To: Nemo Robotics

From: Group 3

Subject: RE: UROV Project Challenges, Design Report/Sale Requirements

Date: Nov. 2, 2016

201 Mullica Hill Road

Glassboro, NJ 08028

Dear Nemo Robotics,

It is our pleasure to present to you the design report of our prototype Underwater Remote Operated Vehicle (UROV) dealing with the task of capping the oil well and removing the debris caused by earthquake.

This design report is the product of our team members co-operation. Specifically, Sean Dugan was in charge of the Executive Summary section; Robert Livingston and Jeremy Rainey were responsible for the Problem Definition section; and finally Thai Nghiem and George Lentini were responsible for the Evaluation section. Also, each team members take part in the process of building the UROV and revising the design report.

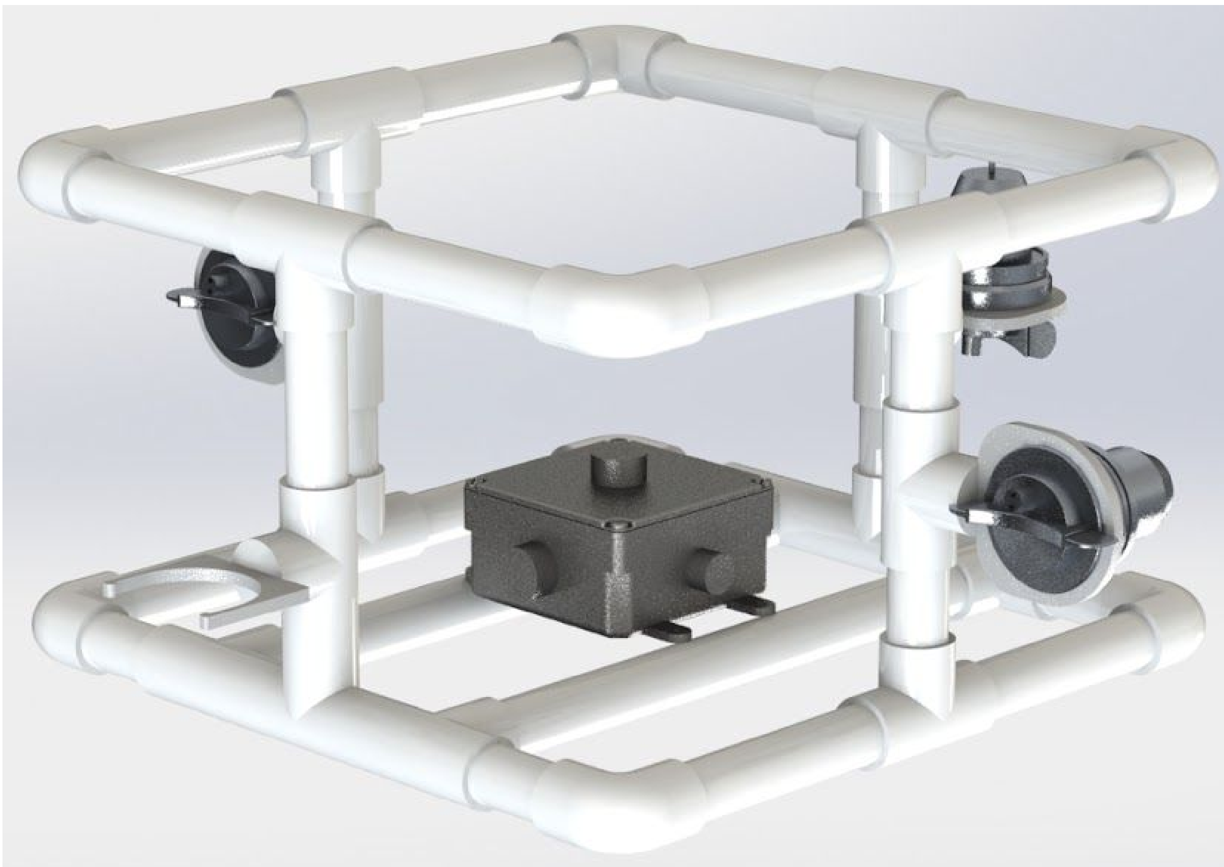
We believe our design is best suited to deal with the task given, which is recovering damages caused by the earthquake. For further information about the details and an in-depth analysis of the prototype design, construction and testing, please reference the attached design report.

Sincerely,

Group 3

George Lentini, Thai Nghiem, Sean Dugan, Robert Livingston, Jeremy Rainey

Sophomore Engineering Clinic 1
Design Report



George Lentini, Thai Nghiem, Sean Dugan, Robert Livingston, Jeremy Rainey

SEC I Section 15

Professor Robinson

10/27/2019

EXECUTIVE SUMMARY

Project Definition

An earthquake occurred and has damaged an oil well that lies on the bottom of the ocean. It was decided that capping the well was the only solution to the oil leak, but due to the circumstances of the situation capping the well with an underwater remote operated vehicle (UROV) was found to be the only option. The objective of this project was to design a UROV that was capable of placing the sealing cap on the oil well, as well as, picking up debris that was scattered about the ocean floor.

Design Description

This report presents a design for a UROV capable of capping an oil well and picking debris up. This design features a fish net at the rear of the UROV with the intent of picking up and trapping debris within the net for removal. The sealing cap is held to the front of the UROV by a ¼` thick acrylic piece designed to hold the sealing cap with enough force to avoid dropping the cap before placing it on designated oil well but not enough force to prevent dislocation upon placing the cap on the oil well. The body of the UROV was designed in a way to provide an exceptional amount of symmetry to making balancing the center of mass of the UROV about the center, to do this a cube like design was implemented with two symmetric PVC pipes across the bottom to allow for the control box to be mounted.

Evaluation

Testing of the design shows that the UROV has the maneuverability required to traverse an obstacle rich environment and pick up debris. Testing also showed that the design for holding the sealing cap functions as intended and allows for the sealing cap to be placed on the oil well without dropping the cap before sealing the desired oil well. With its cost effective design and functionally the design described within this report would help solve the problem of the ruptured oil well.

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PROBLEM DEFINITION

Problem Scope

The intent of this project was to design an underwater remote operated vehicle (UROV) that was capable of placing a cap on a leaking oil well, as well as pick up and retrieve pieces debris.

Technical Review

On April 20, 2010 an explosion occurred on an oil rig owned and operated by British Petroleum (BP) 41 miles offshore of the Gulf of Mexico. The result was roughly 205 million gallon of oil contaminating the water over the following 87 days, the largest oil spill of the 21st century (*1*). In addition to its own massive financial losses, BP was responsible for the complete abolition of the microbial population over an area of 68,000 square miles, causing detrimental effects to the food chain (*2*). Had there been proper systems in place, the oil spill could have been rectified in a matter of hours, saving the lives of countless sea animals.

Various existing technologies have sought to rectify this lack of preparation with fast acting UROV technology. One such device (US patent number 4821665A) is designed solely with the purpose of clearing debris from hard to reach areas where most equipment cannot reach and are too dangerous for divers (*3*). Another similar technology (US patent number 5947051A) is designed to adhere to any surface, even a vertical wall, via suction, preventing it from being pushed away from the area it is working on by currents or the pressure of an oil leak, enhancing operating precision (*4*). These devices can be paired with other technologies designed to either plug or temporarily contain the oil spill.

There are several different methods be explored through which oil spills can be addressed. One very temporary solution (US patent number 20110274496A1) operates as a large scale underwater vacuum. It can be placed directly above the oil leak and used to siphon liquids with a lighter specific gravity than water (oil) to a collection unit at the surface (*5*). While very temporary in nature, the device can be implemented within minutes of the leak occurring, minimizing damages while a more permanent solution is prepared. More permanent solutions can be separated into two categories: The first type, can be seen in the device holding US patent number 8910715B2. The device is designed to be inserted into an uncontrolled oil well. It then deploys a drill tip that splays into a large cap and bores further into the hole, plugging the leak (*6*). The second method can be seen in the device holding US patent number 20110299930A1. Similarly to the previous type, the device is intended to be placed directly into the exposed oil leak. The top of the cap is designed to temporarily stop the flow of oil, utilizing vents to prevent back pressure. With the cap in place, the device injects an underwater concrete into the hole and remains in place until the concrete dries, securely plugging the leak (*7*).

Design Requirements

This design has to meet 4 requirements: reach top speeds within a 10m straightway to allow for the lowest time recorded to complete the straightway, enough maneuverability to traverse five obstacles that lie every 2 meters on a 10 meter track, pick up and clear the largest amount of debris possible in 5 minutes and to carry a cap through the entire course to cap the ruptured oil well. These design requirements were assigned by Nemo Robotics to simulate a situation similar to that of an actual UROV capping a ruptured oil well.

Most of the materials required to complete a working prototype were supplied by Nemo Robotics, but an additional budget of $50 was permitted at the designers' expense. This proposal aims to be as financially efficient as possible, using minimal material without sacrificing performance. A detailed cost analysis can be seen in Table 1 below:

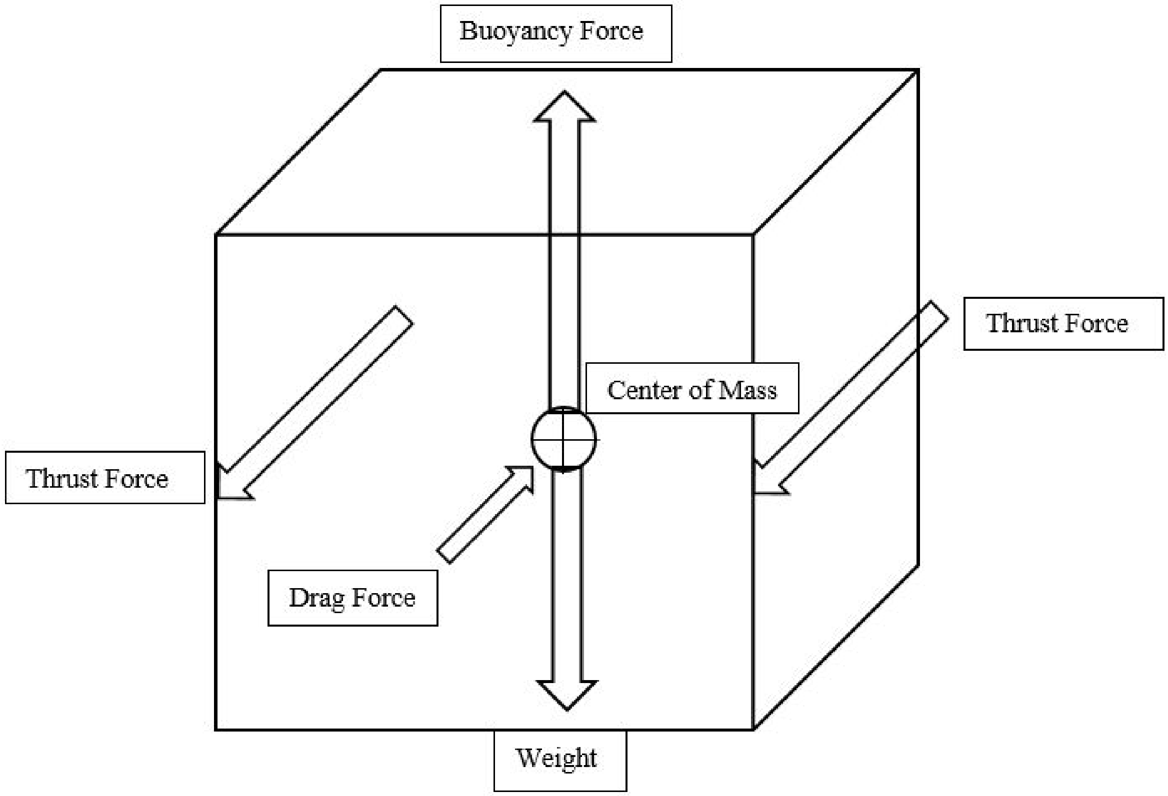
DESIGN DESCRIPTION

Overview of Design

This Underwater Remote Operated Vehicle (UROV) is designed with the purpose of placing a cap on a ruptured oil well and also clearing surrounding debris. To achieve these goals, the UROV has to maintain stability, maneuverability, and speed.

Stability underwater is achieved by orienting the Center of Mass (COM) below the Center of Buoyancy (COB) of the vehicle. The general shape of the frame is a shortened cube to promote symmetry in the distribution of weight. The UROV has a COB that is significantly lower than the COM and is incredibly stable. When dropped into water directly on its side or front, the UROV righted itself quickly. This proves that the prototype is stable in all axises. In this design, the UROV has the control box mounted in a low, central location that lowers the COM (figures 6 & 7 center of mass pictures). Also, the rear motor and oil cap are mounted opposite the oil cap to promote balanced pitch. Both side motors are mounted mirroring each other to result in equal roll and thrust. The rear motor is used to adjust the pitch in the case of an unbalanced load in the scoop and after the release of the oil cap (Figure 1 quad pic thingy).

Another factor of stability is buoyancy. Initially, the buoyancy force of the UROV greatly exceeded the weight of the UROV by 15N. After adding a ballast weight inside of the frame, the buoyancy force and weight differed by 0.89N to provide slight positive buoyancy. A slight positive buoyancy is desirable in this design for this design style so that the UROV may float to the surface in the case of a power failure. This does not inhibit the diving abilities as the motors have a Thrust force of 5N each and can easily counteract the slight buoyancy. (Free Body Diagram)

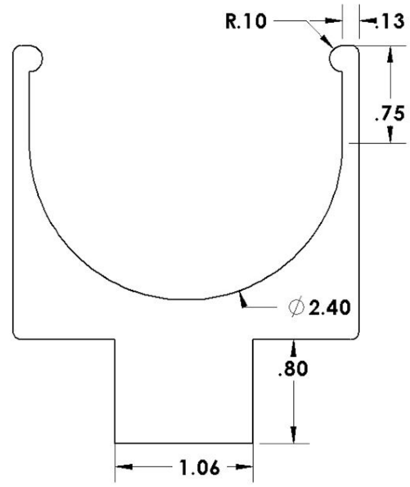


The Maneuverability of the UROV is vital to its purpose. The placement of the oil cap on a well requires a well controlled vehicle capable of minute adjustments. Also, the clearing of debris and maneuvering about any obstacles present calls for quick movements capable of redirecting the UROV quickly and efficiently. These issues are solved by orienting thrust motors on each side parallel to each other (Figure 2). This motor orientation allows for slow yaw with the use of a single motor or quick yaw by opposing the thrust of each motor. These motors provide forward or reverse motion when both motors are used together. They are also mounted externally furthest from the COM to provide the greatest rotational torque possible. The rear motor is mounted vertically to provide elevation (Figure 3). It is also mounted furthest from the COM to orient the pitch of the UROV with great accuracy. Mounting these three motors in such a position reduces the speed at which they maneuver the craft, however, this provides the torque needed to turn the UROV with a full payload. All motors are mounted with custom made acrylic mounts that are pressure fit around the motor body. These mounts are fit into the frame with a tee fitting for a secure fit that allows adjustment in the motor angle if needed. (Motor Mount pic)

Speed is vital as the purpose of this vehicle is to resolve a time sensitive issue. The design of the frame minimizes the drag coefficient at .1422 with a maximum drag force of 1.67 N as the UROV travel through the water.

This UROV is capable of carrying multiple types of payloads specifically being an oil well cap as well as small debris. The oil well cap is attached via an acrylic mount that secures the cap during operation, but allows for easy removal of the cap when placed on the oil well. There are small tabs at the end of the cap mount that keep the cap constrained and require a small amount of force to pull the cap past the tabs. (Cap Mount pic) There is also a rectangular fish net that is mounted on the rear of the UROV for clearing any debris that is present and returning it to the surface. To collect debris on the seafloor, the UROV reverses towards the debris and directs the tail-end of the craft down using the rear motor if needed. The net is 5 inches deep to retain the debris, limit the loss of payload and has a thin metal wire frame to allow the net to slip underneath the debris easily. It is also mounted at an angle to allow the prototype to remain level while collecting debris. In this application, a net is superior to a scoop in that it has less drag, a greater carrying capacity and reduced weight.

Safety is a primary concern in any engineering project. In the case of this prototype, there is very little that can cause injury to either the user or bystanders. The propellers are plastic and run at at a velocity incapable of causing damage if they were to come in contact with skin. The UROV is also designed without any sharp edges, eliminating the possibility of the user hurting himself while handling the prototype. Most importantly, the electrical components are designed with underwater use in mind. All of the component carrying current, namely the motors, control box, and tether, are sufficiently sealed to prevent any possibility of electric shocks.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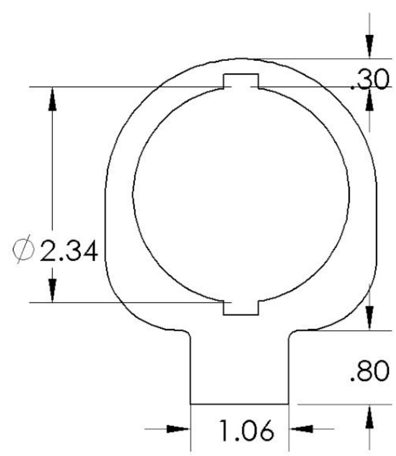
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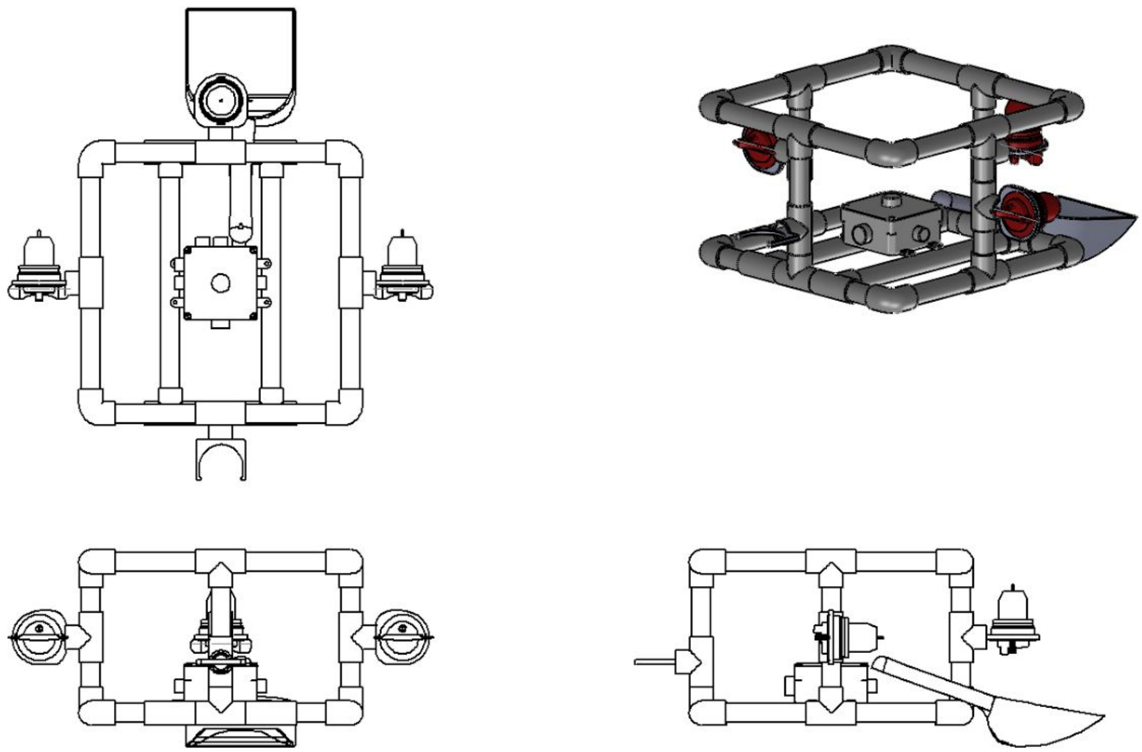


Figure 1. Overall view

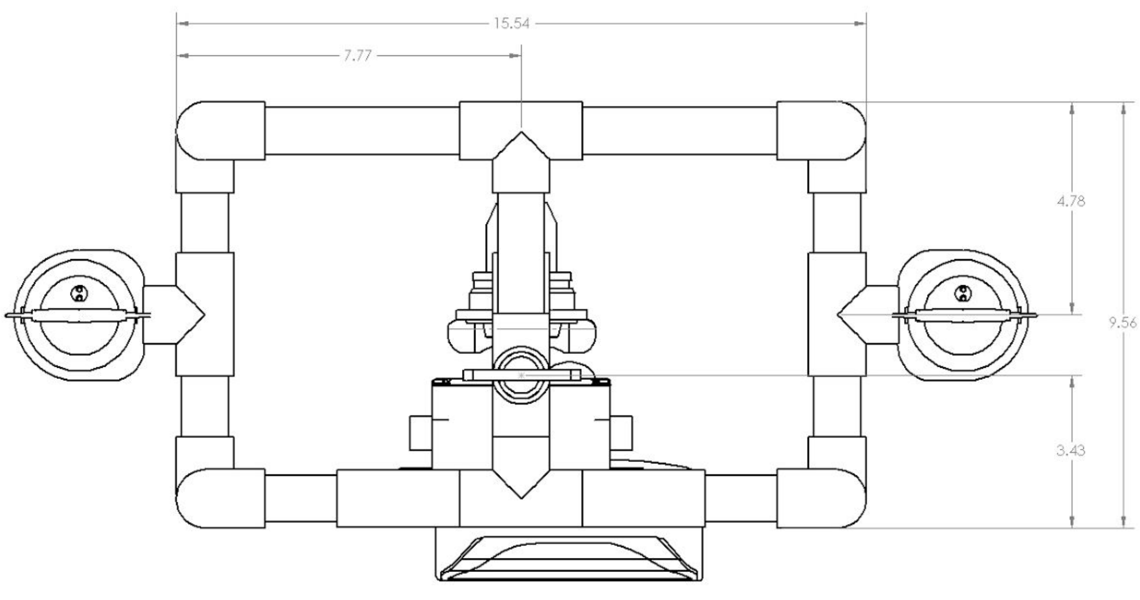


Figure 2. Front View

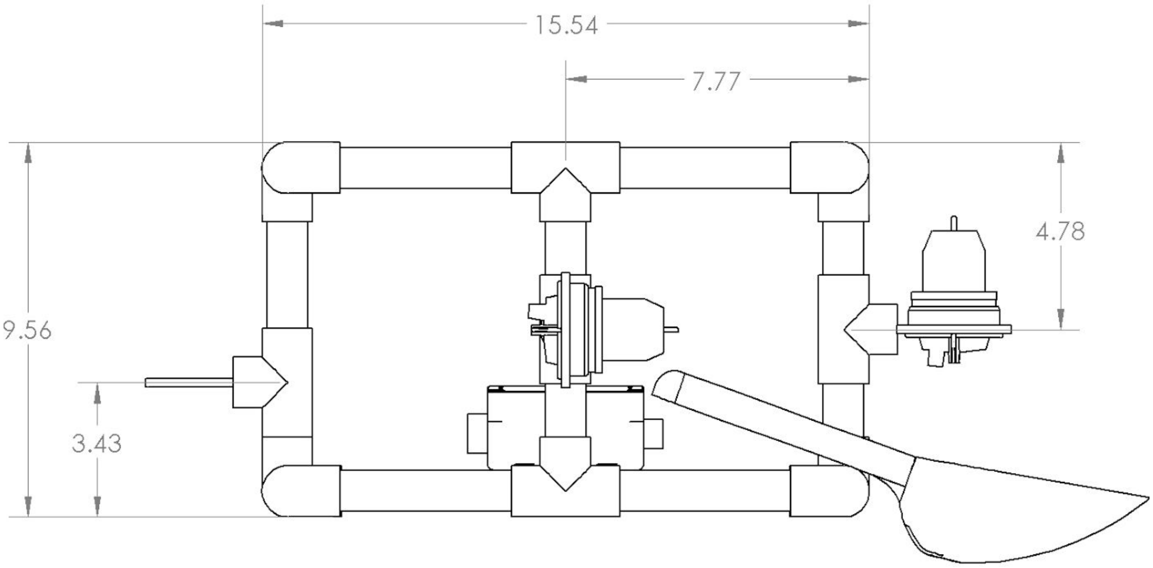


Figure 3: Side View

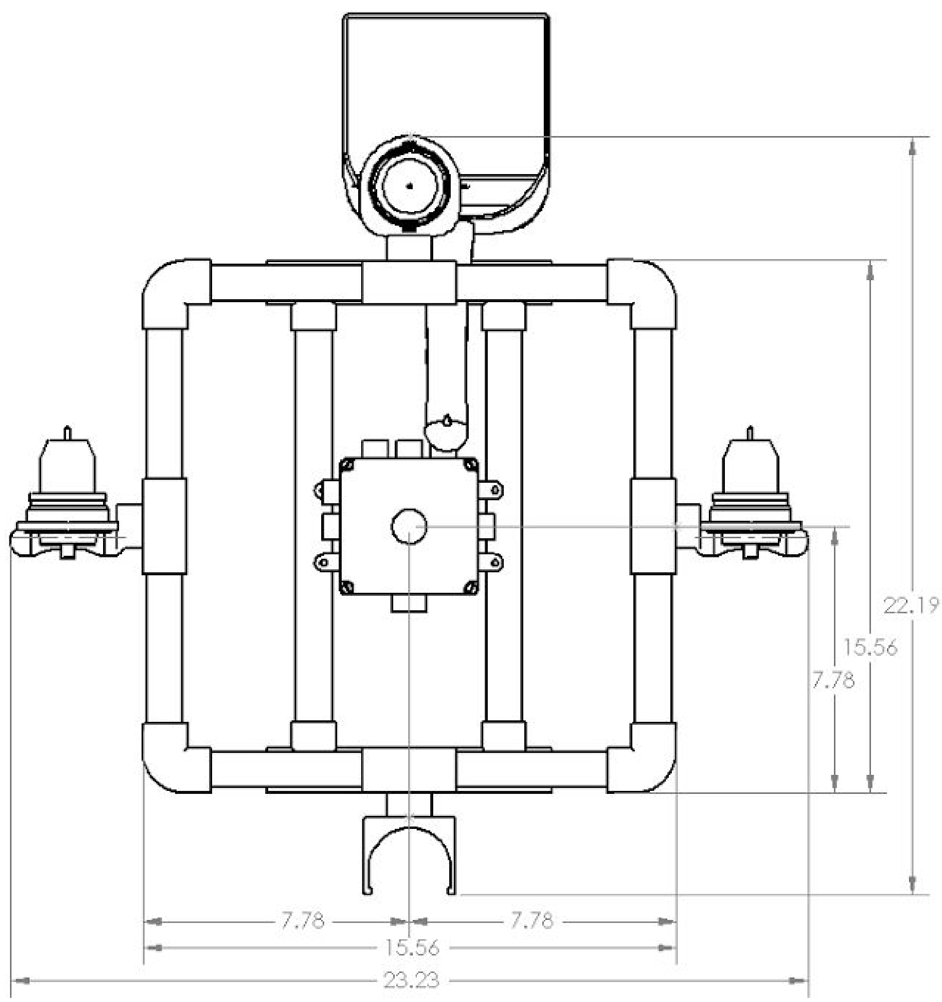


Figure 4. Top View

Figure 5: Center of Mass (Top View)

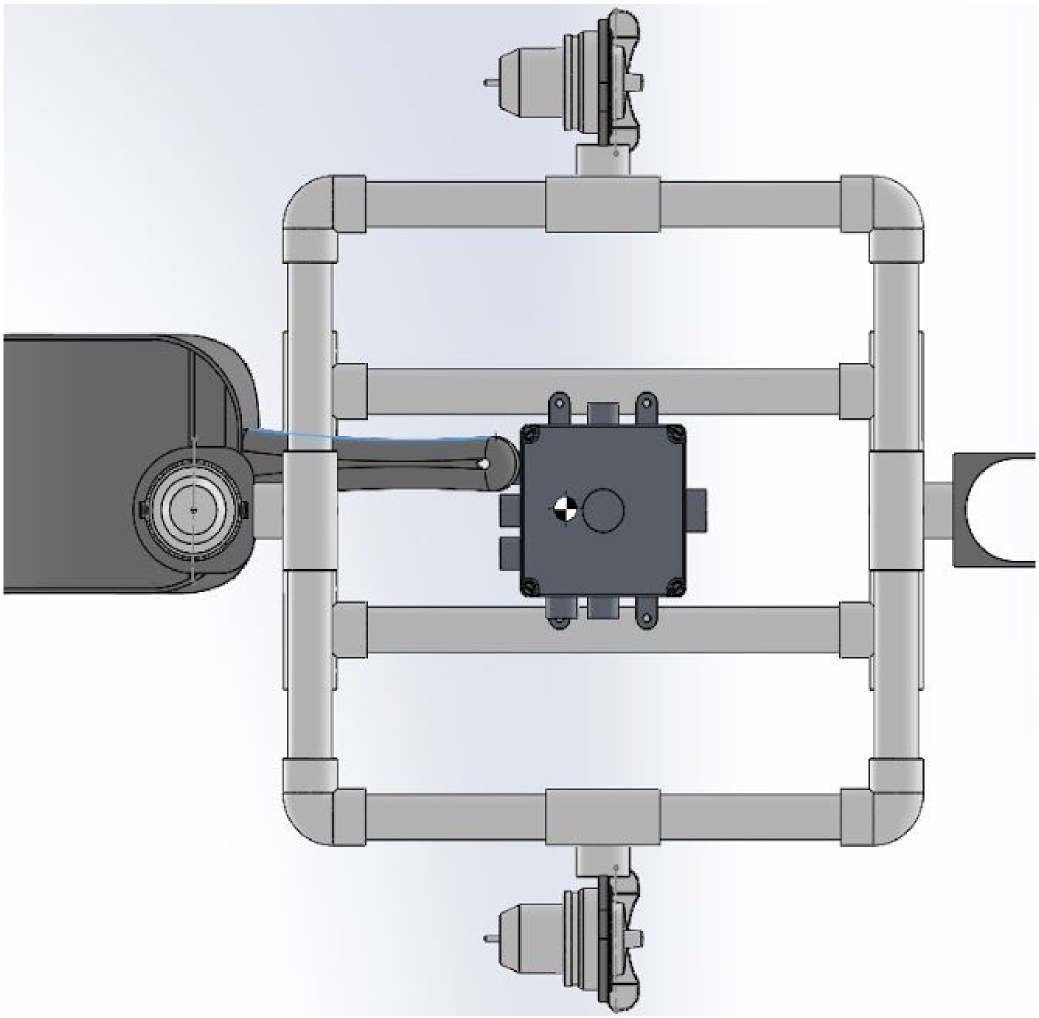


Figure 6: Center of Mass (Side View)

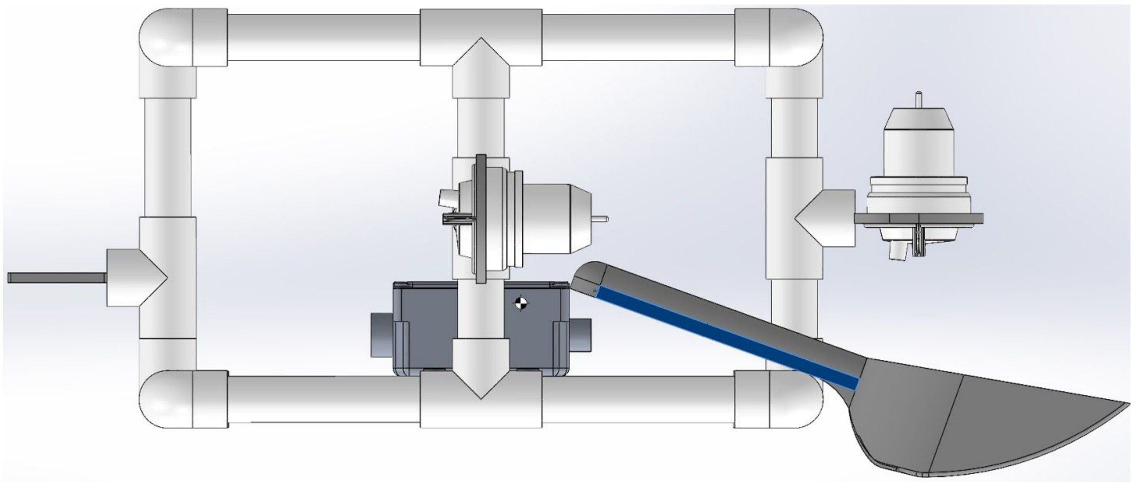


Figure 7: Center of Bouyancy (Top View)

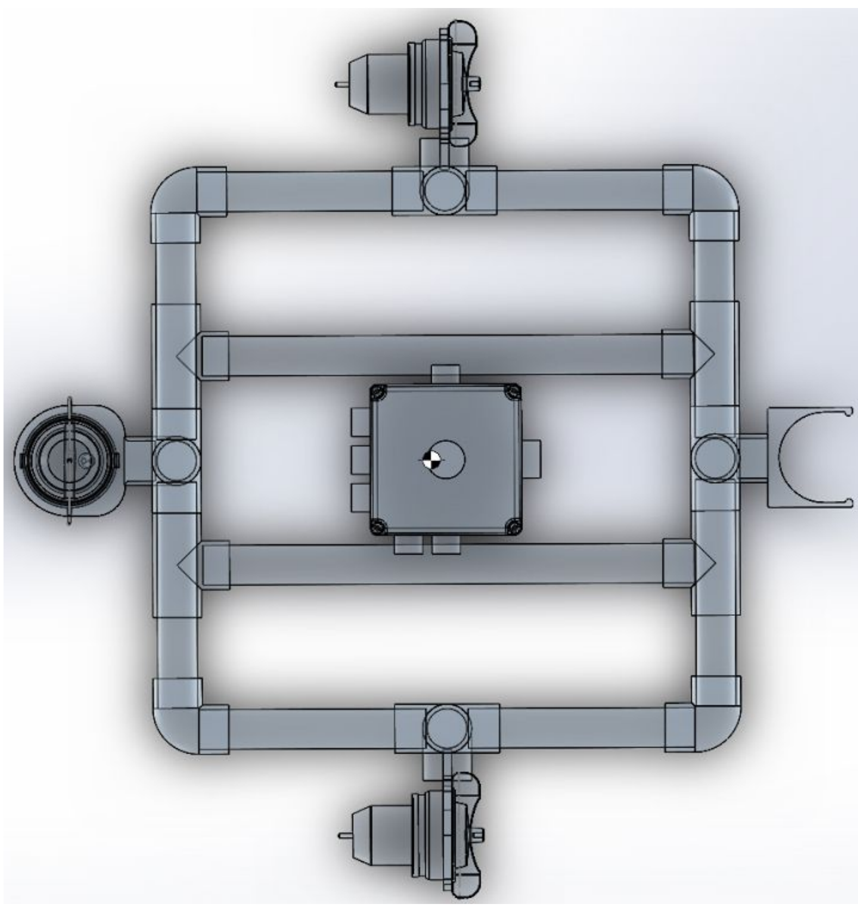
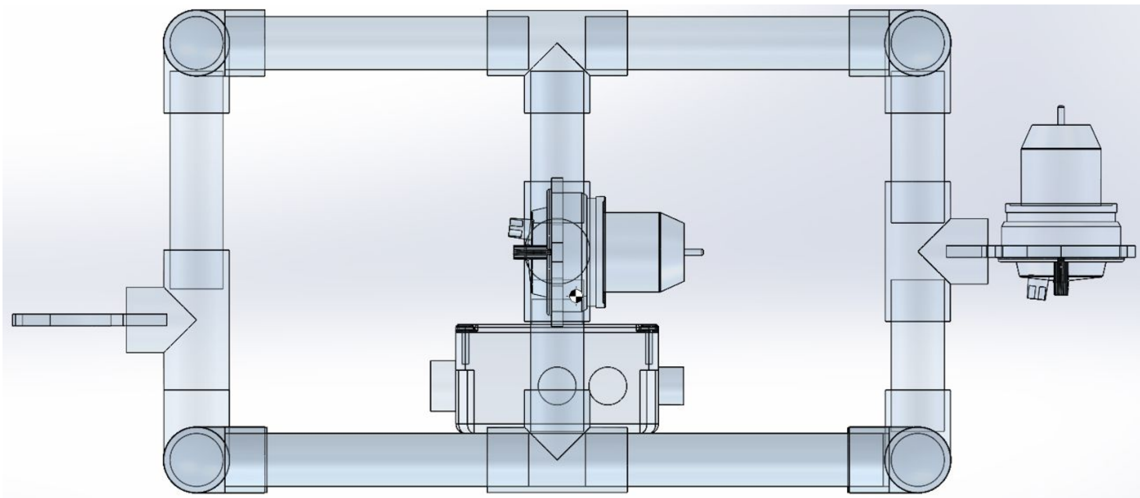


Figure 8: Center of Bourancy (Side View)



Detailed Description

Use- What are unique aspects of the design

In our design we utilized a mesh fish net for picking up the debris on the ground due to its ability to pick up and trap the debris once collected. We also used the laser cutter and acrylic sheets to create motor mounts and a holder for the well cap. By mounting the rear motor vertically on the very edge of the rear of the UROV it can act as an elevator with an acceleration of 7 deg/s^2 to control the pitch of the UROV and thus give us a further amount of control underwater.
Due to the unique positioning of our motors the UROV achieves a max angular acceleration of 13 deg/sec^2 and a maximum velocity of 2.99 m/s which is achieved in only 3.25 sec and 4.86 m. Also due to how the motors are mounted we can have a slightly positive buoyancy of .2N and just use our motors to pitch down to dive or have the UROV naturally rise back to the surface with no assistance after its mission is complete.

How will the design complete the different tasks assigned

In order to deposit the well cap onto the post we will carry the well cap with a holder which was cut out from ¼ in. acrylic plate on a laser printer. To get the UROV down to the bottom we will use three 500GPH underwater motors.

In order to collect the debris we will utilize a pet store fish net which has been mounted at an angle on the back of the UROV. To collect the debris we will back the UROV across the affected area to scoop the debris into the net and due to the net's inherent design once we collect the debris it will be trapped in the net until the debris is retrieved from the net at the surface.

Figure 9:

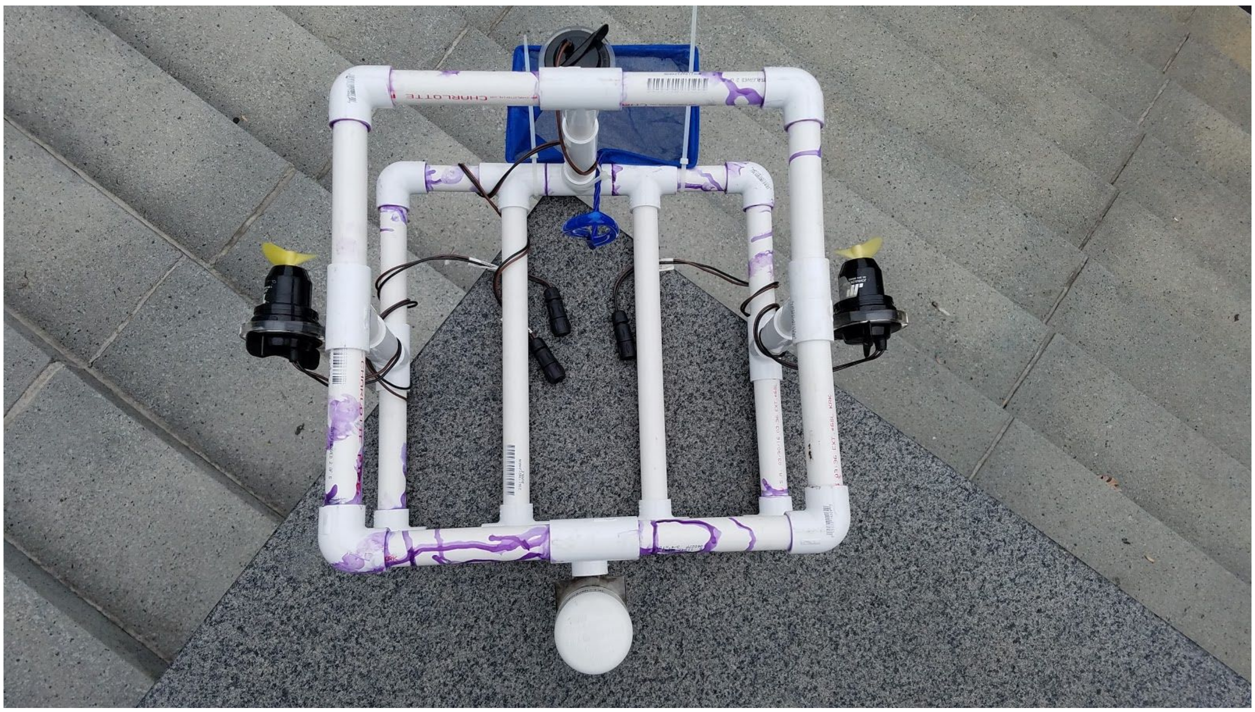


Figure 10:

Figure 11:

Figure 12:

Figure 13:

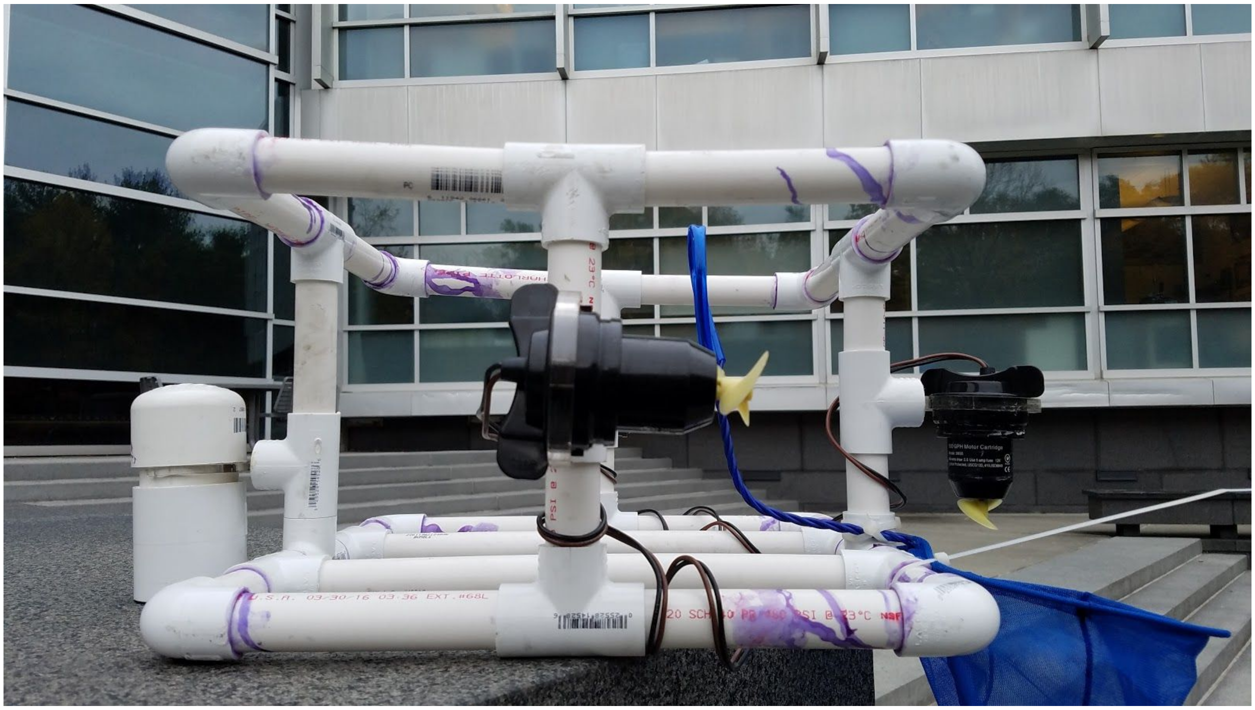


Figure 14:

EVALUATION

Overview

A combination of several technical design methods was applied for the evaluation of the UROV. The first approach was computer simulations using Solidworks to construct the ideal configuration of the ROV, calculate its center of gravity, and calculate its center of buoyancy. Then, experimental testing and user testing of the prototype were conducted in the following week, resulting in several issues being addressed and resolved during the evaluation processes (such as over-buoyancy and propeller failure). A table summarizing key design requirements and how they were tested is provided below:

Table 1. Key design requirements.

Requirements	Target Values	Method(s) Used
Buoyancy	Neutrally buoyant or within 2-3 Newtons	Solidworks simulation, experimental testing
Maneuverability	Easily and reliably maneuverable in order to traverse the obstacle course	Experimental testing, user testing
Cost Effective	Cheap enough to mass produce	Hand calculations
Aesthetically Pleasing	Appealing and not intimidating	Solidworks model view, experimental testing

prototype

Testing and Results

Maneuverability Course

It is important for a UROV to be maneuverable so that it can easily navigate through the area in which it is operating. If there are obstacles and the UROV cannot effectively move around them, it may be unable to complete the assigned task. If deployed in the real world, the UROV will likely see obstacles such as metal debris, underwater vegetation, and irregularities in the sea floor as well as the shape of the machine or device the UROV is working on.

To test its maneuverability, the prototype UROV will ultimately be run through a maneuverability course simulating obstacles that may be encountered in the real world. In addition to this final test, a preliminary test has been conducted to determine the overall control and maneuverability of the UROV. It was placed in a stagnant pool and the motors were systematically activated on their own and in tandem with one another. Once it was confirmed that all the motors were functional, a few basic maneuvers were attempted. While there was no course present through which to drive the UROV, it was possible to whether it functioned as intended and could be controlled effectively.

Upon the first test, the UROV experienced some buoyancy issues that made vertical maneuverability testing infeasible with the given setup. There was not enough time available to correct for the buoyancy issue, so physical testing in the vertical z-plane will have to be addressed on a future date. Despite this, a simple mathematical test can show how to UROV will behave once the required mass changes are made. After the alterations, the UROV has a theoretical buoyancy equating to 0.2 pounds of force directed directly upward. In contrast, the vertical component of the thrust pressing the UROV downward is 5 Newtons or 1.12 pounds. This, in conjunction with the 10 Newtons (2.24 pounds) of thrust from the primary motors acting at a varying angle will allows for a controlled descent. The buoyancy issue did not affect horizontal x-y-plane movement and the testing thereof was successful. The UROV behaved as expected and controlled intuitively.

The test achieved a portion of its goal, namely x-y-plane control. Due to time constraints, the simple issue of buoyancy could not be addressed which caused an inability to complete z-plane testing in the pool. Future tests will address this in practice, but according to the mathematical test that has already been conducted there should be no issues in this area.

Picking up debris

One of the common uses of UROV technology is the clearing of debris that is otherwise inaccessible to humans. Depending on the application, this could include everything from small seashells to pieces of metal weighing hundreds of pounds. Even if its primary purpose is to address other issues, the addition of some sort of claw or scooping mechanism can increase the versatility of the UROV and allow it to adapt to unexpected operating circumstances.

The ability of the framed net utilized in this UROV to properly pick up objects was tested manually by sliding it under small pieces of underwater “debris” simulated by PVC caps while attached to the UROV. The PVC was approached from various directions, angles, and speeds to account for the possibility of a less than ideal approach when actually attempting to pick up debris.

The test was very simple, but was a solid proof of concept. The net worked better than other devices that were also tested, namely a scoop and a frameless net. Barring unreasonable circumstances, the net had no trouble picking up the pvc pieces and was very effective in holding onto the pieces once it had them thanks to the deepness of the net. The goal of the test was not only achieved, but the net exceeded expectations.

Capping the oil well

In the last decade alone, several large-scale oil spills have caused irreversible damage to wildlife as well as millions of dollars in financial losses. In even the most efficient cleanups, it has taken weeks to cap the hole. A properly equipped UROV can drastically reduce this time, having a significant impact on the amount of damage the oil spill causes.

The press fit design of the oil cap holder on the UROV was easy to test. With the oil cap in place, the UROV was moved about and shaken to ensure that the cap was secure. The UROV was then set underwater and the oil cap (still attached to the UROV) was manually placed over a piece of PVC pipe which acted as a pseudo-oil pipe, having ruptured at one end. A light pull on the UROV (not exceeding in maximum reverse thrust of 10 Newtons) caused the oil cap to easily slide out and remain in place on the “oil pipe”, sealing the leak.

The target of the test was clearly met. It was found that the press fit design is viable and should pose no issues in real-world applications, however, the press fit is rather specific and if miscalculated, the oil cap could either get stuck or fall out. In a machine shop allowing for precise machining and measurements, this should not be an issue, but the necessary precision should be noted.

Assessment

While additional testing in a pool is recommended before before coming to a definitive verdict, the prototype appears to function as intended. It was successful in the 3 parameters for which it was tested: maneuverability, picking up debris, and placing an oil cap. None of the experimental or mathematical results suggest any need for design alterations. Additionally, the design is very efficient, minimizing costs. Lastly, the design in very simplistic, making it easy to replicate or manufacture, eliminating the need for any unusual equipment and further reducing costs while also reducing production time.

Next Steps

As has been previously mentioned, additional testing is imperative to ensuring the functionality of the UROV. These tests will be simplified reproductions of the intended uses of the UROV conducted in a stagnant pool. Basic maneuverability underwater is easy to test by simply moving the prototype around and noting its controllability and the effect of the tether on its motion, a variable that is difficult to simulate. The tests addressing the picking up of debris and the placing of an oil cap will be similar to those already conducted, but unlike in previous testing, the UROV will be controlled electronically through a tether rather than through manual manipulation. These tests will further confirm whether the UROV has the precise maneuverability required to safely and effectively operate in real-world conditions.

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Free body diagram-- Not sure where to place this in the text

Assumptions, constraints, design decisions

Stability--- See Design Overview

!@#$%^&*Cost analysis*&^%$#@!

Thruster locations/reason--- See Design Overview safety

Cover letter

Table 2. Cost Analysis

Part Number	Amount	Part Name	Cost per UROV
1	3	Johnson Pumps 500 GPH Motor Cartridge part #28552 (given)	$47.96 for 3 ($15.99 each)
2	1	PVC Pipe (10ft) (given)	$3.27
3	16	PVC Tee Fittings (given)	$12.96
4	8	PVC 90° Elbows Fittings (given)	$4.88
5	1	Aquarium Fish Net	$3.50
6	1	Zip Ties (pack of 100)	$1.50
7	1	PVC Cleaner and Glue (given)	$8.39
8	1	Control Box (given)	unknown
9	1	Great Stuff expanding foam	$3.49
Total cost of given items: **Total cost of additional items:** **Total cost:**			**$ 94.96** **$ 6.99** **$ 101.95**