# Unmanned Underwater Vehicle

**Senior Design Proposal submitted to the Department of Mechanical and Materials Engineering College of Engineering and Applied Science University of Cincinnati**

**in partial fulfillment of the requirements for the degree of**

**Bachelor of Science**

**in Mechanical Engineering Technology**

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**in conjunction with Kyle Shaffer, Mitchell Snow, Skye Foster, Eric Blickley, and Alec Spaeth**

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# Introduction

## Multidisciplinary team

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**Major:** Mechanical Engineering Technology

Role: Skeleton design, Assembly and Fabrication

Alec Spaeth

**Major:** Electrical Engineering

Role: Waterproofing, Depth control electronics

Eric Blickley

**Major:** Electrical Engineering

Role: Electrical design

Kyle Shaffer

**Major:** Aerospace Engineering

Role: End cap design, Propulsion, team lead

Skye Foster

**Major:** Aerospace Engineering

Role: Depth control design

Mitchell Snow

**Major:** Aerospace Engineering

Role: Camera, Control electronics

## Problem Statement

This project is aimed to design and build an unmanned underwater vehicle (UUV) that can be utilized to find objects underwater. It is meant to be a relatively low-cost underwater imaging vehicle that could be used by organizations such as the Cincinnati Police Department and the Cincinnati Fire Department. This submersible must be able to take a photo underwater while being controlled by a remote operator to allow for easier searching of underwater areas by emergency services.

## Project Goals

The primary goal for designing this unmanned underwater vehicle is to create a more cost effective yet reliable alternative to the pricey UUVs that are currently on the market. Using many off the shelf parts as opposed to mostly custom parts will allow this design to still perform as necessary without breaking the bank of prospective users. The project goals mentioned below, made up the core of our development process.

- UUV Project Goals
  - Easy to learn operator controls
  - Reasonable mission time
  - Appropriate speed to fight most currents
  - Ease of maintenance

- Ease of battery change
- Camera that can distinguish between objects
- Live video feed to operator
- Waterproof design

Each of these goals began during a brainstorming process. Then, each of these goals had to be researched extensively to make sure that all the right pieces were acquired to get the expected result. Then, these components had to be implemented into the overall design to make sure they would work along with other components in the overall system. This phase was especially important since due to Covid-19 restrictions, it was quite limited in what could be done as a group. Once the pieces were found that would work well together, they could be installed into the final product for the final stages of testing.

# Research

The current market for Unmanned Underwater Vehicles (UUVs) is filled with a large variety of vehicle sizes and capabilities. This market is estimated to grow to 5.2 billion dollars by the year 2022. [1] The high market value stems from the versatility and usefulness of UUV systems and their moderate per-unit cost. Currently, very few low-cost and versatile UUVs exist.

The main users of UUV systems are the military; however, there is an emerging commercial and research market for UUV systems. UUV systems can fill many rolls: data collection, cost-efficient alternatives to manned systems, and platforms for repetitive or dangerous underwater missions. The small size of UUVs allow them to explore and observe areas where larger manned systems are unable to go.

Critical mission roles of a low-cost UUV as defined by the US Navy include intelligence, surveillance, reconnaissance, mine countermeasures, tactical oceanography, communications, navigation, and anti-submarine warfare[3]. The military is looking at UUVs as a complement to submarines in the same capacity that cubesats/smallsats augment traditional satellites. These systems can be used in a swarm configuration to perform multi-function missions.

Low-cost UUVs also can provide the solution to accurately mapping one of Earth's final frontiers— the ocean. Mapping the ocean is a massive investment of time, due to the large volume, and therefore a massive investment of resources. Developing low-cost UUVs could make this goal more reachable.

The current high cost of UUV procurement, deployment, and maintenance prevents many institutions from obtaining UUVS even though such use would benefit and enhance the institution's goals. As an example, the Clear Lake Fire Department was gifted a drone by an anonymous donor. The drone will be used for underwater search and rescue missions when lakes are frozen over and the fire boats cannot travel through the lake — a capability they did not have before the drone. It is equipped with sonar that costs $30,000, implying the price of the done is substantially more.[3] If the drone was cheaper, then the fire department would have been able to purchase one instead of relying on an anonymous donor.

The scope of the senior design project is to focus on the smaller end of UUV systems — the basic concepts and ideas will be explored without investing extensive capital. Small UUVS are more expensive per volume than larger UUVs as the smaller the UUV the more complicated the internal arrangement becomes. The senior design team proposes the using as many commercial-off-the-shelf (COTS) components and materials as possible. In addition, low cost manufacturing methods will also be investigated, such as 3D printing, to develop the UUV.

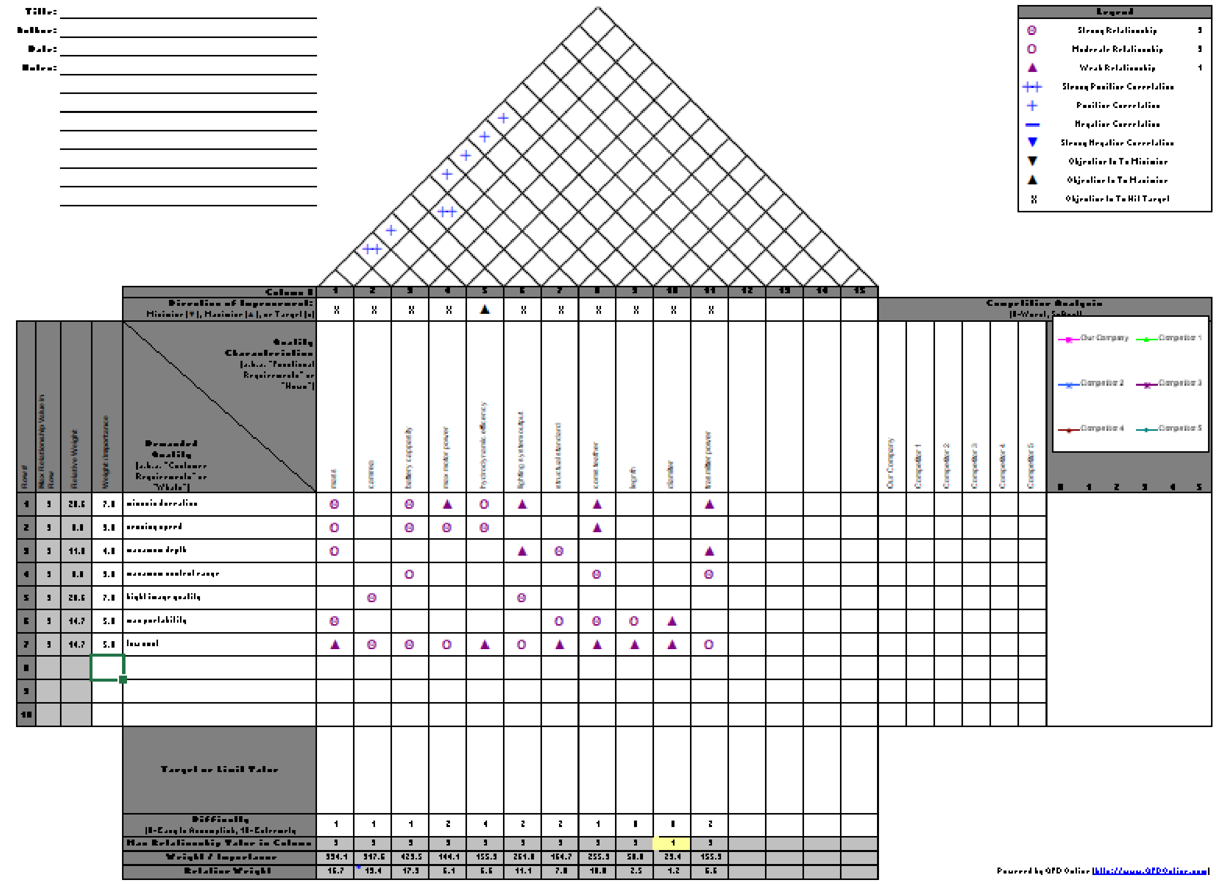
# End User

The senior design project has two classes of end users in mind. The first class of end users would be organizations conducting underwater surveys. This would be search and rescue, damage inspection, or other tasks where the speed of the survey itself matters, both in time from first image to last image as well as total time from call to pack up. The operators in this class would be small to medium size organizations such as police and fire departments, offices of the USCG or other people with an interest in maintaining a waterway such as a port authority. We will expect the operators to have significant knowledge about the waterway but no knowledge about the UUV itself. We also expect their Department to provide training as part of acquiring this system

The other class of targeted users would be photographers and conservationists. This class of user would consist of individuals looking for equipment to conduct artistic or data collection photography. They are expected to have few technical skills with the maintenance and operation of UUVs. Their primary concerns will be simplicity of use and ease of operation.

What is missing in the current state of the technology is vehicles in the hydrodynamic form factor add a low price / for inland water operations and complexity to operate. There are current commercial UUVs for both civilian and military applications that use a hydrodynamic form factor and have impressive performance designed for long range oceanic operations. These are well suited for their current customers militaries, oil and gas, telecommunications etc. They are simply too large to be used in all but the largest of inland waterways. There are low cost UUVs that are in a similar price and size range to our current concept, but they tend to be boxy resembling quadcopters being optimized around an umbilical that tethers them to a ship. This makes them excellent for inspecting a single point or acting as a photography platform for a set scene, but this makes them inefficient for conducting surveys. This is because they both have a limited reach due to the tether connecting them to the controller and low speeds as they are not optimized for hydrodynamic efficiency.

# Quality Function Deployment



# Requirements

We developed the following as our design requirements.  Easy operator controls.  We wanted the controls to be intuitive so a new operator could learn how to correctly control the UUV without extensive time spent on training.  Operation time of at least 30 minutes.  This amount would allow plenty of time for a user to survey a reasonable search grid before needing to return to the user for a battery change.  Top speed of at least 2 m/s.  This speed would allow the UUV to search rather quickly in calm waters but also would allow the UUV to fight against most currents if necessary.  Battery change in under 30 minutes.  The operator would be able to effectively get back to their mission with minimal downtime.  Color camera with high resolution.  The operator must be able to distinguish between different color pool rings at the bottom of a pool.  Live camera feed to operator.  This would allow the operator to easily control the UUV and ensure keep the UUV on track during a mission.  Design shall be waterproof. This would ensure the safety of our UUV by not only keeping the electronics safe, but also ensuring that the buoyancy of the UUV is not compromised.

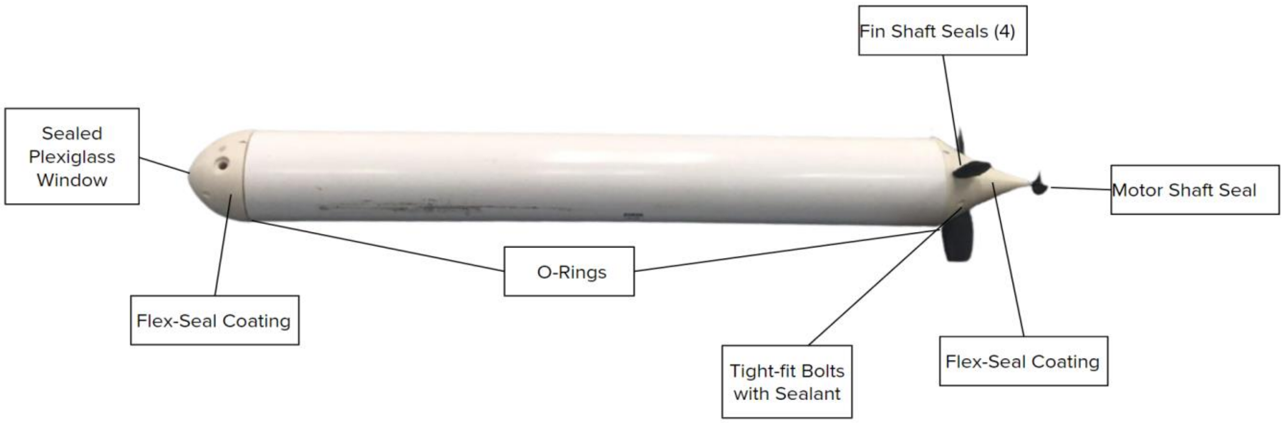
We also developed a list of additional features that are not required but would be nice to integrate. Exterior LEDs would help camera visibility in low light conditions and allow the operator to better see the UUV's position within the water. Exterior indicator lights on the UUV to ensure that the device is powered up once it is assembled. Another light on the comms buoy so the operator has a visual check to make sure the UUV is still powered. Autonomous control. Future iterations could use various sensors and a microcontroller to enable the operators to set up automated control.

# Subsystems

## Waterproofing

Waterproofing the UUV proved to be one of the most challenging parts of this project. There were many important areas on the design that would need to be sealed effectively to ensure the vehicle remained watertight. To allow the camera to have proper vision through the front of the bot a layered piece of plexiglass was siliconed into the nose of the UUV. The design also had to ensure that the end caps that had been designed would have a proper sealing surface once inserted into the main body of the device. To accomplish this two O-ring grooves were placed in the end caps that would allow a set of O-rings to seat effectively, creating a seal between the ABS and the PVC. The end caps were to be secured to the interior skeleton via a pattern of bolts through each cap. These bolts were intended to be a tight fit and have some assistance from a rubber washer to eliminate leaks. Finally, the shafts for our fins and motor had to be sealed. To accomplish this various sealed bearings were used that would still allow these components to have the rotational capabilities that were required, while preventing water from entering the system.

Figure 1




Throughout construction, each of these sealing methods had to be tested without risking damage to the electronics. To complete this task a smaller test bench version of the UUV was built. This used an extra length of pipe that was on hand. This pipe was slightly altered through the addition of a tire valve that could be used to conduct the type of testing that was needed. It was decided to utilize a positive pressure bubble leak test to test the waterproofing methods. This style of test required pressurizing the internal volume of the test bench with approx. 5 psig and then submerging the vessel into a bucket of water while watching for air bubbles escaping from potential leak points. This testing was also done in conjunction with a spot test that utilized soapy water. The test bench was once again pressurized but instead of being submerged, it was sprayed down with a mixture of soap and water. If this solution found a leak point it would bubble up and allow us to pinpoint our leak locations more exactly.

Figure 2

The testing methods proved effective and did reveal many areas of concern. One of these completely unexpected areas was porosity in the end caps resulting in permeation leaks. The end caps were porous enough that sizable leaks were seen throughout the initial testing. An example of these leaks can be seen in Figure 3 below. This became the first major problem when it came to waterproofing.

Figure 3

To try to combat this issue it was decided that applying a coating to the end caps would be the best course of action. Through research it was determined that Flex-Seal brand rubberized coating was the ideal product for our need. The end caps were then received 3 layers of this product and were allowed to cure for a couple days. Once cured they were once again tested to see if this eliminated the problem. In Figure 4 it can be seen that for the rear end cap this solution did remove 100% of the permeation leaks that we had seen in initial testing. However, in Figure 5 it can be seen that the problem was not entirely alleviated in the front end cap. This issue could be resolved through either coating the interior of the end cap as well as the outside or through spot sealing these leaks with silicone.

Figure 4

Figure 5

Another leaking area that had to be tested was the O-ring seals that were planned to be used for the interface between the end caps and the main body of the UUV. We had two different sets of O-rings to test that were sized the same but did have varying hardnesses. One set was tested before the UUV was coated and that test can be seen in Figure 6. The second set was tested once the coating was applied and can be seen in Figure 7. It was quite apparent through a quick observation that neither set of seals was sealing as was intended. An intense flow of bubbles was seen through that sealing point in both tests. These tests were also conducted in many different orientations as it was realized that neither the end caps nor the PVC pipe were perfectly circular. This issue became the second major one that had to be solved.

Figure 6

Figure 7

It was not possible due to lead time and funding to procure a new set of end caps, so a new sealing solution had to be found for the seal between the PVC and the end caps. It was decided to test a semi-permanent solution by using a clear silicone similar to the type that is used to seal aquariums. The sealant was applied and allowed to cure for one day and then was ready for testing. In Figure 8 it was apparent that this solution did create the leak free seal that was intended.

Figure 8

The final leak point that was of concern was the seals for the various different shafts that were utilized for the fins and motor. The sealed bearings that were being used, were intended to be installed around very precise metal shafts. It was not possible to find metal shafts that were of the proper size and access to a machine shop was restricted.  This resulted in the use of wooden shafts.  Wood shafts are obviously not ideal, and they led to several more leak issues. These leak issues appeared to stem from two areas.  One was the fact that the wood was porous and allowed air to escape directly through itself.  Also, the wood did not create a proper seal with the bearings, so air was able to escape from those as well.  This issue can be seen in Figure 9 below.

Figure 9

## End cap design

The designs of the end caps are as shown in  Figures 10 and 11.  The front end cap has a rounded hydrodynamic shape while the rear end cap has a more conical shape to reduce turbulence into the propeller and fins allowing them to be more effective.  In Figure 12, you can see a simulated stress test going on for the end caps.  Both the front and the rear caps exceeded the required factor of safety.  In the process of constructing the UUV, it was determined that the main motor was such that the planned orientation for it in the rear end cap would not work, so there had to be a redesign to accommodate for this.  This came in the form of Figure 13 which is a 3D printed add on to the rear cap that would hold the main motor and the 4 servo motors in the new orientation.

Figure 11

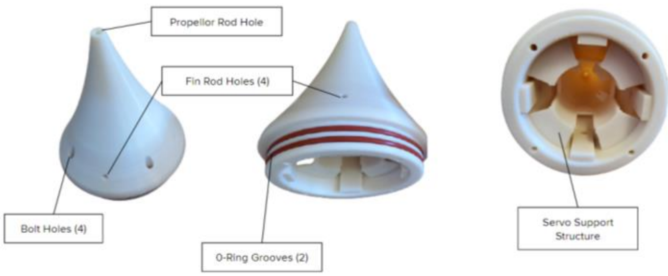



Figure 11

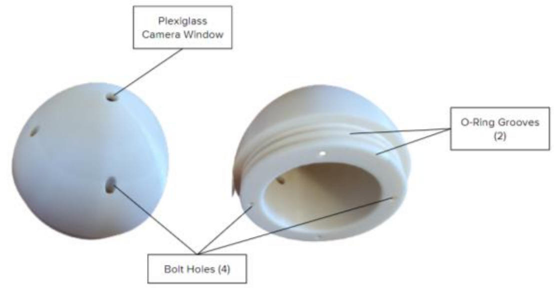
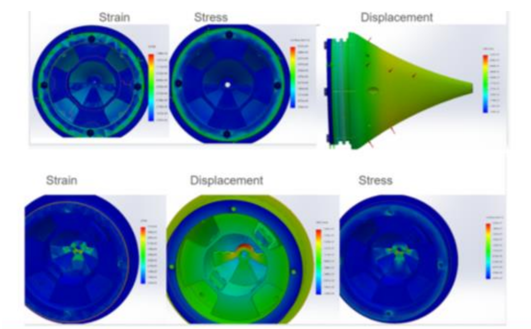
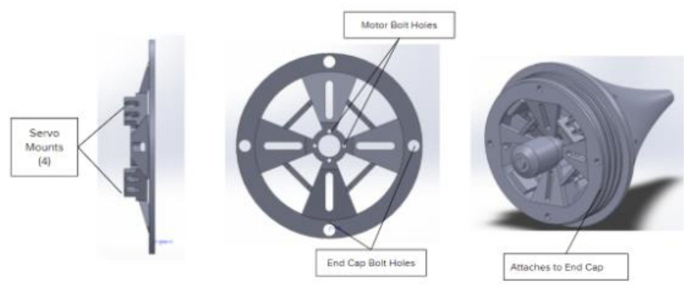



Figure 12




## Skeleton Design

Figure 13




Initially the skeleton was designed in a V pattern, as seen in Figure 14, where the depth control was stationed towards the center for balancing purposes and would allow for electronics to be housed towards the front of the UUV. However, this design was based on incorrect dimensions for the linear actuator; so, a new design was needed to house the depth control and the electronics. That then led to the design in Figure 15 which will house the depth control on the bottom and then house the electronics on the shelf above. The design was chosen for its ease of manufacture above all else, however. Figures 16 and 17 are an FEA analysis that was done on the skeleton. It was determined through the analysis that the skeleton had been overbuilt with a safety factor of 10. Figure 16 is an analysis on displacement while Figure 17 is an analysis on stress and safety.

Figure 14

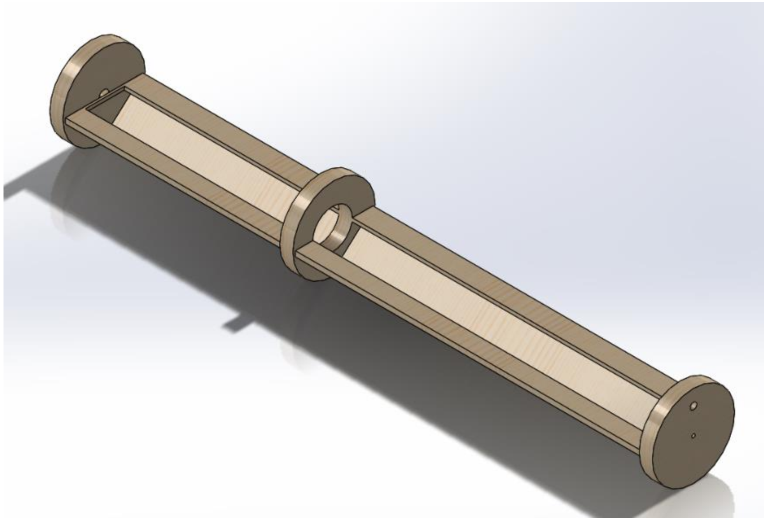


Figure 15

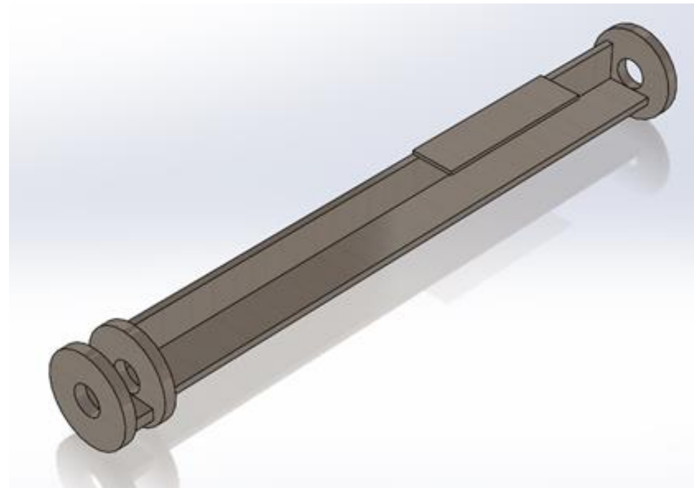


Figure 16

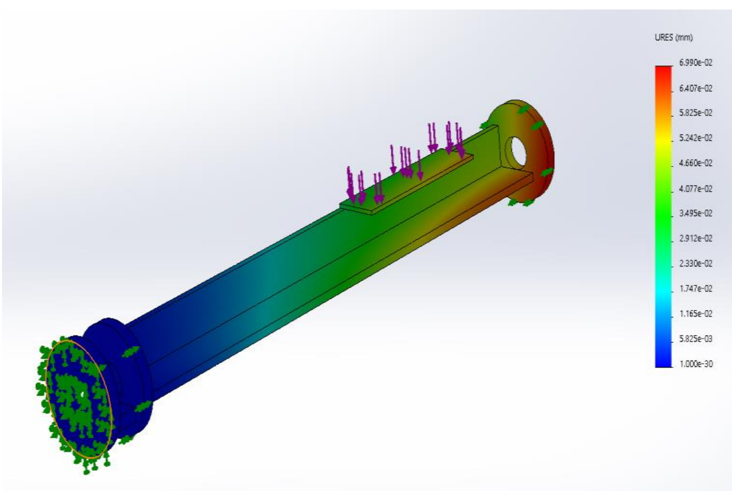
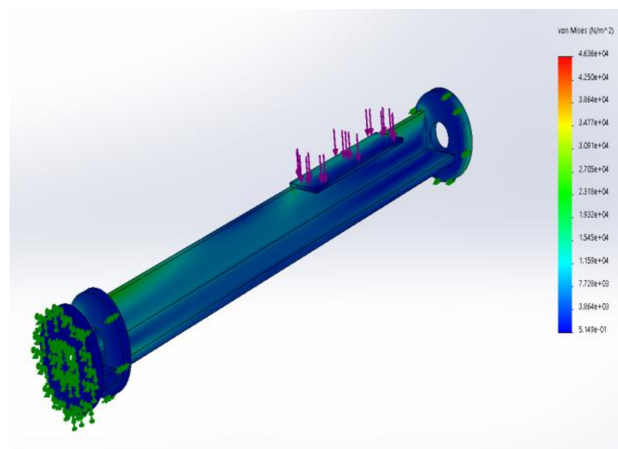



Figure 17



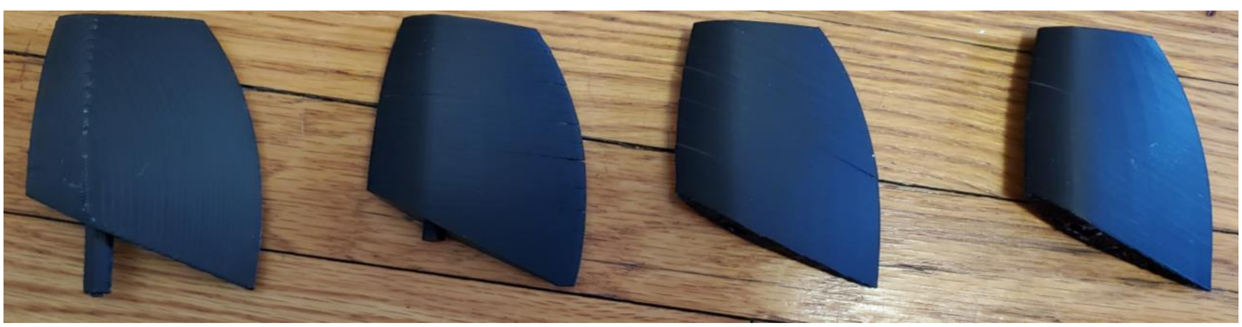

## Propellor and Fin Design

The fins were designed using 3D modeling such that they would be hydrodynamic when they were in the straight position to reduce drag and when the fins were turned, they would efficiently create the intended turning force. The orientation of the fins is shown in Figure 18 as it was determined that it is best to have two vertical fins to yaw, while having two horizontal fins to handle pitch. As can be seen in Figure 19 the fins went through a couple of design iteration due to troubles with the 3D printer. Due to how it was being printed, the final product would end up with various breaks in the fin, and it took several attempts at printing positions to minimize those cracks.

The propeller was a of the shelf commercial design.  Due to the lack of torque in the main motor, it was decided that the propeller should be small so that it does not need to move too much water that would be more than what the motor could handle while still large enough that it can push the UUV. Figure 18 shows how the propeller compares in size to the rest of the end-cap.

Figure 18

Figure 19



## Depth Control Design

The depth control for the UUV was based on the idea of using a large syringe to serve as a ballast tank.  When the UUV needed negative buoyancy to dive it would fill with water from the environment and then expelled some of the water at depth to level out at neutral buoyancy.   To surface it would completely expel the water so that the UUV had positive buoyancy and would float to the surface.  The syringe has a capacity of 500ml and when completely filled will weigh an additional 1 pound. This is the only dynamic ballast in the UUV, but lead bars are dead ballast to trim the UUV for operation

To operate the syringe requires a greater deal of force than a normal servo motor can provide, which is why it was decided to use a linear actuator to fill and empty the syringe. The linear actuator was determined to take about 42 seconds to fully extend or fully retract. Once the syringe is full it was calculated that the UUV will sink at a rate of 1 inch/s and will result in the UUV reaching its intended depth of 10ft in around 1 minute, 20 seconds. Figure 20 is what the completed depth control system looks like.

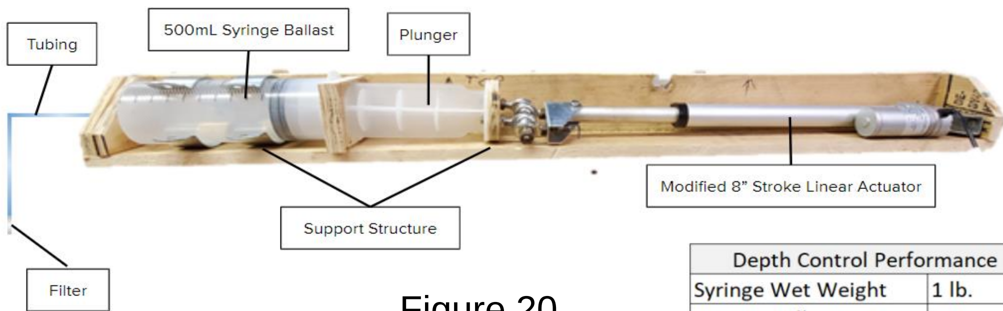



Figure 20

| Depth Control Performance | |
|---|---|
| Syringe Wet Weight | 1 lb. |
| Time to Full Extension | 42 s |
| Est. Sink Rate | 1 in/s |
| Est. Time to Depth | 1 min 20 s |

# Electrical Design

The wiring for the UUV utilizes pre-built electrical components that were then wired together based on what components need to be connected to each other and in what way they need to be connected. Figure number 21 is a diagram of the wiring schematic, displaying how each part will be wired together. The battery is connected to a circuit breaker to minimize damage to the electronics if water enters the UVV and causes a short circuit. The wires will then be split with one pair going to the speed controller and then onto the main motor as that requires the most power. The speed controller then, through a Battery Eliminator circuit (BEC) connected to the receiver and camera, would send its 5V signal to those components. The receiver would send that power to the various motors. The second set of wires coming off the circuit breaker would go to power the motor controller which would power the linear actuator. The Motor controller is being operated by a microcontroller that is receiving input from the receiver.

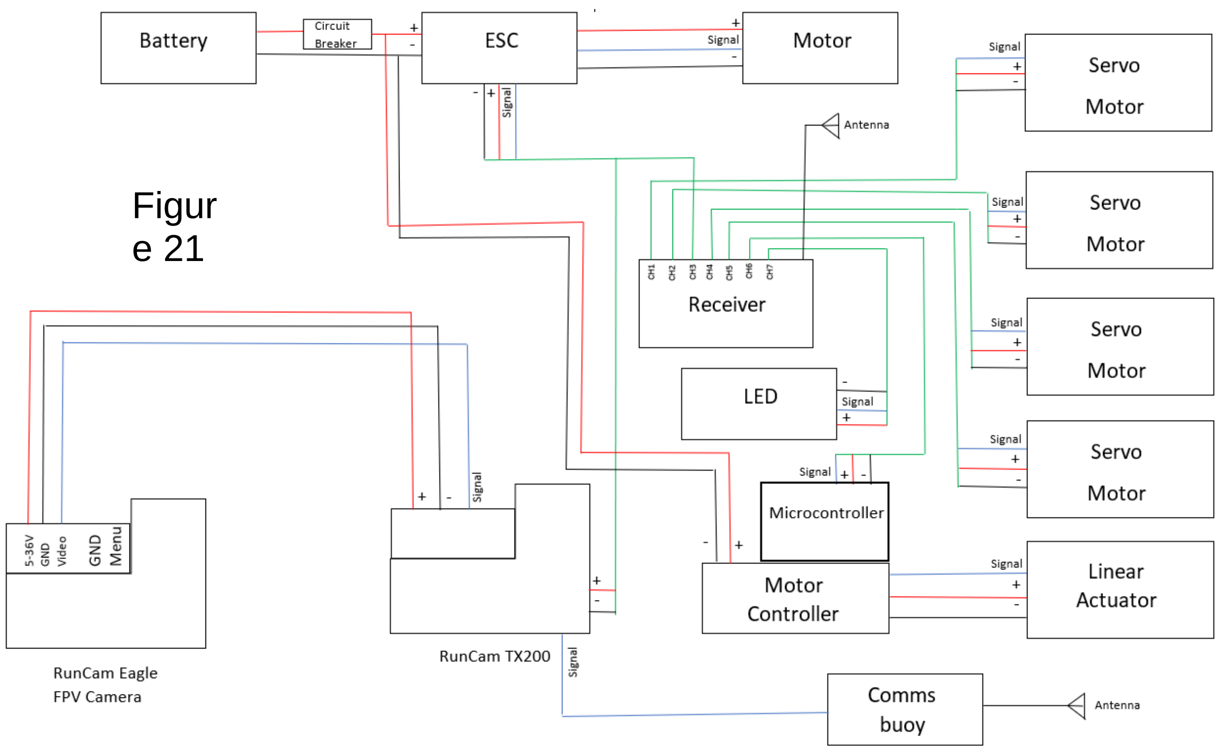



Figure 21

# Control Electronics

Utilizing an RC transmitter that then sent signals to a receiver on the UUV, it was possible to control each aspect of the UUV remotely. The signal sent has a frequency of 72 MHz so that it could penetrate through the water and reach the UUV without interference from the water. The receiver as shown in Figure 23, has 8 channels that can be connected at any given time. One of these channels was being reserved for the BEC from the speed controller to power the receiver and the other components. The wiring of which channels go to what is in Figure 21 above. The transmitter as shown in Figure 22 is able to be programmed for each control to go to a specific channel, or double up with one control activating two channels.

Figure 22

Figure 23

# Depth Control Electronics

As stated previously, the electrical operation of the depth control is handled as shown in Figure 21. The linear actuator as shown in Figure 24, is the main part that operates the depth control. It needs a 12-volt, 3-amp power supply which cannot be brought in from the receiver, so it must be brought in from the battery directly. To control this device, a microcontroller as shown in Figure 26 and a motor controller as shown in Figure 25 had to be implemented. The microcontroller had to be coded using C++ to enable it to take in a PWM signal from the receiver and then output two high/low signals to the DC motor driver. The microcontroller would read the input signal and based on the value it got one of the two pins would be set to high. These high/low signals then would alter the polarity of the linear actuator to have it either retract or extend based on which pin was high.

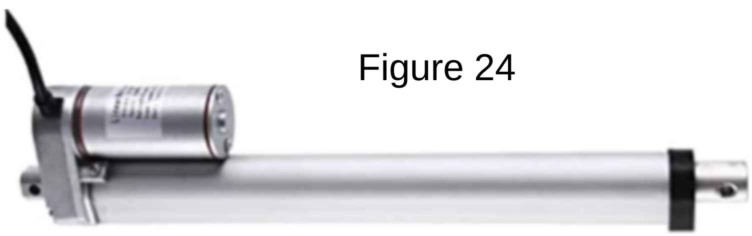


Figure 24

Figure 25

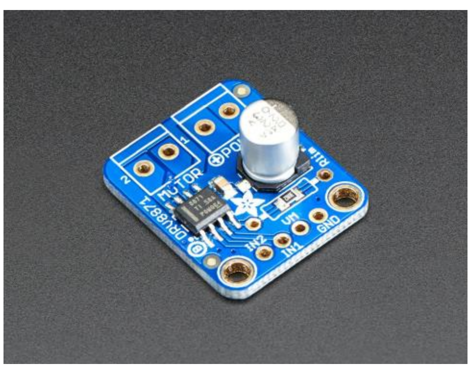
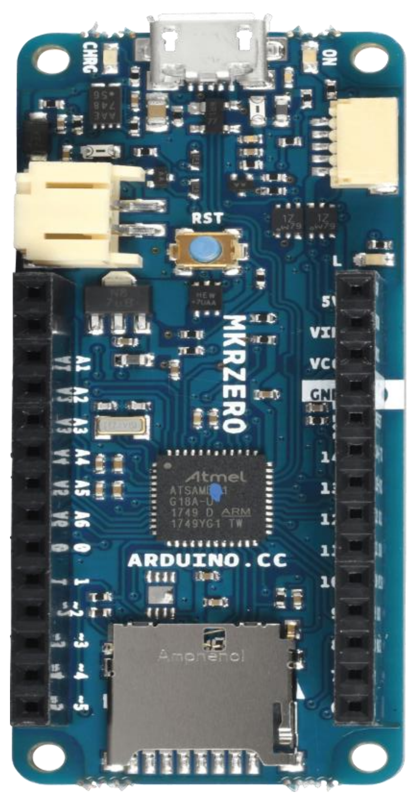


Figure 26



## Propulsion

The propulsion for the UUV was handled by a single motor connected to a propeller. The motor in Figure 27 is a E-flite 25 brushless motor. This motor operates using 14.8 volts, and a continuous amperage of 43 with a burst current of 54 amps. The rpm of the motor is rated at 1000 per volt with a total of 14,800 rpm. As stated previously the motor does not have much in the way of torque and would require a gearbox to reduce the rpm while increasing the torque, however this was not an option with the current configuration of the end cap along with the time that was left to work on the project. Due to this, the propeller had to be small enough that it would not require that much torque to move, and still take advantage of the motor's high rpm to move the UUV through the water.

Figure 27

## Camera

The camera used for the UUV is the RunCam Eagle FPV camera that is placed up against the front of the UUV front end cap. Figure 28 displays what the camera looks like. The field of the view (FOV) for the camera is listed at 150 degrees, however after some testing it was determined to be close to 110 degrees. The camera is able to communicate with the display screen in Figure 30 by using the RunCam TX200 in Figure 29. The TX200 receives power from a split wire coming from the BEC on the speed controller and sends video feed through the antenna shown in the figure. Due to the potential issue of getting video feed from the UUV under the water, it was determined that the antenna should be extended up to the comms buoy that will sit on the surface.

Figure 28

Figure 29

Figure 30

## Battery

The battery used for the UUV is a 13,000 mAh lipo battery that is rated for a 60A load. As can be seen in Figure 31, the battery is sitting on the linear actuator towards the back. This is due to the battery being rather bulky and thus not easy to fit in the frame of the UUV, so it was determined that this would be the best spot for it. To protect the battery, as seen in the wiring schematic there is a 60A circuit breaker which will shut off when the drain on the battery exceeds 60A which would likely cause damage to it, so the circuit breaker will open the circuit before that happens and we can move in to see what the problem is.

Figure 31

# Project management

## Budget

We initially budgeted $1,000 for two vehicles in two version. With Covid-19 restrictions it was revised to a single vehicle. This project was self-funded with additional donations. The final expenses are shown in figure 32.

| Component | Name | Supplier | Cost | QTY in package | #packages Required | Total Cost |
|---|---|---|---|---|---|---|
| - | - | - | $ | # | # | $ |
| Motor | eflite power 25 brushless motor | Already Aquired | Already Aquired | 1 | 1 | $0.00 |
| ESC | 60A RC Brushless Motor Electric Speed Controller ESC 4A UBEC with XT60 & 3.5mm bullet plugs | Amazon | $27.49 | 1 | 1 | $27.49 |
| Prop | To be 3D Printed | 3D Printed | $0.00 | 1 | 1 | $0.00 |
| Fins | To be 3D Printed | 3D Printed | $0.00 | 1 | 4 | $0.00 |
| End Caps | 3D Printed End Caps (Outsourced) | Outsourced | $350.00 | 2 | 1 | $350.00 |
| Servos | | Amazon | $23.99 | 6 | 1 | $23.99 |
| RC Transmitter | Futaba 9c Transmitter | AeroCats | $0.00 | 1 | 1 | $0.00 |
| RC Transmitter Batteries | 3S LiPo | AeroCats | $0.00 | 1 | 1 | $0.00 |
| RC Reciever | Futaba Receiver | AeroCats | $0.00 | 1 | 1 | $0.00 |
| Connectors | XT-60 connectors | getfpv | $9.00 | 5 | 1 | $9.00 |
| Extra Connectors | XT-60 Connectors | getfpv | $5.00 | 5 | 1 | $5.00 |
| 12 awg Wire | 12awg wire | getfpv | $2.50 | 1 | 4 | $10.00 |
| Servo Connectors | servo connectors | amazon | $9.00 | 1 | 2 | $18.00 |
| Heat Shrink | assorted heat shrink | amazon | $10.00 | 1 | 1 | $10.00 |
| 26 awg Wire | 26awg wire | getfpv | $1.00 | 1 | 13 | $13.00 |
| FPV monitor | FPV monitor | getFPV | $71.00 | 1 | 1 | $71.00 |
| FPV Camera | RunCam Eagle 3 1000TVL Starlight CMOS Micro FPV Camera | getFPV | $40.00 | 1 | 1 | $40.00 |
| Short Coax Cable | 3ft coax cable | amazon | $13.00 | 4 | 1 | $13.00 |
| Long Coax Cable | 15ft coax cable | amazon | $11.00 | 1 | 1 | $11.00 |
| F-F SMA Connectors | female to female sma connectors | amazon | $14.00 | 10 | 1 | $14.00 |
| FPV Camera Board | RunCam TX200U Video Transmitter | getFPV | $18.00 | 1 | 1 | $18.00 |
| FPV Camera Control Board | RunCam Key-Board | getFPV | $3.00 | 1 | 1 | $3.00 |
| Battery | Tattu 3300 mAh 4s 35c Lipo Battery | getFPV | $47.99 | | | $0.00 |
| 6" Diameter PVC Pipe | PVC Pipe | Lowes | $67.18 | 1 | 1 | $67.18 |
| Microcontroller | Arduino MKR Zero | Amazon | $27.17 | 1 | 1 | $27.17 |
| Motor Controller | Adafruit DRV8871 | Amazon | $11.27 | 1 | 1 | $11.27 |
| Linear Actuator | Linear Actuator | Amazon | $50.00 | 1 | 1 | $50.00 |
| End Cap Bolts | Fasteners | Lowes | $8.00 | 10 | 1 | $8.00 |
| 500mL Syringe | 500mL Syringe | Amazon | $14.99 | 1 | 1 | $14.99 |
| 300mL Syringe | 300mL Syringe | Amazon | $9.99 | 1 | 1 | $9.99 |
| Cheesecloth | Cheesecloth | Target | $2.99 | 1 | 1 | $2.99 |
| Hose | 1ft section | amazon | $9.34 | 1 | 2 | $18.68 |
| Long Hose | 10 ft section | amazon | $17.86 | 1 | 1 | $17.86 |
| Circuit Breaker | ANJOSHI 60Amp Waterproof Circuit Breaker 30A-300A with Manual Reset Suitable for Car Rv Marine Automotive Stereo Audio Electronic System | Amazon | $20.99 | 1 | | $20.99 |
| Total | | | | | | $885.60 |

Figure 31

# Schedule

The initial schedule is shown in figure 32. With all the integration delays figure 33 shows the semester 2 schedule.

Figure 32

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ~14 weeks in the semester | | - Planned work | | - Possible Work | | | | | | |
| Activity/ Time | 8.21-8.27 | 8.28-9.6 | 9.6-9.13 | 9.14-9.20 | 9.21-9.27 | 9.28-10.4 | 10.5-10.11 | 10.12-10.18 | 10.19-10.25 | 10.26-11.1 |
| **Administrative** | | | | | | | | | | |
| Kickoff Meeting | | | | | | | | | | |
| UUV Show and Tell | | | | | | | | | | |
| | | | | | | | | | | |
| **UUV V.1** | | | | | | | | | | |
| Requirements Creation | | | | | | | | | | |
| Component Research | | | | | | | | | | |
| V.1 Component Selection | | | | | | | | | | |
| V.1 Waterproofing Methods Determination | | | | | | | | | | |
| V.1 Waterproofing Testing | | | | | | | | | | |
| V.1 Sizing | | | | | | | | | | |
| V.1 Detailed Design + CAD Model | | | | | | | | | | |
| V.1 Component Ordering | | | | | | | | | | |
| V.1 Component Integration | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| Fundraising | | | | | | | | | | |

Figure 33

| Activity/ Time | 2.08-2.15 | 2.15-2.22 | 2.22-3.01 | 3.01-3.08 | 3.08-3.15 | 3.15-3.22 | 3.22-3.29 |
|---|---|---|---|---|---|---|---|
| **Administrative** | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| **UUV V.1** | | | | | | | |
| CAD Model re-design | | | | | | | |
| Wire Adjustments | | | | | | | |
| Skeliton/ frame assembly | | | | | | | |
| **Hardware Testing** | | | Hardware Testing | | | | |
| Depth Control Assembly | | | | | | | |
| Leak Testing | | | Leak Test #1 (partial) | | Leak Test #2 (full assembly) | | |
| Empty Dive Test | | | | | | | |
| Circuit Braker Integration | | | | | | | |
| ***UUV Improvements*** | | | | | | | |
| Gear box | | | | | | | |
| Low Battery warning | | | | | | | |
| Propulsion Improvements | | | | | | | |
| Automatic debris detection | | | | | | | |

# Conclusion

## Problems Encountered

There were several problems encountered during the design, construction, and testing process. The biggest challenge came in the form of the effects of the Covid-19 pandemic. Due to the pandemic, it was tricky to get organized. Team members could not gather as they were required to follow Covid-19 safety guidelines. The six feet social distancing guideline made it difficult to find lab space big enough for more than one team member to be working together at the same time. This led to most members completing sub-assemblies on their own before meeting up, and if there was an issue then they would have to go back to their own workspaces to fix the issue before returning. In addition, it was also difficult to get official permission to use any lab space as it took around a semester to get approval. This similar problem was also found in looking for testing space. For this project, it was key that there was a sufficient amount of water space with the appropriate depth to operate in. Because of the requirements for testing the UUV, there were limited spaces that could be used, which then came with its own challenges of getting approval to use the facilities in the first place.

Some other problems encountered came in the form of component ordering and acquiring. Due to the covid situation, some of the items that were used or intended to be used were unavailable for a time due to stock issues and thus there was a delay in obtaining some components which set the project back at certain points. There were also issues with some components not being as the designs required which in some cases like the linear actuator led to redesigns for the skeleton, or the end caps which caused issues during the waterproof testing.

The final problem that did not allow us to get to the final testing stages that were anticipated was the issue with waterproofing. A majority of this issue came from the less than ideal quality of the 3D printed end caps. The end caps had issues with porosity and tolerance issues that derailed a lot of our original plans. This problem was hard to deal with on account of funding and the time crunch that getting new parts would have put us into. Also, the inability to get proper shafts for the fins and motor forced the use of lower quality shafts that were not capable of sealing as was required.

# Future Recommendations

For future iterations of the UUV senior design project, there were some recommendations that came up during the procession of the project that could not be implemented for one reason or another for the V1 UUV and would thus be saved for a V2 or other version. The recommendations are as listed.

- In the future the end caps need to be printed in a better way. This could mean through the use of a higher end, more precise printer or by printing the end caps solid and then machining them into the proper parts. This would have alleviated some of the issues that came with waterproofing and could lead to a far better end product.
- For wiring, move the battery and circuit breaker to the comms buoy on the surface. One of the key problems found with the wiring setup is that there was only one manual shutoff should anything happen, and it was the circuit breaker in the UUV which could not be reached easily should something happen. Thus, it would make sense to have it on the comms buoy which could be relatively easier to reach and shut off. With the circuit breaker on the buoy, it would make sense to have the battery as well so that you do not have two sets of wires going up the tether between the UUV and the comms buoy just to connect to the circuit breaker. As an add on, it is also thought that having some kind of LED light on the comms buoy connected after the circuit breaker would be for the best as it would give a visual indicator that the power was on, which could be seen by people operating on the surface.
- Add the LEDs that were originally planned to go on the nose of the UUV but were not due to setbacks. These LEDs were meant to provide light for the camera should the UUV operate in darkened waters. These lights would be either connected to one of the open channels on the receiver so that they can be turned on and off with the transmitter or have them directly connected to the speed controller BEC so that they are always one when the power is on.
- Add a gearbox to the main motor. As previously stated, one of the biggest issues with the propeller and motor is that the motor, while having a high rpm, did not have much in the way of torque which meant the propeller had to be smaller so that the torque needed to move it would not be more than what the motor could provide. The solution to this would be to add a gearbox which would reduce the rpm of the motor while proportionally increasing its torque. This then would allow the motor to move a larger propeller than was already designed and allow for speedier movements of the UUV as a whole.

- Lastly, it was talked about since the beginning of the project that the UUV could be made to be more autonomous, however at the time it was determined that trying to make the UUV more autonomous than it is currently would be more challenging and cause setbacks as the teams tried to figure out how to do so. Nonetheless, making the UUV more autonomous would be an excellent goal for future versions. The UUV is currently controlled by an RC transmitter and receiver, however it could be made to have everything wired up to a microcontroller that is then being operated by a written program so that the UUV will go in set motions before returning to base without any guidance from the team outside of starting its mission. This can even be taken one step further were using sensors, the UUV could receive data and then through a program, act on that data on its own without following a set list of movements in a basic program. Both of these, especially the latter would require extensive programming knowledge and work, which none of the team members had under their belt at the time.

## Summary

During the two semesters dedicated to working on the UUV, the team accomplished a lot. Using components previously intended for hobby aircraft along with other parts, a functional electrical system was designed and constructed. The frame for the UUV which included the main body that held most of the electronics, the end caps, the fins, the propeller, etc.... were designed, constructed, and secured together. During the waterproofing tests, leaks were found, and steps were taken to seal them off, and with each test, more progress was made to making the UUV completely waterproof. The most important part was the knowledge that was learned along the way. There were parts of this project that most members were not initially familiar with. However, through working on the project, a better understanding of project design was acquired; team members learned more about how to plan missions; an understanding of what needs to be done for more successful waterproofing was gained; and what it takes to better design for manufacturing became better understood. Lastly, this project was once that could only be born through the efforts of people from multiple disciplines. Each member could complement each other and make up for gaps in knowledge from other members. No single discipline is taught everything necessary to make a functioning UUV, so having multiple disciplines was essential.

The UUV Senior Design project was an experience that will help all the team members in their future careers. It exposed them to experiences they were partially familiar with if familiar at all, and allowed them to fully explore, test, and learn from the experiences. It cannot be understated how learning from these experiences born out of a project that required multiple disciplines to tackle, will help in future careers where they will be working on projects that might require similar levels of interdisciplinary work. These experiences now will help make these future projects easier to address how to handle and then subsequently easier to deal with. So, in conclusion, the UUV senior design was a great learning experience for seniors about to graduate and work in the engineering world.

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