upward from $200 for any sort of prefabricated device of that grade.

The first thing we did was take a trip to Divers Direct to see what kind of a possible product we could purchase or reproduce. Upon detailed research we were able to determine that the Pelican Micro 1060 Diving Box rated to IP67 would be sufficient for the prototyping purposes that we required it for. The only issue with this enclosure was that it did not have an entry port for cabling.

Since a water tight entry tube was required for our design, we immediately discussed using a threaded tube with a hex nut on each end. After ample design discussion this was clearly the most simplistic and effective method possible. We tapped a ¾ inch hole into the top of the pelican box, which we determined to be an adequate size which would not damage the integrity of the box itself. The threaded tube was put into place with a layer of PTFE tape wrapped tightly around the diameter of the tube. The tube was put into place with a marine grade sealant and tightly secured at both ends of the lid so that the sealant could properly permeate both surfaces providing optimal coating and preventing any air bubbles that may have persisted. As you can see from *figures 19-23* the design is quite simplistic and allows for a cluster of cables to be tightly packed within its inner diameter.

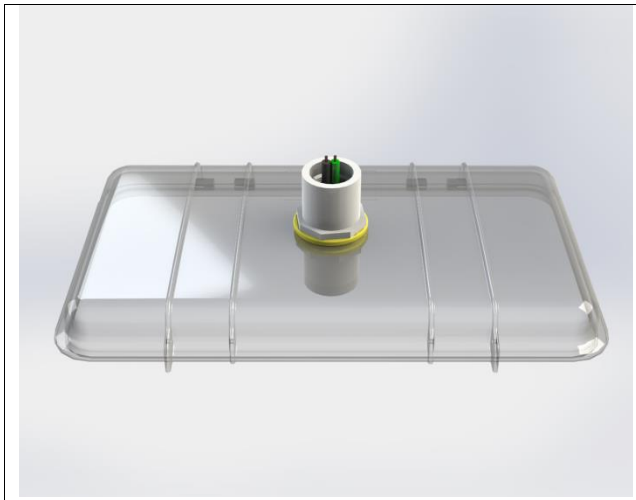


Figure 19 - Structural, Wire Entry Simulation (Top View)

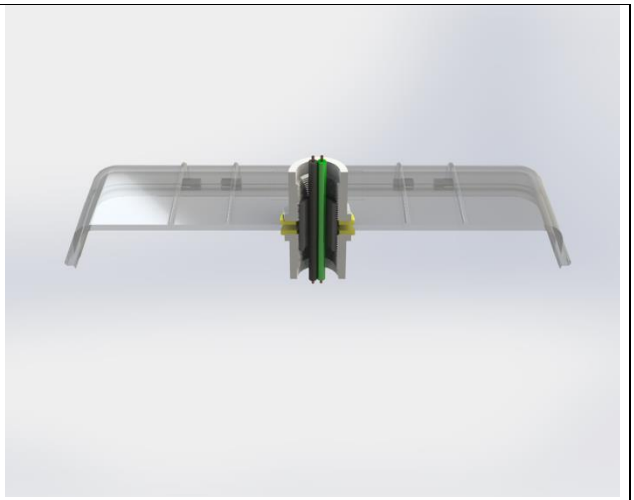


Figure 20 - Structural, Wire Entry Simulation (Top View - Sectional)

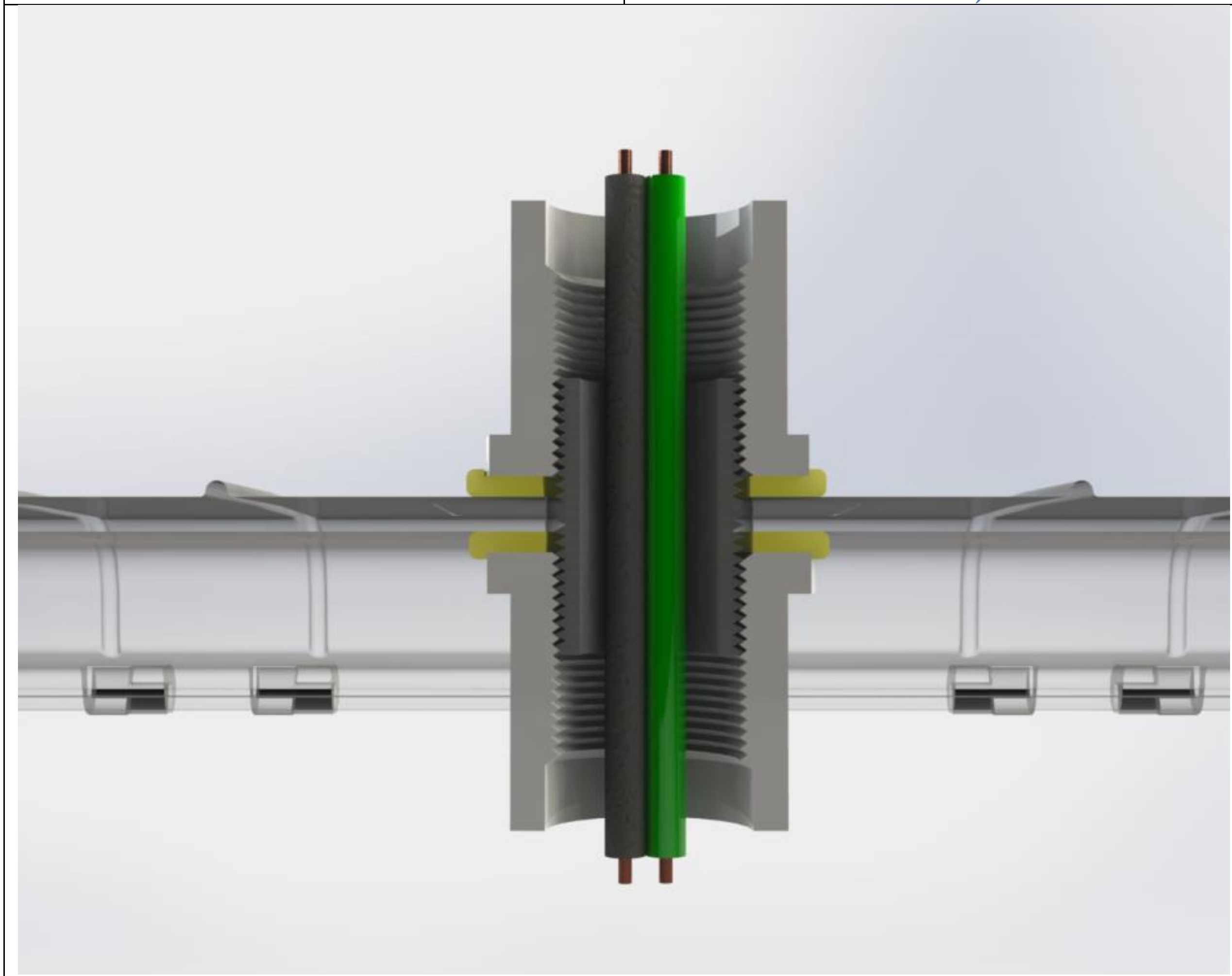


Figure 21 - Structural, Wire Entry Simulation (Close up - Sectional)

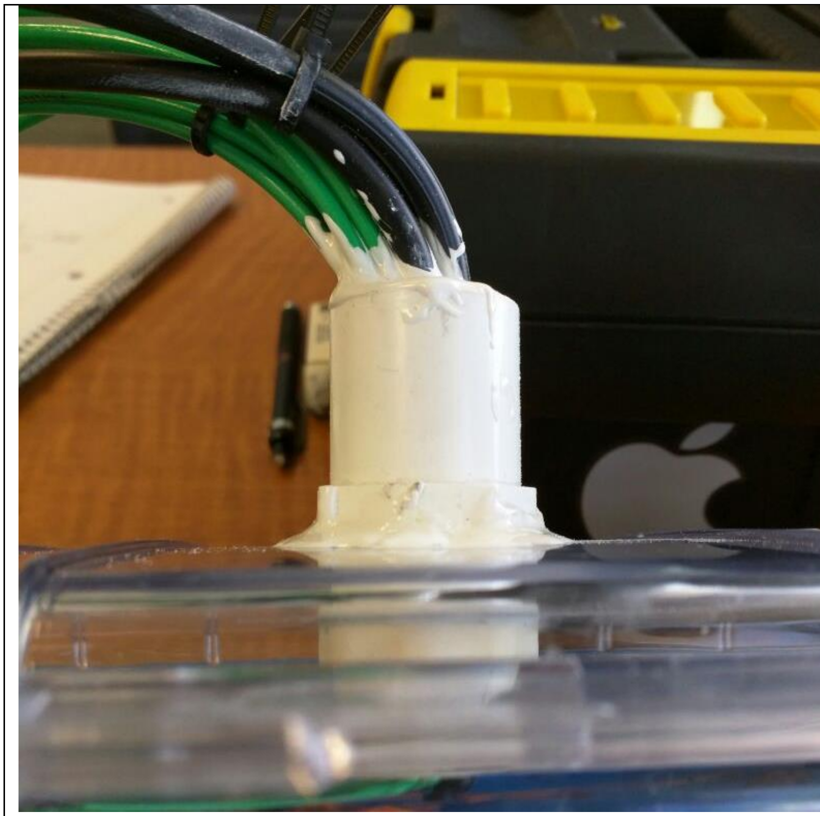


Figure 22 - Structural, Wire Entry

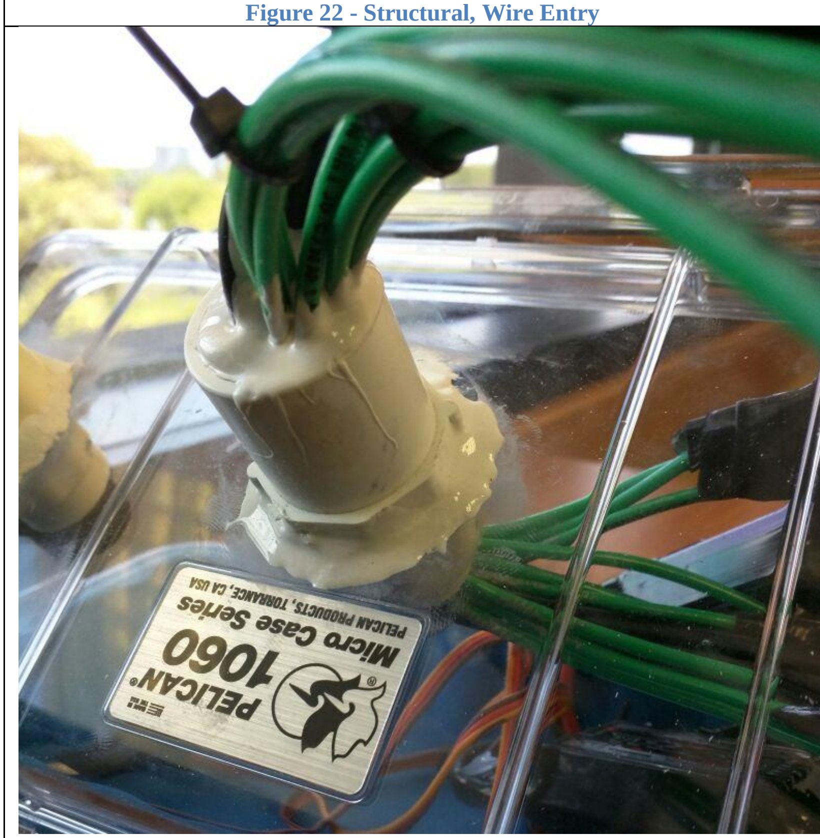


Figure 23 - Structural, Wire Entry (Angled View)

5.5 Force Analysis

Overview

The structure has been modeled as a solid body as to avoid contact errors within our simulation program. By fixing the opposite end as to where the force is applied to, we were able to properly indicate the reflected force upon the structure. First by simulating the mounting bar that the motors will be mounted on and then applying a point load upon the point of contact of 5 lb.-f (Which is beyond the indicated force of the motors, 1200g), we are able to properly see if the beam itself would be able to withstand the motors driving force under maximum conditions. After ensuring that the beam could withstand these conditions we subject the frame that the beam would be mounted to, to the same conditions. This ensures that our frame can even withstand the potential, maximum force that the beam could exert from the motors. With this data we also calculate the factor of safety to make sure our system is well beyond the safety margin, before we actually would physically test this.

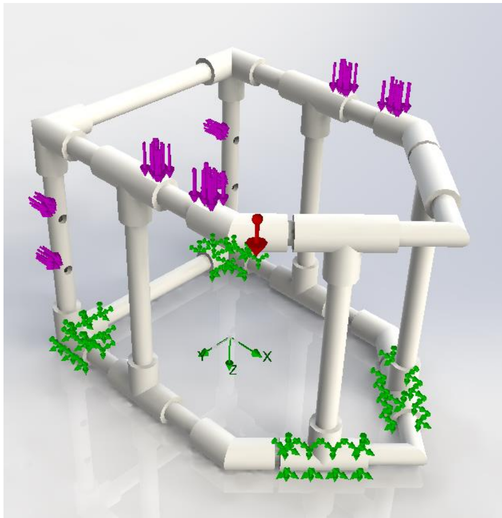
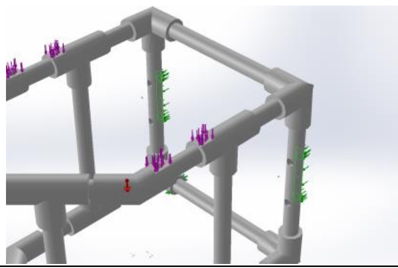
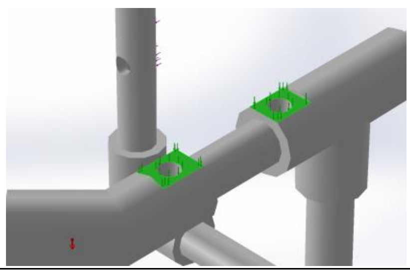
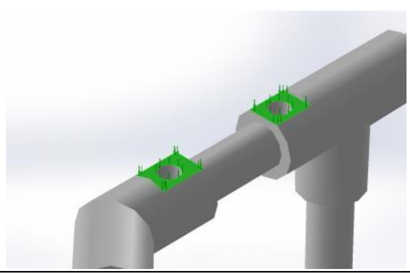
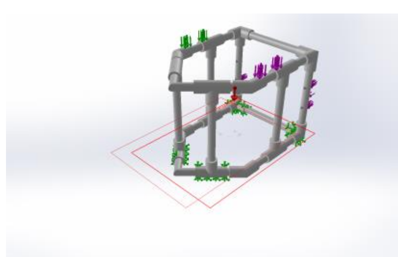


Figure 24 - Simulation, Model Information

Table 7 - Loads and Fixtures

Resultant Forces				
Components	**X**	**Y**	**Z**	**Resultant**
Reaction Force [lbf]	-9.97681	0.00530925	-10.7786	14.6873
Reaction Force [N]	-44.3791	0.0236167	-47.9457	65.3322

Load Name	Load Image	Load Details
Force-1		5 [lbf]
		22.24 [N]
Force-2		5 [lbf]
		22.24 [N]
Force-3		5 [lbf]
		22.24 [N]
Gravity-1		386.22 [in/s^2]
		9.81 [N]

Discussion

From the 5 lb-f point loads that are applied on each of the joints between the aluminum mounting bar and the frame a resultant force of 14.7 lb-f (65 N) is generated. Due to the solid construction of our frame we believe that we would have no problem withstanding that applied load, which is discussed in the following sections.

5.6 Stress Analysis

Overview

From the point loads described in the previous section increased stresses and strains in the frame and its joints are created. By using the built in stress/ strain analysis of SolidWorks which using the Von Mises Stress theory as well as the Equivalent Strain to calculate the minimum and maximum stress/ strain values throughout the system.

Table 8 - Stress Table

Stress			
Name	**Type**	**Min**	**Max**
Stress	VON: von Mises Stress	0.000827975 [psi]	619.654 [psi]
		5.70869 [N/m^2]	4.27237e+006 [N/m^2]

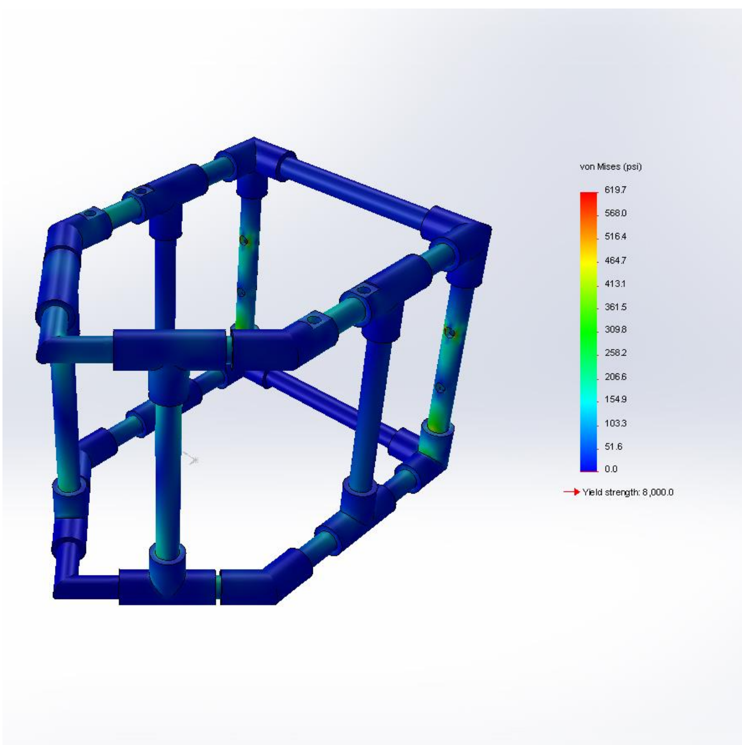


Figure 25 - Simulation, Stress Analysis

Table 9 - Strain Table

Strain			
Name	**Type**	**Min**	**Max**
Strain	ESTRN: Equivalent Strain	4.16807e-009	0.00125933

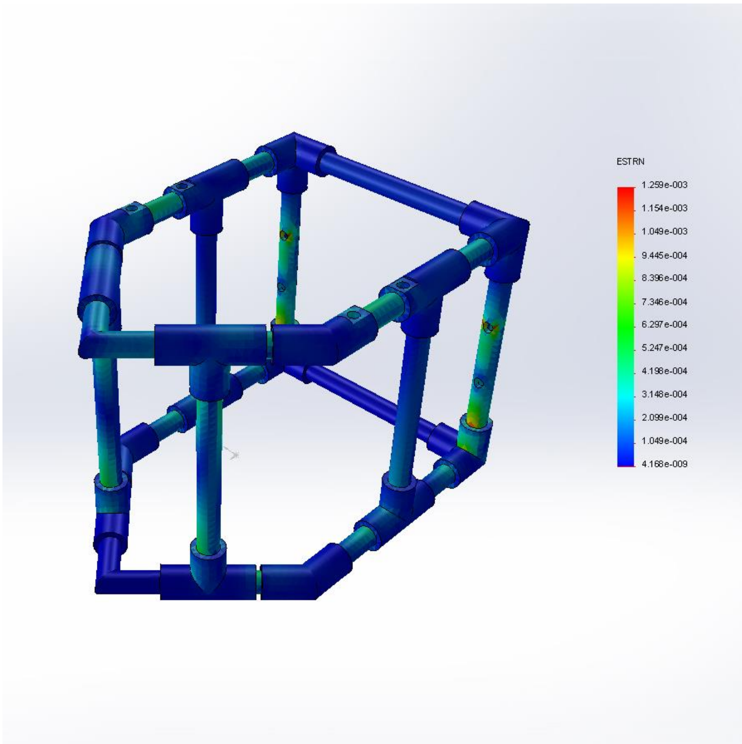


Figure 26 - Simulation, Strain Analysis

Discussion

Similar to the method we used for the Force Analysis section, we also simulated a solid body as reference to the frame. From the data gathered from a continuous load on the structure a stress and strain analysis was performed. A max value of 620 psi and 0.00125933 were produced from the resulting calculations.

5.7 Material Selection

As seen in our design selection we went with a rectangular design so we wanted a material that would prove to be sustainable, easy to manipulate, and cost effective at the same time. Initially we all decided to begin with 0.5’’ PVC pipes. This material was extremely cost effective and readily available; which, allowed us to constantly improve on the design as we worked. PVC was chosen as a temporary measure; however, the material has proven itself to be structurally adequate for the purpose of what we needed.

Table 10 - Volumetric Properties

Volumetric Properties	English	SI
Mass	0.823555 [lb]	0.373558 [kg]
Volume	22.3489 [in^3]	0.000366234 [m^3]
Density	0.0368498 [lb/in^3]	1020 [kg/m^3]
Weight	0.822997 [lbf]	3.66087 [N]

Table 11 - Material Properties

Material Properties	English	SI
Name	PVC	
Model type	Linear Elastic Isotropic	
Default failure criterion	Max von Mises Stress	
Yield strength	8000 [psi]	5.51581e+007 [N/m^2]
Tensile strength	4351.13 [psi]	3e+007 [N/m^2]
Elastic modulus	290075 [psi]	2e+009 [N/m^2]
Poisson's ratio	0.394	
Mass density	0.0368498 [lb/in^3]	1020 [kg/m^3]
Shear modulus	46252.5 [psi]	3.189e+008 [N/m^2]

5.8 Design Based on Static and Fatigue Failure Design Theories

Overview

The factor of safety was also calculated when running the analysis of the system. This is the overall best approach for approximating whether or not our design is able to withstand the maximum allotted force that it can be subjected to.

Table 12 - Factor of Safety Table

Strain			
Name	**Type**	**Min**	**Max**
Factor of Safety	Automatic	12.9104	9.66213e+006

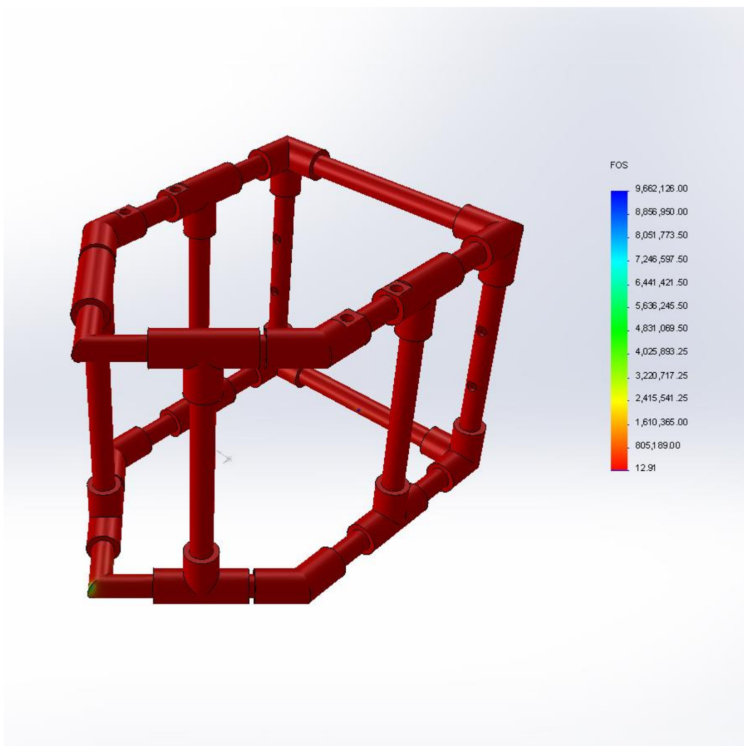


Figure 27 - Simulation, Factor of Safety Analysis

Discussion

In order to be perfectly safe when designing our frame, the minimum factor of safety is the important value to assess. The simulation produced a value of 12 for our safety factor which we believe to be more than required for our design; this number is taking into account for load much higher than what we expect to experience.

5.9 Deflection Analysis

Overview

Just as the load and stress analysis that were done, the deflection analysis was also generated using the same simulation parameters. With this test we will be able to note if the apparatus will deflect beyond safe operating conditions.

Table 13 - Deflection Table

Strain			
Name	**Type**	**Min**	**Max**
Strain	URES: Resultant Displacement	0 [in]	0.0128933 [in]
		0 [cm]	0.0327489 [cm]

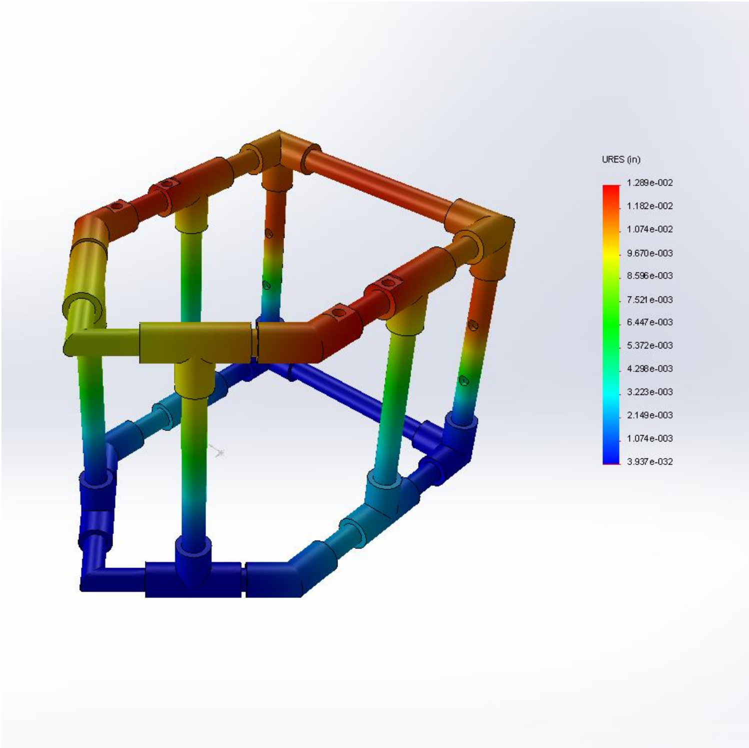


Figure 28 - Simulation, Deflection Analysis

Discussion

Again in order to test for the optimal conditions of the frames safe operation, the maximum value of the deflection will be the number that is important. While most of the solid body is practically unaffected by the force load, the maximum observed deflection of the frame is approximately 0.013 in.

5.10 Component Design/ Selection

Devices

Figure 29 - Component, Xbox 360 Control

Figure 30 - Component, Xbox 360 Wireless Receiver

Figure 31 - Component, Robotic Claw - MKII

Figure 32 - Component, Robotic Claw Pan/Tilt Bracket - MKII

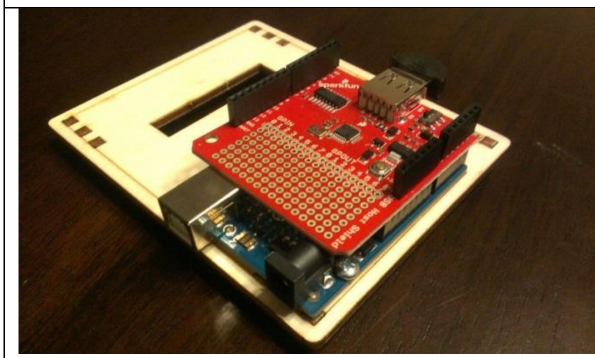


Figure 33 - Component, Arduino UNO

Figure 34 - Component, GoPro Hero 3

Functionality

Figure 35 - Component, HobbyKing Donkey ST3508 730KV Brushless DC Motor

Figure 36 - Component, Octura X470 1.4 Dia. Beryllium Copper Propeller

Figure 37 - Component, HS-5086WP Metal Gear, Micro Digital Waterproof Servo

Figure 38 - Component, HS-5086WP Metal Gear, Micro Digital Waterproof Servo

Figure 39 - Component, HobbyKing Brushless Car ESC 100A

Figure 40 - Component, Astra Depot Aluminum High Powered 6W 6000k Xenon White LED

Finishing Products

Figure 41 - Component, Loctite Threadlocker blue 242

Figure 42 - Component, 3M™ Marine Adhesive Sealant 5200 Fast Cure

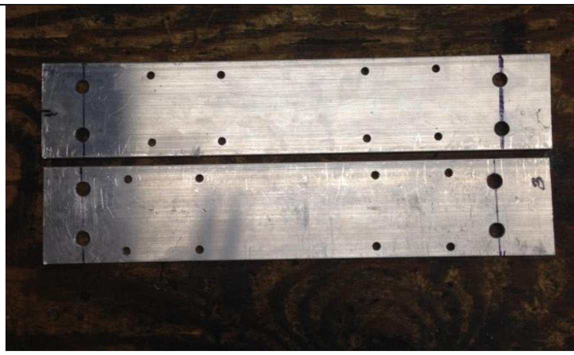
Figure 43 - Component, JB Weld WaterWeld Epoxy Putty

Figure 44 - Component, Scotch Outdoor Mounting Tape

Figure 45 - BenzOMatic Solder Core Rosin

Figure 46 - Component, Assorted Shrink Wrap

Misc

 Figure 47 - Everbilt Flat Bar Aluminum	 Figure 48 - Component, Hex Bolt (1/4 in x 1-1/2 in)
 Figure 49 - Component, Everbilt Zinc Machine Screws Round Head Combo #8-32x1-1/2 inch	 Figure 50 - Component, Everbilt Zinc Machine Screws Round Head Combo #8-32x1-3/4 inch
 Figure 51 – Component, Southwire Landscape Wire	 Figure 52 - Component, Cerrowire Appliance Wiring

5.11 Finite Element Analysis

Overview

Mesh Details	
Mesh type	Solid Mesh
Mesher Used:	Curvature based mesh
Jacobian points	4 Points
Maximum element size	0 [in]
Minimum element size	0 [in]
Mesh Quality	High
Total Nodes	95008
Total Elements	54561
Maximum Aspect Ratio	8.5054
% of elements with Aspect Ratio < 3	99.2
% of elements with Aspect Ratio > 10	0
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:16
Computer name:	NIKKO-PC

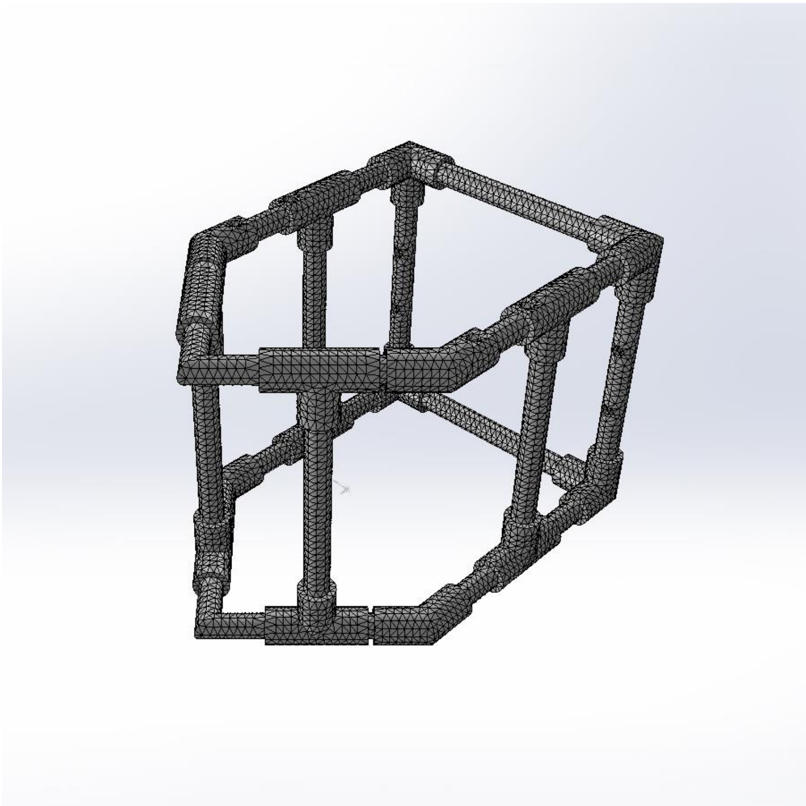


Figure 53 - Simulation, Mesh

5.12 Design Overview

The structural design of our MATE ROV consists of a flow-through hollow frame design which incorporates aluminum mounting bars which the 2-DOF manipulator arm as well as the Pelican Diving Box are affixed to. The structure has been modeled as a solid body made out of PVC to avoid contact errors within our simulation program, although the pipes are still hollow. By fixing the opposite end as to where the force is applied to, we were able to properly indicate the reflected force upon the structure. First by simulating the mounting bar that the motors will be mounted on and then applying a point load upon the point of contact of 5 lb-f a good approximation of the systems operating conditions can be determined. An overall factor of safety of 3 for the system was observed indicating that our design was a success and can withstand more than what our motors produce.

5.14 Cost Analysis

Table 14 - Cost Analysis

Part	Cost	Donated
Power		
Computer Power Supply 12V	$30	
HobbyKing Donkey ST3508 730KV Brushless DC Motor	$40	
Control		
HobbyKing® ™ Brushless Car ESC 100A w/ Reverse (Upgrade version)	$111	
HS-5086WP Metal Gear, Micro Digital Waterproof Servo	$43	
HS-5646WP High Voltage, High Torque, Programmable Digital Waterproof Servo	$42	
Microsoft Xbox 360 Wireless Controller	$60	X
Arduino UNO Kit	$50	X
Maneuverability		
Octura X470 1.4 Dia Beryllium Copper Propeller	$80	
Functionality		
PVC Piping	$130	X
GoPro Hero 3 /W Underwater Enclosure	$200	X
Robotic Manipulator Assembly (No Servo)	$70	
Propeller Adapter to suit 5.0 mm motor Suit (Collet)	$20	
Microsoft Xbox 360 Wireless Receiver for Windows	$15	X
Pelican Micro 1060 Underwater Diving Box	$28	
Astra Depot Aluminum High Powered 6W 6000k Xenon White LED	$12	

Part	Cost	Donated
Miscellaneous		
Everbilt Flat Bar Aluminum (2 in x 1/8 in x 36 in)	$11	
Everbilt Zinc Machine Screws Round Head Combo #8-32x1-1/2 inch (6pk)	$6	
Everbilt Zinc Machine Screws Round Head Combo #8-32x1-3/4 inch (8pk)	$1	
Hex Bolt (1/4 in x 1-1/2 in)	$2	
Hex Nut Zinc (1/4 in)	50¢	
Southwire Low Voltage Landscape Wire Black Stranded RoHS Compliant 14/2 (50 ft)	$22	
Cerrowire Appliance Wiring Rated T90 Nylon 105 Degrees C (50 ft)	$10	
Heat Shrink Tubing Assorted Pack (150 pcs)	$7	
BernzOmatic Electric Solder Lead-Free Rosin Core (3 oz)	$7	
3M Marine Adhesive Sealant 5200 (3 fl oz)	$8	
Scotch Outdoor Mounting Tape (1.66 YD)	$5	
JB WATERWELD EPOXY PUTTY (2 oz)	$8	

5.15 Discussion

At this moment the total amount we would spent on our current parts list is right around $1020. We were looking for alternatives to reduce the cost without affecting the quality. This is one of the features we want to iterate on that separate us from previous models. We were budgeted initially to spend right around $600-$700 so we planned to reduce our overall cost anywhere from $150-$250 in order to meet our goal. We are seeking to implement a design that can perform just as well or better than other models but at a fraction of the price. Some of the more expensive components were donated to us from either close friends or small business owners, effectively reducing our planned spending to approximately $488. This is a good range for us since we are self-funded and have no specific sponsors to our name. We also ordered additional parts for trial and error, these specific components are not included in the cost analysis, but the total amount comes out to approximately $150. Our cost analysis doesn't include taxes and shipping; with those added expenses the total cost should come out to be around $1200.

We overshot out budget quite a bit from our initial assumption. This price doesn't even include our trial and error purchases which we did not use in our final design. The reason for such a large oversight was because we didn't account for all the minor fixings and sealants that would end up coming out to a few hundred dollars in the end. We feel that the initial goal of around $600 is still possible if all of the research and trial and error we have accomplished would have been done prior to starting this project. The price compared to other similar model underwater ROVs is still relatively inexpensive, which we find to be one of our most redeeming characteristics.

6. Prototype Construction

6.1 Overview

In chapter six you will read about all the considerations taken to implement the final design into a prototype. This chapter outlines all the individual components, cost, and design overview for the prototype. Also included in this chapter is an overview of the actual construction of the prototype so that you can see exactly how the vehicle was put together.

6.2 Description of Prototype

The overall design of the MATE ROV will be centered on the idea of a central, water-tight, enclosed main body that houses the electrical components that govern the control and data gathering of the system. A sealed camera will be used to gather optical and sensory data which will be then be analyzed onshore via a laptop display. A robotic claw will be used to physically move or adjust specific objects in question. The whole body will be constructed out of water resistant materials such as PVC and Nylon. Any moveable components will rely on water-safe bearings.

6.3 Prototype Design

Initially we went with a more rectangular design because we thought the bull bar (angled frontal bars) in the front would make mounting things easier; however, it proved to not be that beneficial so we switched back to a more square design. The bars at the front of the design will serve for mounting our lights. We are planning on housing the electronics in a dive box that we will have to mount towards the center of the ROV. In addition we are leaving some space towards the back just in case we want to put our horizontal thrusters mounted internally too.

Figure 54 - Prototype 01 View 01

Figure 55 - Prototype 01 View 02

Figure 56 - Prototype 02 View 01

Figure 57 - Prototype 02 view 02


Figure 58 - Prototype Frame with Loose Housing


Figure 59 - Prototype Painted Frame


Figure 60 - Prototype Aluminum Mounting Bars


Figure 61 - Prototype Motor Mounted

6.4 Parts List

Table 15 - Part List

Part	Count
Power	
Computer Power Supply 12V	1
HobbyKing Donkey ST3508 730KV Brushless DC Motor	4
Control	
HobbyKing® ™ Brushless Car ESC 100A w/ Reverse (Upgrade version)	3
HS-5086WP Metal Gear, Micro Digital Waterproof Servo	1
HS-5646WP High Voltage, High Torque, Programmable Digital Waterproof Servo	1
Microsoft Xbox 360 Wireless Controller	1
Arduino UNO Kit	1
Maneuverability	
Octura X470 1.4 Dia Beryllium Copper Propeller	4
Functionality	
PVC Piping	20’
GoPro Hero 3 /W Underwater Enclosure	1
Robotic Manipulator Assembly (No Servo)	2
Propeller Adapter to suit 5.0 mm motor Suit (Collet)	4
Microsoft Xbox 360 Wireless Receiver for Windows	1
Pelican Micro 1060 Underwater Diving Box	1
Astra Depot Aluminum High Powered 6W 6000k Xenon White LED	3

Part	Count
Miscellaneous	
Everbilt Flat Bar Aluminum (2 in x 1/8 in x 36 in)	1
Everbilt Zinc Machine Screws Round Head Combo #8-32x1-1/2 inch (6pk)	5
Everbilt Zinc Machine Screws Round Head Combo #8-32x1-3/4 inch (8pk)	1
Hex Bolt (1/4 in x 1-1/2 in)	8
Hex Nut Zinc (1/4 in)	8
Southwire Low Voltage Landscape Wire Black Stranded RoHS Compliant 14/2 50 ft)	1
Cerrowire Appliance Wiring Rated T90 Nylon 105 Degrees C (50 ft)	1
3M Marine Adhesive Sealant 5200 (3fl oz)	1
Scotch Outdoor Mounting Tape (1.66 YD)	1
Cerrowire Appliance Wiring Rated T90 Nylon 105 Degrees C (50 ft)	1
Heat Shrink Tubing Assorted Pack (150 pcs)	1
BernzOmatic Electric Solder Lead-Free Rosin Core (3 oz)	1

6.5 Construction

To begin with the construction we purchased two 10' poles of ½ inch PVC piping. With the acquired PVC we both pipes into segments of 6'' leaving us with twenty pieces of 6'' PVC pipes. We used 6'' segments because we are trying to achieve an efficient, compact and economic design. By starting with the 6'' we could design a larger scale version and always cut off more PVC. In addition, we purchased six Triple 90's, 4 T connectors, and four 45 degrees connectors. The triple 90 pieces were used to construct the rectangular top of the prototype connected by the 6'' PVC that was previously cut. Next we took two pieces of the 6'' PVC and cut them into 2'' pieces so that we could connect the T pieces relatively close. The T connectors were used to have PVC run from the top to bottom of the design for frame reinforcement and motor mounts. Coming out the other end of the T connector was some more of the 2'' pieces that now connect to our 45 degree elbows which give the design its triangular shape. At the end is another triple 90 which connects to the 45 degree elbows and also runs a 6'' piece from the top and bottom for additional frame support. For the prototype construction we strictly used PVC for the frame. Aluminum mounting bars for the motors were placed upon the back and top of the frame and an aluminum mounting bar for the robotic manipulator was affixed to the fascia of the frame. Two high powered 6 W 6000k LED Arrays are affixed to the front bottom segment of the frame to ensure that the water we are navigating is always well lit. A high definition camera (GoPro Hero 3) is mounted to the front of the frame above the manipulator claw to ensure that the claw and front of the apparatus is always visible on screen.

6.6 Prototype Cost Analysis

Due to the fact that our prototype mainly consists of the frame design, our cost is relatively low. As of now we've spent about $130 total between PVC and the angled connecting pieces. Our final design of our prototype comes out to be $1020, this is the price of the working model.

6.7 Discussion

The prototype is constructed from 0.5'' PVC with multiple connecting components between each segment. Aluminum mounting bars are affixed on top of the frame in order to provide additional structural stability as well as a flat surface to mount the motors upon. The edges of the mounting bars are smoothed out in order to prevent the bars from getting caught on obstacles as well as to provide a safe operating condition. Since our motors are mounted on the outer regions of the ROV we designed propeller shrouds out of tin cans that could be used to house the propellers safety as well as provide a fitted channel for the water flow to travel through.

7. Testing and Evaluation

7.1 Overview

The MATE underwater ROV is tested within the confines of a private pool where we will have the freedom to maneuver around without the risks of various outside factors. The pool is confined to a depth of 6 feet so it will be mainly used for the purpose of testing the controls and functionality of the ROV. Further testing within a private facility and/or the ocean will be considered in order to test the ROV's various functions within a much larger scale with the presence of multiple environmental factors.

7.2 Design of Experiments – Description of Experiments

Our experiments are centered on testing the waterproofing of the system as well as testing the overall functionality and performance. Our first test is to attempt to run the system under strain out of water to ensure that our motors and controls are able to perform at an optimal state. The second test is to submerge the water proofed sections without the electronic components underwater to see if there are any leaks, if a leak occurs a pressure test using a pump and spray bottle will be implemented. Any further tests will be for the performance of the system underwater in a completed state.

Testing the wires before and after the voltage travels through them to account for any power loss is a necessity. We will accomplish this via a Multimeter to ensure that proper readings are indicated. This is intended to be a confirmation to our theoretical calculations.

7.3 Test Results and Data

Wire Analysis

One important aspect to test of the apparatus is to make sure that the voltage supplied remains as constant as possible through the extended distances of the cabling. Since all wires have an internal resistance and a slight drop of voltage through them, it is important to test these parameters, both under and not under load. We accomplished testing these specific parameters first theoretically and then compared them to the observed values. The values were read off of a Square D Power Logic Energy Meter which allows for very accurate measurements of amperage under high loads.

Table 16 - Test Results, Wire Resistance

Wire Resistance	
Calculator	**Theoretical**
0.079 [ohm]	0.024 [ohm]

The parameters for these values are set to 50 feet cabling and 12 gage AWG wire. The resistivity of copper at 20 C is approximately $\rho = 1.724 * 10^{-8}\ ohm\ m$ the diameter is approximately 0.0808 inches for 12 gage wiring and the resistance per 1000 feet comes out to be around 1.588 ohms. And the maximum allowable current is 41 amperes.

$$R = \frac{\rho L}{A}$$

Equation 2 - Resistance of a Wire

$$R = \frac{(1.724 * 10^{-8})(50)}{\pi\left(\frac{0.00673333}{2}\right)^2}$$

$$R = 0.024\ ohm$$

Table 17 - Test Results, Voltage Loss

Voltage Loss (Nickle Metal Hydride 7.2V)		
Input Voltage	**Output Voltage**	**Voltage Loss**
8.4[V]	7.8[V]	0.6[V]
12[V]	11.4[V]	0.6[V]

$$V_{out} = V_{in} - (I * R)$$

Equation 3 - Voltage Loss

$$V_{out} = 12 - (.024 * 25)$$

$$V_{out} = 11.4$$

From the values indicated above we were able to see that there is a minimal voltage loss through the 50 ft cabling. This is the ideal scenario because it will ensure that our device gets an ample supply of voltage to the components that are housed within the dive box. The wire that was used is Southwire landscape Wire that runs for low voltage and has 14 gauge 2 copper stranded wires. The voltage loss is very low as assumed; if you take into an account much higher amperage such as 100 amps a larger loss would be expected.

Buoyancy

It is important to calculate the buoyancy of our system. Our apparatus must have a slightly positive buoyancy so that it can resurface slowly over time if need be. In order to calculate the buoyancy a volumetric analysis of the system to determine the displacement of water compared to the actual weight of the apparatus must be performed. The major addition to the volumetric differences is the fact that the cavity that houses the electronic components is hollow and thus full of air. Results below indicate that our apparatus has very small, but positive buoyancy, which will be further increased when we add the floatation foam to the top portion of the ROV. This is good because if the ROV fails it will naturally resurface over time.

Table 18 - Test Results, Buoyancy

Buoyancy			
Density of Water	**Volume Displaced**	**Weight of URSA**	**Buoyancy**
1000 [kg/m^3]	0.00095 [m^3]	0.94 [kg]	$0.95 - 0.94 = 0.01$
1.940 [slugs/ft^3]	0.03355 [ft^3]	2.08 [lb]	$2.094 - 2.08 = 0.014$

Figure 62 - Testing Results, Testing Divebox 1

Figure 63 - Testing Results, Testing Divebox 2

Water Proofing

The most challenging aspect of the project was getting the electrical components to be in a small enough vessel to fit within our frame, while being large enough for heat dissipation and at the same time remaining water tight. We did several layers of testing to ensure that the electrical box would not have any leaks.

First and foremost we put a thin layer of water absorbent cloth within the unaltered Pelican Micro 1060 Dive Box. After placing the moisture indication cloth within the dive box we ran a high power hose over the box to check to see if any water with high pressure could penetrate the box or cause the hinges to open. With the success of this test we placed the box at the bottom of a 3 foot pool and slowly moved it toward the depth of 6 feet and kept it there for a prolonged period of time slowly rotating it around to make sure no bubbles were forcibly keeping out the water. We then removed the water absorbent cloth and closely analyzed it for any moisture that could have seeped in.

After successfully passing the previous tests we were able to go onto the next stage of adding the wire entry tube which was shown previously in *figures 19 – 23.* The altered box went through the same process of testing as the unaltered iteration, but with a pressurized cap preventing any water from leaking into the box from the tubes opening before the wire and sealant was added. This process was repeated again after the ROV was fully assembled and all of the electronic components were added in.

Motor Output

Since we lack the proper equipment to measure the motors RPM observationally the best method to measure the speed was by theoretical calculations.

$$RPM = V * kV$$

Equation 4 - RPM

$$RPM = 18 * 720$$

$$RPM = 12960$$

And the horse power surmounts to

$$HP = \frac{I * V}{745.7}$$

Equation 5 - Horse Power

$$HP = \frac{100 * 18}{745.7}$$

$$HP = 2.41$$

The value provided for horse power is assuming we are able to produce amperage of 100 amps which is the max of the electronic speed controls, but in actually the wire is limited to 41 amps and we are in actuality only able to produce around 1 HP. The motors are only capable of accepting 35 amps with a power output of 330 W or 0.44 Hp. So under the best conditions with minimal power lose we can expect a horsepower of around 0.40.

Propellers

The output potential of the propellers coupled with the motors is definitely important when it comes to calculating the theoretical speed and from that the theoretical force that would be acting upon the apparatus at the expected depth.

Table 19 - Testing Results, Propeller

Octura Propeller				
Prop#	**Diameter**		**Pitch**	**Shaft**
X470	70 [mm]	2.76 [in]	$1.4 * 2.76 = 3.864$ [in]	¼ [in]

$$v = \frac{RPM}{ratio} * \frac{Pitch}{C} * \left[1 - \left(\frac{Slip}{100}\right)\right]$$

Equation 6 - Speed of Propeller

$$v_{max} = \frac{720 * 18}{1} * \frac{3.864}{1056} * \left[1 - \left(\frac{0}{100}\right)\right]$$

$$v_{max} = 47\ MPH$$

$$v = \frac{720 * 18}{1} * \frac{3.864}{1056} * \left[1 - \left(\frac{50}{100}\right)\right]$$

$$v_{exp} = 23.71\ MPH$$

v_{max} Is the max possible speed assuming the brushless motor has no slippage, while v_{exp} is the expected speed if the motor slips 50%. This is a theoretical average not the actual speed observed.

When using MPH the value of C is

$C = 1056$

When using KPH the value of C is

$C = 656$

7.4 Evaluation of Experimental Results

The experimental results yield very compelling data. We can see that the theoretically the system is sound and produces the desired results we were looking for in an effective manner. The machine is very capable of running the full course that it is supposed to without losing the integrity of the hull due to the vibrations and force applied on the system. With a positive buoyancy of 0.01 the system will self-resurface which was one of our important goals. The voltage drop across the wires is very small which we observed by how well the motors preformed under continuous load.

Our frame has no problem handling the force and torque generated by the motors and with the Loctite we added to the threading the bolts have not come undone.

7.5 Improvement of the Design

Improvements on any design could always be made; the difficult parts are if the changes are plausible.

Structural

Having a lighter frame with the same or similar structural stability would be ideal, to accomplish this we would need to construct the chassis out of titanium or aluminum which would provide ample strength to weight ratio compared to PVC. Flattening the front of the frame would allow for better mounting of the claw and lights, as well as simplify the design overall. Adding on bumpers for the safety of the claw is also a thought about improvement. Ideally if we were able to get our system to be rated an IP68 we would be able to go much deeper in the water for longer periods of time without the worry of minor leaks getting into the circuitry.

Power

More efficient and powerful motors that are constructed specifically for underwater use would be the ideal scenario. At the moment we are using brushless motors, which are fine for prototyping or small scale designs underwater, but we would want a motor with an IP68 rating, graded for deep underwater usage. Higher quality wires that are able to maintain a perfect 12 Volt supply without dropping over the extended distance would also be a noted improvement.

Controls

Making the inputs pressure sensitive is the next step in improving our controller layout and design. Due to specific time constraints we limited our design to simple on/off motor controls that use the code to accelerate over time, but we are planning to finish the controller inputs by making them pressure sensitive. Having an additional control for the use of the claw would also serve to make the visual process more appealing to the person controlling the ROV.

Price

We put emphasis on the total cost of our design since we first started to draft up the initial drawings. Since we are on a limited budget and for the most part self-funded; if we overshot what we could afford we wouldn't have been able to complete the project. As an improvement we would have loved to spend more to be able to buy higher IP rated products as well as professional grade wires and fittings, but overall our idea was to minimize the cost of the total system so that our design could be used more universally by people of lower income interested in learning about marine aquatic life. By redesigning the system more effectively I feel we could cut down the total price by several hundred dollars, namely find the specific parts that get the job done at the minimal level without being excessive in any way.

7.6 Discussion

Over all a basic redesign of the entire system would be the idealistic thing to do. If cost were no concern a much lighter and sturdier material would have been chosen as well as a more advanced and water proofed system. Cost is the greatest limiting factor of all, the choices we made were centered on us having to self-fund the majority of the design.

8. Design Considerations

8.1 Assembly and Disassembly

Ease of disassembly for maintenance purposes are required. While working with water we must always consider the combination of water and electronics and its effects on short circuiting components. The bolts are all able to be removed from the motors as well as the mounting bars. If you take apart those you would be able to remount different motors as long as they are compatible with our slotting on the aluminum mounting bars. For the most part the only component that needs to be opened and closed in the central brain of the system, it was constructed out of a dive box, so it is possible to open the latch if necessary. Any bolt that is loosened or removed must be Loctite again before operation. To take apart our system you would only need a small wrench and a Philips screw driver.

8.2 Maintenance of the System

8.2.1 Regular and Major Maintenance

Regular maintenance includes checking for proper operation of thrusters and assuring all seals are properly lubricated and watertight. Rinsing the DC brushless motors off with some fresh, clean water after use is suggested as it will promote the longevity of the system. Do not run the system excessively under high strain, this could cause an overload to the electronic speed controls housed in the dive box.

8.3 Environmental Impact

While there are no immediate considerations for the environment since this entire project is self-contained, there is always the chance of small amounts of oil leaking into the water through the bearings. Additionally, we must be aware of battery disposal.

8.4 Risk Assessment

The biggest Risk in our project is if it will fail. Putting any sort of electronic devices underwater is always a risk that doesn't have many ways to get around if you make a mistake. If the electronics get wet we will have a fuse set up as a failsafe. Overall our project has very little risk because we are keeping our costs and size of our device to a minimum. Our design takes into account that our system may fail; we chose to make our design with slightly positive buoyancy so it could self-resurface if needed.

9. Design Experience

9.1 Overview

Chapter nine encompasses our overall experience and knowledge gained by participating in this design project. This section displays the standards used, issues encountered, and overall global impact. During every stage of the project we needed to keep in mind how we could gear our project to not only impact our society but societies all across the world. While keeping in mind the different elements that come into play when trying to make something that has a possibility of global implementation.

9.2 Standards Used in the Project

- 12 volts, 25 amps DC. Conversion to lower voltages is permitted topside and on the ROV. Onboard electrical power is not permitted.
- Pneumatics and hydraulics are permitted provided that the team passes the MATE Fluid Power Safety Quiz and follows the specifications included within the competition manual.
- Lasers are permitted provided that the team follows the specifications included within the competition manual.
- Camera is required.

9.3 Contemporary Issues

Yellowstone River is considered one of the greatest trout streams of the world. With the recent oil spill on January 15th, 2015 leaking approximately 50,000 gallons of oil from a pipeline the environmental impact will be devastating to the wildlife of the area. This is where our UW ROV has its purpose. With the use of our simple UW ROV URSA we will be able to do mock testing for maintenance and supply to the various offshore oil pipelines. Hopefully with regular scheduled checks and remote unmanned maintenance we would be able to detect possible damage to a pipeline before it got to the level of extreme leakage.

9.4 Impact of Design in a Global and Societal Context

Our design doesn't particularly revolutionize the way underwater ROVs have an impact on the global and societal scale, although ROVs themselves have a huge growing desire. Military has begun to use remotely operated vehicles underwater now so they can safely deploy a mobile vision source far away without the need of having a person personally onboard the craft. By keeping the design simple and small it is possible to cheaply deploy multiple crafts to various areas minimizing the various risks that having onboard personal would produce. As impact on society goes, personal boundaries between where is it acceptable to have remotely operated camera or spying devices would be allowed. There is already an ongoing dilemma in regards to Quadcopters equipped with cameras on the beach, and this would just be another addition to that issue.

9.5 Professional and Ethical Responsibility

There is a moral and ethical aspect to every project that you work on. It is important that the work you do is your own and unique to the intellectual rights of the student designing the work. Enlisting unapproved outside help is also questionable. The product we design should be as we described and indicated throughout the report. There is a responsibility to be as straightforward and honest as possible.

9.6 Life-Long Learning Experience

The knowledge gained from this endeavor is unmeasurable. The vast amount of time and research that is required to make a fully functional UWROV is something that you could only understand if you try to take on the project yourself. Teamwork and cooperation as well as prompt time lines and scheduling was a very important aspect of the project that was required. Without a competent team and a proper time line set forth, the project would never have come to fruition.

9.7 Discussion

This section has encompassed all of our overall experience and knowledge gained by participating in this design project. The standards used, issues encountered, and overall global impact have all been discussed. Every project no matter how big or small has an impact on the global scale as well as the societal. It is important to keep ethics in mind throughout the project and ensure that all of what you do is your own. By following these guidelines and paying close attention to the details a life-long learning experience will be felt.

10. Conclusion

10.1 Conclusion and Discussion

Our specific goals that we set out to accomplish were mostly met; we were able to progress to the level we intended for the prototype. A successful model was built on the concepts we previously laid out before starting the actual build. Our device preformed successfully under the heat and force load that was generated from the motors and electronic speed controls having a theoretical minimum safety value of 12 which is well beyond the required amount. We credit the exploratory heat dissipation to the fact that our apparatus uses forced convection from cold water conditions naturally. We were able to get the claw to operate as desired and it was capable of panning as well as clamping down upon an object without destroying it. URSA theoretically was able to travel through the water at speeds up to 20 MPH with an average drag coefficient of around 0.11 which is the expected ideal of our flow-through system that we carefully designed.

10.2 Evaluation of Integrated Global Design Aspects

Our idea of producing multiple tri-fold brochures available in multiple languages was the main focus of our global design. We wanted anyone that would be looking at our operations manual to be able to comfortably understand what we laid out without having to struggle to figure out the exact meaning behind each statement. We were able to produce multiple brochures in multiple languages; they are very clean and easy to understand.

10.3 Evaluation of Intangible Experiences

The amount of technical and realistic experience gained from the completion of this project is without compare. The sheer amount of work that goes into the design and testing of any completed project was something very foreign to us as engineering students who have only experienced textbooks and equations up until now. On top of the amount of work that goes into it the real life lesson of teamwork and cooperation was thoroughly tested throughout the assignment.

10.4 Commercialization Prospects of the Product

The future goal of this project would be to market to companies that require delicate underwater procedures to be done, such as underwater scavenging, harvesting, or maintenance. Various companies such as NAVSEA, Odyssey Marine Exploration, and Global Marine Exploration would be companies that could benefit from our product development and design. Making the product run as efficiently as possible at a minimal costs is our most prominent consideration. Lowering the overall cost of the product while at the same time simplifying the total process of assembly and maintenance are the key goals to making our product marketable to the public. The lower cost will allow us to sell the product at a healthy profit margin, while at the same time making replacement of faulty components a hassle-free process. The simplistic design and hope for an even further simplistic approach will allow anyone to be able to assembly and use the product regardless of technical knowhow or experience with engineering. We also aim to make the device modular so that different components that are approved could be easily swapped on and off for the specific purposes the user desires, thus also effectively reducing the overall cost to the consumer based on their specific need.

10.5 Future work

We would love to continue working on this design; the time and effort we put in to produce a working prototype was significant so we wish to finalize our design and produce a complete working apparatus in the future.

Having a lighter frame with the same or similar structural stability would be ideal, to accomplish this we would need to construct the chassis out of titanium or aluminum which would provide ample strength to weight ratio compared to PVC. Flattening the front of the frame would allow for better mounting of the claw and lights, as well as simplify the design overall. Adding on bumpers for the safety of the claw is also a thought about improvement. Ideally if we were able to get our system to be rated an IP68 we would be able to go much deeper in the water for longer periods of time without the worry of minor leaks getting into the circuitry. More efficient and powerful motors that are constructed specifically for underwater use would be the ideal scenario. At the moment we are using brushless motors, which are fine for prototyping or small scale designs underwater, but we would want a motor with an IP68 rating, graded for deep underwater usage. Higher quality wires that are able to maintain a perfect 12 Volt supply without dropping over the extended distance would also be a noted improvement.

Besides all of the potential design improvements we would like to look into developing a micro model of the underwater ROV. We are looking to be able to design a complete simple micro-scale UWROV capable of operating under limited conditions for a short period of time for the purpose of teaching our juniors the joy of mechanics as well as underwater exploration at a low cost and space capacity.

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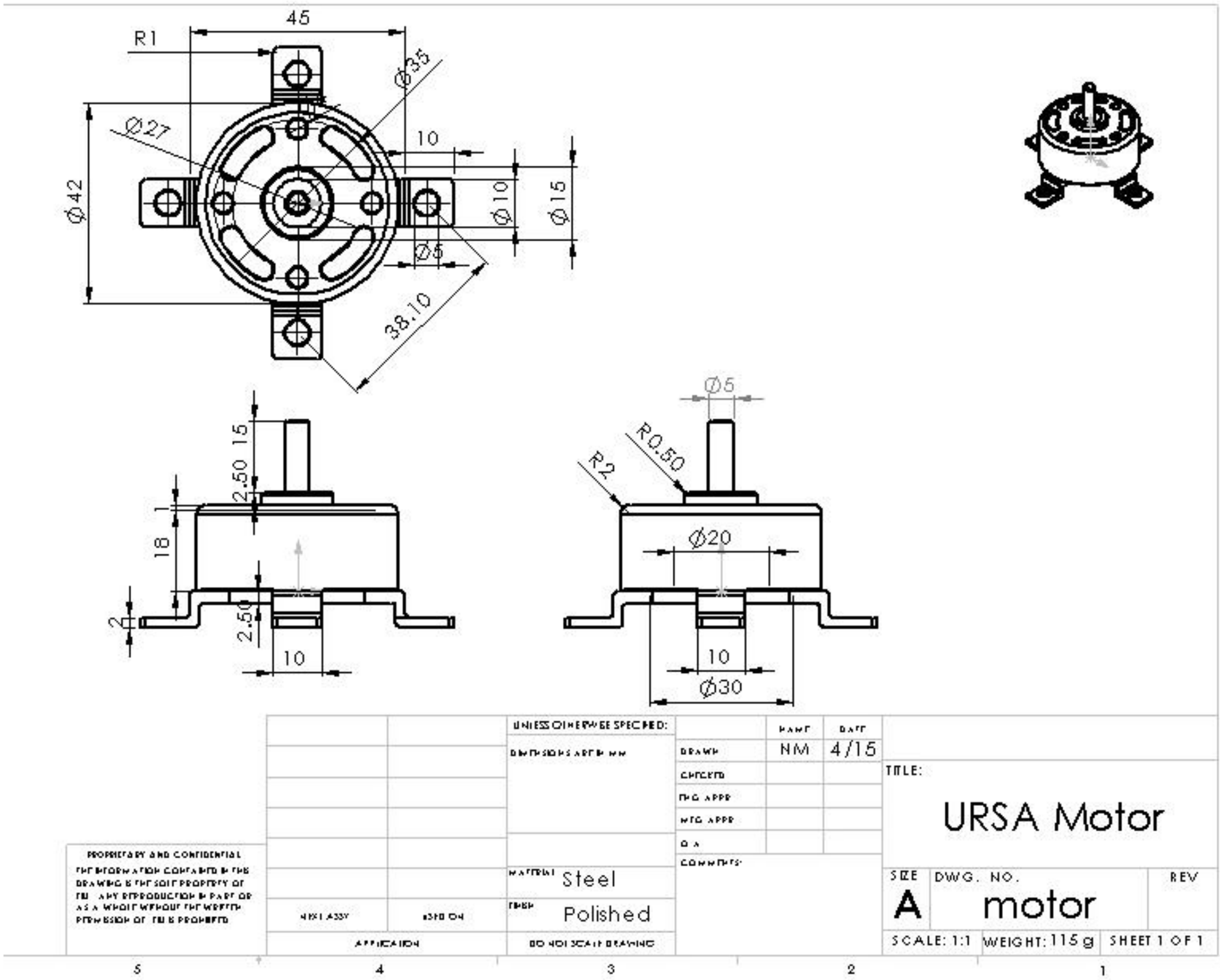
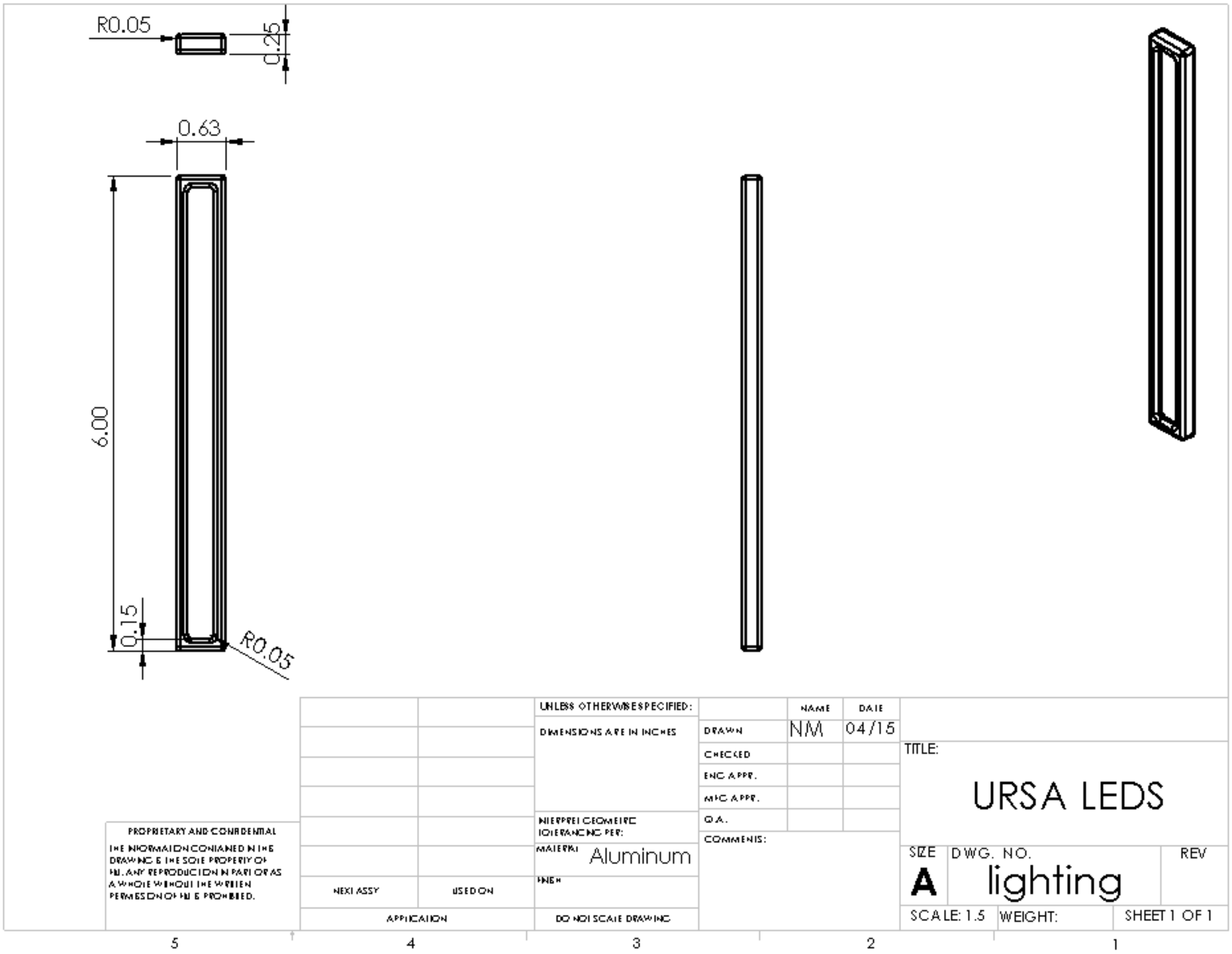
Appendix

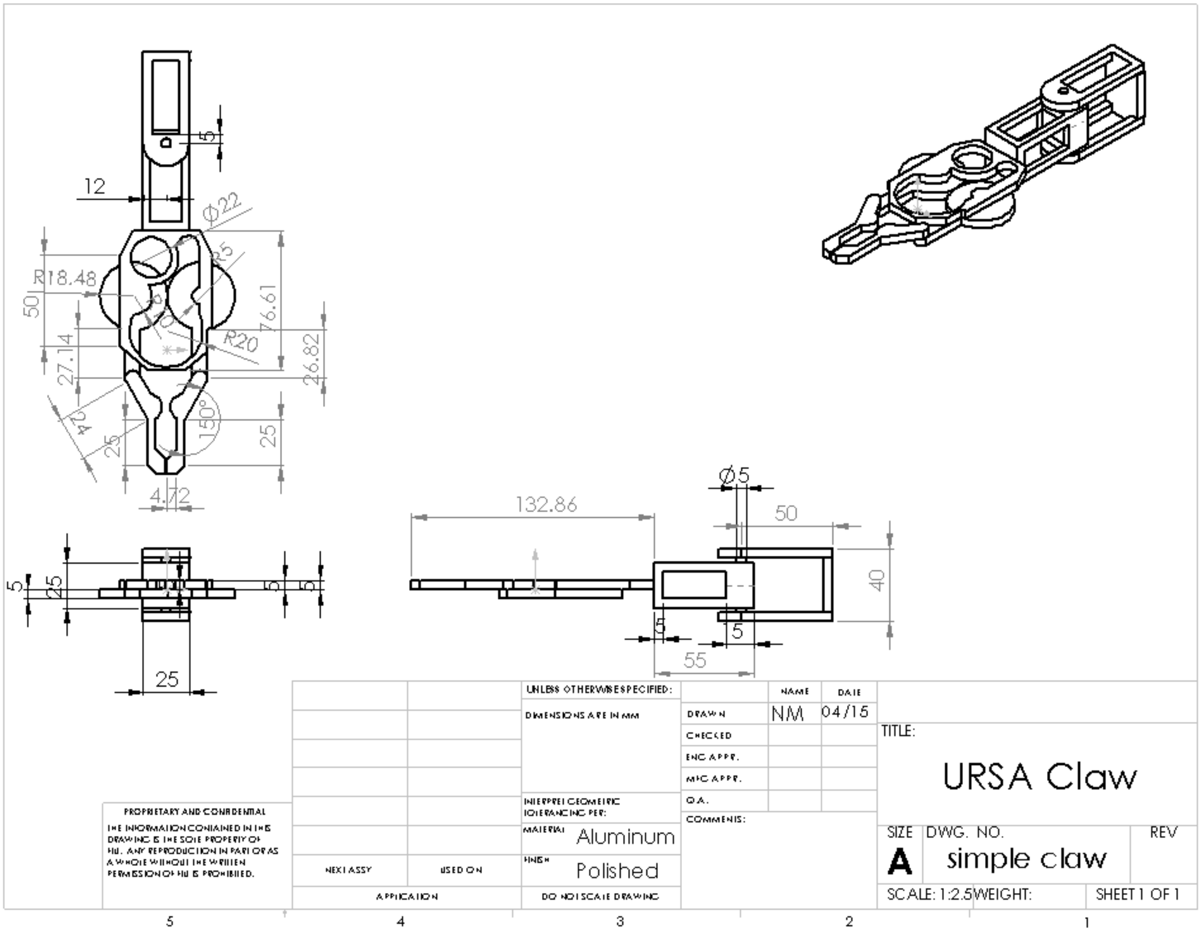
Appendix A: Detailed Engineering Drawing of all Parts



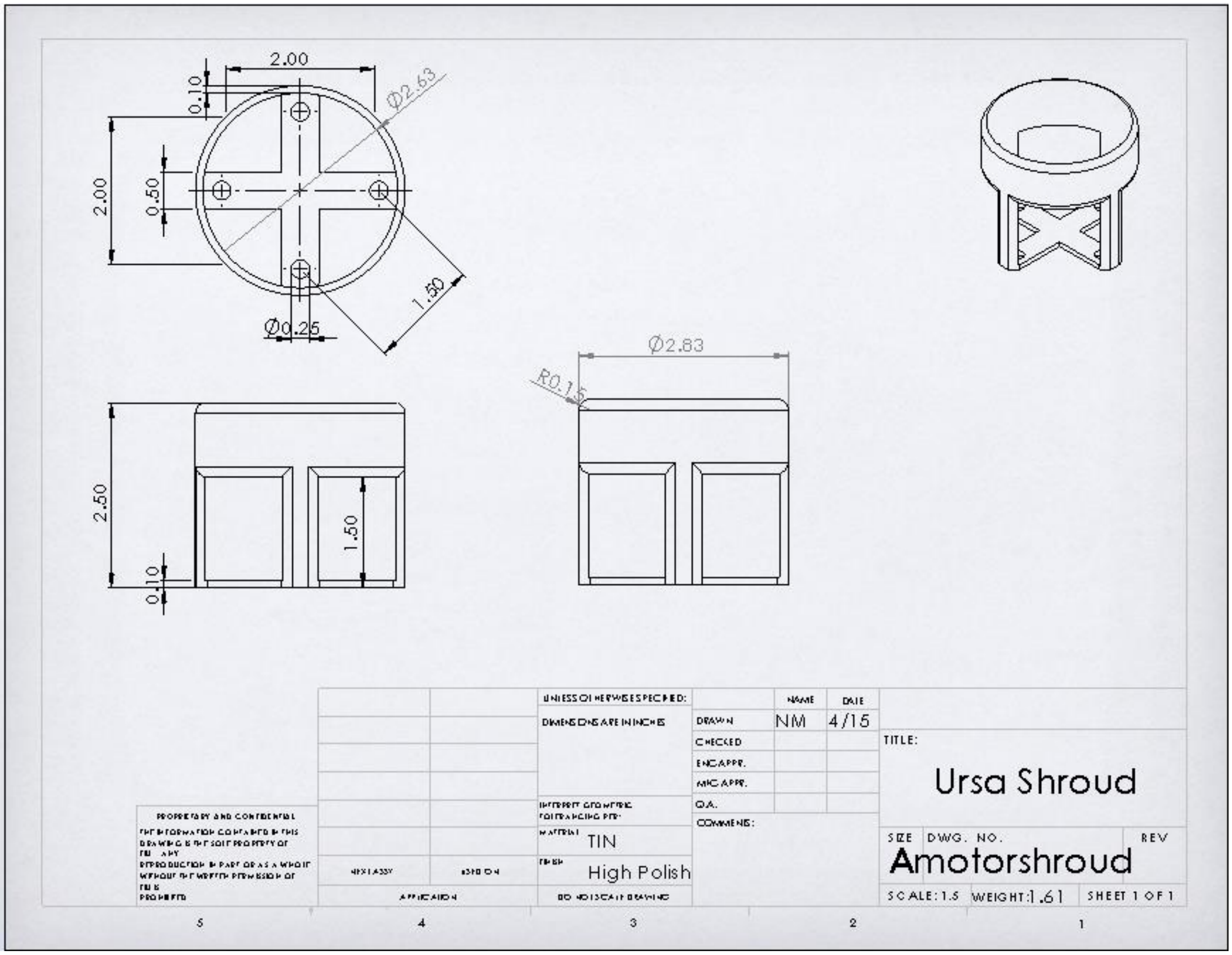
A 1 - Drawing Diagram, Motors



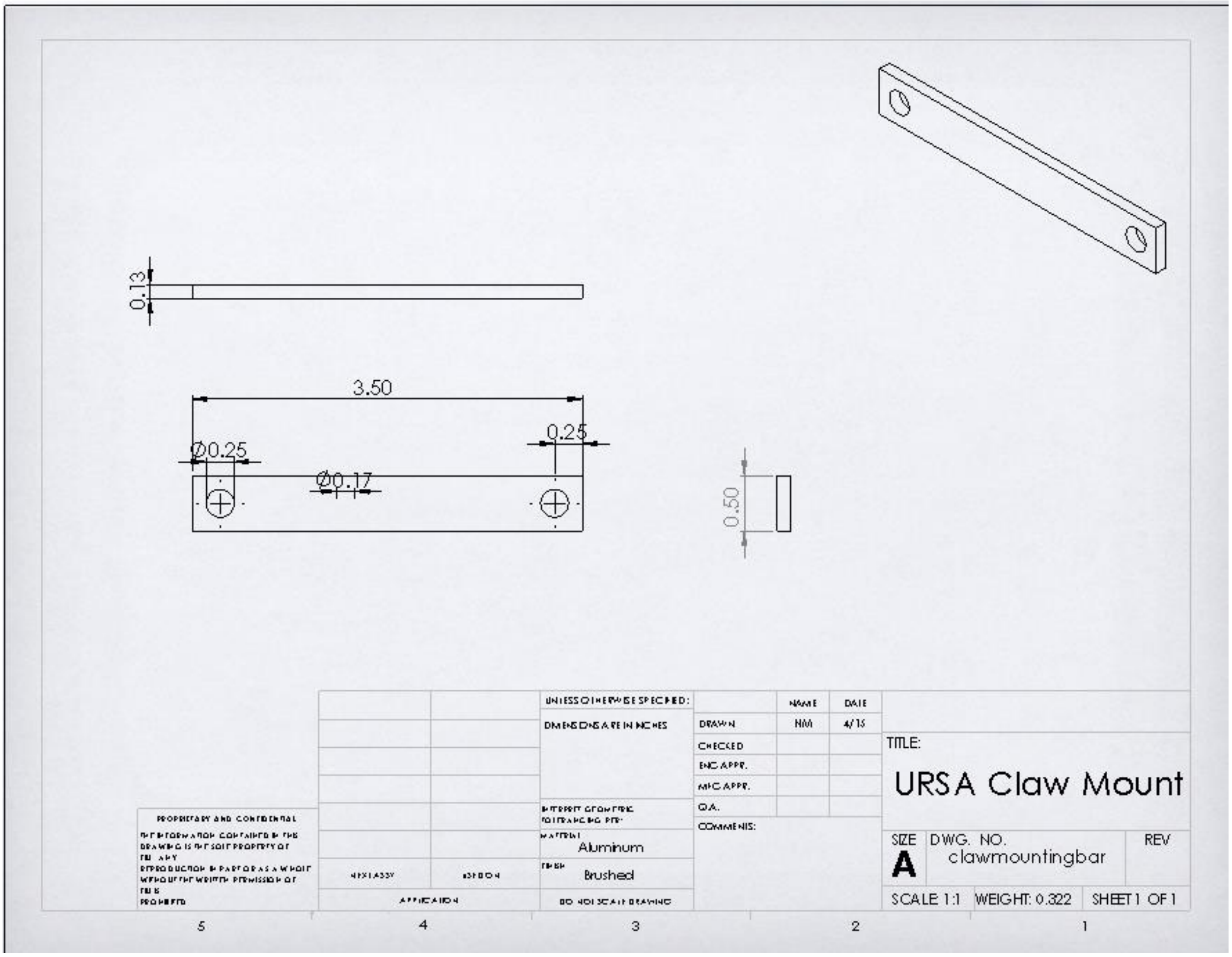
A 2 - Drawing Diagram, LED Lighting



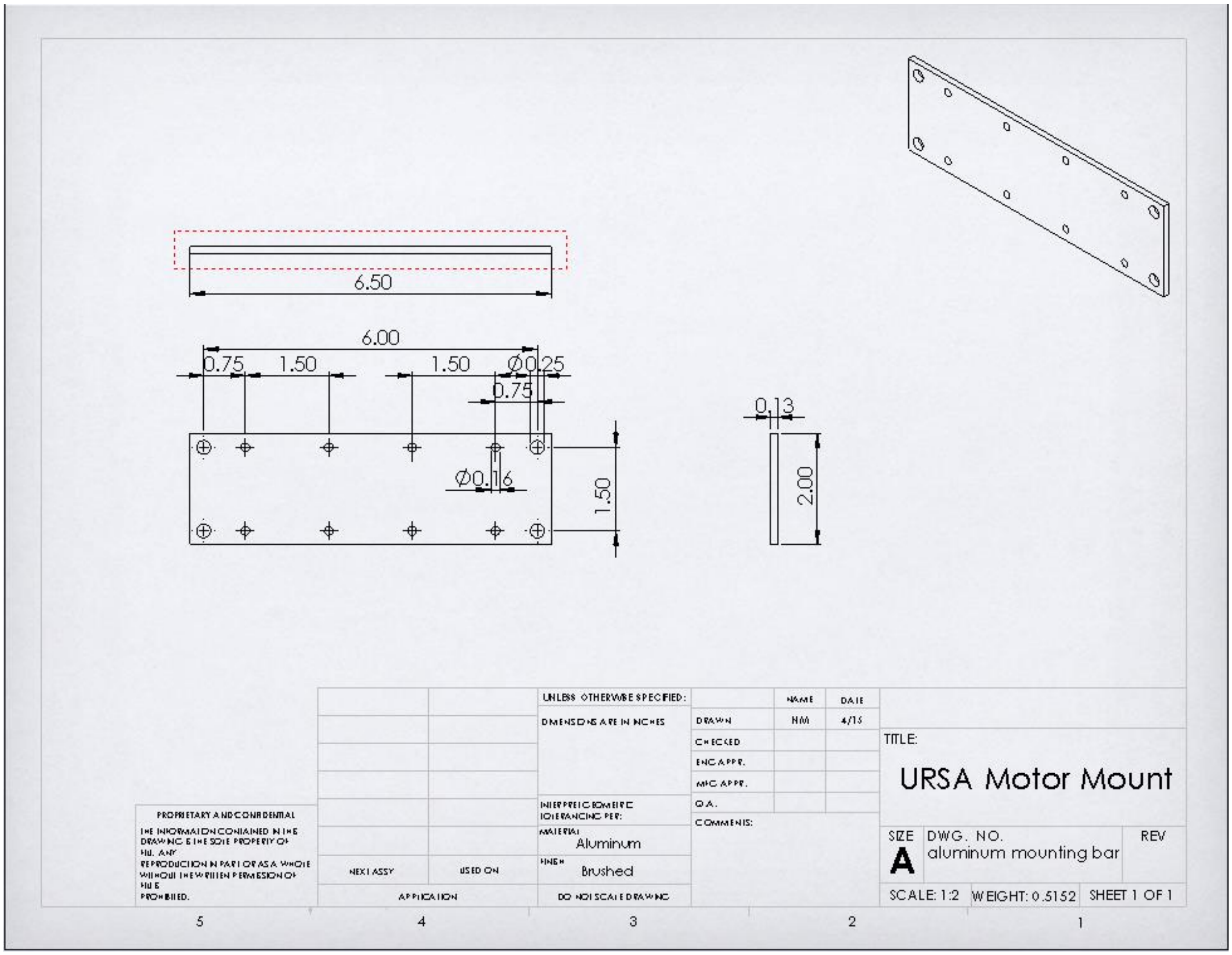
A 3 - Drawing Diagram, Simplistic Claw



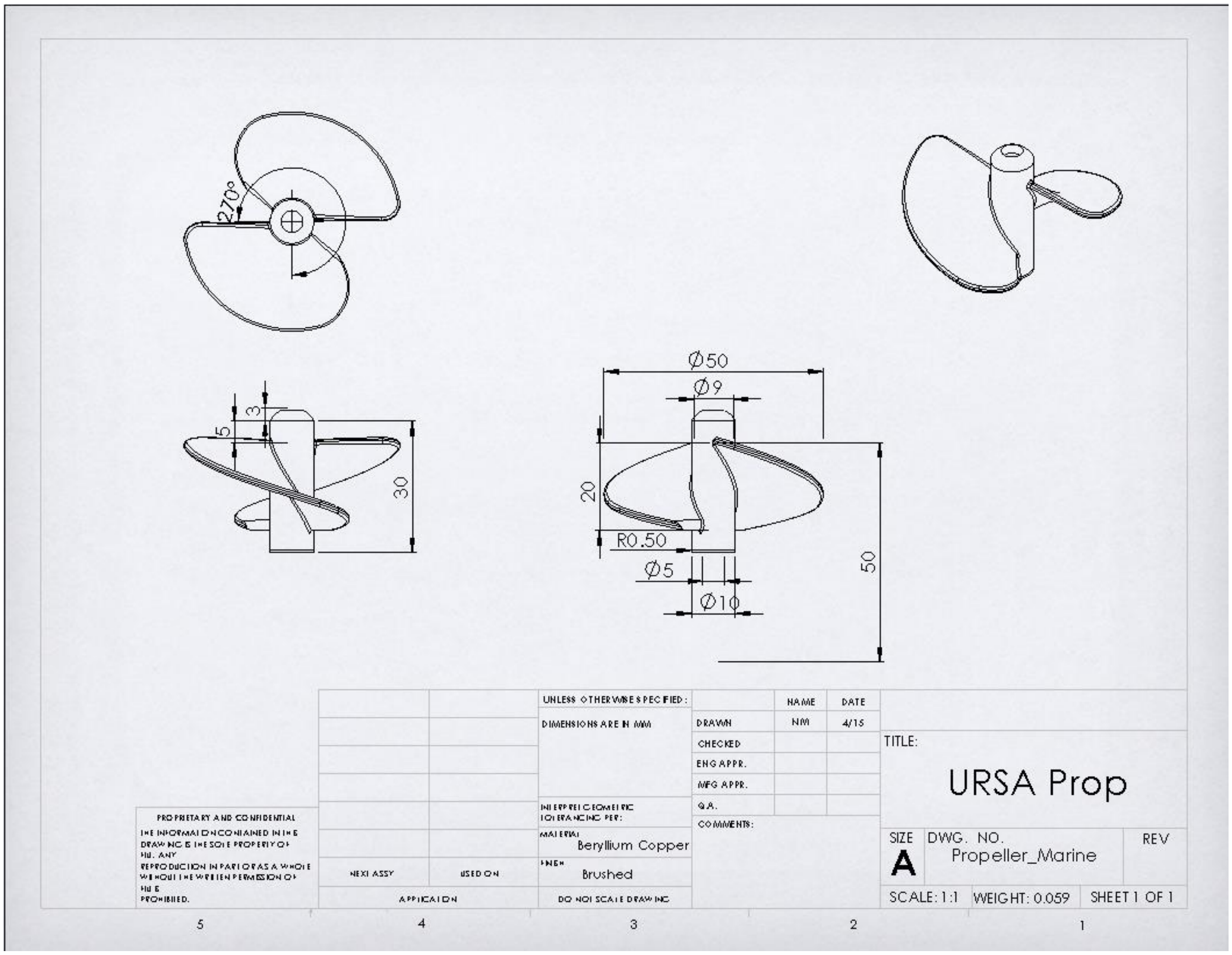
A 4 - Drawing Diagram, Motor Shroud



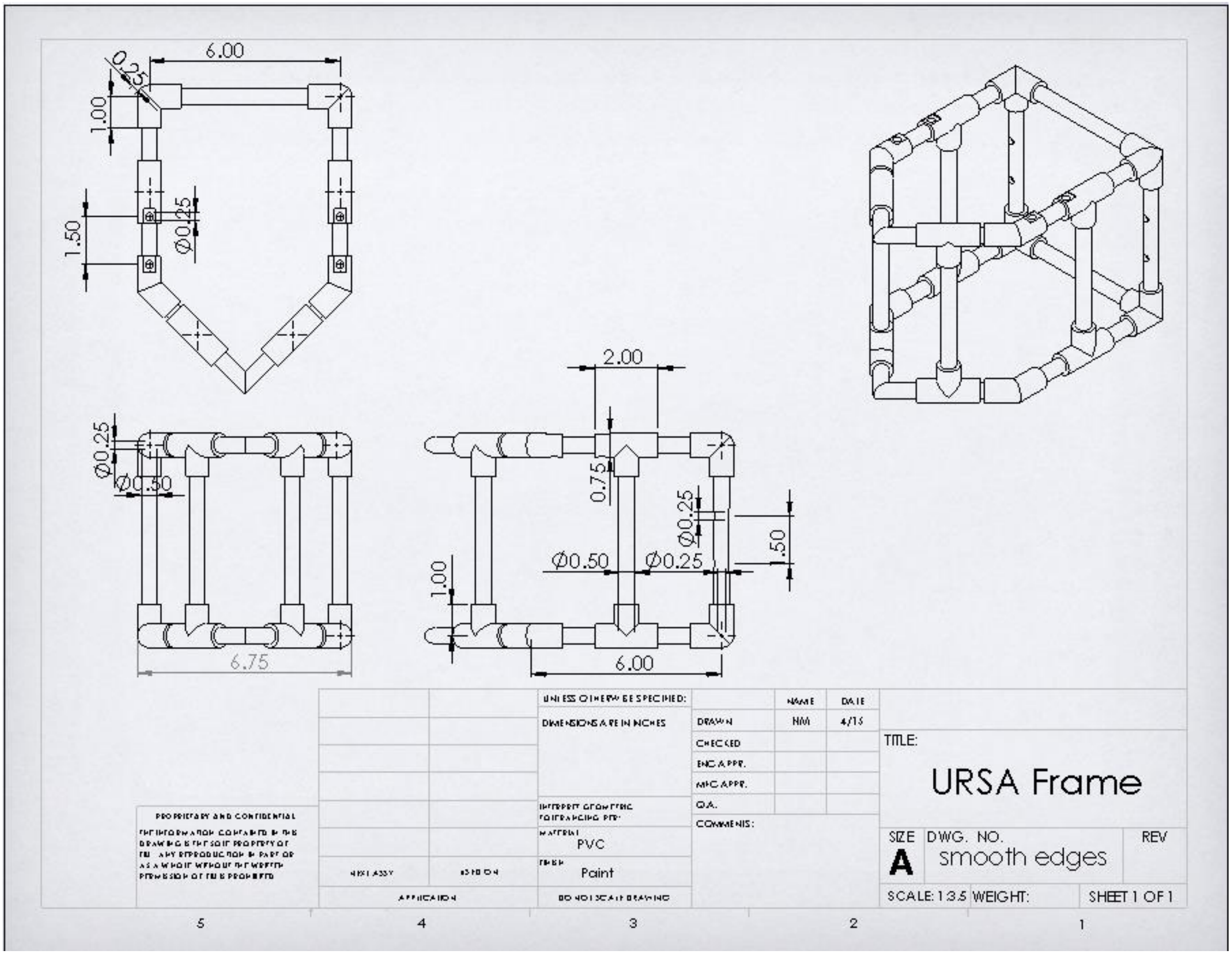
A 5 - Drawing Diagram, Claw Mount



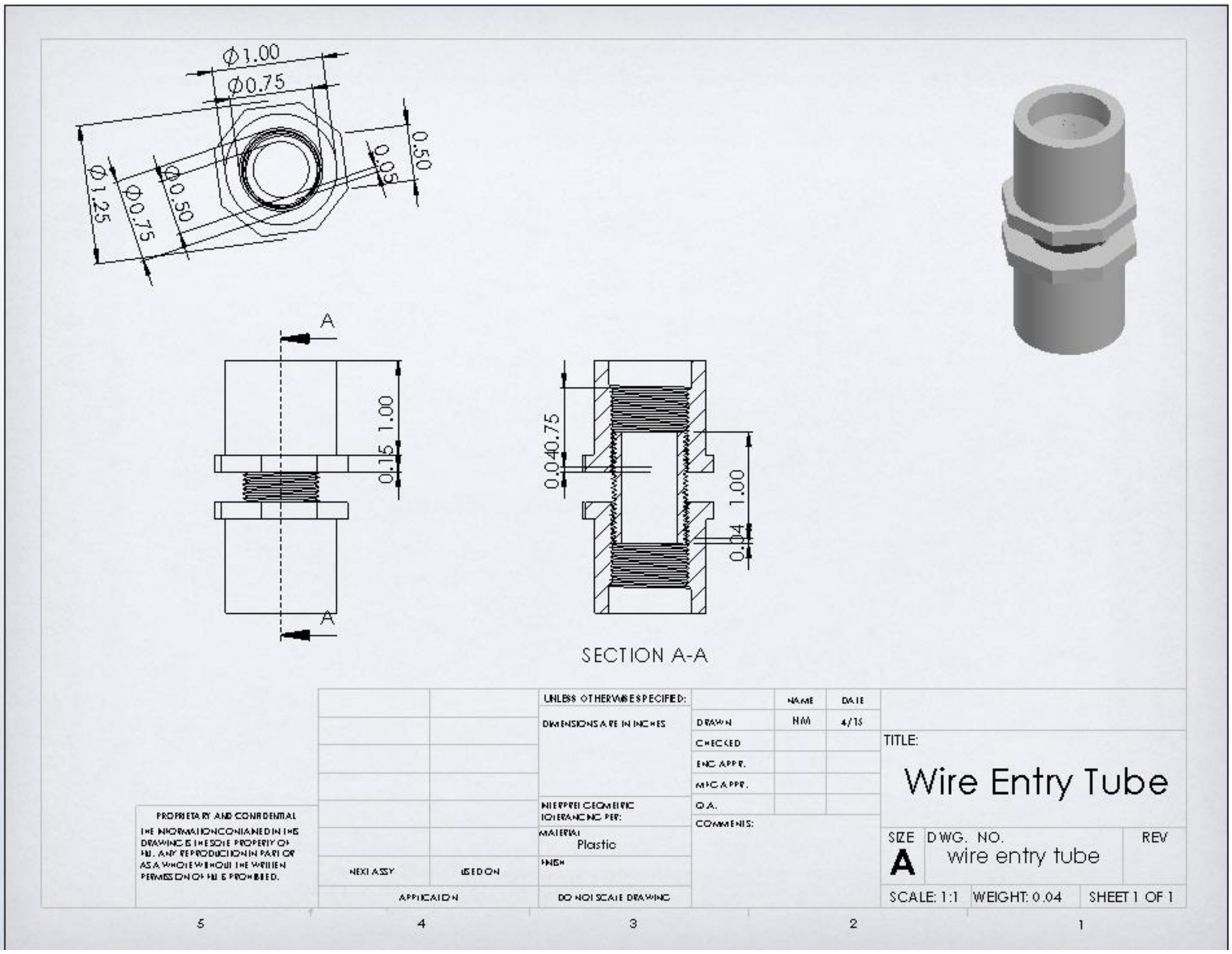
A 6 - Drawing Diagram, Motor Mount



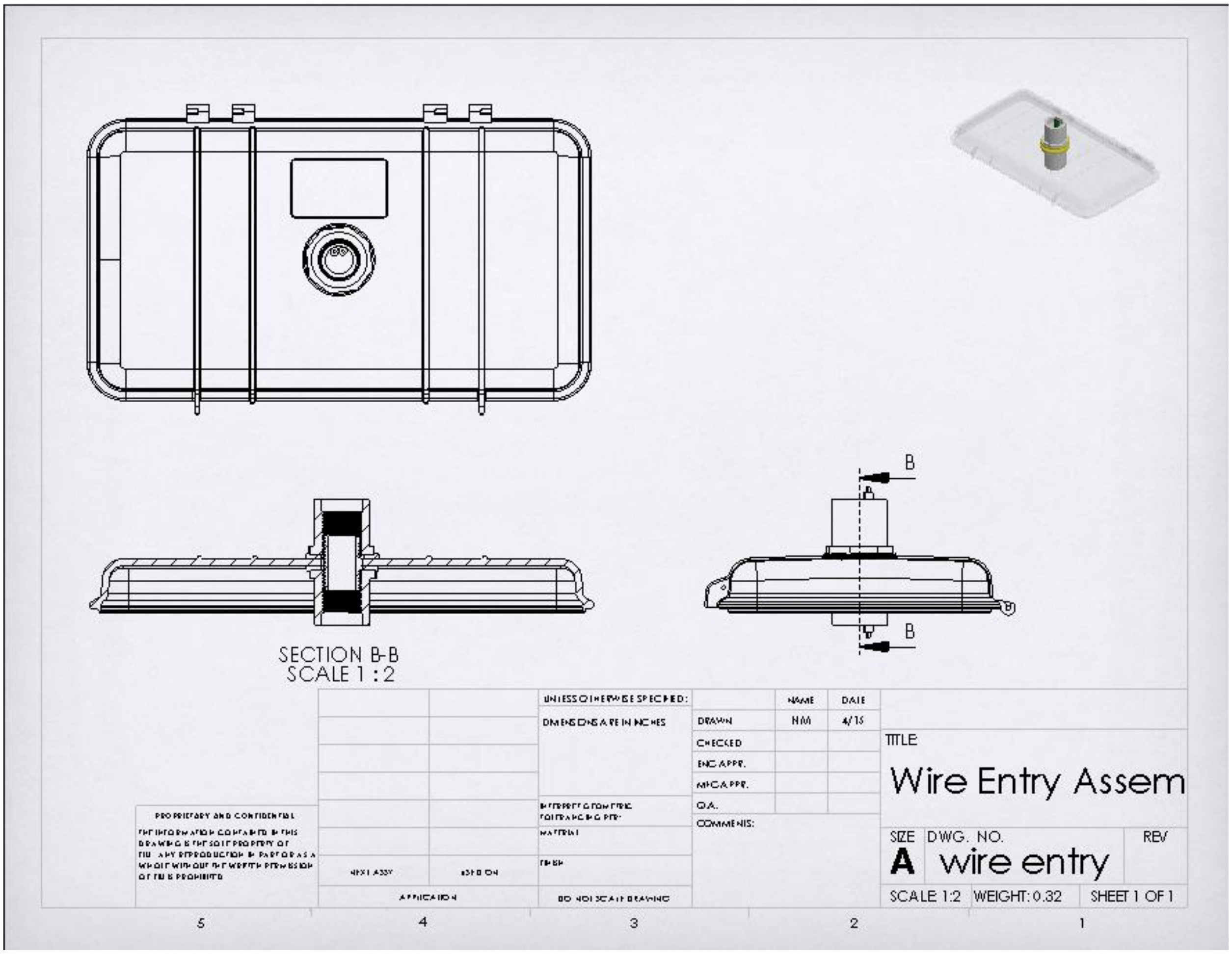
A 7 - Drawing Diagram, Propeller



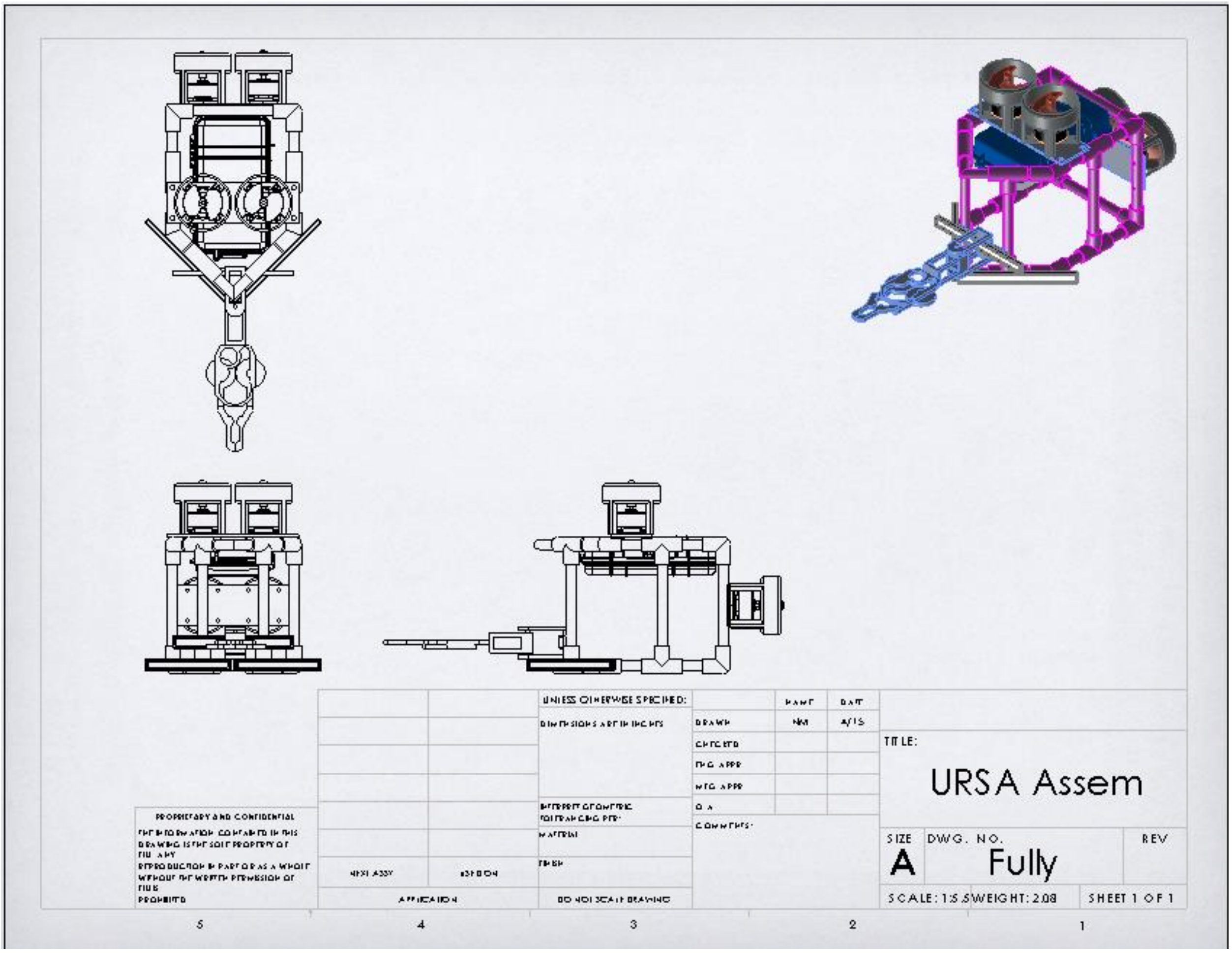
A 8 - Drawing Diagram, URSA Frame



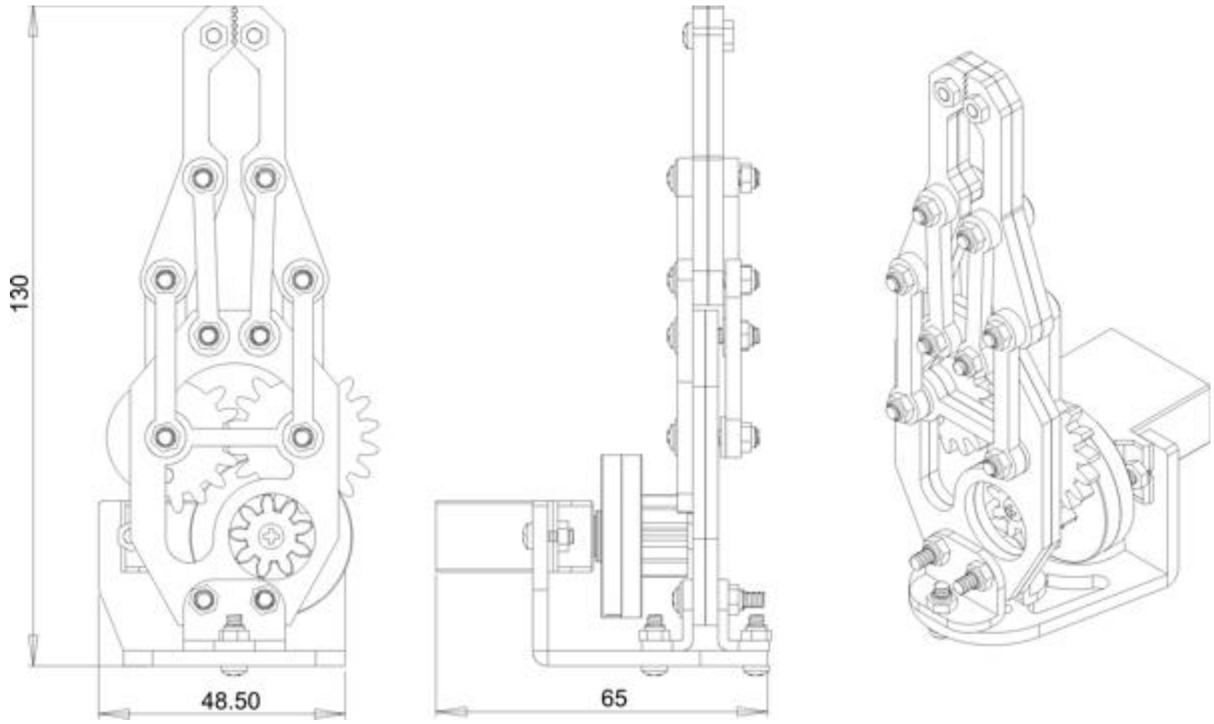
A 9 - Drawing Diagram, Wire Entry Tube



A 10 - Assembly Diagram, Wire Entry

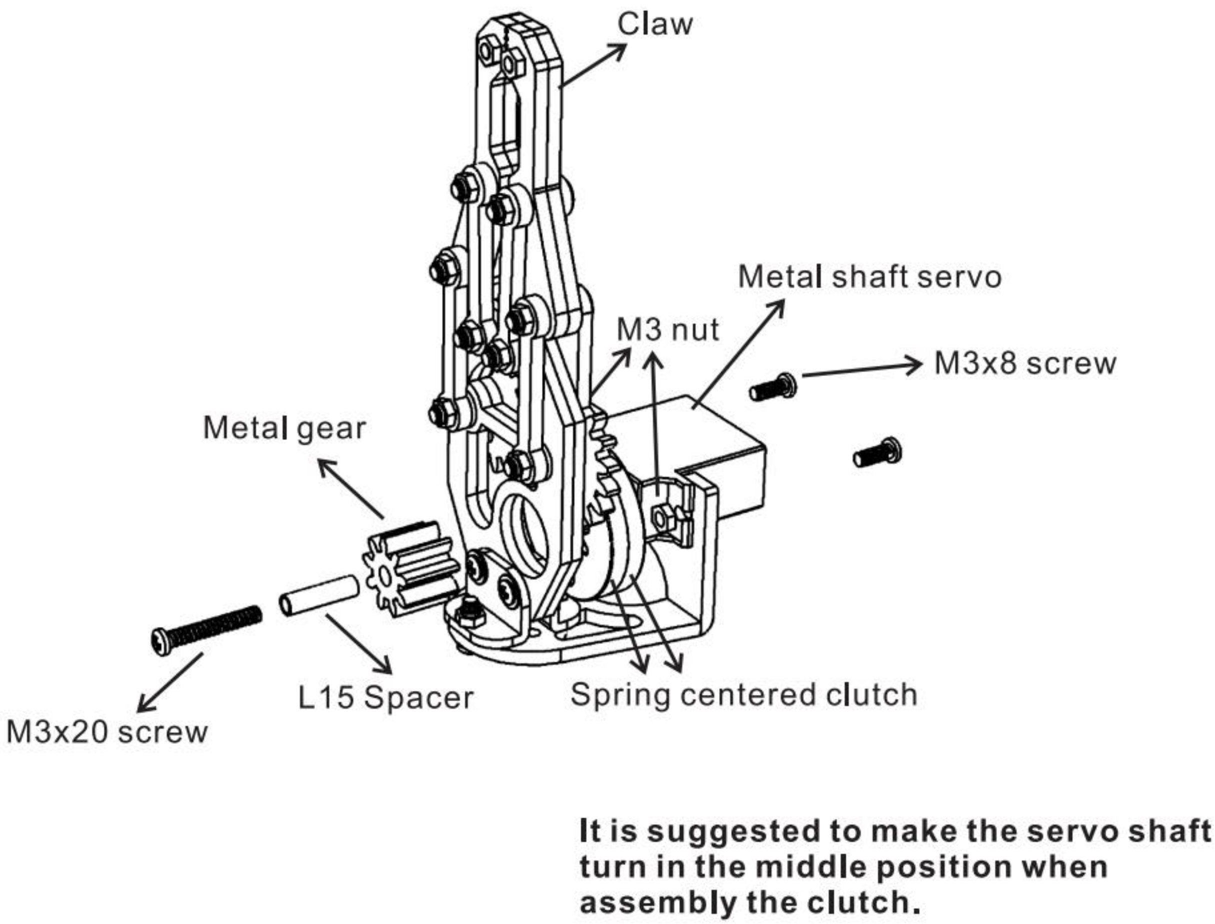


A 11 - Assembly Diagram, URSA



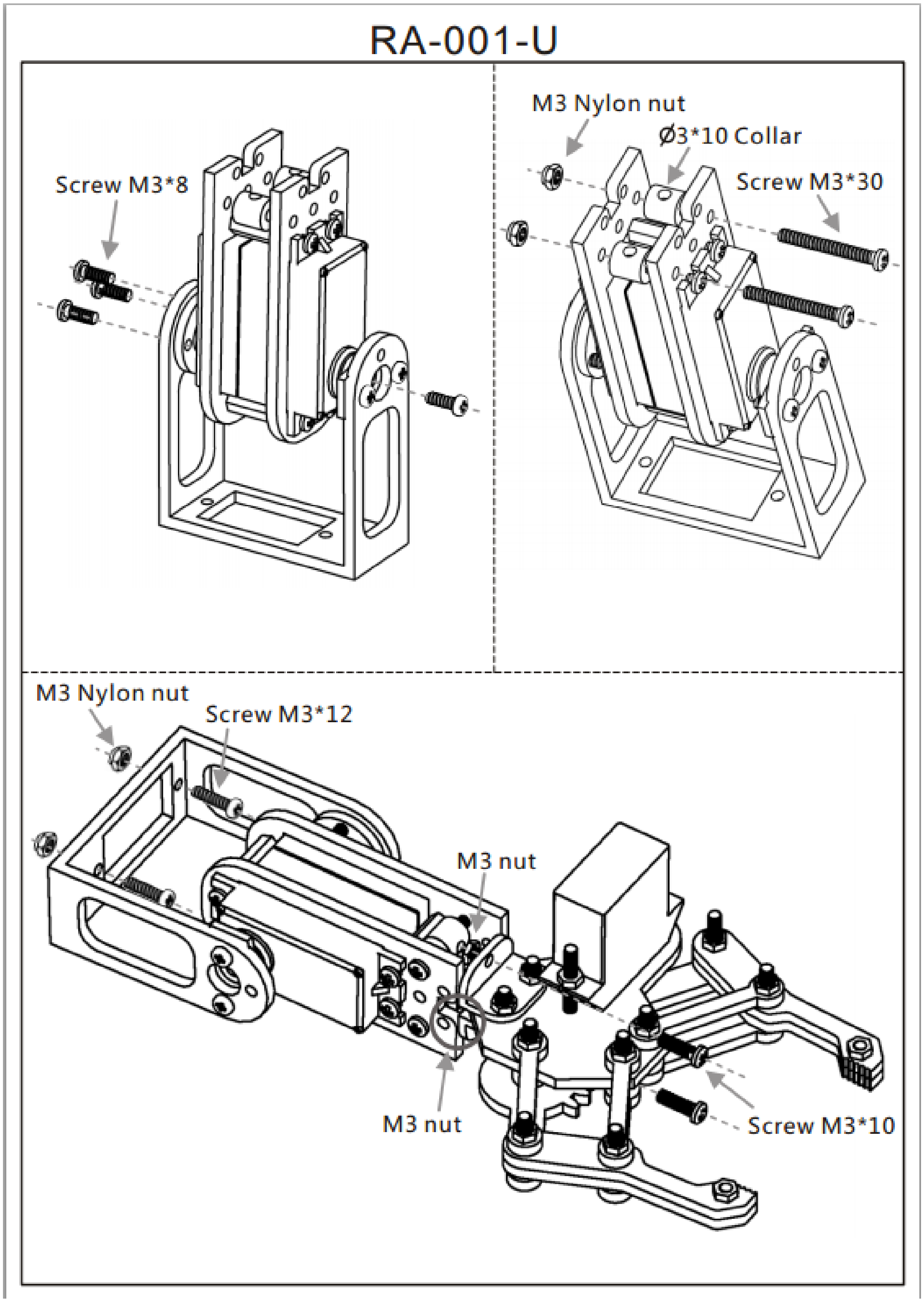
A 12 - Drawing, Robotic Claw MKII (SparkFun)

Figure 13 depicted above is a simple engineering drawing of the model MKII robotic claw that we are using within our ROV design.



A 13 - Assembly Diagram, Robotic Claw MKII (SparkFun)

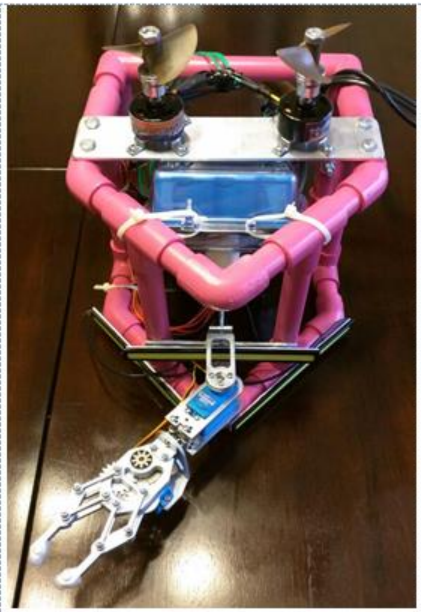
Figure 14 depicted above is a simple engineering assembly drawing of the model MKII robotic claw that we are using within our ROV design.



A 14 - Assembly Diagram, Robotic Claw Pan/ Tilt Bracket – MKII (SparkFun)

Figure 15 depicted above is a simple engineering assembly drawing of the model MKII robotic claw Pan/Tilt bracket that we are using within our ROV design.

Appendix B. Multilingual User's Manuals (in English, Spanish, and Italian)



URSA Prototype

Specifications

Model Name	URSA	
Height	6 in	15 cm
Length	8 in	20 cm
Width	6 in	15 cm
Operating Voltage	12 Volt	
Operating Amperage	25 Amp	
Top Speed	20 MPH	9 m/s
Camera Resolution	1080p30 5MP 3FPS	
LED Power	60 Watt	

Who We Are

About URSA

Compact, Lightweight, and overall economic design leads to a simplistic yet fully functional underwater remotely operated vehicle that can be effortlessly controlled via Xbox360 controller.

Contact Us

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URSA - MATE ROV

Underwater Research and Scientific Apparatus - Marine Advanced Technology Education Remotely Operated Vehicle

B 1 - User Manual, English 1

Controller Layout

Legend

- A Button
- B Button
- X Button
- Y Button
- Lift
- Thrust
- Left Directional
- Right Directional
- Tilt Claw Up
- Tilt Claw Down
- Full Speed Dive
- Full Speed Surface
- Open Claw
- Close Claw
- Back
- Start

Customization

Since our controller buttons are mapped to the computers keys, it allows for simple reconfiguration of the controller layout. Our specific configuration is listed on the legend to the left. Any button left at the default value is unmapped.

Micro Class

"These ROVs are used as an alternative to a diver, specifically in places where a diver might not be able to physically enter such as a sewer, pipeline or small cavity." - Anon

Arduino

The Arduino programming language uses both C and C++ which allows for both simplistic and complex coding. We coded the controls and motor settings using this platform.

RealTerm

RealTerm is a Serial commander that simplifies the input process from the keys being pressed, removing the input lag that is normally experienced.

KeySticks

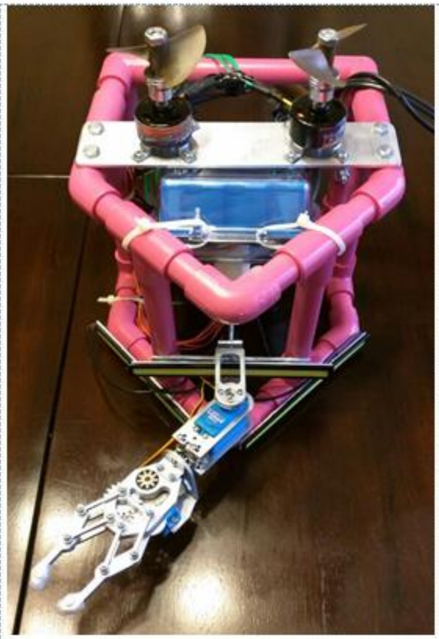
KeySticks Allows for mapping individual keys from the keyboard to the Xbox 360 Control. This is the program that will be used if you wish to change the layout.

Prototype Features

Features

- MK-II Robotic 2-DOF Manipulator
- GoPro Hero 3 Camera
- LED Array 6W 6000K Xenon White
- Brushless DC Motor 730 kV
- Pelican Micro 1060 Underwater Case
- Xbox 360 Control
- Xbox 360 Wireless Transceiver
- Octura X470 2.76" (70 mm) Dia Prop

B 2 - User Manual, English 2



URSA Prototipo

Dettagli Tecnici

Modelo	URSA	
Altezza	6 in	15 cm
Lunghezza	8 in	20 cm
Larghezza	6 in	15 cm
Tensione Di Esercizio	12 Volt	
Amperaggio Operativo	25 Amp	
Velocità Massima	20 MPH	9 m/s
Risoluzione Fotocamera	1080p30 5MP 3FPS	
LED Potere	60 Watt	

Chi Siamo

Di URSA

Disegno economica, compatto, e leggero ad un veicolo semplicistico ancora pienamente funzionale sottomarino comandato a distanza che può essere facilmente controllato tramite controller (videogiochi) Xbox360.

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B 3 - User Manual, Italian 1

Controller Disegno

Legenda

- Pulsante - A
- Pulsante - B
- Pulsante - X
- Pulsante - Y
- Ascensore
- Spinta
- Girare Sinistra - Artiglio
- Girare Destra - Artiglio
- Pulsante - Su
- Pulsante - Sotto
- Immersione Massima
- Salire Massima
- Aprire - Artiglio
- Chiudere - Artiglio
- Pulsante - Indietro
- Pulsante - Inizio

Personalizzazione

Poiché i nostri pulsanti del controller vengono assegnati ai tasti computer, consente per semplice riconfigurazione del layout di controllo . La nostra configurazione specifica è quotata alla leggenda di sinistra. Ogni pulsante rimanendo a default non viene assegnato.

Micro Class

"Questi ROV sono usati come alternativa ad un subacqueo specificamente in luoghi dove un subacqueo potrebbe non essere in grado d'entrare fisicamente tale tubazione fognaria o piccole cavità" - Anon

Arduino

Il linguaggio di programmazione Arduino utilizza Sia C e C ++ che permette sia la codifica semplicistica e complesso. Abbiamo codificato i comandi e le impostazioni del motore usando questo programma.

Realterm

RealTerm è un comandante di serie che semplifica l'inserimento tasti, eliminando il ritardo che normalmente esperienza.

Keysticks

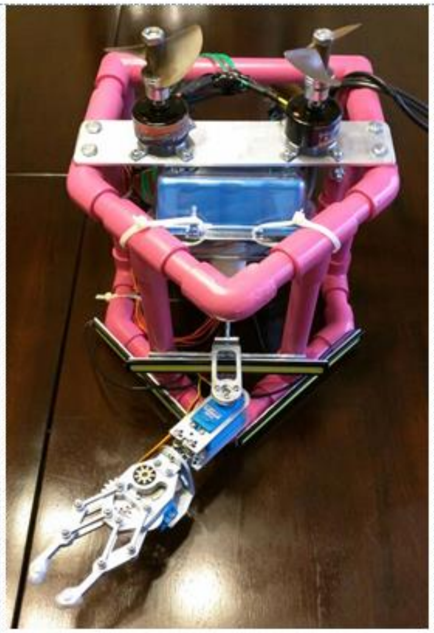
Keysticks assegna tasti specifici dalla tastiera al controller Xbox 360. Questo programma sarà utilizzato se si desidera cambiare il layout.

Caratteristiche Prototipo

Caratteristiche

- MK-II Robotica 2-DOF Artiglio
- GoPro Hero 3 Fotocamera
- LED Fila 6W 6000K Xenon Bianco
- Brushless DC Motore 730 kV
- Pelican Micro 1060 Custodia Subacquea
- Xbox 360 Controller (Videogiochi)
- Xbox 360 Wireless Sensa Fili
- Octura X470 2.76" (70 mm) Dia Elica

B 4 - User Manual, Italian 2



URSA Prototipo

Especificaciones

Modelo	URSA	
Altura	6 in	15 cm
La Largo	8 in	20 cm
Ancho	6 in	15 cm
Voltage Operativo	12 Volt	
Amperage Operativo	25 Amp	
Maxima Velocidad	20 MPH	9 m/s
Resolucion De camara	1080p30 5MP 3FPS	
LED Poder	60 Watt	

Quienes Somos

Acerca de URSA

El Diseño compacto, ligero, y economico llega a un simple pero completamente funcional vehículo submarino operado por control de Xbox 360.

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Underwater Research and Scientific Apparatus - Marine Advanced Technology Education Remotely Operated Vehicle

B 5 - User Manual, Spanish 1

Diagrama del Control

Diagrama

- Botón - A
- Botón - B
- Botón - X
- Botón - Y
- Levantar
- Empujar
- Izquierda direccional
- Derecha direccional
- Inclinación Garra Hasta
- Inclinación Garra de Down
- Completo de buceo velocidad
- Completo Superficie velocidad
- Abrir garra
- Cerrar Garra
- Volver
- Comienzo

Personalización

Assignando los bottones del control a las teclas de la computadora deja aserle cambios a la diseño. Nuestra configuracion del diagrama esta en la izquierda. Los bottones que quedan no estan assignados.

Micro Class

"Estos ROVs se utilizan como una alternativa a un buceador, específicamente en lugares donde un buzo podría no ser capaz de entrar físicamente tal como una alcantarilla, tubería o pequeña cavidad" - Anon

Arduino

El lenguaje de programación Arduino utiliza tanto C y C ++ que permite tanto la codificación simple y complejo. Se codificaron los controles y ajustes del motor utilizando esta plataforma.

RealTerm

RealTerm es un comandante de serie que simplifica el proceso de entrada de las teclas, eliminando el desfase de entrada que normalmente se experimenta.

KeySticks

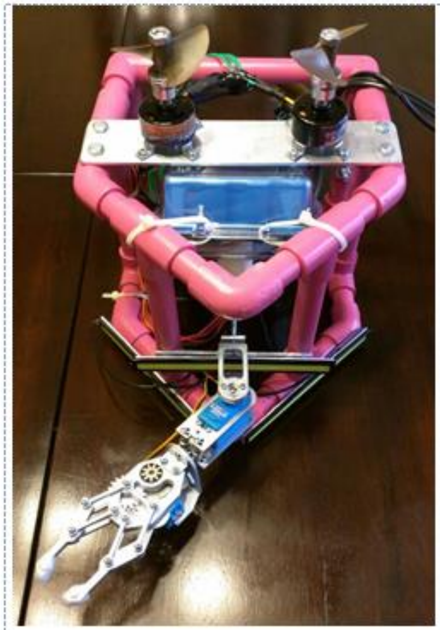
Permite asignar teclas al control del xbox 360. Este es el programa que se utilizará si desea cambiar el diseño.

Características Prototipo

Características

- MK-II Robotic 2-DOF Manipulador
- GoPro Hero 3 Camera
- LED colección 6W 6000K Xenon Blanco
- Brushless DC Motor 730 kV
- Pelican Micro 1060 Underwater Case
- Xbox 360 Control
- Xbox 360 Wireless Transceiver
- Octura X470 2.76" (70 mm) Dia Helice

B 6 - User Manual, Spanish 2



URSA Prototype

Özellikler

Modelin Adı	URSA	
Yükseklik	6 in	15 cm
Boy	8 in	20 cm
En	6 in	15 cm
Çalşma Voltajı	12 Volt	
Çalışma Akımı	25 Amp	
Maksimum Hız	20 MPH	9 m/s
Kamera Rezülasyonu	1080p30 5MP 3FPS	
LED Gücü	60 Watt	

Biz Kimiz

URSA Hakkında

Kompakt ve düşük hacimli, hafif ve tamamen ekonomik bir tasarım, basit ama çok fonksiyonlu, uzaktan Xbox360 ile kontrol edilen ve kontrolu çok kolay olan bir sualtı taşıtıdır.

İletişim

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B 7 - User Manual, Turkish 1

Denetliyici Düzeni

Legend

- A Tuşu
- B Tuşu
- X Tuşu
- Y Tuşu
- Kaldır
- At/Fırlat
- Sol Yönlü
- Sağ Yönlü
- Kepçe/Pençeyi Kaldır
- Kepçe/Pençeyi Indir
- Tüm Hızla Dal (Maksimum Dalma Hızı)
- Yüzeydeki Maksimum Hız
- Pençe/Kepçeyi Aç
- Pence/Kepçeyi Kapat
- Geri
- Başlat

Özelleştirme/Kişiselleştirme

Kumanda düğmeleri bilgisayar tuşları ile eşleştirilecek şekilde tasarlandığı için bu denetleyici düzenin basitçe yeniden yapılandırılmasına izin veriyor. Özel yapılandırma düzeneği sol tarafta listelenmiştir. Kullanılmayan herhangi bir düğme, varsayılan başka bir değerle eşlendirilmemiştir.

Mikro Sınıfı

"Bu ROV'lar alternatif dalgıç olarak özellikle atık su kanalizasyon ve küçük oyuklar gibi dalgıçların girmesi imkansız yerlerde kullanılmaktadırlar." - Anon

Arduino

Arduino programlama dili C ve C++ `ı aynı anda kulanıyor, bu da hem basit, hem de karışık kodlamasına imkan veriyor. Biz denetliyci ve motoru ayarlarını bu platformu kullanarak kodlandırdık.

RealTerm

Realterm tuşların basılmasını kolaylaştıran ve normalde gecikmeyi önleyen bir seri komutanıdır.

KeySticks

Xbox 360 Kontrol klavyeden tek tek tuşları eşlendime için izin verir. Bu düzeni değiştirmek isterseniz, kullanılacak olan program işte budur.

Prototype Features

Özellikler

- MK-II Robot 2-DOF manipülatör
- GoPro Hero 3 Kamera
- LED Array 6W 6000K Beyaz Zenon
- Fırcasız DC Motor 730 kV
- Pelican Micro 1060 Sualtı Kılıf
- Xbox 360 Kontrol
- Xbox 360 Kablosuz Haberleşme Cihazı
- Octura X470 2.76 '' (70mm) Dia Prop

URSA - MATE ROV فارسی

دستگاه زیردریائی علمی تحقیقاتی -برای آموزش دانش پیشرفته دریائی با قابلیت کاربری از راه دور

ما که هستیم

درباره یوآراس آ

فشرده بودن، سبکی و اقتصادی بودن طراحی منجر به یک ماشین زیر دریای ساده اما در عین حال با کارائی کامل گشته که به راحتی قابل کنترل با کنترلر ایکس باکس **360** می باشد.

تماس با ما

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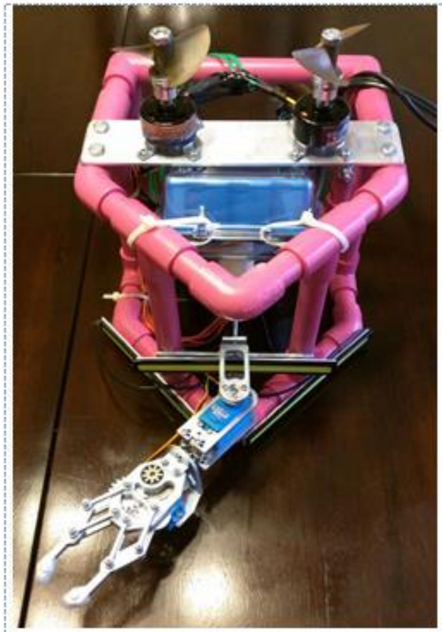


نمونه اولیه یوآراس

مشخصات

نام مدل	یوآراس ۱	
ارتفاع	6 اینچ	سانتیمتر 15
طول	8 اینچ	سانتیمتر 20
عرض	6 اینچ	سانتیمتر 15
ولتاژ کاری	12 ولت	
جریان کاری	25 آمپر	
بیشترین سرعت	بر 20 مایل ساعت	بر متر 9ثانیه
رزولوشن دوربین	1080p30 5MP 3FPS	
توان ال ای دی	60 وات	

B 9 - User Manual, Persian 1

مونه اولیه یوآراس

مشخصات:

- بازوی روباتیکی، MK-II Robotic 2-DOF
- دوربین، GoPro Hero 3 Camera
- ال ای دی، LED Array 6W 6000K Xenon White
- موتور، Brushless DC Motor 730 kV
- کیس، Pelican Micro 1060 Underwater Case
- کنترل، Xbox 360 Control
- فرستنده-گیرنده، Xbox 360 Wireless Transceiver
- پراپ، Octura X470 2.76" (70 mm) Dia Prop

ویژه سازی

از آنجائی که دکمه های کنترل با راینه کوپل هستند، امکان تغییر در چیدمان کنترلر به راحتی میسر می باشد. چیدمان خاص استفاده شده توسط ما در علائم لیست شده در سمت چپ آورده شده است. دکمه هائی که کاربری آنها تغییر داده شده و مشابه کاربری اوریجینال می باشد در لیست ذکر نگردیده اند.

تلاس میکرو

ماشینهای کنترل از راه دورزیر سطحی به عنوان جایگزینی برای غواص در نظر گرفته می شوند به خصوص در مواردی که غواص امکان ورود به منطقه را ندارد مانند فاضلاب، خطوط لوله و محفظه های کوچک.

آردوئینو

آردوئینو قابل برنامه نویسی با هر دو زبان c و c++ می باشد که به این دلیل امکان برنامه نویسی به صورت ساده و پیشرفته به صورت همزمان امکان پذیر است. کنترل ها و تنظیمات موتور از طریق این پلتفرم کدنویسی گردیدند.

ریل ترم

ریلترم یک دستورگر در حالت سریال می باشد که فرآیند گرفتن ورودی از دکمه فشرده شده را از طریق حذف تاخیر که معمولا مشاهده میشود ساده سازی می نماید.

کی استیک

اجازه مرتبط کردن دکمه های مستقل از کیبورد با کنترل ایکس باکس 360 را فراهم می نماید. این برنامه در مواقعی استفاده میشود که کاربر قصد تغییر پترن کنترل را داشته باشد.

Controller Layout

Legend

- A: دکمه A
- B: دکمه B
- X: دکمه X
- Y: دکمه Y
- L: بلند کردن
- R: نیروی محرکه
- حرکت به چپ
- حرکت به راست
- حرکت رو به بالای چنگک
- حرکت رو به پائین چنگک
- LT: سرعت دایو کامل
- RT: سرعت کامل سطحی
- LB: باز کردن چنگک
- RB: بستن چنگک
- عقب
- شروع

B 10 - User Manual, Persian 2

Appendix C. Detailed Raw Design Calculations and Analysis (Scanned Material)

$$dT = dL\cos(\phi + \alpha_i) - dD\sin(\phi + \alpha_i)$$

$$dQ = r\,[dL\sin(\phi + \alpha_i) + dD\cos(\phi + \alpha_i)]$$

$$dL = \frac{1}{2}\rho V_e^2 c\, C_l\, dr$$

$$dD = \frac{1}{2}\rho V_e^2 c\, C_d\, dr$$

D - Prop dia | m |
n - prop speed | rev/s |
Q - Torque | Nm |
T - thrust | N |
ρ - Fluid Density | kg/m³ |
μ - Fluid Visc | m²/s |
K - Fluid Bulk Emod | N/m² |
u_0 - Flight velocity | m/s |

Buoyancy tests

$$W = V \cdot \rho$$

W - weight
V - volume
ρ - Density

$$B_{uo} = W_{DW} - W_{eov}$$

$$RPM = V \cdot K_V$$

$$HP = \frac{Amps \cdot volt}{745.7 \left(\frac{watt}{hp}\right)}$$

$$F_{thrust} = \rho \cdot A \cdot V \cdot (V - V_i)$$

K_V - Rating
A - Area of Stream

$$F_d = \frac{1}{2}(\rho \cdot C_d \cdot A \cdot V^2)$$

$$Speed = \frac{RPM}{ratio} \times \frac{Pitch}{C} \times [1 - (slip/100)]$$

$C = 1056$ mph
$= 656$ kph

C 1 - Scanned Equations

Appendix D. Copies of Used Commercial Machine Element Catalogs (Scanned Material)

RANGER Missions

DESIGN BRIEF

1) SCIENCE UNDER THE ICE (international venue = ice tank)

- Maneuver through a 75cm x 75cm hole in the ice.
- Collect a sample of algae from the underside of the ice sheet.
- Collect an urchin located on the seafloor.
- Use a species identification handbook to identify and count species of sea star.
- Deploy a passive acoustic sensor in a designated area.
- Measure the dimensions of an iceberg and calculate its volume.
- Use coordinates to map the location of the iceberg.
- Use the location, heading, speed, and keel depth to determine the threat level of the iceberg to area oil platforms.

2) SUBSEA Pipeline inspection & REPAIR (international venue = offshore engineering basin)

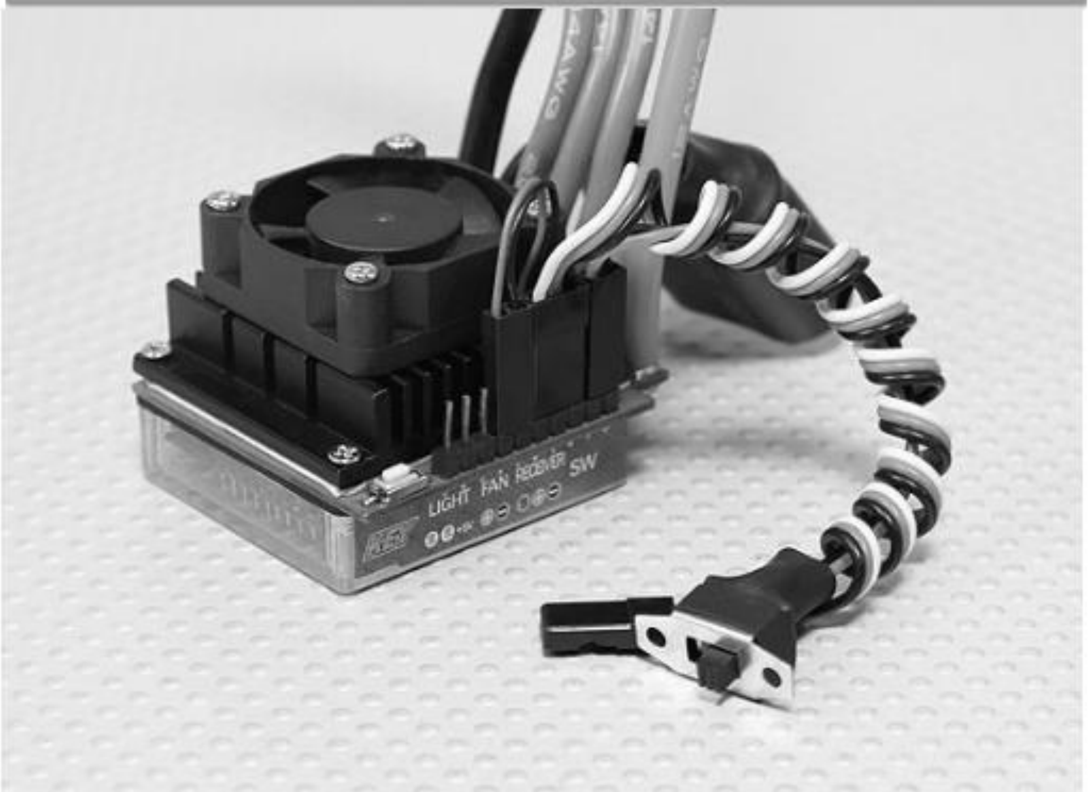
- Conduct a CVI (close visual inspection) of an oil pipeline for corrosion.
- Turn a valve to stop the flow of oil through the pipeline.
- Examine a gauge dial to determine that the pipeline oil pressure is zero.
- Measure the length of the section of corroded pipeline.
- Attach a lift line to the corroded section.
- Cut (simulated) the section of corroded pipeline.
- Remove the section of corroded pipeline and return it to the surface.
- Install and secure an adapter flange over both cut ends of the pipeline.
- Install a gasket into a wellhead.
- Insert a hot stab to simulate injecting corrosion prohibiter into the wellhead.

3) OFFSHORE OILFIELD PRODUCTION & MAINTENANCE (international venue = flume tank)

- Test the grounding of anodes by measuring the voltage of specified points along the "leg" of an oil platform.
- Determine which anode(s) is not properly grounded.
- Measure the height of a wellhead from the seafloor.
- Use a map to determine the pathways of flow through a pipeline system.
- Turn valves to ensure that oil will flow through the specified pathway.

D 1 - Scanned Catalog, Ranger

HobbyKing® ™ Brushless Car ESC 100A w/ Reverse (Upgrade version) (US Warehouse)



HobbyKing® ™ upgrade version ESC provide more power support to the MCU, resulting better throttle response and high speed performance.Also software upgrade gives better startup effect and support different type of motors.

Features:
Full protection feature including low voltage, over-heat, throttle signal lost, startup protection and self-check.
Compatible with sensorless brushless motor.
Excellent startup performance, linear and quick throttle response.
Supports highest motor speed 240,000RPM(2 poles), 80,000RPM(6 poles) and 40,000(12 poles).
Easy to configure with program card.
System can automatically detect throttle neutral point, and neutral range is adjustable.
Three work modes for different environments.
4 step reverse force adjustment
5 step start force adjustment.
3 step brake force adjustment
5 step drag brake force adjustment,
4 step initial brake force adjustment.

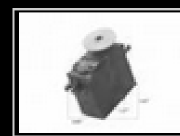
Specification:
Input voltage: **5V-17V (support 2-4S lithium batteries)**
Cont. Current: **100A**
BEC output: **3A /5.5V (switch)**
Size(length X width X high): **47x41x29mm**
Weight: **95g**

D 2 - Scanned Catalog, ESC Specs [HobbyKing® ™ Brushless Car ESC 100A]

HS-5646WP High Voltage, High Torque, Programmable Digital Waterproof Servo

Part No: 35646W

Additional Views



Click image above for full size. ‹ Previous Photo Next Photo ›

Product Description

Our waterproof servos have what it takes to keep your radio control vehicle, airplane or robot watertight! With high torque, dual ball bearings and metal gears, our digital waterproof servos have the industry's first IP67* rating ranking them among the most durable and reliable servos for wet conditions. Whether you are manning your power boat, bashing in the mud, directing your underwater robot, or water landing your 25% plane, the **HS-5646WP** will dependably keep your mind at ease.

Features

- Industry's First IP67-Rated Waterproof Case
- Strong Three-Pole Ferrite Motor
- Metal Gear Train with MP First Gear
- Dual Ball Bearing-Supported Output Shaft
- 7.4v 2-Cell LiPo Capability
- Standard Programmable Digital Circuitry

IP = International Protection Code
6 = Dust Tight
7 = Immersion up to 1M

Specifications

Motor Type:	3 Pole
Bearing Type:	Dual Ball Bearing
Speed (6.0V/7.4V):	0.20 / 0.18
Torque oz./in. (6.0V/7.4V):	157 / 179
Torque kg./cm. (6.0V/7.4V):	11.3 / 12.9
Size in Inches:	1.65 x 0.83 x 1.57
Size in Millimeters:	41.8 x 21.0 x 40.0
Weight oz.:	2.15
Weight g.:	61

D 3 - Scanned Catalog, Servo Specs [HS-5646WP High Voltage, High Torque, Programmable Digital Waterproof]

HS-5086WP Metal Gear, Micro Digital Waterproof Servo

Part No: 35086W

Additional Views

Click image above for full size.

‹ Previous Photo Next Photo ›

Product Description

The HS-5086WP is the smallest in Hitec's class of waterproof servos. With heavy-duty metal gears and a ball bearing supported output shaft, the HS-5086WP is among the most durable and reliable micro servo for wet conditions. Possessing the same size as our popular HS-65MG and the industry's first IP67*rating, this spunky mini will keep your RC vehicle, boat, aircraft or robot watertight, no matter what the weather or surroundings.

Features

- Metal Gear with MP First Gear
- Top Ball Bearings
- 3-Pole Cored Ferrite Motor
- Industry's First IP67-Rated Waterproof Case*
- Programmable Circuit

IP = International Protection Code
6 = Dust Tight
7 = Immersion up to 1M

Specifications

Motor Type:	3 Pole Metal Brush Ferrite Magnet
Bearing Type:	Top Ball Bearing
Speed (4.8V/6.0V):	0.18 / 0.15
Torque oz./in. (4.8V/6.0V):	42 / 50 oz-in
Torque kg./cm. (4.8V/6.0V):	3.0 / 3.6 kg-cm
Size in Inches:	1.22 x 0.60 x 1.22 in
Size in Millimeters:	31.0 x 15.2 x 31.0 mm
Weight ounces:	1.0 oz
Weight grams:	28.5 g

▾ Advanced Specifications

Control System:	Programmable Digital
Operating Voltage Range:	
Idle Current @ 6.0v:	3 mA
No Load Running Current @ 6.0v:	280 mA
Stall Current @ 6.0v:	1800 mA
Dead Band Width:	2
Potentiometer Type:	2 Slider 500K Cycle Rated
Connector Wire Length:	9.8 in / 250 mm
Connector Wire Type:	Flat
Connector Wire Strand Count / Gauge:	40 Strand / 25 ga.

D 4 - Scanned Catalog, Servo Specs [HS-5086WP Metal Gear, Micro Digital Waterproof Servo]

Weight

Camera: 2.6oz (74g)

Camera with housing: 4.8oz (136g)

Video Modes

Video Resolution	1080p	960p	720p	WVGA
Frames per Second (fps) NTSC/PAL	30, 25	30, 25	60, 50, 30, 25	60, 50
Field of View (FOV)	Medium	Ultra Wide	Ultra Wide	Ultra Wide
Screen Resolution	1920 x 1080	1280 x 960	1280 x 720	848 x 480
Aspect Ratio	16:9	4:3	16:9	16:9

Video Format

H.264 codec, .mp4 file format

Advanced Video Capture Settings

Spot Meter

Spot Meter is ideal for filming within a dark space with the camera pointed towards a brighter setting (such as filming the outdoors from within a car).

Looping Video

Record a continuous video loop that overwrites itself until you press the shutter button to stop it. It's ideal for saving space on your memory card while waiting to catch a moment of action.

One Button

Upon powering on, the camera automatically begins recording video or capturing Time Lapse photos.

Photo Modes

Still Photo

5MP, Wide FOV, 2592 x 1944 screen resolution

Burst Photo

3 photos/1 second

Time Lapse

0.5, 1, 2, 5, 10, 30, 60 second intervals

Photo Modes Overview

Photo

Capture a single photo.

Burst Photo

Capture 3 photos per second.

Time Lapse

Automatically capture a series of photos at timed intervals. Time Lapse mode is ideal for capturing photos when the camera is out of reach.

Image Quality + Optics

Ultra sharp 6-element aspherical glass lens

Fixed f/2.8 aperture

Ultra wide-angle field of view

Battery + Charging

Rechargeable lithium-ion battery

Rated at 1050mAH, 3.7V, 3885mWh

Battery Life

The chart below indicates the approximate continuous recording time (hr:min) you can expect when shooting in various video modes using a fully charged battery.[1]

	With Wi-Fi Off	With Wi-Fi On + Using Wi-Fi Remote	With Wi-Fi Off + Using LCD Touch BacPac™
Video Mode	**Estimated Time**	**Estimated Time**	**Estimated Time**
1080p 30 fps	2:15	2:00	1:30
960p 30 fps	2:45	2:30	1:45
720p 60 fps	2:15	2:00	1:30
720p 30 fps	3:00	2:30	1:45

[1] Actual performance may vary based on settings, environmental conditions and other factors. Maximum battery capacity will normally decrease with time and use.

Audio

Format: 48kHz sampling rate, AAC compression

AGC (automatic gain control)

Internal mic: Mono

External mic: Stereo supported with 3.5mm microphone adapter (sold separately).

Ports

Mini USB

Charging

Connecting to a computer for playback/file transfer/charging

Supports 3.5mm stereo microphone via optional adapter (sold separately)

Supports playback to composite TV via optional cable (sold separately)

Micro HDMI

Supports playback to HDTV via optional cable (sold separately)

microSD

Memory card

Storage

microSD memory card with a Class 10 or UHS-1 rating required.

Up to 64GB capacity supported

Record times vary with resolutions and frame rates

Photo + Video Playback

HDTV

Requires a micro HDMI to HDMI cable (sold separately) or the included USB cable

Note: Some TVs do not support the USB cable option.

TV

Requires a mini USB to composite cable (sold separately) or the included USB cable

Note: Some TVs do not support the USB cable option.

LCD Touch BacPac™ (sold separately)

Attach to your camera for preview and play back of videos and photos.

GoPro App

Use your phone or tablet to preview and play back videos and photos.

Computer

Connect via mini USB to USB cable (included), or copy files from the microSD card to your computer.

Minimum system requirements for best playback on Mac® and Windows® computers

Mac OS® X 10.8 and later / Microsoft Windows 7, 8.x

Intel® Core 2 Duo™ or Intel® Dual Core™

4GB for Mac / 2GB RAM (4GB or greater recommended) for Windows

Windows: Graphics card that supports OpenGL1.2 or later

5400 RPM internal hard drive (7200 RPM drive or SSD recommended)

D 5 - Scanned Catalog, Camera Specs [GoPro Hero 3]

Product Description

- Condition: Brand new
- Package includes: 2 pieces of COB LED daytime running light
- Size(Approx.): Total L 6 3/4" x W 5/8" (17cm x 1.5cm)
- Color: 6000K Xenon white
- Working Voltage: DC 12V
- Wattage: 6w x2
- Number of LED: COB SMD x2
- Cable length: 30" (75cm)
- Material: Heavy duty Aluminum body.

Features:

- High power COB SMD LED light bulb, slim design.
- Emit Super bright xenon white light, high intensity.
- Enhance lighting in rainy and foggy days & brings more safety.
- Low power consumption and vibration resistant.
- With 50000 working hours life expectancy.
- Our LED light are guaranteed to be the highest quality.
- Easy installation, easily stick on with self-adhesive tape.

Fitment:

- Universal fit any vehicle car van truck with 12V power.

* Please Read All Description and Fitment Before Ordering the Product.
* Not D.O.T. approved, for off road use only.
* Note: Professionals install is strongly recommended to avoid trouble caused by inexperienced installer!

D 6 - Scanned Catalog, LED Specs [Astra Depot]

Specs:
RPM/v: **730kv**
Dimensions: **41 x 28mm**
Shaft: **5.0mm**
Voltage: **11.1v~14.8v**
Weight: **115g**
No-load current: **1.9A @ 11.1v**
Max Current: **35A**
Max Watts: **330W**
Mounting Holes: **51mm**

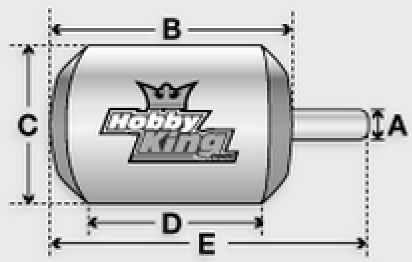
Prop Data:
12x6 - 11.1v - 16A - 1060g Thrust
13X4 - 11.1v - 15A - 1140g Thrust
10x5 - 14.8v - 16A - 1180g Thrust

PRODUCT ID: ST3508-730

This product available from a warehouse near you!

Product Config Table

Kv(rpm/v)	730
Weight (g)	115
Max Current(A)	35
Resistance(mh)	0
Max Voltage(V)	15
Power(W)	330
Shaft A (mm)	5
Length B (mm)	28
Diameter C (mm)	42
Can Length (mm)	18
Total Length E (mm)	44



COMPARE

Update/Add my own data
Customer Data

D 7 - Scanned Catalog, Motor Specs [HobbyKing Donkey ST3508-730kv Brushless Motor]

3M™ Marine Adhesive Sealant 5200 Fast Cure White, PN05220, 3 oz Tube, 6 per case

3M ID 60980045581 UPC# 00051135052204

3M™ Marine Adhesive Sealant 5200 White. The adhesive sealant is extremely strong, retains its strength above or below water line. Stays flexible too - allows for structural movement. Has excellent resistance to weathering and salt water.

- High performance polyurethane adhesive/sealant becomes tack-free in 48 hours, cures completely in 5-7 days
- Strong seal retains strength above or below the water line
- Excellent resistence to weathering and saltwater
- Marine, general industrial

Bonding, attaching, and assembling

Stress caused by shock, vibration, swelling or shrinking is effectively absorbed. Check the bonding and sealing jobs this product can handle for you: fiberglass deck to fiberglass hull, wood to fiberglass, portholes and deck fittings, motors on fiberglass transoms, under moldings, hull seams above and below water line. Center board trunk joints. Between struts and planking. Stern joints. Deck housing, etc. Easy to apply with manual caulking gun. Remains workable with trowel or spatula up to four hours after application. Won't sag or flow in vertical or horizontal seams.

Specifications

Application Method	Hand or pressure caulk
Brand	3M
Capabilities	Sustainability
Color	White
Consistency	Medium paste
Consumer Label	Yes
Container Volume	3 fl oz (US)
Cure Rate	3 mm/24 hr
Elongation	>900 Percent
Hardness	60 Shore A
Industries	Marine , Transportation , Specialty Vehicle , Construction , General Industrial
Product Form	Tube
Skin Time	60 - 120 Minute
Solids Weight Percent (Approximate)	95 Percent
Tack Free Time	1 Hour
Tensile Strength	600 psi

D 8 - Scanned Catalog, 3M™ Marine Adhesive Sealant 5200 Fast Cure White

STRENGTH	900 PSI
SET TIME	25 Minutes
CURE TIME	1 Hour
CURE COLOR	Off White

USE ON

- Automotive
- Ceramic
- Epoxy Putty Sticks
- Fiberglass
- Metal
- Plastic/Composite/PVC
- Under Water/Wet
- And More

WATERWELD EPOXY PUTTY

$ 7.99

WaterWeld will plug or seal leaks and patch holes and cracks in almost anything. Ideal for repairing plumbing, fuel tanks, tub and shower, drains, pool and spa, boats and potable water tanks; setup occurs even under water. After curing, it can be drilled, tapped, filed, sanded and painted. WaterWeld has a set time of 15-25 minutes and sets hard in one hour. WaterWeld cures to an off-white color, is rated at a tensile strength of 900 PSI and will withstand temperatures up to 300ºF.

GREAT FOR

- Plumbing, Tub, Shower & Drains
- Fuel Tanks
- Marine & Boats
- Potable Water Tanks

ADD TO CART

MADE IN THE USA

SHARE:

D 9 - Scanned Catalog, JB Weld WATERWELD EPOXY PUTTY

PRODUCT OVERVIEW Model # 411/DC | Internet # 100575385 | Store SKU # 490070

Scotch Outdoor Mounting Tape can be used on a variety of surfaces. It's faster, safer and more versatile than screws and nails. Outdoor Mounting Tape comes in various sizes.

- For indoor and outdoor use
- Weather resistant and highly conformable
- Works on many surfaces including metal, glass and plastic
- Weight capacity: holds up to 10 lbs.-1 in. holds a 1/4 lbs., 4 in. hold 1 lbs.
- Size: 1 in. x 60 in.
- Color: black

SPECIFICATIONS

DIMENSIONS

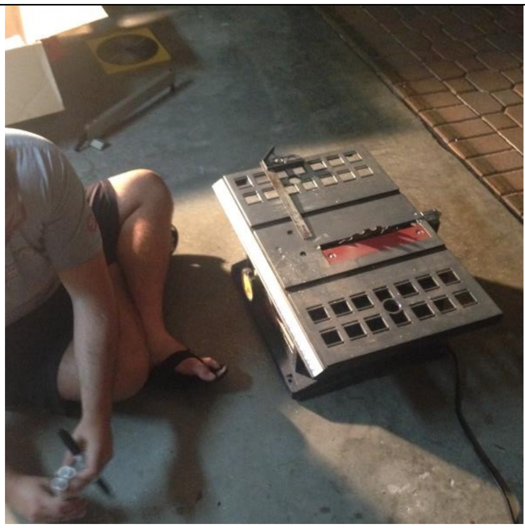
Assembled Depth (in.)	1.125 in	Assembled Width (in.)	3.75 in
Assembled Height (in.)	5.375 in	Product Width (in.)	1

DETAILS

Adhesion level	High	Number of rolls included	1
Color Family	Grays	Paint Product Type	Double Sided Tape
Indoor/Outdoor	Indoor/Outdoor	Recommended surfaces	Brick,Glass,Metal
Maximum application temperature (F)	105	Returnable	90-Day
Minimum application temperature (F)	50	UV/sunlight resistant	Yes
Moisture Resistant	Yes		

D 10 - Scanned Catalog, Scotch Outdoor Mounting Tape

Appendix E. Project Photo Album

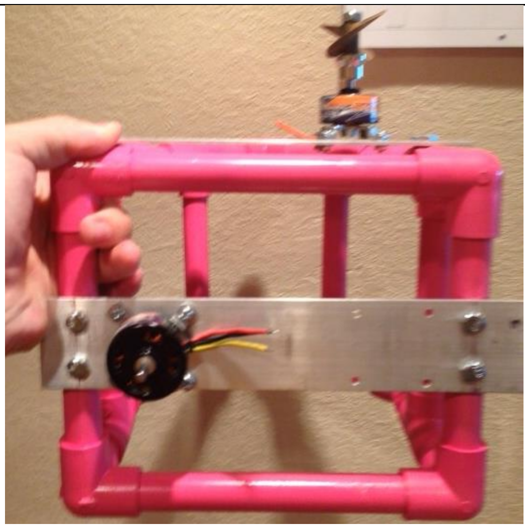


E 1 - Photo Album, Cutting PVC

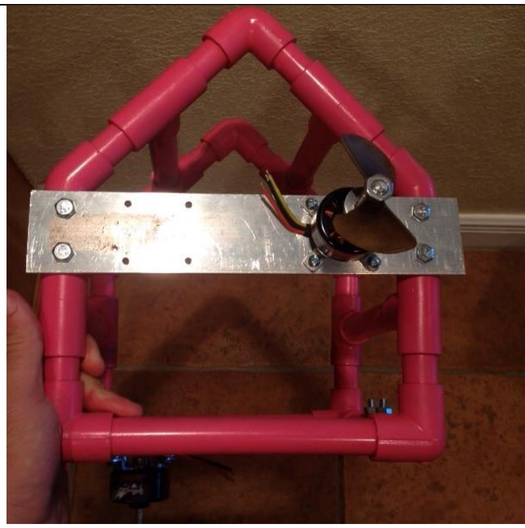
E 2 - Photo Album, Spraying PVC

E 3 - Photo Album, Drilling Aluminum Mounting Bars

E 4 - Photo Album, Drilling Aluminum Mounting Bars 2



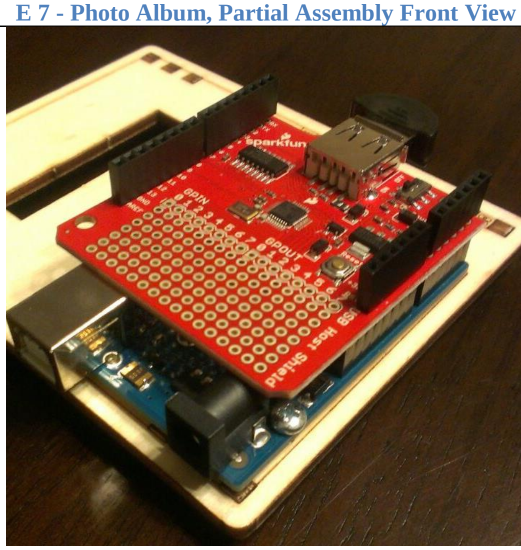
E 5 - Photo Album, Partial Assembly Rear View



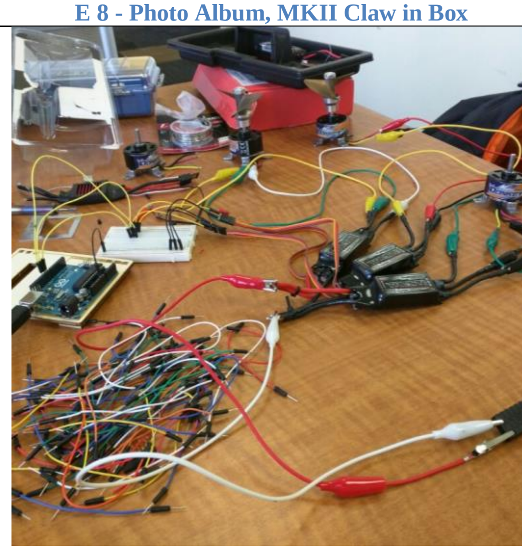
E 6 - Photo Album, Partial Assembly Top View

E 7 - Photo Album, Partial Assembly Front View

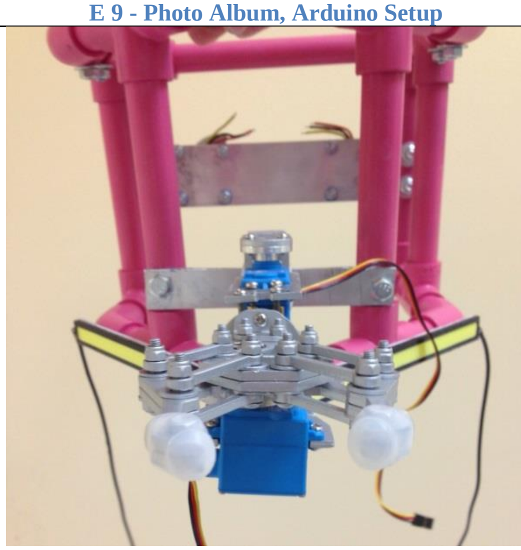
E 8 - Photo Album, MKII Claw in Box



E 9 - Photo Album, Arduino Setup



E 10 - Photo Album, Electronic Layout

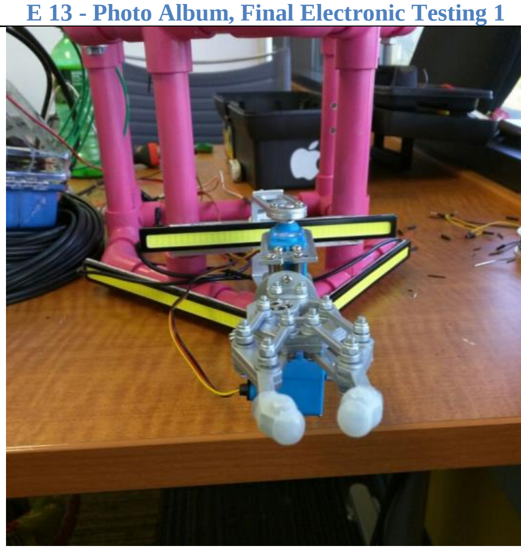


E 11 - Photo Album, Mounted Claw

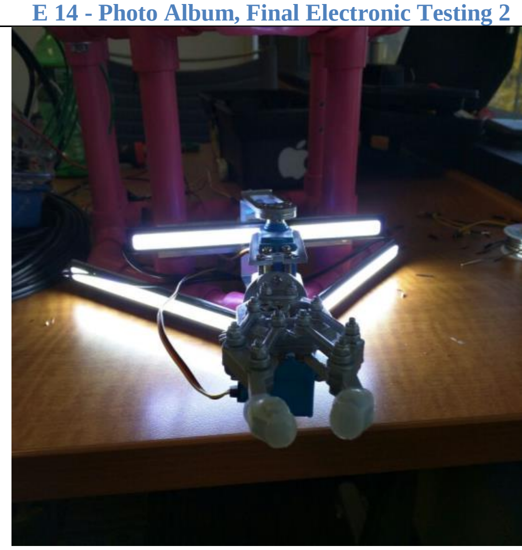
E 12 - Photo Album, Heat Shrunk Wires

E 13 - Photo Album, Final Electronic Testing 1

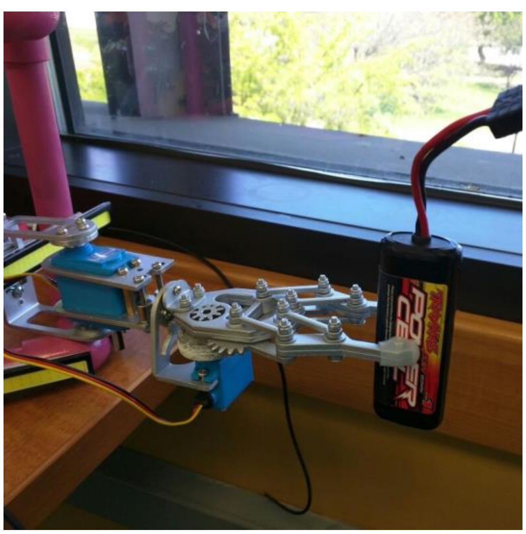
E 14 - Photo Album, Final Electronic Testing 2



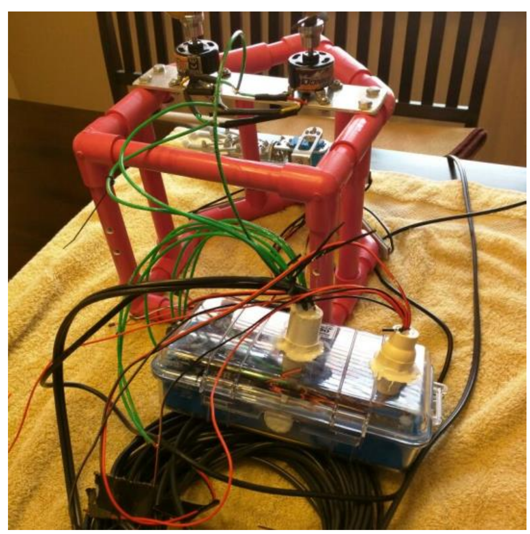
E 15 - Photo Album, LED off



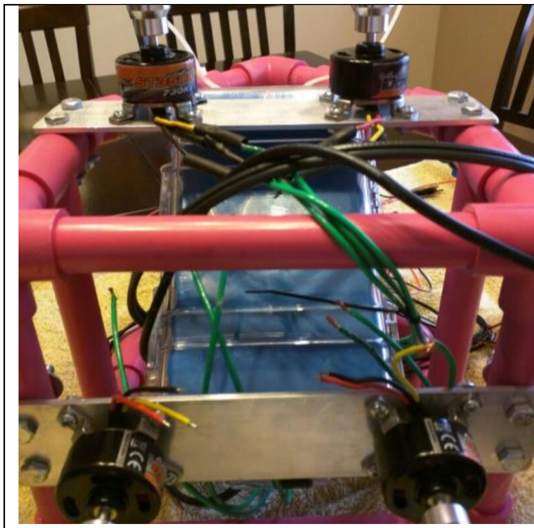
E 16 - Photo Album, LED on



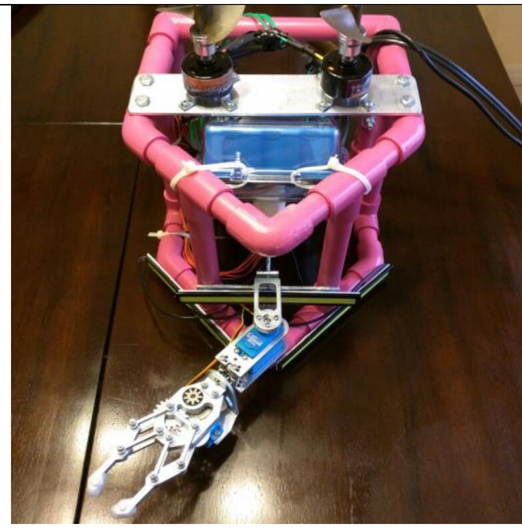
E 17 - Photo Album, Claw Holding Object



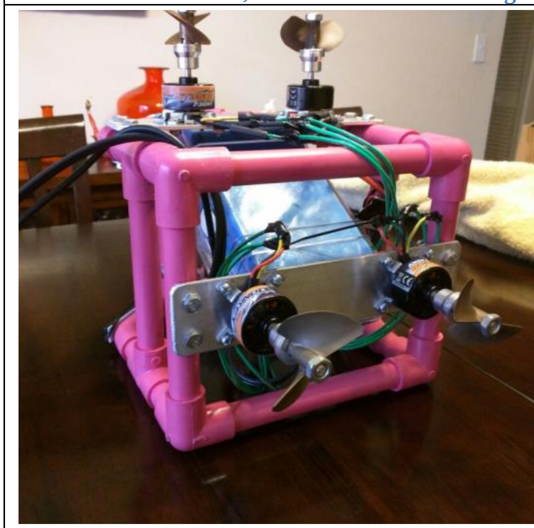
E 18 - Photo Album, Wire Box before Mounting



E 19 - Photo Album, Wire Box after Mounting



E 20 - Photo Album, Assembled (Front Top View)



E 21 - Photo Album, Assembled (Rear View)

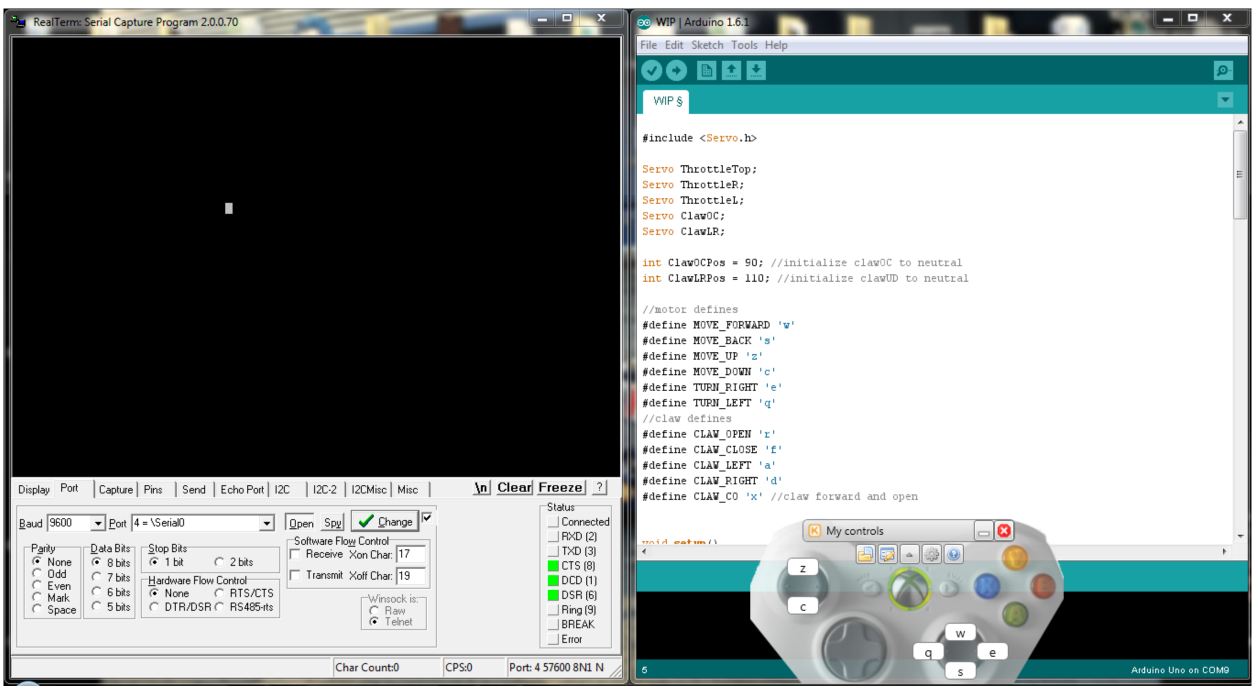
E 22 - Photo Album, Assembled (Angled View)

Appendix F. Code

```
#include <Servo.h>

Servo ThrottleTop;
Servo ThrottleR;
Servo ThrottleL;
Servo ClawOC;
Servo ClawLR;

int ClawOCPos = 90; //initialize clawOC to neutral
int ClawLRPos = 110; //initialize clawUD to neutral

//motor defines
#define MOVE_FORWARD 'w'
#define MOVE_BACK 's'
#define MOVE_UP 'z'
#define MOVE_DOWN 'c'
#define TURN_RIGHT 'e'
#define TURN_LEFT 'q'
//claw defines
#define CLAW_OPEN 'r'
#define CLAW_CLOSE 'f'
#define CLAW_LEFT 'a'
#define CLAW_RIGHT 'd'
#define CLAW_CO 'x' //claw forward and open


void setup()
{
  Serial.begin(9600);
  ThrottleTop.attach(9);  //movement motor attachments
  ThrottleTop.write(70);
  ThrottleR.attach(10);
  ThrottleTop.write(70);
  ThrottleL.attach(11);
  ThrottleTop.write(70);
  ClawOC.attach(6); //claw servo attachments
  ClawOC.write(90); //intializes position of claw
  ClawLR.attach(5);
  ClawLR.write(110);

  delay(500);
}

void loop()
{

char byte = 0;
```

```
Serial.readBytes(&byte, 1);
    if (byte == MOVE_UP){ //Up if statement
    ThrottleTop.write(115);
    }
    else if (byte == MOVE_DOWN){ //Down if statement
    ThrottleTop.write(70);     //this should be a reverse servo number
    }
    else if (byte == MOVE_FORWARD) { //Forward if statement
    ThrottleL.write(115);
    ThrottleR.write(115);
    }
    else if (byte == MOVE_BACK) { //Back if statement
    ThrottleL.write(70); //These should both be motor reversing servo numbers
    ThrottleR.write(70);
    }
    else if (byte == TURN_RIGHT) { //Turn right if statement
    ThrottleL.write(115);
    ThrottleR.write(70); //this should be a reverse number
    }
    else if (byte == TURN_LEFT) { //Turn left if statement
    ThrottleL.write(70); //this should be a reverse servo number
    ThrottleR.write(115);
    }
    else if (byte == CLAW_LEFT) {
    // full left lock is 11*5+90=145
    ClawLRPos = ClawLR.read();
      if (ClawLRPos<155) {
       ClawLRPos += 5;
       ClawLR.write(ClawLRPos);
       }
     }
   else if (byte == CLAW_RIGHT) {
   // full right lock is 90-(11*5)=35
   ClawLRPos = ClawLR.read();
   if (ClawLRPos>55) {
    ClawLRPos -= 5;
    ClawLR.write(ClawLRPos);
    }
   }
    else if (byte == CLAW_CLOSE) {
    ClawOCPos = ClawOC.read();
     if (ClawOCPos<155) {
     ClawOCPos += 5;
     ClawOC.write(ClawOCPos);
     }
   }
   else if (byte == CLAW_OPEN) {
   ClawOCPos = ClawOC.read();
    if (ClawOCPos>35) {
    ClawOCPos -= 5;
```

```
        ClawOC.write(ClawOCPos);
        }
      }
      else if (byte == CLAW_CO) {
      ClawLRPos = 110;
      ClawLR.write(ClawLRPos);
      ClawOCPos = 40;
      ClawOC.write(ClawOCPos);
      }
        else {
        ThrottleTop.write(70); //these should all be neutral position 90
        ThrottleR.write(70);
        ThrottleL.write(70);
        }

byte = 0;
delay(1);
}
```



F 1 - Code, Screenshot