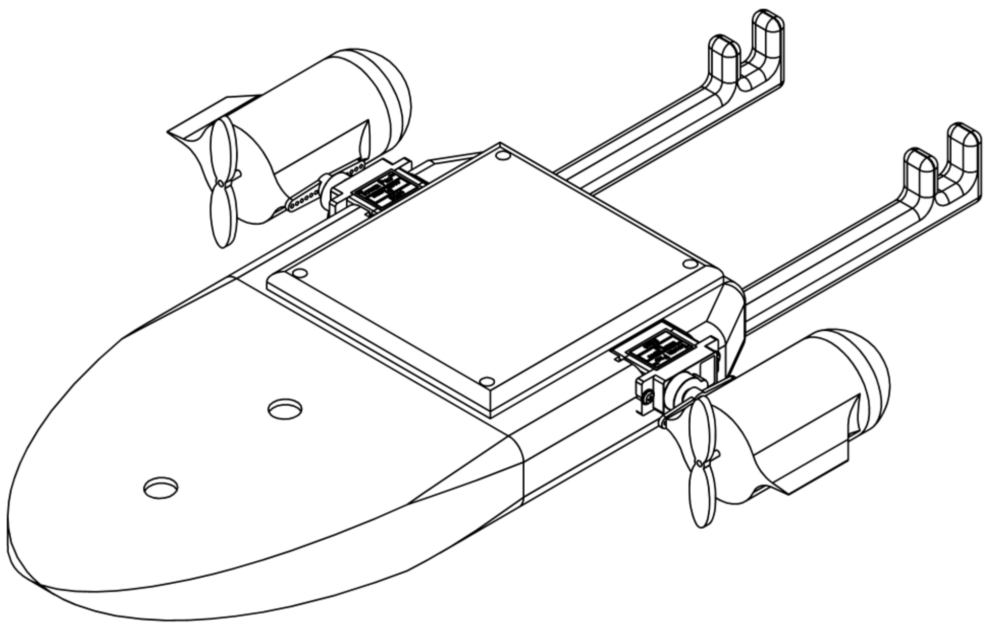

Water Monkeys

Robotics Organization for the Community OC
Orange County, California

Team Mentor

Kash Shah

UC Riverside Student

Team Members

Pranay Dhoopar - 11th Grade

Team Captain, Design Lead, Technical Design Report, Builder

Bryce Do - 11th Grade

Designer, Building Lead, Driver

Darshan Amin - 10th grade

Designer, Technical Design Report, Builder

Dimitri Kouloumbis - 9th Grade

Technical Design Report, Course Build Lead

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Technical Design Report

Himanshu Patel - 10th Grade

Technical Design Report Lead

David Pantoja - 11th Grade

Treasurer, Course Builder

Table of Contents

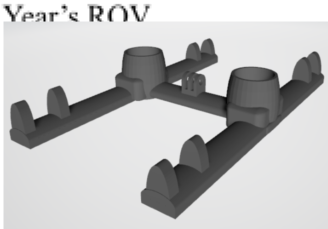
Technical Design Report

Abstract: The ROV design described below has been created to make a universally portable and efficient way to tackle the overall ocean pollution crisis. This meant that the ROV needs to be able to be lightweight and easily maneuverable to access areas typically unable to be accessed by humans, as well as be able to collect trash and data for humans to analyze about the areas to make future decisions. To create such a robot means that it would need a camera, depth sensors, as well as a redesigned thruster and thruster control system to allow it to be easily maneuverable and precise in its movement. These requirements were addressed by using lessons from previous years' competitions. A brief description of the ROV's structure and function goes as follows: the base of our ROV is a 3D printed hexagon. On each side of the base, a hook is attached with a net allowed to connect underneath to allow the robot to pick up marine debris. To address maneuverability and weight, the ROV uses a completely redesigned propulsion system; it uses only two motors, alongside two rotating servos, controlled by a flight controller. On the center of both chassis, we have attached a nine-gram servo, which allows 360-degree rotation, hence increased maneuverability. The rotational design drew inspiration from the VTOL plane design when creating our servo's rotation. In the center of the base, components of our ROV, such as the battery, camera, depth sensor, and flight controller are securely and safely housed and protected from water. The flight controller was added to control the VTOL design for the ROV, and allows the ROV to stay stable by using a corrective input to the motors. This allows for stable maneuvering and ensures that the ROV will not get stuck in tight spaces when navigating the ocean. Overall, this ROV design tackles many of the key issues of the ocean pollution crisis. Because the 2021 Mission Course involves waterway cleanup, our ROV will be able to address the factors of it too.

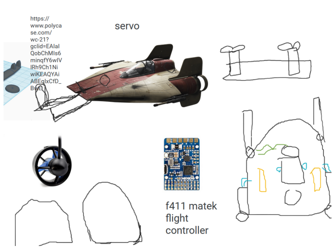
Task Overview: The overall issue is the rampant pollution in the world's oceans has not only churned out patches of floating garbage, but has polluted the seafloor with additional sunken debris. Locally, off the west coast of California, there exists the Eastern Garbage Patch, which is a part of the more expansive Great Pacific Garbage Patch. A garbage patch functions through a series of currents and a circulating gyre; the gyre's swirling motion traps any traveling debris and accumulates the nonbiodegradable trash. The eastern patch is not limited to surface-water garbage, as about 70% of marine debris has been discovered residing on the seafloor beneath the garbage patch. These statistics show that this is a growing and key issue that needs to be solved through identification and cleaning. To assess the growing state of the garbage patch, aerial drones have been deployed which track and view the situation. However, for marine debris residing on the seafloor, a ROV would be very helpful. The solution in solving the crisis lies in finding and collecting trends in data about the marine debris, and using those findings to better raise awareness or develop a mechanical solution. In terms of data collection, a sensor pack can be developed for real-time analysis as well as be utilized for any future inquiries. Our ROV will tackle these issues by being able to pick up smaller marine debris, and also collect data about larger areas with the camera and depth sensor, so that scientists can address them. Part of the challenge includes navigation through more turbulent areas of water. Exploring a cave, with uneven levels of water within, requires our ROV to have the capacity to travel through more shallow water. This will require the ROV to have a stable and accurate maneuvering system. Overall, our ROV will provide a solution to these tasks by addressing maneuverability, including a camera and sensor setup, and hooks with a net - to be able to identify marine debris areas and collect smaller marine debris.

Design Approach: When our team began working on thinking of ideas, we approached our tasks with the Engineering Design Process (EDP). We began by asking and defining the constraints and expectations for solving the ocean pollution crisis.

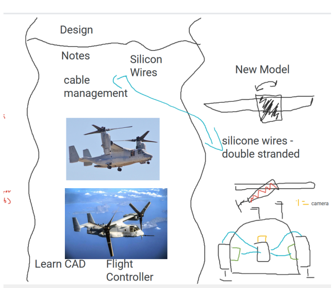
Last Year's ROV



Beginning with our model from last year (as shown to the left), we evaluated what went well and what went wrong so this could be applied to the real world tasks. We noticed that the flat design definitely helped with decreasing **drag** and was better able to **maneuver** the course than the stock PVC design from 2 years ago; this is because of an overall reduction drag. Because maneuverability was a key point from our new tasks, we decided that we would make our new ROV as flat as possible. Since our new ROV will be used in the ocean and needs to be able to maneuver in places inaccessible to humans, the new design thus needed a camera, however, we would need to use a smaller camera than previously used by the GoPro, and possibly **waterproof** it ourselves. The dual hook bay in between was perfect for pushing trash and the hooks were able to address all other parts of the mission course which involved picking up items and moving them. Because the new ROV would be used with various pieces of trash, we decided we will keep the hooks as well as add a net to the undersides to maximize the types of trash we would pick up. The weight of 6 motors (2 up and down, 4 back and forth) was the most hindering aspect of the ROV. Maneuverability was a key part of our design expectations, so this was something we would tackle when beginning the design of our new ROV. From this analysis, our team decided to take the best parts of the old ROV, the dual hook open bay and the camera. The main concepts we looked to address and further iterate were the weight and efficiency of motors and the weight of the camera.

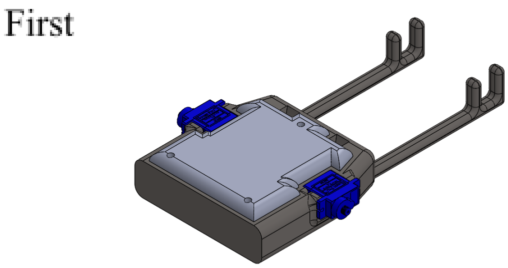


Google Jamboard Sessions



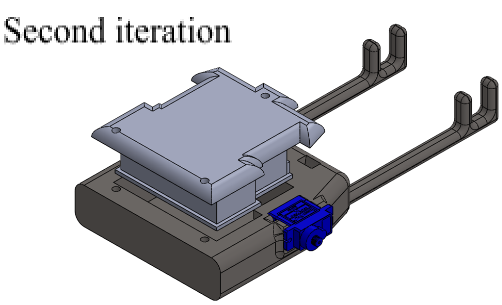
After noting all the positives and negatives from the previous competition, our team set out to begin brainstorming for this year's design. The first matter to address was the thruster system. Our team conducted virtual meetings for the bulk of the competition, so we used Google Jamboard to collaborate together by sketching and including reference images (see left for 2 brainstorm sessions). Our propulsion system makes a **radical** change by ditching the vertical motor. The reasoning behind this was because one vertical motor was not efficient enough and two motors were too heavy in previous competitions. Our design instead decides to use two 9-gram servos **analogizing** and taking inspiration from the VTOL planes as shown in the images, where the motors can be rotated. This allowed the design to use the same motors vertically and horizontally. To address maneuverability and stability, we came up with the idea to use a flight controller to allow for the ROV to remain stable with the accelerometer and the corrective input formula. Because of this we would need to use an RC drone controller for the ROV, along with an antenna at the end of the tether to connect the RC controller.

After having initial brainstorming sessions on Google Jamboards, we created a **design specification** including more specific requirements for our ROV. The key requirements from our design specification that were not included in the initial brainstorm sessions were that the ROV should include a waterproof casing for the electronics, a camera, and a depth sensor. The waterproofing was essential. The camera and depth sensor were for navigation purposes, as well as to store data of key points of interest when navigating the ocean, mainly areas with marine debris or inaccessible caves. After creating the design specification, we created a parts list (see Appendix A) and then set out to our first CAD model.



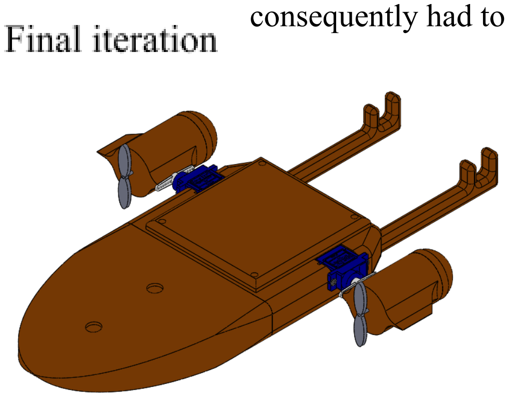
To the right is the first iteration of our ROV design. It includes two servo slots on each side, two hooks for trash with a net connection on the underside. The housing underneath the lid allows for enough space for electronics including the on board battery, flight controller, and brushed ESC. There are two holes on the top for wires to go in that are intended to be filled with glue and baking soda to prevent water from seeping in. There two holes in the very front of the ROV are the camera and the depth sensor.

Discussion on this first iteration involved addressing a better method to prevent water from entering the lid being screwed on. **Buoyancy** and **ballast** were also discussed. We decided buoyancy would be addressed through infill settings of the 3D print which would affect the amount of air in the ROV. We would address ballast by gluing fishing weights as necessary when testing.



To address the waterproofing of the electronics, we decided to create a double wall seal, with the ledge shown in the image to be smothered with toilet bowl wax. This would address any water that seeps in and create a secondary boundary for the electronics to keep them dry.

Discussion on the second iteration included making custom motor casings to connect to the servos, as well as adding a hollow **tail** for **stability** - this was an **analogy** to a design of a plane. Lastly, when we put the design through a 3D printing splicer, we realized that many of the walls of the design were too thin to print so we consequently had to make the overall design much larger.



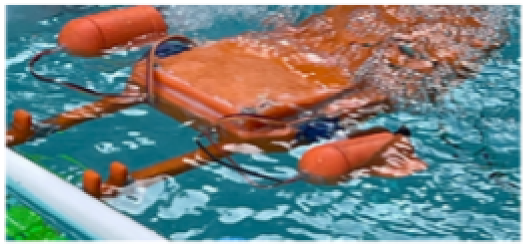
The final iteration of the design added the tail. The tail was hollow with two holes to allow it to fill up with water to keep it stable while maneuvering. The motor casings had a curved front as well as fins to make the hydrodynamics of the ROV more efficient by angling the direction of the water.

Throughout the iteration process, we felt like we fulfilled all of the design specifications by housing the electronics in the center, having hooks for trash, implementing ease of maneuverability, a waterproof seal, camera, depth sensor, and adjustable ballast and buoyancy. The next part would be testing in practice. (**See Appendix C for detailed drawings**)

Experimental Results: The first part of the ROV to test was the buoyancy. When tested in the water the ROV was positively buoyant, so we needed to address ballast. Because our plan was to have adjustable ballast, we tested different amounts of weights glued on and checked the depth of the ROV to choose the right amount of buoyancy. We first tested in a pool rather than the ocean to be safe. The final weight we chose was 1 oz because it was the closest to the halfway point in 6ft, which we decided meant it was neutrally buoyant.

Weight	Depth (from pool surface in a 6ft deep pool)
¼ oz	4 in
½ oz	2 ft 8 in
1 oz	3 ft 2 in
1 ½ oz	4 ft 5 in
2 oz	6 ft (touch pool floor)

Added-Weight to Depth Chart to test buoyancy



ROV positively buoyant without weights

Water leaking into the ROV compartment

During our testing process, we also had to program the flight controller to calibrate the values of the servos. After trial and error for the angles of the servos, we set the PID (Proportional, Integral, Derivative), used to calculate the speed of the servos, to 300%. The goal of the trial and error was to increase the turn radius of the servos to allow for more control. Soon during our testing process, however, we would soon face a major problem. Although our waterproof toilet bowl wax seal was holding up, one thing we did not consider was water seeping through the 3D printed plastic. We had chosen PETG because of its waterproof properties, but our infill settings had allowed water to begin seeping, filling up the pockets and then seeping into our ROV electronics housing. This was a major problem that caused our flight controller and ESC to fry up.

Water had flooded through over time seeping in from the lid because of the infill of the plastic. We had an extra flight controller and decided to waterproof it and try it, but we did not have an extra ESC, so we were unable to continue testing. As a result of the pandemic, we were limited on time and resources, and unfortunately did not have much build time to further restart to print a new lid and try again. We however have full intention to continue to iterate this design. The rest of this section will talk about the intended tests we had planned. The next section will talk about, where our team will go forth with this design.

For the other tests planned, we were going to drop different weights of trash, and time how long it would take to pick them up and bring back to the deck, with multiple trials for each to test the strength of the ROV, and how the marine debris collection aspect could be tested. We also planned to test maneuverability by testing within three different sized tight spaces and timing multiple trials to see how maneuverability could be improved. As for the camera and flight controller, the data we were able to collect while working was adequate to address the design specification of capturing data during marine debris research.

Reflections: Overall, from our planning and testing, we feel that our team was really able to complete with a new and innovative design that would be able to address marine debris and ocean pollution through the accumulation of small marine debris, filming, and collecting data. We were really excited about coming up with a brand new design that was multifunctional and could be applied to many different situations, and most importantly, in the real world. Though we were limited in time and resources by the pandemic, preventing us from being able to pull off a fully functioning ROV, we felt we were certainly close. Our plan is to continue forward with this design and be able to fix the waterproofing issues for it to be used effectively for long periods of time without being damaged. Looking back, we feel that maybe if we did more research, we may have prevented the issue before it happened, and possibly have been able to avoid the problem all together. Though the pandemic limited us in the time we were able to meet and the amount of available people attending said meetings, we feel like this will be a learning experience for next year about how much time we will need to effectively plan and rebuild our ROV.

Next Steps: Starting as soon as summer, after our team is vaccinated, our team is ready to pick up where we left off, and begin testing different waterproofing techniques for our electronics. Since our design was effective in the short time we were able to test it, we would like to keep a similar structure of thrusters, but will look to improve our waterproofing techniques. We currently have three different ideas for this. The first idea is to use a much higher infill on the lid and test that. The second idea is to use a watertight electronics box and model the design around that. Essentially the servos, motors, hooks, and tail would all be attached to this electronics box. The final idea we currently have is to use a water tight pipe enclosure, similar to the ones used in RC submarines and model the servos, motors, hooks, and tail around the pipe enclosure.

We will test these techniques by submerging the enclosures into deep water without electronics for long periods of time, examine how much water seeps in, and then move forward based on our results. Our team really hopes that once we are able to meet in person, we will be able to test effectively and have a fully functional ROV in the future. We are also excited to use it in next year's competition. We will modify it slightly in accordance to the specifics of the courses, but because our ROV is highly multifunctional, we feel that it will be able to be used. Overall, we are very excited about the things we will be able to accomplish with our ROV in the future.

Acknowledgements: Throughout our journey to creating the ideal ROV, our team was laboriously influenced and supported by our mentor and one of our teachers. First and foremost, we would like to express our immeasurable gratitude to the mechatronics and design technology teacher at Troy High School, Mr. Goodman. Although he is constantly faced with the commissions and duties of being a teacher, he guided us along the way of the Engineering Design Process, and even made suggestions for our design. Furthermore, he voluntarily provided us access to 3D printers, despite his obligations to other students. He gave our team the ability to print throughout his own day, and even overnight. For these reasons, we give our heartfelt thanks to Mr. Goodman. Last, but most definitely not least, we would like to thank our unbelievable mentor, Kash Shah. Kash is currently pursuing mechanical engineering as a student in college. We are obliged to have the guidance and mentorship that he provided over the course of building our ROV. His experience as a high school student previously involved in the SeaPerch program, as well as his knowledge from studying mechanical engineering, was extremely helpful upon seeking his advice about our design iterations.

References:

Gargenta, E. (n.d.). Creating Neutral Buoyancy in ROVs. Retrieved January 12, 2021, from http://www.bios.edu/uploads/2014_lesson_plan_neutral_buoyancy_in_ROVs.pdf
This article was critical in the development of a ROV that could incorporate buoyant aspects. The information from the source was also helpful in providing equations to quantify ROV measurements in addition to research about PVC pipes and 3D printing. Primarily, the article gave us an overview of the necessary steps and components to construct our ROV, though not many of the specific instructions were utilized.

Hutchison, F. (2013, March 7). 2, 3 and 4 blade propellers are they all the Same? - Seattle WA. Retrieved April 15, 2021, from https://www.pyiinc.com/articles/2-3-and-4-blade-propellers-are-they-all-the-same
In deciding on whether to use a two, three, or four blade propeller, we consulted this source. Given that we did not need the increased blade area of the four blade, nor the increased speed of the three blade, our team opted to use the two blade. This gave us a blade with less drag and complications. The article details individual situations that each blade type would be ideal in, thus providing enough information for us to determine the best choice.

National Geographic Society, C. (2012, October 09). Great Pacific Garbage Patch. Retrieved April 29, 2021, from https://www.nationalgeographic.org/encyclopedia/great-pacific-garbage-patch/
Information about the Great Pacific Garbage Patch, in addition to solutions and conservation efforts can be found here. We used this article to learn about the local pollution issues and the extent to which it negatively impacts our environment. The article also provides further clarification on how to approach solving the local garbage patches, while also suggesting, to a greater extent, solutions that could gradually eliminate polluting effects in general. Data and additional statistics are given.

Underwater Robotics at RMSST. (n.d.). Buoyancy. Retrieved January 12, 2021, from http://underwaterrobotics.wikidot.com/buoyancy
This article provided a more in-depth approach to tackling the issue of our ROV's buoyancy. It detailed how to apply buoyant principles in our ROV. Our design required the ROV to incorporate the ability to float within water.

Stachiw, J. D. (2006). Acrylic plastic as structural material for underwater vehicles. Retrieved February March 10, 2021, from https://ieeexplore.ieee.org/document/1405581
This source gave us an insight to the structural integrity of our ROV. We ultimately decided to construct our ROV out of PETG. The usage of PETG gave way for better shape and buoyancy, in addition to its waterproof nature. The PETG plastic was 3D printed. Though it ended up lighter than we initially intended, the density of the PETG was easily remedied in response.

Thone, S. (2009). Buoyancy. Retrieved January 29, 2021, from https://www.homebuiltrovs.com/howtobuoyancytips.html
Further research was done on developing the buoyant nature of our ROV. The article allowed us to figure out that a symmetrical and lighter ROV design would help with buoyancy. The ROV was thus able to be designed in a more structured manner.

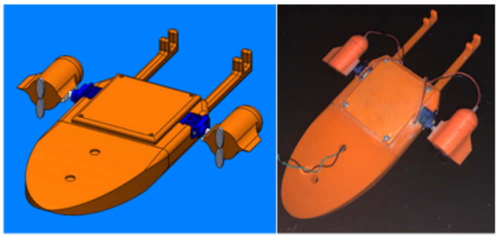
Appendix A: Budget

Part Name	Cost	Quantity	Total Cost
1 KG Roll of PETG	23.99	1	23.99
DC Motors	2.99	2	5.98
1 11.4 V 3s Battery	8.99	1	8.99
Brushed ESC	16.25	1	16.25
Matek F411 WSE Flight Controller	45.79	1	45.79
24 AWG Wire	7.65	1	7.65
BetaFPV Camera	19.99	1	19.99
2mm shaft Propellers	4.5	1	4.5
Toilet Bowl Wax	1.99	1	1.99
3/4" #8 Screws	7.99	1	7.99
Electrical Tape	2.99	1	2.99
TBS Tango 2 Controller	159.99	1	159.99
TBS Nano Rx Receiver	30.99	1	30.99
		Total	337.09

Appendix B: Team Fact Sheet

Water Monkeys

Robotics Organization for The Community OC, Placentia, California, United States of America



Real World Solution

3 Years participating in SeaPerch

1 Times at the International SeaPerch Challenge

Our SeaPerch is unique because:

Our SeaPerch is unique due to a variety of reasons. The most striking feature is our thruster system which is based on a VTOL plane design. The ROV only utilizes 2 motors because it uses two 9-gram servos that allow rotation. Additionally, the ROV is unique because of the many electronics on board, such as a camera, flight controller, servos, and an ESC. The flight controller allows for corrective stability using an algorithm. The camera was used to help guide us through the water, as it can be difficult to look through water and maneuver the ROV.

SeaPerch Design Overview:

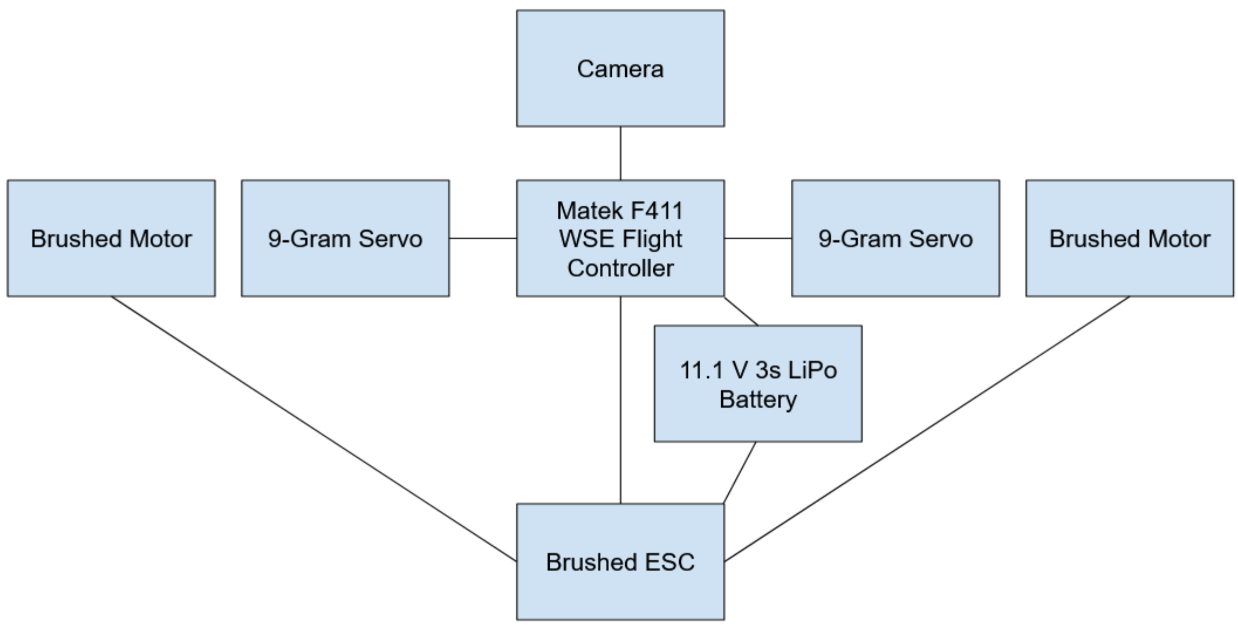
At the core of our design, we have a hexagonal 3D printed base with two 90° angles. Extending on each side is a hook with an attachable net which is used to lift and move the trash. At the center of the chassis, there are 9-gram servos which allow 360° rotation for the motors. The rotation of the servos is based on the VTOL plane design. At the center of our base, we added cutouts that house and waterproof components such as our battery, Matek F4111 WSE flight controller, camera, depth-sensor, and a lightweight 11.1V LiPo battery.

Our biggest takeaway this season is:

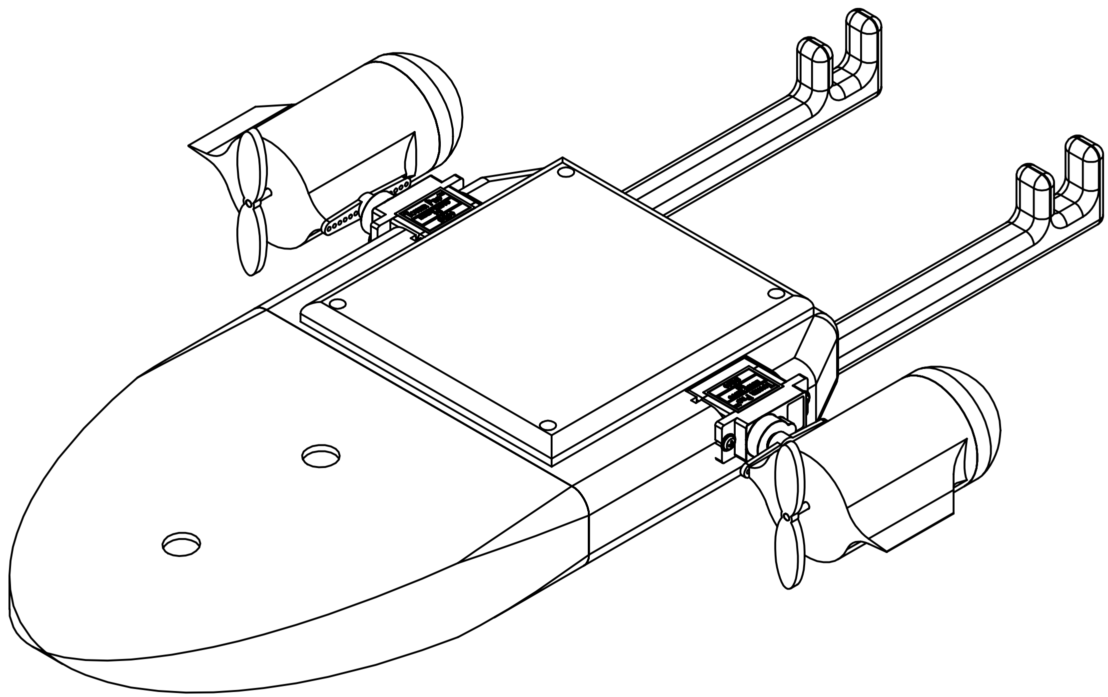
Our biggest takeaway from this season is that we need to improve our waterproofing techniques without damaging our ROV. Currently, our ROV uses toilet bowl wax seals to protect the battery and chip. But, the infill of the plastic caused water to seep through the lid which led to severe damage to the chip and battery. Our team has already started to find solutions to this problem. Our two possible solutions are to use either a higher infill on the lid, a watertight electronics box, or a watertight pipe enclosure, which should all lead to further water security.

Appendix C: Engineering Notebook
The following section will include an electronic schematic as well as the detailed drawings of our final product to help understand the ROV design better.

Electronics Schematic:



This flowchart shows all the connections of the electronic components. The next pages will include detailed dimensioned drawings of the assembled components and individual parts.



TITLE:

ROV Assembly

SIZE

A

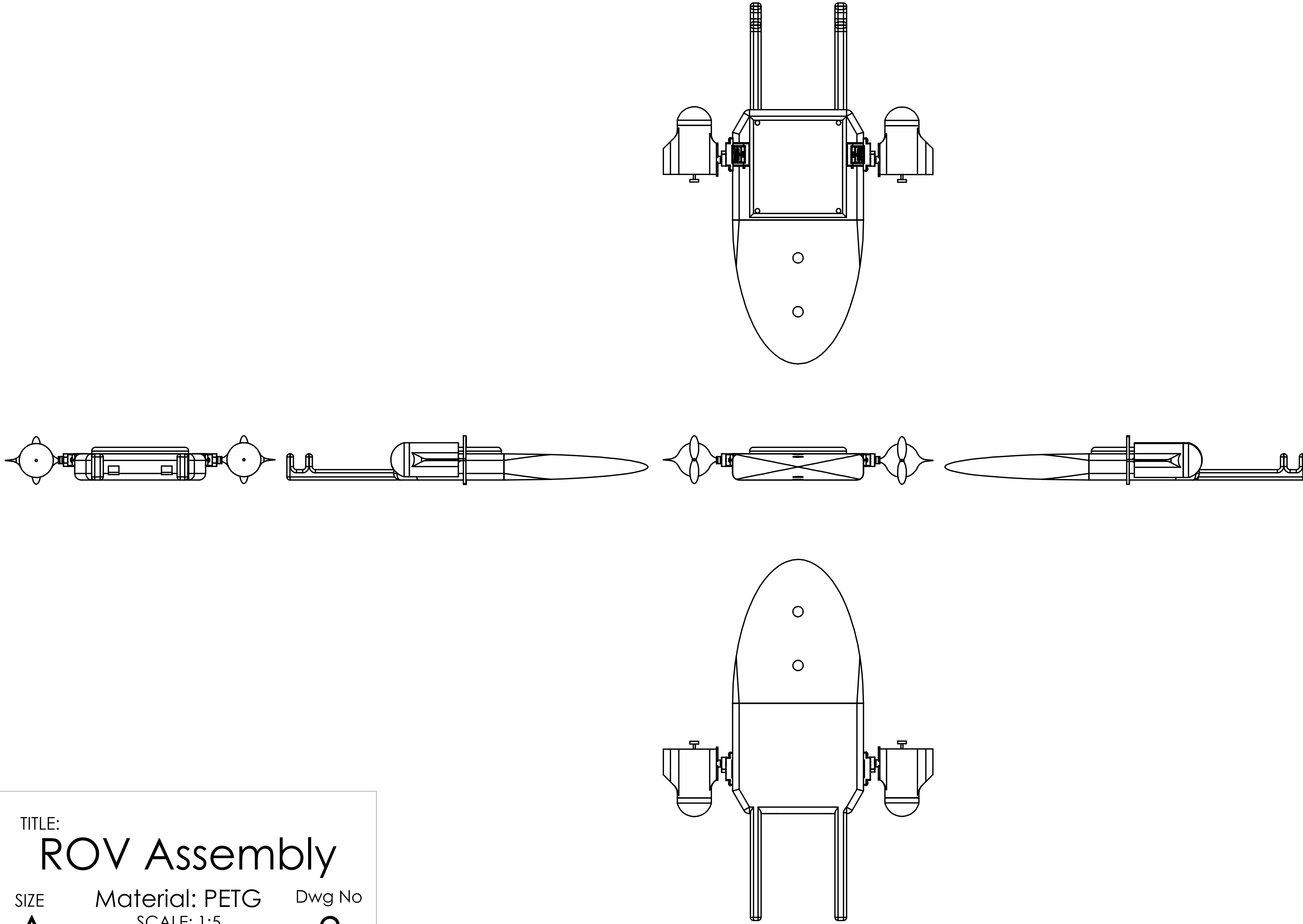
Material: PETG

ISOEMTRIC VIEW

DO NOT SCALE DRAWING

Dwg No

1

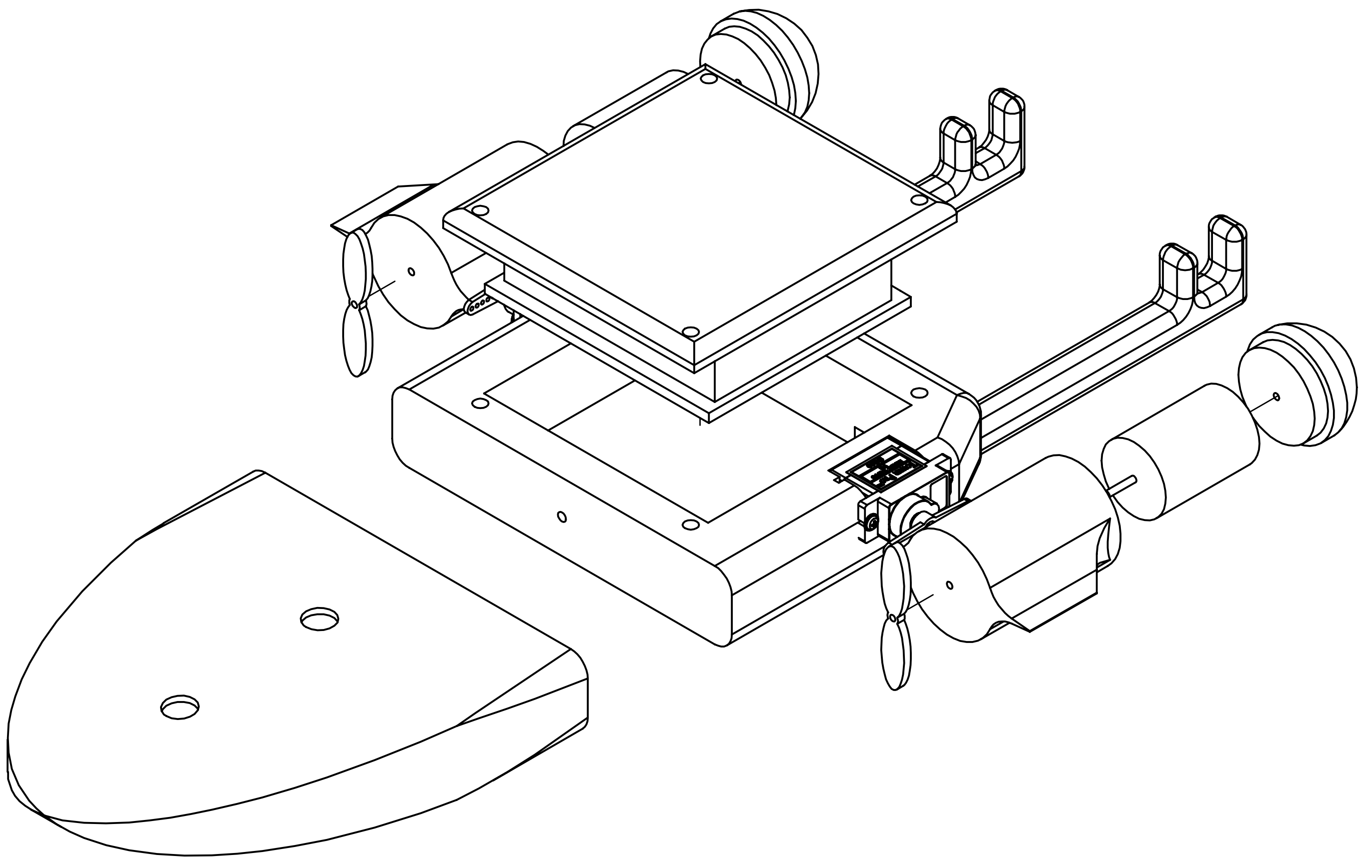


TITLE:
ROV Assembly

SIZE
A

Material: PETG
SCALE: 1:5
DO NOT SCALE DRAWING

Dwg No
2



TITLE:
ROV Assembly

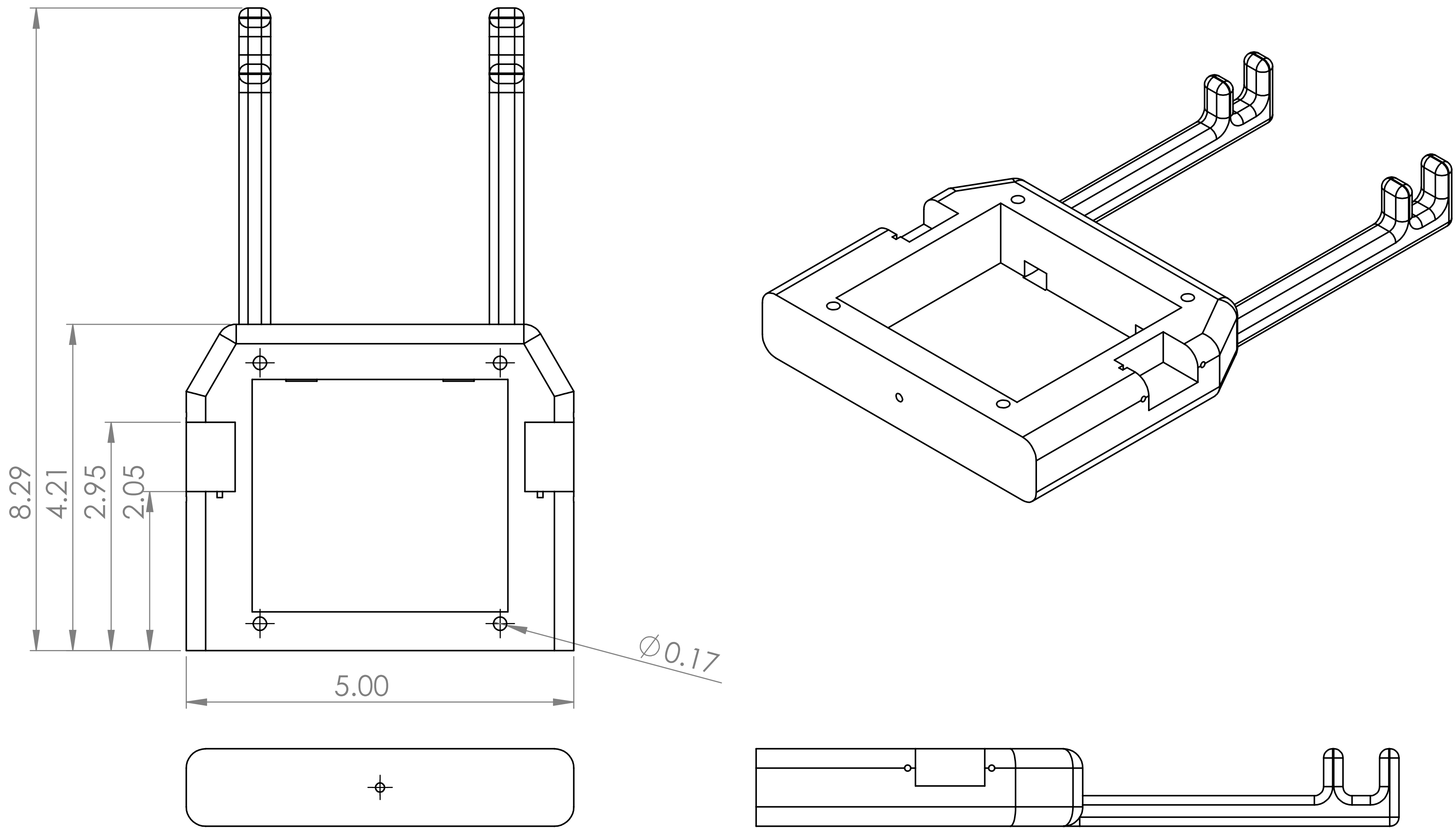
SIZE A

Material: PETG

EXPLODED ISOMETRIC VIEW

DO NOT SCALE DRAWING

Dwg No 3



TITLE:

ROV BODY

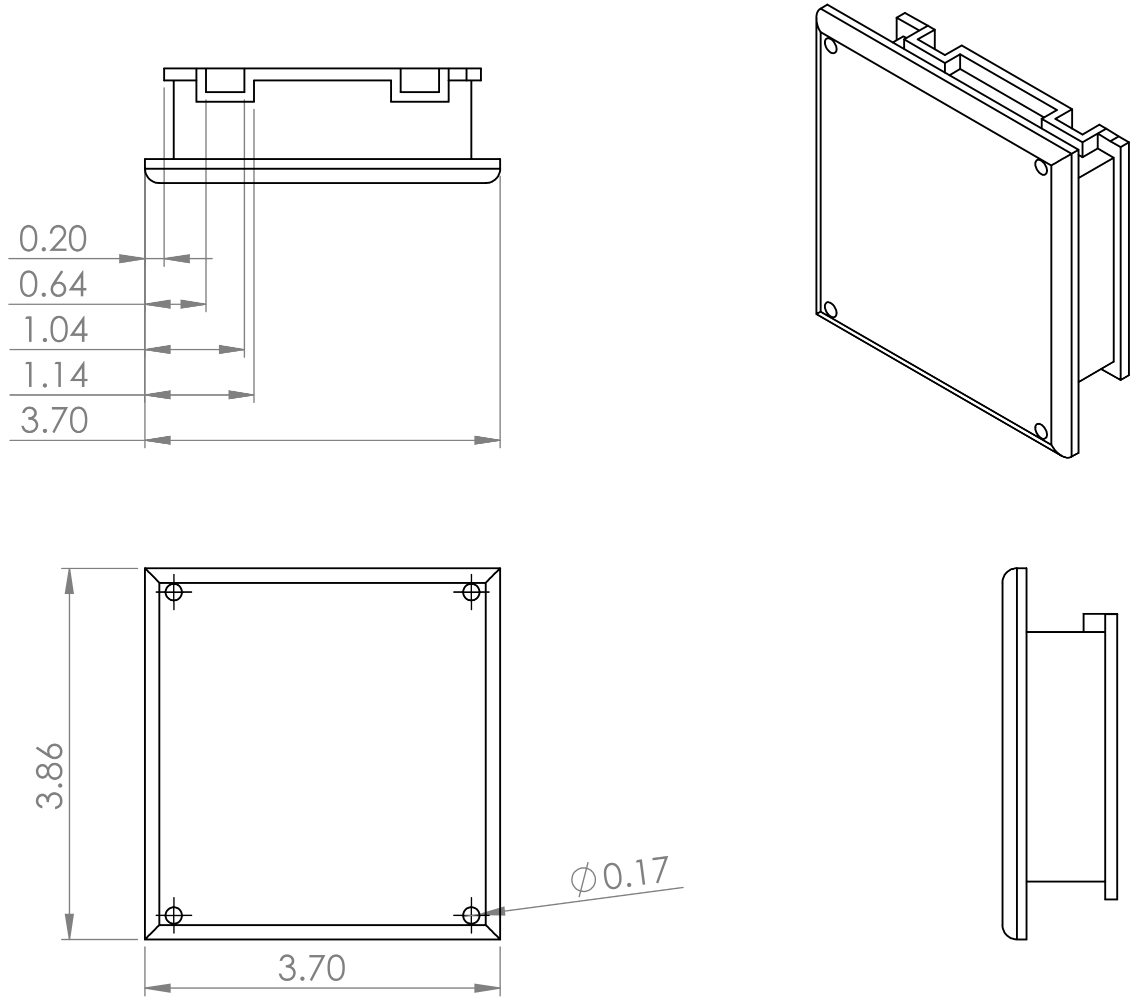
SIZE
A

Material: PETG

SCALE: 1:2

DO NOT SCALE DRAWING

Dwg No
4



TITLE:

ELECTRONICS LID

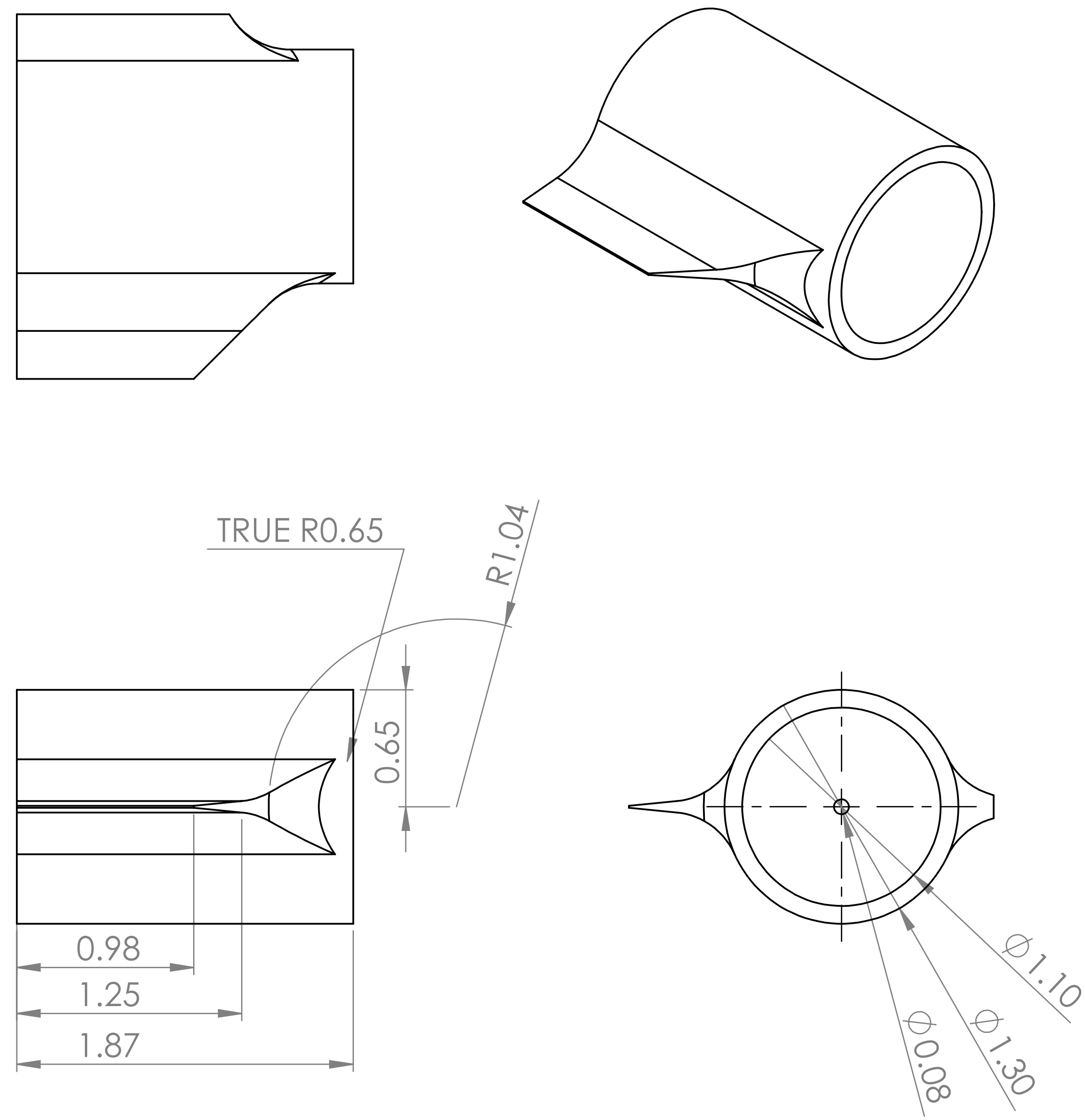
SIZE A

Material: PETG

SCALE: 1:2

DO NOT SCALE DRAWING

Dwg No 5



TITLE:

Motor Casing

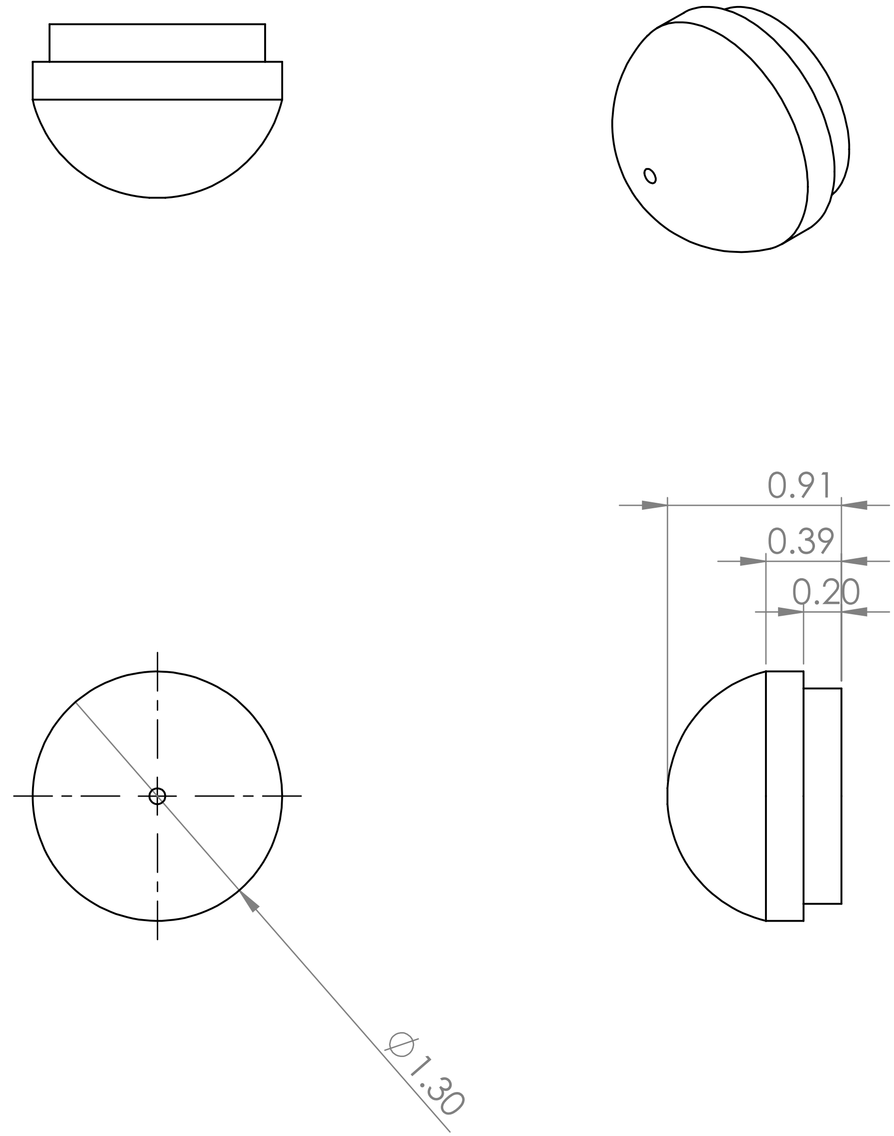
SIZE A

Material: PETG

SCALE: 1:1

DO NOT SCALE DRAWING

Dwg No 6



TITLE:

Motor Casing Lid

SIZE
A

Material: PETG
SCALE: 2:1
DO NOT SCALE DRAWING

Dwg No
7