DESN1000
Underwater Remotely Operated Vehicle
Term 3, 2022

Final Report

By Team 3 │ 5 ½ Asians

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Executive Summary

This project tackles one of today's most pressing global environmental challenges, plastic pollution, where the aim is to create an underwater ROV that is capable of collecting plastic waste in aquatic environments. The final design of the ROV featured a cube shape to create a simple base for structural stability and shifting of the centre of buoyancy. However, this resulted in a creative limitation as the cubic chassis is common shape and makes it hard to deviate from a standard look, making it not very innovative and creative. For the end effector, a L shaped pipe was selected as thorough testing showed that it was the most effective in achieving the most consistent ring collection as well as securing the rings in such a way that they remain attached to the ROV, fitting the projects aim of "collecting". Another design decision we made was opting for custom propeller guards instead of the ones provided to allow for a slimmer fit as we felt the given propeller guards were too chunky and was not aerodynamic enough to match our goal for the ROV.

The design performed effectively and efficiently, collecting many of the rings under timed conditions. As innovation was found wanting in the final design, a recommendation in the case of making another revision of the prototype would be to be more creative by utilising a different shaped chassis or creating a new type of end effector with mechanical controls instead of playing safe with the simple yet effective design.

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1. Introduction

Plastic consumption is at an all-time high, with over 380 million tons of plastic produced per year, with 4.7 to 12.7 million tonnes of this waste ending up in the oceans. In conjunction with plastic's long-term decomposition and subsequent microplastics produced, it poses a significant threat to all aquatic life resulting in millions of marine wildlife being killed by ingestion and entanglement. To help mitigate this critical issue of marine plastic pollution, the NSW government has tasked a project of constructing an underwater ROV that is required to complete a timed underwater course involving the retrieval of rings - simulating plastic waste collection.
To recap, the design proposal follows a comprehensive guide of the processes in designing and creating the underwater ROV. An initial breakdown of project objectives into a succinct problem statement (Team 3 2022, p. 4) addresses all components of the task, thus acting like scaffold summarising the problem's context, definition and restrictions for project guidance. Additionally, the key findings of the concept generation stage led to the final conceptual design of the ROV with a cube-shape paired with an L shaped pipe end effector and custom propeller guards which maximised motor thrust while minimising the footprint of the ROV.

The final report opens with an in-depth review of the final design of the underwater ROV both at the system and detailed sub-system design levels. The construction of each mechanical component as well as the rationale behind these decisions is explained, providing a comprehensive guide of the process in prototyping, designing and creating the final design. In addition, changes made to adjust for the obstacles faced during the testing phases such as maintaining ideal buoyancy by changing placement of pool noodles will be explored further into the final report.

This is followed by a thorough analysis of the Final Competition results with an extensive coverage of how every aspect of the design, such as innovation, simplicity, and ease of manufacturing, contributed to the final score. The final score is then reflected on to provide an understanding on the strengths and limitations of the final design, as well as a discussion of how our earlier design decisions and testings contributed to the outcome.

2. Final Design and Implementation

2.1 ROV Chassis:

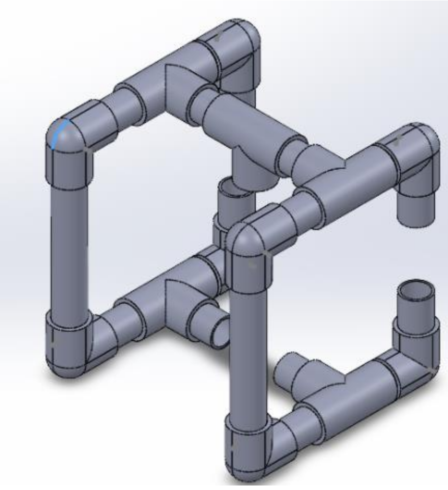


Figure 1 - ROV Chassis

2.1.1 Description:

The main chassis is comprised of two 224.8mm×206mm rectangular frames constructed from PVC T-Joints, 90° elbow joints and piping of various lengths, connected by crossbeams across the bottom and the top. The three gaps present in the beams allow the installation of the motor guards. The top crossbeam has a T-Joint as a mounting point for the end effector. The total dimensions of the chassis are 224.8mm × 206mm × 218mm.

2.1.2 Prototyping Process:

Prototyping of the Chassis was carried out using iterative design. An initial prototype was decided on in the Design Proposal and then through repeated testing and adjustment, the final design came about.

Given the size restraints from the project prompt, design of the Chassis constituted a major component of the Conceptual Design Process. The versatility of the rectangular prism design allowed for numerous variants of the Chassis design. The basis for the final design was chosen as it provided the most stable, sturdy and versatile design for the smallest price tag (~$70 was spent, with ~$50 dollars of parts used in the ROV). This design also allowed for an amount of modularity which was overall beneficial to the iterative design phase of prototyping.

One major issue that was encountered during prototyping of the Chassis was its balance within the water, with the ROV either tilting back during operation causing an element of unintended lift or later listing forward when loaded and making upward lift unfeasible. This issue was remedied with the application of porous material to the exterior of the Chassis. With further testing, this method allowed the uneven weight distribution in the ROV's construction to be neutralised by its buoyancy, thereby allowing it to remain level in operation and when loaded.

Another issue encountered was the speed and capacity at which the Chassis could be filled with water. This was another important aspect of the Chassis' design as any remaining air bubbles of significant size could greatly affect the ROV's balance and significantly hamper its handling. The solution to this problem was to perforate the Chassis' pipes at various points with a hand drill to allow for numerous points of escape for any air within the ROV, ensuring that it would be filled with water.

2.1.3 Viability:

As previously stated, the total cost of the Chassis was ~$50, roughly a third of the budget. Construction of the prototype was relatively simple, requiring 2-4 people 2-3 hours to construct the first iteration. With the design fully crystalised, it is predicted that 1-2 people could complete construction of one unit's chassis in under an hour (Construction is shown in Appendix I). Furthermore, the minimal number of specialised tools used in construction (Total list: Hand Saw, Hand Drill, Disk Sander, Mallet/G-Clamp) means that a company seeking to mass produce this ROV design would not need to invest as much into training. The natural friction fit of the component negates the need for any adhesive or other permanent joining methods, meaning that the ROV in its entirety, but primarily its chassis, can be used immediately upon completion of its manufacture or disassembled for ease of storage or maintenance. This, however, has not negatively impacted the structural integrity of the ROV, as impact testing has shown this chassis design to be highly resistant to structural failure with only friction fitting. Overall, this chassis design contributes positively to the ROV's viability as a product due to its low cost, ease and speed of construction and the quality of the build. Assembly is shown in Appendix I.

2.1.4 Components List: ROV Chassis

Table 1 – ROV Chassis Components

Component Type	Material	Quantity
20mm diameter 90° Elbow Joint	PVC	8
20mm diameter T-Joint	PVC	5
41mm×20mm diameter Pipe	PVC	4
46mm×20mm diameter Pipe	PVC	4
67mm×20mm diameter Pipe	PVC	4
61mm×20mm diameter Pipe	PVC	2
43.6mm×20mm diameter Pipe	PVC	2
156.8mm×20mm diameter Pipe	PVC	2

2.2 End Effector:

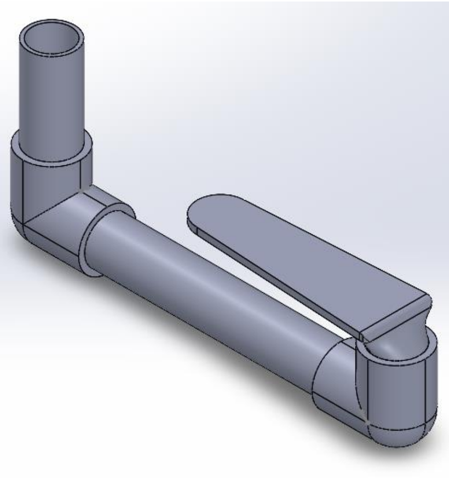


Figure 2 - End Effector

2.2.1 Description:

The End Effector is comprised of a pair of 90° Elbow Joints, two pieces of PVC pipe (170mm & 70mm) and a custom "hook" made from a flattened and bent segment of PVC pipe. It is mounted onto the chassis at the included attachment point.

2.2.2 Prototyping Process:

The prototyping process for the End Effector was relatively short, only going through two physical iterations despite the numerous and varied concepts put forth by the designers. The complexity of some of these designs led to the self-imposed design limitation of simplicity as more complex designs would be significantly harder to manufacture and greatly increased the points of failure for the ROV during operation.

The first physical prototype of the end effector was a length of PVC mounted at an inclined angle. While it was perfectly capable of retaining captured rings, the angle at which the pipe was mounted made collection difficult. This was remedied by angling the pipe downwards and attaching an extra bend to the end, being the version detailed in the design proposal, to ensure the rings did not slide off once captured.

This solution was, however, unsatisfactory. Due to the height at which the pipe was mounted, the rings could contact the floor and not just slide off, but tip over, making their recapture impossible with current means. Furthermore, adding extra length to the end-bend would re-introduce the problem the last iteration had with collection. As such, a new design with a backswept hook was proposed and constructed. This hook would be mounted onto the end of the end effector which would be mounted at a declined angle. This would allow for the easy collection of the rings, and with the decline, gravity would pull the rings into the hook, preventing escape.

2.2.3 Viability:

This end effector design costs ~$6 in PVC components, allowing the mechanical components to stay well within the budget of $150 at a current total of ~$62. Construction of a majority of the end effector is simple, similarly to the chassis, but the fabrication of the custom hook makes construction slightly more difficult. During construction of the prototype, a large amount of time was spent experimenting with methods of reshaping the PVC, and the most convenient and efficient was found to be heating the pipe with a heat gun and manually flattening it between two flat objects. To carry out such an operation optimally requires a moderate amount of experience, and in a factory environment will require excellent ventilation to avoid poisoning from any fumes released during the process. Again, the friction fit of the components eliminates the need for adhesives, allowing for ease and speed of assembly. Overall, this end effector contributes neutrally to the viability of the ROV as a product due to its low cost but moderately difficult manufacturing. Assembly is shown in Appendix II.

Components List: End Effector

Table 2 - End Effector Components

Component Type	Material	Quantity
20mm diameter 90° Elbow Joint	PVC	2
170mm×20mm diameter Pipe	PVC	1
70mm×20mm diameter Pipe	PVC	1
Custom “Hook”	PVC	1

2.3 3D Printed Components:

Figure 35 - Motor Guard

Figure 4 - ROV Controller

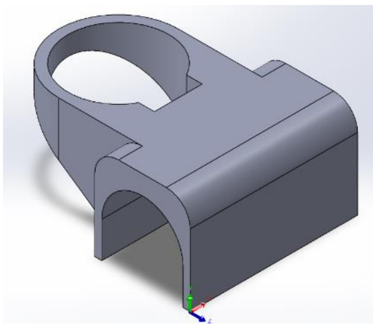


Figure 53 - Mascot Holder

2.3.1 Description:

The 3D printed components of the ROV are the Propeller Guards/Mounts, the Mascot Holder and the Controller Casing.

The guards are comprised of a 61.8mm external diameter, 30mm tall, 3mm thick ring with attachment points for piping at opposite ends. An attachment point for the motor is mounted in the centre of the ring with three equally spaced spokes, one of which splits at the ring wall to allow wiring to be routed behind the guard, away from the propeller blades.

The mascot holder is comprised of a ring attached to a bracket which slips onto the middle T-Joint on the top crossbeam. It is secured with zap ties. The ring is sized to accommodate a medical specimen container with a transition-interference fit, allowing for sturdy attachment but also easy removal.

The controller casing is a printed piece shaped similarly to a console controller with an internal cavity to house the control electronics. The casing has a hinged cover secured with magnets to prevent the electronics from escaping and to protect them from any potential damage.

2.3.2 Prototyping Process:

The guards went through numerous prototypes, but only two were physically used. The designs that were rejected at the conceptual phase had severe issues which made their use impractical or would violate the design specifications to implement. The first physical prototype, while functional, was inefficient during operation due to it causing a major blockage to the waterflow. This was fixed by integrating the guard into the chassis as a connector between two pipes. This design minimised the effect of the guard on both the efficiency of the ROV's operation and its profile.

The mascot holder went through very little prototyping. Once a location was decided for its placement, an initial concept was generated. This initial concept had been designed with numerous components to minimise the number of defects produced during printing. However, upon further review, the precision of the mascot holder was deemed insignificant, and the initial design was discarded in favour of a new, simplified design. This design was then put into production and was used in the final product.

The controller casing went through two physical prototypes. The first design was a box with the silhouette of a console controller, with the internal cavity being large enough to house the electronics and the cover having holes for a potentiometer knob and joystick to be accessed. While aesthetically distinct and serviceably functional, this initial design also had a number of issues, mostly relating to its ergonomics. In operation, some of the electrical components outside of the controller (LiPo battery, motor ESCs) would heat up. This, combined with the fact that they had to be manually secured (held in hand), would cause the operator moderate discomfort and could potentially represent a safety hazard. Along with this, the boxy nature of the design, while slightly offset by its controller-like shape, made it even less comfortable to operate. An ergonomically unrelated issue was the securing of the cover. This design had no in-built method of keeping the cover attached, which could have led the contained electronics to spill out, and as such was secured with tape. This solution, while functional, was both inconvenient for maintenance and adjustment of the electronics and aesthetically unappealing. The second prototype addressed all these issues, introducing a more ergonomically contoured shape to better fit in the hands of the operator, straps and pockets to hold hot components and a hinged cover secured with magnets to allow easier access to the electronics and provide a more discreet appearance.

2.3.3 Viability:

The use of 3D Printed components was completely viable in to prototyping and final construction of the ROV. The main caveats of 3D printed components would be an untuned machine being used to print the components of the ROV, resulting in parts that lack the strength required to act as a structural component. However, this issue is circumvented with the rigorously tuned and tested 3D printer, alongside proper slicer settings that guarantees a component that can be both structural and functional within the ROV. The final iteration of the propeller guards has proven to work exceptionally well, where during testing and the final competition, was able to work flawlessly to both house the three motors and also structurally support the ROV itself. The mascot holder worked well in holding the specimen container responsible for keeping the ROV mascot dry. The controller casing was very functional as it allowed for a wide range of flexibility the design and positioning of electronics to control the ROV. The nature of 3D printing to make the controller also allowed for the design of an ergonomic controller that was easy to hold and use. These results evidence the viability of 3D printed components being used for both functionality and structural purposes.

2.3.4 Components List: 3D Printed Components

Table 3 - 3D Printed Components

Component Type	Material	Quantity
Propeller Guard/Mounting	PLA	3
Mascot Holder	PLA	1
Controller Top	PLA	1
Controller Body	PLA	1
Joystick Extender	PLA	1

2.4 Control Electronics

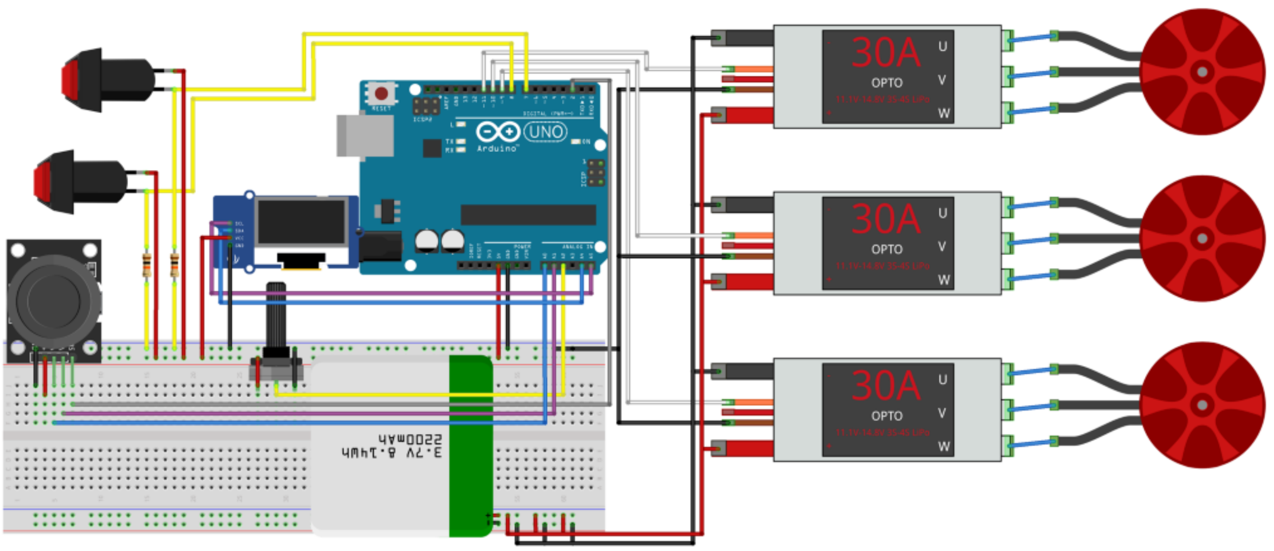


Figure 6 - Control Electronics

2.4.1 Description:

The control electronics are housed within a controller that consists of a top and bottom piece which are held together with a hinge. It is responsible for the operation of the three motors on the ROV.

The microcontroller used for the project was an Arduino Nano (ATMEGA328P) which links the main electronic components via input/output pins and the use of C++ code to program functionality. The controller electronics consist of a joystick, a potentiometer, two trigger buttons made from two simple mechanical key switches and an OLED display.

The controller uses a joystick to control the two motors at the back alongside two trigger buttons that allowed for changing the maximum speed that the ROV can travel at. A potentiometer was used as the method of input to control the middle downwards facing as it allowed for very fine adjustments of the motor speed, as well as the fact that the motor did not require quick ramping of its speed. The OLED display allowed for visual confirmation of the motor's current speed, thus allowing the motor speed to be monitored when the ROV is submerged in the pool.

The controller design was influenced by game and drone controllers to provide an ergonomic experience for the ROV driver. It features a custom contoured underside, giving a natural grip, accompanied by deliberate placements of input electronics to give the most streamlined experience for controlling the ROV.

2.4.2 Prototyping Process:

The ROV controller has experienced multiple iterations upon its design, with the initial prototyping of the electronics and wire placement to the overall position of components within the controller.

The initial concept generation of methods to control the ROV, including potentiometers, buttons, switches, force sensors, joysticks, rotary encoders, etc. After discussing the pros and cons of each electronic input method, the team deduced that a combination of the potentiometers with another input method would result in the most consistent control of the ROV.

The first iteration of the electronics for controller consisted of three potentiometers that would be responsible for controlling one motor each. This approach would allow for prototyping of controlling the motor speeds as the potentiometers would indicate just how much acceleration and deceleration the provided drone motors would require as to not lose control. An Arduino UNO was used at this stage of prototyping. The motor acceleration/deceleration are shown in figure

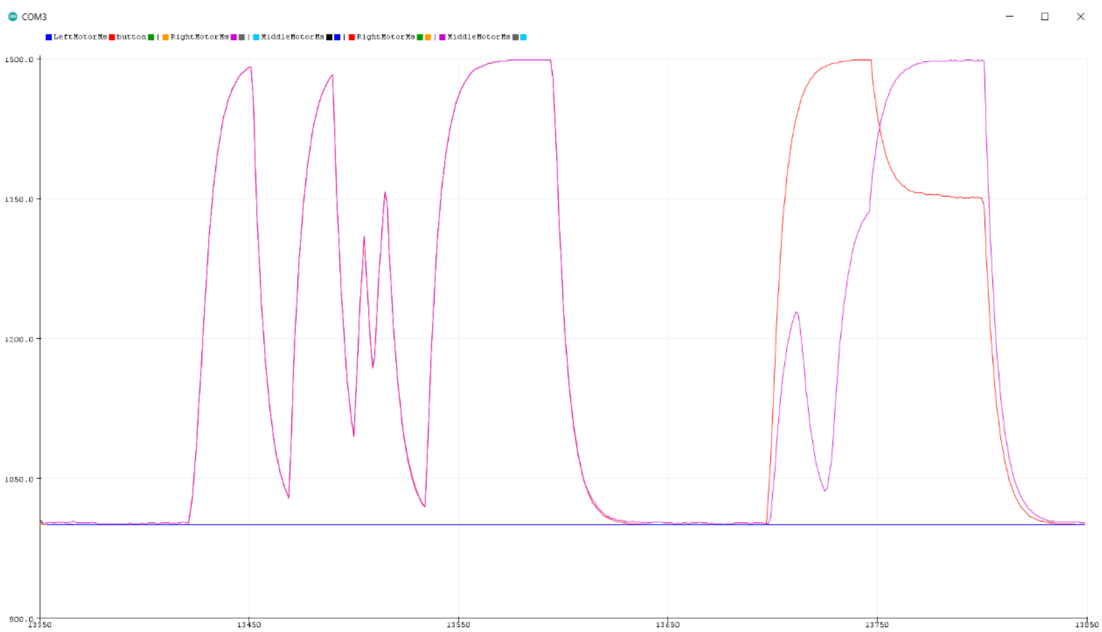


Figure 7 - Motor Acceleration and Deceleration Simulations

The second iteration of the electronics for motor control entailed the transition from two potentiometers for controlling the rear motors to one joystick. The change of input to the joystick was decided as it allowed for finer control over all movement directions (forward, left and right) for the ROV. However, this change to a joystick would leave behind the simple controller code for controlling two potentiometers to directional acceleration and deceleration method of control. This method consisted of sectioning the controller to left, right and forward, and making each section accelerate the ROV at a constant speed. Unfortunately, this method did not allow for tight manoeuvres of the ROV, unless it were travelling at a very slow pace as it required waiting for the motor to completely decelerate in its current direction of movement before being able to move in another. This solution was also very unpolished and was not suitable for the fine control needed for the ROV's required task. This joystick control was accompanied by a potentiometer used for the controlling the speed of the middle motor. The first iteration of the controller was also 3D modelled and printed out to house the electronics. An Arduino UNO was used at this stage of prototyping.

Iteration three of the electronics consisted of completely changing the method of approach to mapping the joystick position to the two rear motors via mathematics (See calculations in appendices). Instead of simply splitting the region into three parts, the region was split into two and polar coordinates were used to transform the values outputted from the joystick to their respective motor speed values to allow for smooth transitions between the forward, left and right movement directions of the ROV. The controller continued use of the previous controller body and an Arduino UNO. This control method proved to be functional and was able to successfully control the ROV as evidenced during testing, however some issues were discovered within the code that would require future adjustment.

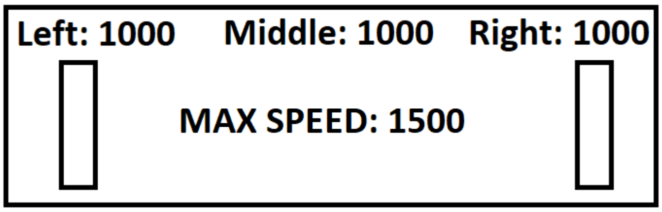


Figure 8 - OLED Controller Interface

Iteration four of the controller electronics introduced the extra functionality of two trigger buttons that would allow for adjustment of the ROV rear motor max speed (displayed on the new OLED screen). This extra functionality would allow the ROV to adjust its speed as the current method of mapping the joystick position to the motor speed, by default, only allows for one max speed – initially in iteration three, the max speed of 2000 microseconds was used. The OLED screen also displays the current speed of the three motors, as well as a visualisation of the rear motor speed to indicate how much motor speed was used in comparison to the current max motor speed (Figure 5). A new controller consisting of a controller top, controller body and joystick extender was designed for the fourth iteration of the controller. This new controller design housed all the current electronics while introducing a very ergonomic design in contrast to the previous box design. The new controller design also featured a spot for holding the battery and the ESCs. The microcontroller was switched to an Arduino Nano as the prototyping for the majority of electric components with the Arduino UNO was finished and it would drastically decrease the amount of space used within the controller.

2.4.3 Viability:

The controller in total costs around $20 which fit well within the $150 budget, even with consideration of other components that contribute to the total budget. The final controller is completely viable as it allows for fine and smooth control of the ROV. It provided feedback to the user for the current motor speeds as well as the utilisation of an ergonomic design for ease of use. The multitude of iterations to reach the final product, accompanied by advice from mentors allowed for the production of a very functional controller. The addition of changing the max speed mapping was integral to achieving hyperfine control of the ROV when collecting the rings. The controller itself was not only tested on our ROV design, but it was also hooked up to another group's ROV which had similar motor positions and was able to control it flawlessly. Thus, the final design of the controller was extremely viable.

2.4.4 Components List: Control Electronics

Table 4 - Control Electronics Components

Component Type	Quantity
Jumper Wires	50
Trigger Buttons	2
Potentiometer	1
Joystick	1
OLED Display	1
Arduino Nano	1

2.5 ROV Cost Analysis

Table 5 - ROV Component List

Component	Quantity	Price
PVC Pipe 1m	2	$21.00
PVC L-Joint	10	$30.00
PVC T-Joint	5	$11.00
3D Printed Parts	7	$10.00
Potentiometer	1	$1.00
Joystick	1	$4.00
Trigger Buttons	2	$1.00
OLED Display	1	$5.00
Spray Paint	3	$10.00
Arduino Nano	1	$4.00
Jumper Wires	50	$1.00
	Total	**$98.00**

The total cost of the ROV has been continually considered throughout the project and has been documented in table 5. The cost for the ROV chassis has been optimised to avoid the use of three-way PVC joints which cost considerably more than L and T joints. The cost of electronics had also been reduced with the switch from an Arduino UNO to and Arduino NANO in the final product, hence significantly decreasing the total cost of electronics used for the ROV project. Finally, the total cost of $98 for the ROV has met the $150 budget constraints.

3. Analysis of Final Competition Results

The finals competition results entailed near full marks for the practical aspect of the competition, near full marks for durability and an average rating for innovation. Images of the ROV can be seen below in the figure 9 and 10 below.

Figure 9 - Final ROV

Figure 10 - ROV Controller

3.1 ROV Overview and Ease of Manufacturing

In the initial stages of designing the ROV, achieving a higher ease of manufacturing by selecting the most cost-effective materials and minimising any potential complexities in the manufacturing process was prioritised. The cheapness and sturdiness of the PVC pipes made it an optimal choice for the material of the ROV's chassis. Furthermore, the simplistic yet effective cubic chassis for the ROV achieved stronger structural integrity while not requiring many PVC pipes to complete. Thus, selecting a cubic shape for the chassis and the PVC material allowed for greater ease of manufacture.

3.2 Ring Collection and Navigation of Final Course

The practical ring collection aspect of the final competition exhibited the ROV's ability to collect rings and keep them stored within the vehicle while moving. Unfortunately, only four of the five rings were collected, caused by a lack of practice with the ring collection course. This lack of practice was due to the inaccessibility of simulating the final competition during testing, which would be mitigated if the course were more technical in the collection aspect rather than simply collecting five rings in quick succession. The navigation of the ROV was limited by the use single direction motors. This meant the final competition course would not allow any errors to be made in the navigation of the ROV, as the vehicle itself could only move forwards, left and right. If the limitation of movement were removed, i.e. Through the provision of bi-directional motors or through personal sourcing of motors, the final competition would be more forgiving in errors to collect the five rings. Despite these limiting factors, the course was still completed within two minutes of the five-minute time limit.

3.3 Durability and Innovation

Using a cubic shaped chassis achieved higher structural integrity and durability and an optimal centre of buoyancy, allowing the structure of the ROV to maintain itself during the run. Unfortunately, a drawback of this cubic shape is that it's very commonly used.

While the ROV itself was not very innovative, the controller featured design decisions unseen amongst the designs of other groups, namely the contoured shape and the OLED display, which made the controller much more ergonomic, as well as allowing the operator to monitor the speed of the motors.

3.4 Reflection on Design Proposal and Compliance Testing

From the compliance testing, valuable insight regarding the mascot holder prompted for the creation of a new robust system capable of enclosing the mascot properly. For this testing phase, an impromptu mascot holder consisting of plastic sealable bags and duct tape was used, resulting in marks being lost due to not being properly attached to the ROV. As a result, the team 3D printed a new system which affixes to the ROV and effectively encloses and keeps the mascot dry.

Another key finding from the compliance testing was the issue with keeping rings from falling off the end effector. While all the rings were collected successfully, the rings would tend to shift forward away from the ROV when it would stop abruptly. The previous end effector in the design proposal consisted of a pipe angled upwards, where gravity would help keep the rings falling downward. However, the diminished effects of gravity meant that the rings could still shift forward and upwards away from the pipe. To mitigate this issue, a new iteration of the end effector was created with the goal of keeping the rings tightly secured while following the size constraint. With its hook-like design as opposed with the previous end effector in the design proposal, this helped in ensuring the rings would not fall out once collected.

4. Conclusion and Recommendations

In conclusion, the 10-week project that the team embarked tested an individual's creativity and energy resulting from the influx of different issues and repeated remodelling and improvement to the ROV required as the project progressed to achieve the desirable results on the competition day. The process involved many different areas of expertise collaborating to create the final product, a prototype of an ROV capable of collecting microplastics in the ocean in an effort to preserve marine life and be more environmentally conscious. It was a valuable learning experience as it was a taste of the kind of work that real engineers experience on a daily basis and it resulted in valuable expertise gained in the subject of R&D, the ability to work together in a team to achieve the projects standards and goals as well as form a standard of consistency to finish the project set over a long duration of time.

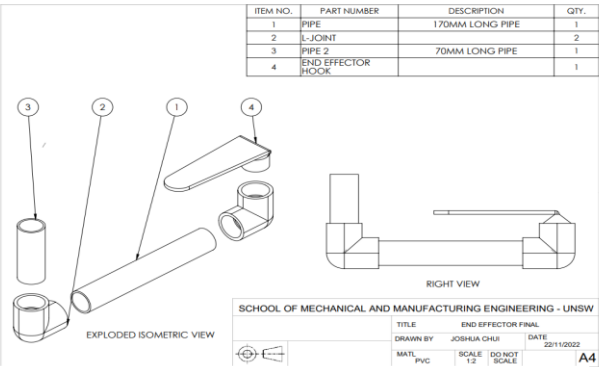
Furthermore, the whole experience was documented in the form of design journals that contained the group and individuals' journey in their progress throughout the 10-weeks to allow for more insight and practice for future projects. During the process the group found some issues with how the tasks were presented and such listed below are some recommendations to improve the foundation and execution of the underwater ROV project. One recommendation is the timelier distribution of components as it was a major issue that the third motor was only made available in the last week before the competition and many groups did not have enough time to troubleshoot and test for issues with its addition before the competition. Another recommendation is the increase of involvement with the other groups in the ROV project. Every group is filled with unique individuals with their own wealth of knowledge which could mutually benefit one another, thus having sessions where you can meet other groups to discuss the project and let both sides critique or praise each other with pros and cons can encourage further development and fine tuning of the ROVs.

5. Bibliography

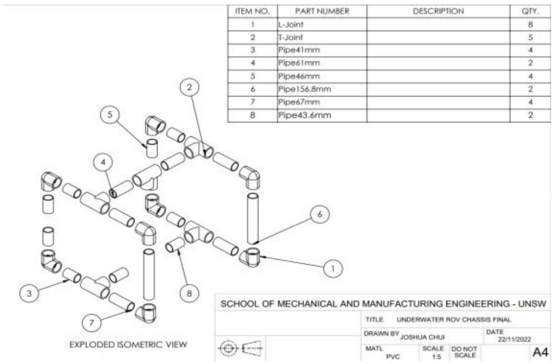
5.1 - Problem Statement:

Team 3. (2022). *Design Proposal.*

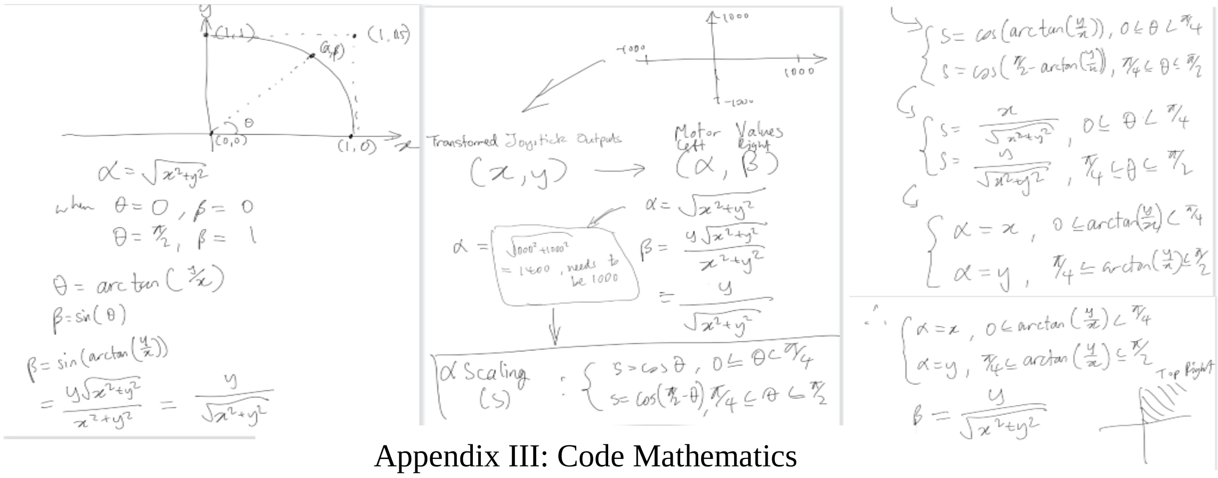
6. Appendices



Appendix I: End Effector Bill of Materials



Appendix II: Chassis Bill of Materials



Appendix III: Code Mathematics

```
Joystick_Controls_V3
#include <math.h>
#include <Servo.h>

#define PI 3.141592654

// Joystick & Motor Variables
Servo ESCLeft;
Servo ESCRight;

int VRx = A0;
int VRy = A1;
int SW = 2;

int xPosition = 0;
int yPosition = 0;
int SW_state = 0;
int mapX = 0;
int mapY = 0;
int leftMotor = 1000;
int rightMotor = 1000;
float joystickAngle = 0;

// Potentiometer & Motor Variables
Servo ESCMiddle;

int potValue = 0;

void setup() {
  // Potentiometer & Motor Setup
  ESCMiddle.attach(11,1000,2000);
  // Joystick & Motor Setup
  ESCLeft.attach(9,1000,2000);
  ESCRight.attach(10,1000,2000);
  Serial.begin(9600);

  pinMode(VRx, INPUT);
  pinMode(VRy, INPUT);
  pinMode(SW, INPUT_PULLUP);


}

void loop() {
  // Potentiometer & Motor Control
  potValue = analogRead(A2);
  potValue = map(potValue, 1023, 20, 1000, 2000);
  ESCMiddle.writeMicroseconds(potValue);

  // Joystick & Motor Control
  xPosition = analogRead(VRx);
  yPosition = analogRead(VRy);
  SW_state = digitalRead(SW);
  mapX = map(yPosition, 0, 1023, 300, -300);
  mapY = map(xPosition, 0, 1023, 300, -300);

  if (SW_state == 0) {
    goto serialTests;
  }

  // ROV moves forward
  joystickAngle = atan(mapY / mapX);
  if (mapY > 0) {
    if (mapX > 0) {
      // ROV turns Right
      // Split right quadrant into two regions to apply scaling effect to mapY
      if (joystickAngle >= 0 && joystickAngle < PI / 4) {
        leftMotor += (int) mapX;
        rightMotor += (int) mapY * (mapY / sqrt(pow(mapX, 2) + pow(mapY, 2)));
      } else if (joystickAngle >= PI / 4 && joystickAngle <= PI / 2) {
        leftMotor += (int) mapY;
        rightMotor += (int) mapY * (mapY / sqrt(pow(mapX, 2) + pow(mapY, 2)));
      }
    } else if (mapX < 0) {
      // ROV turns Left
      // Split left quadrant into two regions to apply scaling effect
      if (-joystickAngle >= 0 && -joystickAngle < PI / 4) {
        leftMotor += (int) mapY * (mapY / sqrt(pow(mapX, 2) + pow(mapY, 2)));
        rightMotor += (int) -mapX;
      } else if (-joystickAngle >= PI / 4 && -joystickAngle <= PI / 2) {
        Serial.print("Left");
        leftMotor += (int) mapY * (mapY / sqrt(pow(mapX, 2) + pow(mapY, 2)));
        rightMotor += (int) mapY;
      }
    }
    ESCLeft.writeMicroseconds(leftMotor);
    ESCRight.writeMicroseconds(rightMotor);
  }

  // Serial Tests
  serialTests:
  /*
  Serial.print("X: ");
  Serial.print(mapX);
  Serial.print(" | Y: ");
  Serial.print(mapY);
  Serial.print(" | MotorStatus: ");
  Serial.println(SW_state);     // 0 for off and 1 for on

  Serial.print(" | MotorStatus: ");
  Serial.println(SW_state);     // 0 for off and 1 for on
  */
  Serial.print("LeftMotorMs: ");
  Serial.print(leftMotor);
  Serial.print(" | RightMotorMs: ");
  Serial.print(rightMotor);

  Serial.print(" | MiddleMotorMs : ");
  Serial.println(potValue);


  // Resets motor speed
  rightMotor = 1000;
  leftMotor = 1000;

  delay(100);
}
```

Appendix IV: Control Code