Project Radian Robosub Technical Design Report

Nicholas Ross, Nicholas McCutcheon, Ryan Hays, Phoebe Hays, Cole Bramante, Justin Rhee, Nathan Rhee, Bryce Evans, Andrew Fantino

***Abstract*—This is Project Radian Robosub's first year at competition. As a first year team, our goal is to create a functional submarine that uses visual processing to complete tasks. We hope to qualify and complete a few of the basic maneuverability based tasks. Our team heavily utilizes rapid prototyping and 3D printing, and have designed our robot around simplicity and reliability, with the exception of our dynamic ballast system.**

I. Competition Strategy

A. General Design Approach

As a first year team, our primary objective is to create a functional underwater vehicle. We do not believe it is realistic goal to create a reliable and functional submarine during our first year while also trying to complete advanced tasks like buying gold chips or playing slots. Instead, we've opted to build a submarine with only the essential components necessary for three-dimensional movement and environment detection, by way of cameras. Since much of our time would be spent figuring out basics that returning teams have had years to optimize, this simplistic and reliable design process was our best approach.

The one exception to this rule is in our ballast system. Where the most conventional strategy seems to be to make the sub as neutral as possible and to descend and ascend using only thrusters, we challenged ourselves to create a dynamic ballast system, similar to the way full scale submarines and fish control their buoyancy.

B. Task Scoring Strategy

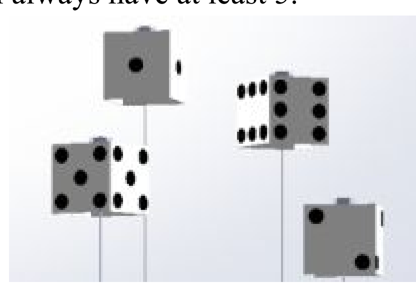
Upon qualifying, our team plans on being successful in the following scorable events: Find Casino with Coin Flip, Enter Casino (gate) with fixed heading and called color, Follow the Path, and Play Craps with 11. All of these tasks are achievable within the capabilities of our submarine: visual detection and three dimensional maneuvering.

Find Casino with Coin Flip: The submarine will pan clockwise or counter clockwise until the front facing camera detects the gate.

Enter Casino (gate): The Red (R) values in the pixels within each half of the gate will be compared to determine the desired side, and the heading will be maintained with onboard gyroscopes.

Follow the Path: A downward facing camera will detect the orange path markers and help orient the sub to the next scoring task.

Play Craps: We plan to have our sub hit the dice valued five and six. They will be identified with the front facing camera, by determining which two dice have the most black area, or the least white area. The die orientation will not matter, as the die valued two, when viewed from a corner, can only have four black dots, while the die valued five and six will always have at least 5.



Our submarine is also relatively small, with an extremely small airtight compartment. This allows us to attach minimal ballast, and achieve the lowest weight category.

II. Design Creativity

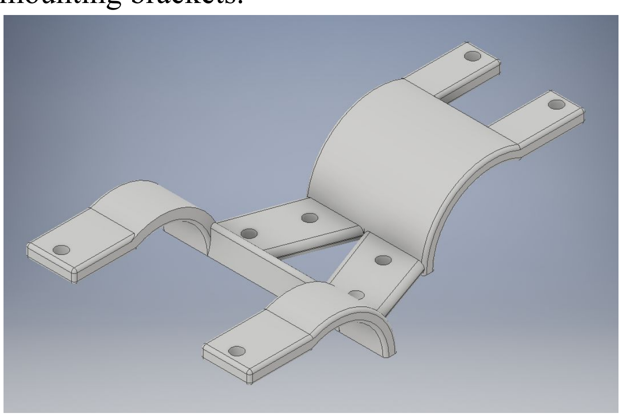
When it comes to items like our frame and thrusters, we went for a simple design we could prototype quickly and easily. This lead to our frame being made out of PVC piping, and most of our brackets being 3D printed. This allowed for easy adjustments to our design as we learned what were good design choices and what weren't.

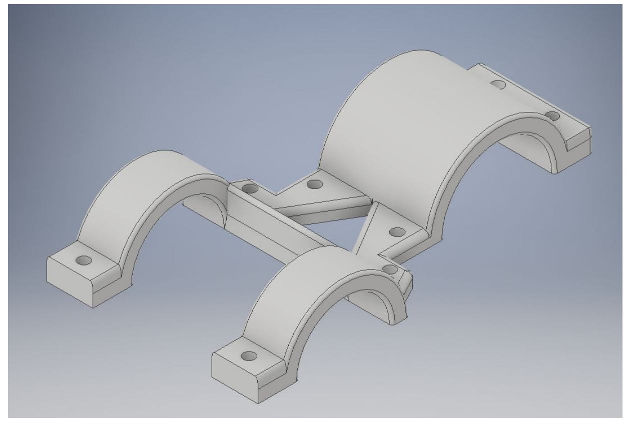
A. Thrusters

For a time we strongly considered using T100 thrusters from Blue Robotics, as they seemed robust and powerful, and wouldn't require much work on our part. Mainly due to our tightly constrained budget, we decided instead to repurpose bilge pumps and use them as thrusters by removing some parts of the outer shell and adding a shroud to control flow. They have proven to be a reliable at a very reasonable cost, but were relatively underpowered, so we designed our own propellers to increase the overall efficiency of our thrusters, as described below and in the experimental results section.

B. CAD and 3D Printing

Our team used professional 3D modelling software and 3D printers to fabricate some of our more complex parts, such as our thruster mounting brackets, case mounts, and propellers. Each of these parts was designed, printed, tested, and reprinted multiple times before the final designs were complete. One such evolution is shown below in our thruster mounting brackets.

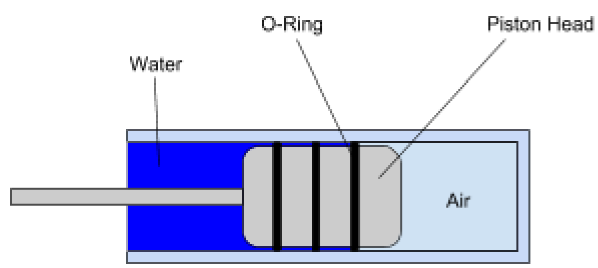




We were worried about the PLA material used in 3D printing degrading with exposure to water because of its biodegradability, but upon submerging a piece for several months with very little mass loss, we determined it was not an issue.

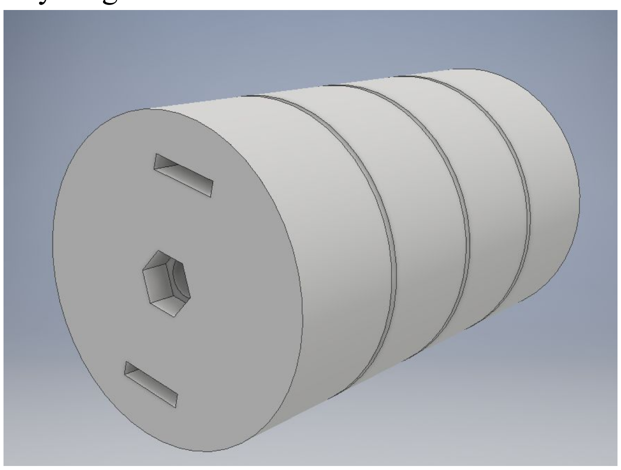
C. Dynamic Buoyancy System

As previously mentioned, a more complex component into which our team invested much time was a dynamic buoyancy system. To begin our process, we first began to propose various design ideas and list the positive and negative aspects of each. We decided to use a design in which a piston compresses a fixed amount of air, effectively reducing the amount of water displaced by our submarine and increasing the buoyant force acting upon the submarine. A diagram of this design is pictured below.



The reason we chose this design was due to its relative simplicity, dependability, and the control it offered. For example, another potential design idea we considered was using compressed air to expel water from containers on our submarine, thereby increasing our submarine's displacement. However, we felt that it would be more difficult to control how much air is expelled from a compressed air canister than it would be to control a motor that extends and retracts a piston. Furthermore, a compressed air dynamic buoyancy system would require that we buy numerous compressed air canisters to replace those that have been expended.

Another obstacle our team faced was how to manufacture the components of this buoyancy system in a manner that was financially feasible. To overcome this obstacle, our team ended up 3d printing various components from PLA or PTEG plastic and also purchasing materials from our local recycling center.



While the creation of a dynamic buoyancy system isn't necessary for any of the challenges, we thought it would be a good challenge, extremely rewarding, and would give our submarine more flexibility in the case that our thrusters are not powerful enough to control our depth.

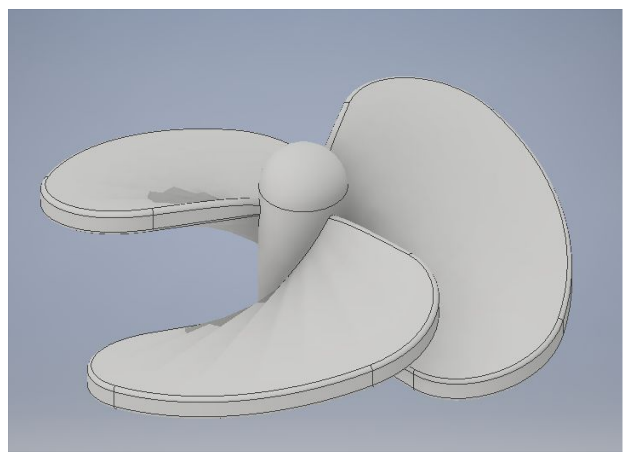
III. Experimental Results

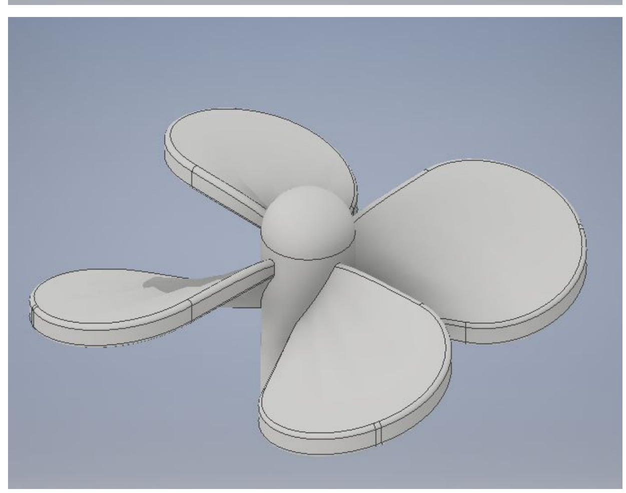
A. Initial Electrical Connector Testing

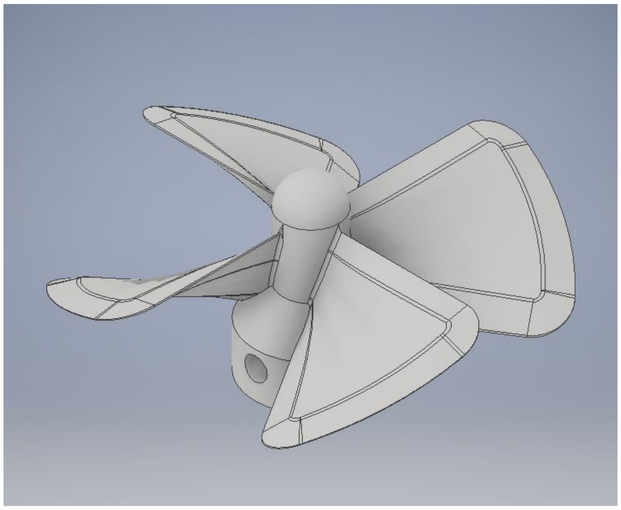
Our first goal as far as experimentation goes was to make sure that we were not wasting large portions of our limited budget. We knew that were were going to need to drill holes in our watertight box. We also knew that we didn't want to randomly puncture our high-quality case without any assurance that we would be able to fill them back in. To achieve this assurance, we determined to assess our connectors on some inexpensive tupperware. We drilled a hole in the tupperware and inserted the connector, securing it with marine epoxy. Once we saw that it was able to prevent the tupperware from being flooded with water, we drilled a hole in our water-tight case and installed the connector, once again using marine epoxy. We had to wait to test how well these seals held back the water until we had access to a pool, so we began our selection of propellers.

B. Propeller Testing

We determined which of the propellers created the most thrust by creating a testing setup that would make it easy to compare the thrust of each design. It consisted of a thin wood plank which we secured to a table at one end and held the propeller in a bucket of water. When we ran power to the motors, it would push the end of the plank upward. We measured the distance that it rose and developed a propeller based on the designs that worked the best. This allowed us to produce the most thrust possible with our propellers. Some of the major iterations of our propeller design are shown here:







C. Final Electrical Connector and Case Testing

Once we had access to a pool, we put a weight in our electronics case to simulate our electronics and dropped it 10 feet under water. After 10 minutes, we pulled it out and saw that it was flooded to the halfway point of the box. At first, we thought that this water was coming in through the seal provided by the manufacturer of the box. We added extra silicone to the seal and tested it again as soon as possible. Once we pulled it back out of the pool, we realized that our flaw was in the connectors. Our earlier test of these connectors had been on the surface of the water rather than ten feet under water. This realization led us to use extra marine epoxy and add dielectric grease to keep water from flowing through the pins of the connectors, which we discovered to be the main source of our leak issues. After locating any holes in our epoxy through additional testing, our case was finally waterproof enough to put our electronics in.

D. Full System Tests

As of the completion and submission of this paper, we have performed two tests of the electrical system submerged in water. The first ended very quickly, with a PWM coding issue stopping us from functioning. The second test, run very recently, resulted in about 90 seconds of functional tethered operation. Upon testing the maximum power capacity of the system by ramping all six thrusters to 100%, our primary fuse blew and our test concluded.

IV. Acknowledgements

As a team we would like to thank our primary sponsor, Project Radian, for their support. They have given our team a makerspace to work in, monetary support, and mentoring from a previous team, Nautilus. Getting to the point we have, and learning what we have would have been impossible without this support.

We would also like to thank Andrew Ross for his financial support and mentorship.

Thank you.