Scraps

Technical Documentation 2019

-by

MantaRays

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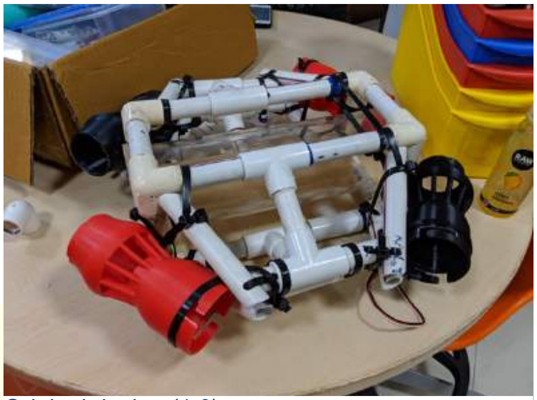
Abstract

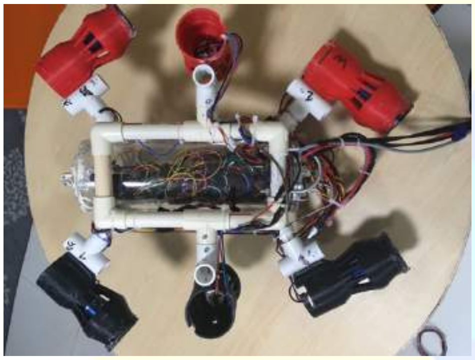
Scraps 3.0 is the latest and first creation by Team Manta Rays. The versatile abilities of Scraps are due to its technologically advanced construction that includes six brushless BLDC motors, which are controlled using 6 Blue robotics bidirectional ESCs, for propulsion combined with its lightweight PVC build and acrylic electronic chamber which allows for easy maneuverability. Scraps is equipped with 3 low latency HD 1000TVL cameras. It comes with two mechanical manipulators for ease of carrying out tasks, and uses a custom designed tether that provides it power as well as Arduino communication lines. Scraps is controlled from the topside using a Logitech 3D Pro Joystick connected to an Arduino USB Host Shield. While focusing on constructing the most versatile and powerful ROV, the result is Scraps. Scraps embodies the international spirit of using advanced technology at an affordable cost with the complete construction costing just under $500 USD. With a team of 7 hard-working students (5 competitors), we were able to construct Scraps in under 6 weeks. Scraps is the result of the passion for marine technology and the motivation gained from the myriad of opportunities this project presents to the company. The lessons learned from Team MantaRays previous experiences have propelled the team to take innovative turns in design to create the best budget ROV of the competition, embodying both smooth movement and efficient workmanship. The following technical document consists of the design rationale and the processes required to produce our ROV, Scraps.

Contents

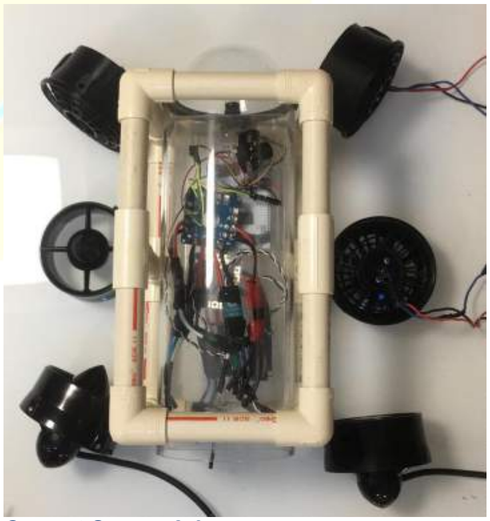
Design Rationale


Original design (1.0)

Our team's approach to create Scraps was not to make a complex and sophisticated design, but to make a more simplistic and realistic design which can be put to real world use and not just the competition aspects. We believe the ROV has to perform the task assigned quickly, with minimum maintenance and operational costs. Hence, we chose components that are readily available should there be a breakdown in its operation. Also, a simple design helps a faster troubleshooting by its employees which reduces breakdown time in real world applications. We chose to continue with our drone-like design as it provides a lot of benefits, such as making the movement of the ROV swift as it cuts through the water and regulates excessive water currents coming from the thrusters. It also acts on a firm platform to mount the thrusters controlling horizontal plane movement. The diagonal edges are inclined at 45 degrees, However, certain issues with earlier models of the design caused us to make improvements. These issues mainly pertained to the structural integrity of the ROV. Post-deployment, the ROV's structure was found to have various failures. Thus, we created an improved model.


Improved design of Scraps (2.0)

Inspiration from a Manta Ray

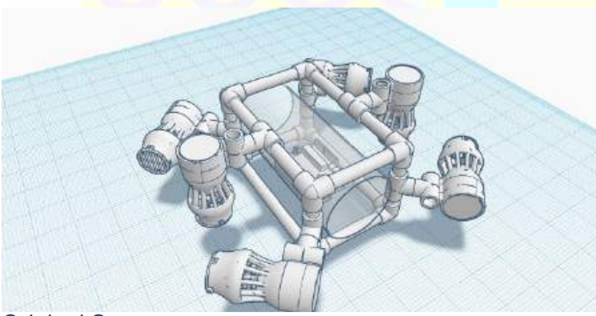

Current Scraps 3.0

Our inspiration was the manta ray and the commonly seen quadcopter drone. We used the wing-like structure to provide stability and equal weight distribution across Scraps. We also use the compact like structure as seen from the top area of the manta ray it is very compact and tight. Along with the tail it could be seen as the tether of the rover. However, as our ROV's design evolved, we slowly began to move away from the shape of a manta ray, and instead, opted for a design similar to that of a common quadcopter.

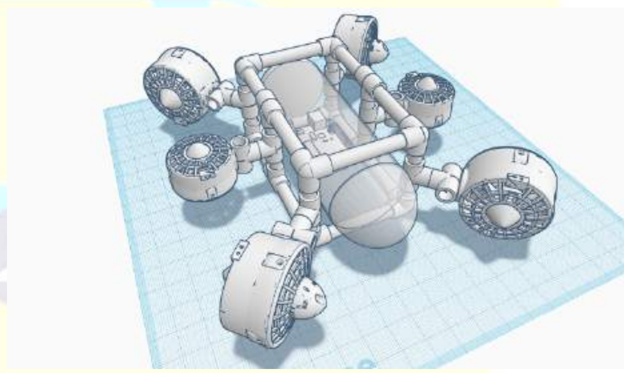
Mechanical Design Rationale

Structure

In the initial planning stages, members of Team MantaRays chose PVC due to the easiness of editing on the trial and error process. We chose PVC, as it is durable, lightweight, and cost-effective (and we had some leftovers from our Studio6 Underwater ROV session). The strength of PVC ensured that the thrusters and payload equipment could be attached directly to the structure without the need for an intermediate mounting "bracket." The chassis is made up of various styles of the PVC cuts. The sides of the EC compartment include a wedge to mount the main robotic arm of Scraps. The chassis also consists of mounts for the cameras carried by the ROV. This design is made keeping in mind the streamline flow of water. Initially, we mounted the thrusters on the inside of the frame while keeping the general shape and structure of the ROV compact. However, we were not satisfied with the motion of the ROV as the force vectors were not balanced and hence, we moved to a new configuration where we lowered the position of the thrusters and mounted them on the opposite ends.



Original Scraps



Latest modified Design

Materials decisions

We preferred to build our ROV with PVC as the design is feasible to make changes and alterations. Also is quite economical and it is suitable for water operations. However, once we get a more robust build, MantaRays is all set to use metals like Aluminum. Scraps' propulsion system is heavily 3D printed. Future improvement also involves 3D Printing parts of our ROV.

Electronics Chamber

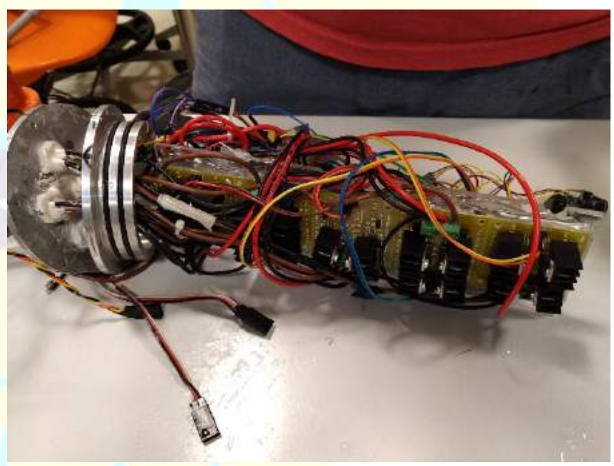
The Electronic Chamber (EC) is made of a cylindrical mold of acrylic. All wires connecting the electronics within the EC with components outside, such as the thrusters and cameras, are passed through multiple Bluerobotics penetrators. The gland connectors are waterproofed with epoxy fluids, Teflon tape, and O-rings so that no water passes through the wires. The end cap consists for holes for attaching the gland connector and it is screwed to the hull. Two 1000TVL 90-degree CMOS Camera and one High Definition 1200TVL CMOS Camera with 2.8mm Lens FPV Camera for RC Drone MultiCopter camera. The EC closes with an O-ring, a flange, and an end Cap.

Blue ESC

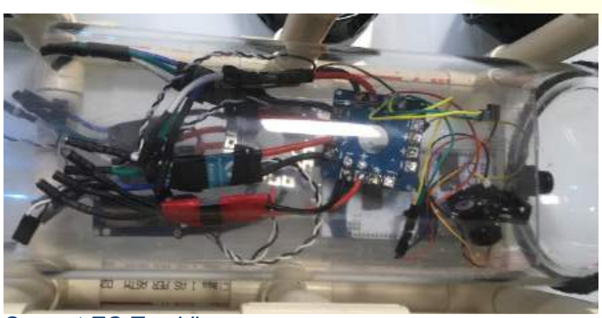
Design Alteration Decisions

Initially Scraps had an EC similar to BlueRobotics Enclosures. However, we found it is difficult to use the flange with the side O-Rings and the system complexity can be greatly reduced by eliminating it. We custom designed a metal plate epoxied to the tube which eliminates the use of side O-rings. Only 1 face O-ring is Required. We decided to buy BlueRobotics Penetrators as they are robust and allow changing end caps easily unlike our original epoxied penetrators.

Initially we used L298N motors drivers and custom high current DC Motor Drivers.



Scarps V1 EC



Current EC Top View

Current EC Bottom View

However, as we switched to Bi Directional ESCs, the EC was more spacious and well managed allowing us to add components with ease.

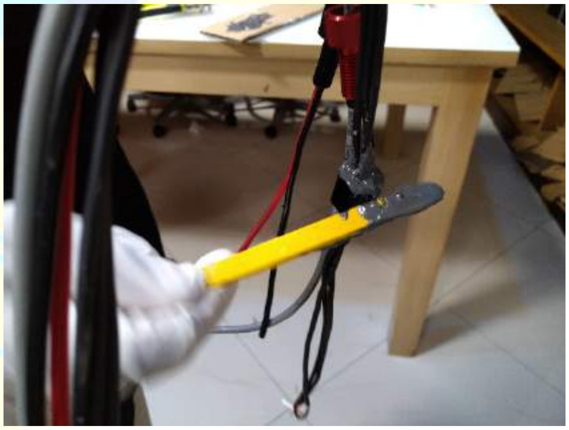
A BlueRobotics EC would have costed over 190$, we fabricated our EC in less than $30. Its economical yet easily maintainable and has less wear of O-rings.

Buoyancy

Team MantaRays decided to build Scraps slightly positively buoyant so as to enable it to float back to the surface in case of any disruption in the power supply. This was achieved by using the electronic chamber as the main source of positive buoyancy on the ROV. This saved us the effort of designing ballast tanks and dealing with pneumatics and air compressors, this also saved a considerable amount of money. The PVC chassis and thrusters provide negative buoyancy. The placement was decided and altered to make a well-balanced ROV after taking in a note the center of gravity (CG) and the center of buoyancy (CB). The important task was to ensure that the CB was above the CG otherwise the ROV would be imbalanced and would flip over in the water. This was ensured by the in-house self-balancing fixture, thus providing good stability to the ROV. Compact pieces of the foam are also attached to the tether of Scraps to reduce the drag caused by the tether during ROV movement under water.

Waterproofing

Waterproofing Electronic chamber is the home of all the equipment that enables the ROV to function. Team MantaRays had to ensure that it is completely waterproof to function at a depth of 40ft. This was a complicated task as waterproofing an object that is to be permanently sealed is comparatively easier than waterproofing a re-openable container. We developed an in-house flange with double O-rings Protection using CNC technology. These O-rings are basically a gasket which acts as a mechanical seal between irregular surfaces, and it fully prevents the permeability of water or such fluid when under compression. A lot of wires had to be passed through the electronic chamber, so to prevent seepage of water, we installed penetrators & glands on the end-cap of the chamber. Marine epoxy was used to seal test enclosures. Cameras were enclosed in the



Epoxing the Penetrators

watertight enclosure made of acrylic with a gland at back for the wire. DC motors were waterproofed with grease. The connections were enclosed in a case. Company members have waterproofed 270 Degree servo used in Scraps.

Also, the decision to use economical cameras inside the acrylic chamber rather than expensive waterproof cameras outside the chamber reduced our complexity as well as helped save us on the build.

Tether

Tether

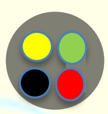
To improve the reliability of the data signal and greatly reduce the latency, we switched to Serial communication and Analog RCA cables. Using I2C serial communication, the communication is faster than CAT6 Ethernet connections. The I2C bus is connected to the 4-core cable in the tether. Scraps' Tether also contains two, 10 AWG Power lines. The Power supply cables can carry up to 24A of transmission current and the cables were selected due to its durability, minimum resistance, and flexibility. The power lines are rated for the resistance of 0.08 Ohms and with estimated peak draw of 25A, we suffer a voltage drop of only 1.06. This provides us a minimum operating voltage of about 11volts. The tether length is 15 m long. The tether produced by team MantaRays is firm and negatively buoyant. As a result, small pieces of foam are attached to the tether every 50cm to make it neutrally buoyant as it adds additional drag to the ROV.

AV Cables

Power (+)

Power (-)

4 Core Communication Cable



Tether Cross-Section

Payload Rationale

Robotic Arms

Primary Gripper

The mechanical manipulator arm carried by MantaRays is its main payload system and consists of two waterproof servo motors of torque 11 kg. The gripper of the arm is made of aluminum. Base of the arm was mounted onto the front PVC shaft of the ROV chassis. Intense discussions were held while designing the manipulator arm as company members realized that the arm is of great importance for the smooth functioning of the ROV. The edge of the gripper consists of a hook-like curve, which will deal with the U Bolts and hooks present in the props. Scraps mechanical arms are capable of completing multiple tasks using the same design.

Analog Joystick

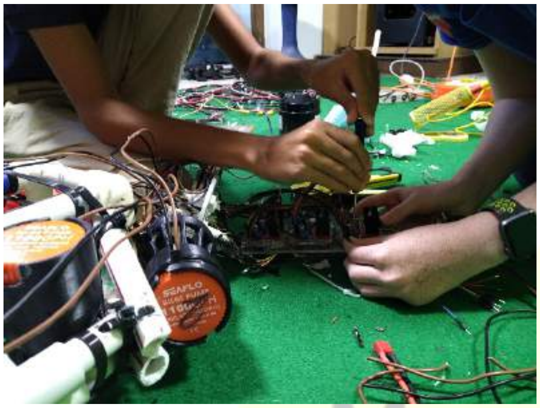
Measuring tool

The 'Measuring tool' is used to measure distances of objects from the ROV in the seabed. The measuring tool is a simple ruler held in place with the robotic arms. The HD camera can read the distance shown on the Tape once it has begun maneuvering to measure distance. This allows a direct simple distance reading without the use of complex image processing/expensive underwater equipment. This system is simple in design, cheap to build and very efficient. This system requires minimal mechanical control from the pilots on the station. The tool is mounted directly onto the chassis of Scraps along with the buoy marker. This reduces the additional stress on the pilot allowing him/her to focus more on controls.

Decision to Waterproof Servos inhouse

We chose to waterproof servo motors inhouse. This helped us save a lot more over waterproof Servos. Our Servos cost about $6 whereas a waterproof Servo costs just over a $100.

Electronics Rationale



Cameras

Scraps use one High Definition 1200TVL CMOS Camera with 2.8mm Lens FPV Camera for RC Drone Multi-copter and one 1000TVL 90-degree CMOS cameras which provide real time video. These 3 Cameras, which are inside the EC, have two facing front and one facing down. All the electronics in Scraps are placed within the acrylic Electronic Chamber (EC). The EC houses the PCB and associated wiring for the thrusters and motors. The size and complexity of the circuit have been reduced significantly due to the use of custom designed PCBs. The electric board of Scraps has been designed for maximum isolation between high power and low power signals, so as to reduce the likelihood of electromagnetic interference between the wires in the EC. A 12 to 6V Custom Converter powers the servos present in the ROV.

Arduino

An Arduino Mega 2560 module acts as the heart of the electronics present in Scraps and coordinates all activities of the ROV. The control box also features an Arduino for the Joysticks and point to point I2C Serial Communication.

Arduino Mega

Software Rationale

Scraps uses a Logitech 3D Pro Joystick in order to control the ROV. The numerous orientations and controls on the joystick allow for an optimal level of maneuverability and allows the pilot to manage Scraps' 6 Degree of Freedom (DoF) with ease. In order to pull off this feat, Scraps uses a variety of C++ libraries in combination with a Serial communication system for 2 Arduino Mega boards. A list of equipment is below used in the system:

Logitech Joystick 3 axis

Name	Voltage (V)	Amps (A)	Power	Quantity	Total Power

Arduino Mega	12	0.2	2.4	1	2.4
Servos	6	1.2	7.2	2	14.4
Cameras	12	0.2	2.4	2	4.8
Brushless DC Motors	12	2	10	6	60
Sensors	5			6	

The robotic arm is controlled using two small Arduino joysticks. The variety of controls allows for great maneuverability under water. Furthermore, the current control system is extremely compact, being able to fit into a small box or briefcase while still maintaining high levels of control. The ROV uses a total of 4 servos, two of which control the rotation of the manipulator, and the other 2 which are used for gripping objects, all of which are driven using a PS3 remote.

Image Detection Algorithm

Algorithm description: The algorithm for detection and recognition of the sign goes as follows:

Step 1: Image acquisition with the help of standard OpenCV method, VideoCapture, a stream of image frames is captured from the analog camera mounted on the ROV.

Step 2: Preprocess Pre-processing involves the following stages:

Resizing the image: This is done so that we can reduce the workload of the algorithm. This also helps with increasing accuracy for detection of contours.

Gaussian smoothing: Decreases noise and improves the contour approximation for shape recognition.

Grayscale and L*a*b: Conversion of the image to grayscale and L*a*b form.

Thresholding: We threshold the image before detecting the contours

Contour detection: The contours are detected from the image

Step 3: Detecting the shape Once we have a pool of contours, we can simple check for the number of contours to detect a particular shape, for example, we can say that a particular image has a triangle if the number of contours is 3, while it is a rectangle if the number of contours is 4.

Power specifications:

Power available: 300 Watts

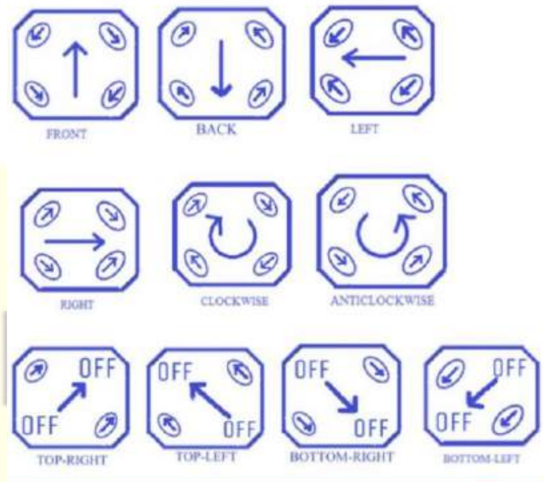
Peak Power Usage: 275 Watts, loss due to tether Resistance - 25 watts

Mission Specifics

We amended a lot of changes to our ROV to able to make it more suitable for Inshore operations.

6DOF motions

With programming and thrust vectoring, we have achieved 6 DOF Motions with our thrusters. The program which the system uses to drive is quite simple. Each ESC has a specific range of values at which it supplies a certain amount of power to the BLDC motors. At 1500, the system initializes, at 1100, the motor rotates in reverse, and at 1900, the motor rotates normally. The system maps the signals received from the Logitech joystick to values between 400 and –400, and then subtracts or adds the value to 1500 and then writes the value to the ESCs. Each ESC receives a different value depending on its position. Furthermore, the system allows for the ROV to move in various directions at the same time. Also, all mappings are real-time unlike traditional sequential conditioning.



all horizontal Motions

Rotating Arm

The primary design we created was not reliable and it was modified to increase redundancy. The circular acrylic piece has 2 cuts which fit additional acrylic pieces with round edges. This piece is attached to a 360-degree Servo. There are various advantages of using a 360 Servo over traditional DC Motors. DC Motors are more complex to waterproof and require both additional power source and a higher current driver. However, Servos are directly controlled using PWM and a power source available on the ROV. This reduces system complexity. The 360 Servo is rated at 10 kg-cm torque which can make it usable in real life conditions where higher torque might be required for jammed threads.

Control Box

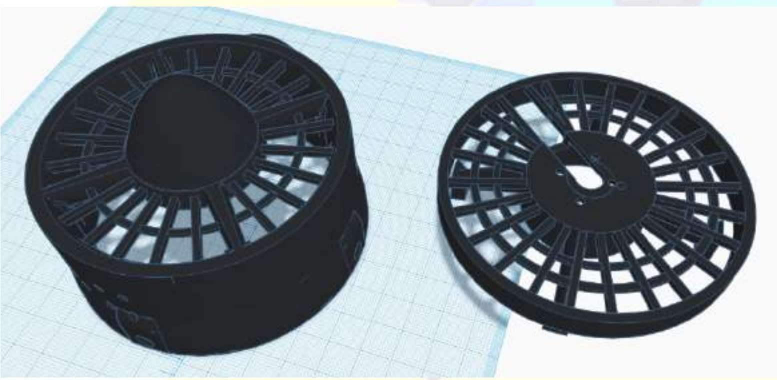
Our control box consist of 2 joysticks, on surface Controllers and Displays for the Camera. We built it out of an unused old case saving a lot than a Pelican Case.

Control Box

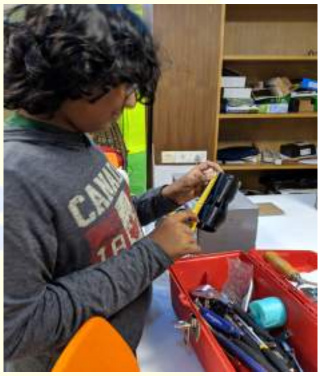
Innovation (Out of the box)

3D printed Case and propellers

Our team had various item missing that we didn't want to buy. We had many 3D printers so our design head Ayden mentioned using them so he designed all the 3D printed parts. The casing for the motors which had a thin cut-out piece that we had to use wire-cutter or crimpers to tear out. The cut out allowed us to slide the wire which connected to the motor in a more secure spot. The 3D print cost us no money which allowed us to spend the money other items. The propellers were a lifesaver the previous ones we intended to use were flimsy. Ayden designed some propellers which when we tested were quite strong then later Jonah added epoxy onto the propellers which strengthened the propellers tenfold. We designed all this thanks to tinker-cad. Also, we made the propellers taking an inspiration from T100 but we implemented the shrouds into it making it a shroud inbuilt case which is easy to screw in and robust.



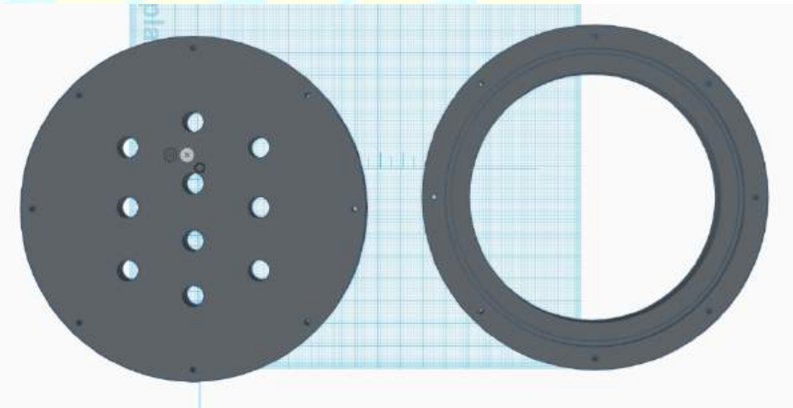
Custom designed Motor housing with inbuilt shrouds



Head of Design Ayden

Build vs. Buy

We had multiple occasions where this predicament happened, such as when we had to choose between buying props or construct completely new ones. At this time, we hadn't thought of 3D printing, which later we ended up using in this case, we decided build over buy due to the money difference between buying and building. This



Custom Designed flange and End cap for CNC Machining also happened with the motor cases and we choose build over buy. We had many occasions including some of the electronics and building parts which would be like taking a small piece of aluminum and constructed our own bracket or something like that. One of the ones we actually dealt with that included building materials would be buying a piece that we could slide into the acrylic tube or design one. We ended up designing one that was slightly damaged due to the drilling of holes for wires which caused bigger holes which was actually beneficial, so it was okay.

Summary of Build vs Buy

Component	Buy cost	Build Cost
Thrusters	$120	$20
Electronics Chamber	$190	$29
Servos (Waterproof)	$90	$8
Total Savings	$920	

Custom 3D Printed Thruster

Workroom/DT classroom

New vs. Reused

Although we haven't actually competed in a MATE competition previously, we did reuse parts from Studio6, which is when students explore a path for one week and we did ROV exploration. We reused various parts to cut down on the time related and monetary. costs of our ROV. These parts included the prop attachment, the bilge pump/motors, and some other parts that were from previous projects found in our design technology lab. Others include some Tetrix parts, screws from Tetrix, and other construction parts.

Safety

Manta Rays employees follow the following protocols for Safety:

- Seek safety
- Aim safety
- Follow Safety
- Ensure safety
- Teach safety
- Yield safety

"The safety of people shall be the highest law" – Marcus Cicero

Team MantaRays holds safety of its members and Scraps components in high stead. As a result, the team always carries out precautionary drives and maintains a safety before embarking on the day's activities. Team members have ensured that no sharp edges are present in the chassis or payload systems existing in Scraps. The components with sharp edges were meticulously redesigned to ensure this. The design of Scraps ensures that it can be easily handled without damaging or risking life and property.

All members of Team MantaRays followed the following guidelines meticulously during the building of Scraps:

Workshop Safety:

- Team members had to wear appropriate clothing before entering the workshop.
- Safety shoes must we worn at all times in the workshop.
- Rubber gloves must be worn while dealing with electrical equipment and adhesives.
- The workstation must be kept clean and ventilated at all times.
- All team members must have access to the fire extinguisher and first aid kit.
- Avoiding flammable materials at work station.
- Work on electronics must be done with power supply switched off.
- No loose ornaments must be worn and hair must be tied up while working with the ROV.

Operational Safety:

- Only members who have the ability to swim must enter the pool during test run.

- A member must be present near the power supply switch and at the station at all times.
- All requirements of the Safety Checklist are to be met before beginning test-run.
- Wires must be properly insulated and no loose strands must be present so that short circuits are avoided
- No harmful equipment must be present near the pool during test-runs
- All swimmers must use swimming goggles during their time inside the pool for clear visibility.
- Members managing tether or in close proximity of the pool must wear life jackets

Required Training	Required Protective Equipment
Transporting the ROV	Non-Slip or Closed-Toe Shoes
Assembling the ROV	Safety glasses
Setting up the wiring and voltage	Protective Gloves
Launching the ROV	Life Jacket
Retrieving the ROV	

Safety Analysis

No.	Action	Risk	Precautions	Consequence Rating (1 - 10) (See scale Below)	Persons Responsible.
1	Piloting	Electrocution due to possibly exposed wiring.	No exposed wiring. Use of strain relief. Taping of loose connections and exposed wiring with electrical tape.	6	
2	Retrieving ROV	Falling in the body of water, possible hypothermia or electrocution.	Wearing a Life Vest on deck, tether management, and deck support.	6	
3	Creating connections in electronics	a. Shorting of wires. b. Incorrect connections leading to dysfunctionality.	a. Isolation of ground wires and power wires. b. Labeling and organization of wires.	4	

4	Communication	False signals leading to incorrect idea of position leading to collision or damage to ROV.	Set roles and communication standards or conventions.	3	
5	Dropping tools or heavy objects.	Injury of foot or leg.	Use of closed toed shoes. Practice of caution when using tools.	5	

Consequence Rating Details:

(Based on a scale of 1 to 10)

1. Not noticeable to all members.
2. Is easy to fix; it does not cause damage or causes very minor damage.
3. Is a cause for concern, but is not a major issue.

- Can cause various issues for the ROV build.
- Causes one or more team members to be harmed, although damage is very minor OR causes damage to ROV which is moderately easy to repair, but is concerning.
- Causes one or more team members to be harmed, although the damage is not permanent OR causes damage to ROV which is difficult to repair, although its functionality is stable.
- Causes one or more team members to be harmed, with the damage causing an inability to complete tasks OR causes ROV's functionality to be severely hindered.

- Damage to team member(s) is permanent and causes an inability to do their tasks OR causes damage to ROV which requires replacement of many parts and severely hinders functionality.
- Damage to team member(s) is life-threatening OR causes damage to ROV that is irreparable.
- Major damage to team member(s) or ROV resulting in an inability to compete.

Project Management

We, as a team, are used to schedules since in the middle school, we have numerous after-school activities. At first, we would meet at lunch time, but when the competition got closer, we started meeting after school. We were interrupted by our Spring Break. We had to start meeting every day, usually till eight or nine at night. We tried to build a schedule but that was thrown off by the inability to obtain quality parts in and around India. We planned to start every meeting with an introduction of the tasks for the day. This was often difficult because of schedules and the realization, by the ASB administration, that we had to conform to school activity schedules. The Saturday meeting usually had all of our teammates which was getting a lot of work done but eventually some of the people dropped out due to those people losing interest. Each person had to take on more responsibility.

: Build day

Schedule

The last week of March we started to plan the overall build and looked over requirements and what not. Then that very Saturday we got situated and started to build and we finished the beginning design which was the rectangular shape in the middle of the build which holds the acrylic tube. The next week, the first week of April, we started to add components such as the 3D printed cases and started designing the propellers. Along with the start of coding during the first time, we started the coding and we started hooking components. We met during lunch a few times then we met that Saturday which is when we did more of the coding rather than the building. Now it is the second week of April and the electronics are getting more advanced and we started to decide to use a joystick a Logitech 3d pro joystick. We started to finalize the PVC build which would be adding the 45-degree PVC which would start the beginning of making the octagonal shape. During the lunch times of that week we started to cut the PVC for the “Wings” or the stability areas of the Rover which are pretty much the sides of the Rover. That Saturday was when we started to construct the rover together and we used zip ties to put the 45-degree cut piece to the wings. The zip tied areas varied put the 45 cut pieces

:""Scraps" the original

were the ones that had all the zip ties or most of them out of the whole vehicle. Now it is the third week of April and we did not have any lunch time meetings and only 2-3 kids met that Saturday and we didn't do as much we just finished some 3D printing. The week of when we had to turn in the technical report rolled around. During this week we finished off the all the electrical things which were hard then the CEO started to work on the tech doc.

Starting new construction

Logistics

Over the last few weeks, we have been ordering electronics and other materials from Robo.in, and various other websites and companies. Almost all of our components were local. We also built a nice relationship with our 3d printer.

Outreach and Inspiration

We were inspired by one of our mentors Mirza a previous Explorer team competitor, who introduced the competition to us. He is the one who helped one of our other mentors Mr. White in our school's Studio6. He was one of the ones who helped us get through and build mighty fine underwater Rovers. He outreached to various other students including some from the elementary school which one ended up joining our team.

One of our Mentors, Mirza, providing guidance

Critical Analysis

Our design is effective, although there are still many improvements that could be made. Firstly, the design would have been long-lasting if we used aluminum instead of PVC pipes since our design had some unorthodox angles that tees could not replicate. As a result, we ended up using zip ties to connect the pipes together which is not an ideal way to secure parts. If we had more time, we would have built our design using other materials instead of PVC pipes, but we were limited to 4-5 weeks to finish "Scraps", and building with PVC pipes saves more time. A positive aspect of our rover's design is that it incorporated a Logitech 3d pro joystick which has more control compared to other controllers. Unfortunately, when testing the joystick many issues occurred, so we replaced it with a basic controller that connects to switches.

Testing and Troubleshooting

Another day of troubleshooting

We did not have many failed attempts when testing our prototype rover, but the issues we did have resulted in a lot of troubleshooting. For example, we tested the speed of the ROV. The motors worked outside of the water, but as soon as we put it in the water, they stopped working. We later found out that an unconnected servo wire was touching the metal cap on the acrylic tube which shorted with the servo wire outside the tube through the water, this was easily fixed by covering the bare ends of the servo wires with tape. This was only one of many acts of troubleshooting.

Challenges

Troubleshooting again

The first challenge we had was the angles for the motors because they were not 45 degrees, this would cause the motor to cancel out each other which would not provide enough trust for the ROVer. We fixed this by attaching PVC T's to bring the angel from 60 degrees down to 45 degrees. This cause the trust to combine, this provided more thrust but it still wasn't enough for the rover. This change caused us to change some of the electronics. The motors did not have the maximum voltage, so we changed some of the motor drivers to have maximum trust. We also tried to increase the propeller size and alter the design. In our first test of the ROV, the negative and positive wires connected causing our Arduino to fry. Tackling this challenge, we replaced the Arduino and assured the wires were secured and didn't connect. The next challenge was waterproofing the acrylic tube, in our first waterproofing test there was minor leakage, we epoxied the leaking point. In the next test, the leakage was even less but it was leakage we tackled this by adding bolts to the screws of the acrylic tube cap.

When we purchased the Arduino shields from a local company, the shields were not working and were shorting when we connected them to the Mega. After several attempts, we did some research and found that shields made after 2016-2017 had a flaw. There was an issue with connectivity in the power (5v/3v) area of the shield. After soldering the connections, the shields worked. We may be starting to see some wear on those shields because we had to reset the Arduino several times during a trial run. We will have additional shields with us during the competition just in case one goes out.

Non-Technical Challenges

The limit of time in the first couple of weeks slowed down our progress. Some of the members also didn't find work to do due to the slow work speed. This caused some conflict between some team members, but it got solved and the team worked together fluently. Some members also had other school work and other activities which caused them not to be able to participate in all meetings. Other team members even had to quit because they had to do too much school work and couldn't help enough with Scraps our ROVer. We had regular discussions about these problems and fixed most of them

Team problem solving

Lessons Learned

When building the arms for our ROV, we attached metal parts to a servo using a screw when testing the arm, the servo wasn't able to open and close the pincher of the arm. From this, we learn that even though tightening screws well might help it stay in place for moving parts leaving just a little room for movement brings greater results. This also affected our build when we tried to attach the cap to the acrylic tube, we tightened the screws too much and broke the threading in the cap so it didn't let us close it tightly if we just have given the screws a little room the threats would have broken. Failing in while building and prototyping helped the build and fixed problems so we don't have them in the competition. Some of them being leakage, shorting of component and wire breaking these "fails" teach us valuable lessons in troubleshooting and teamwork.

Future Improvements

The mess that is no more.

One thing that could improve our future ROV is the base building material. For this competition, we used PVC due to its availability and ease of use, along with its sturdiness and low cost. In addition, our ROV could have more stability if we used a sturdier material for the chassis. So, we have a faster more agile build. Also, our arms should be able to reach out to grab objects for the different tasks. So we plan to add multiple manipulators. Also, we plan to add self-adjusting buoyancy with sensors and a GUI.

Total Budget			
Item (part and #)	**Cost (Rs)**	**US$**	**Purchased vs. Reused**
PVC (10 foot and connectors)	(500)	$7.16	Reused
BLDC Motors	(2916)	$41.7	Purchased
Bluerobotics Bidirectional ESC	(10489.88)	$150	Purchased
Arduino Mega (2)	(1700)	$24.34	Purchased
Arduino Shield (1)	(200)	$2.86	Purchased
Hardware (nuts/bolts)	(400)	$5.73	Reused
Acrylic Chamber	(1600)	$22.91	Purchased
TVL Cameras (2)	(2700)	$38.65	Purchased
Servo Motors (2)	(800)	$11.45	Reused
Step down converter	(120)	$1.72	Purchased
Tether wire (power) 4Core 15m	(1400)	$21.19	Purchased
AV RCA 3 wire (15m)	(420)	$6.01	Purchased
Electronic components- jumper wires, power distribution board, breadboard	(850)	$12.17	Reused
Gripper arms	(900)	$12.88	Purchased
Marine Epoxy	(2100)	$30.06	Purchased
Thruster Adapters	(700)	$10.02	Reused
Joystick modules	(450)	$6.44	Purchased
Flange w/cap	(2500)	$35.79	Purchased
Zip ties	(1500)	$21.47	Reused
Hot glue	(200)	$2.86	Reused
Wiring penetrators	(280)	$4.01	Purchased
Thruster and propeller (3D print) Filament	(900)	$12.88	Reused

Pool noodle	(199)	$2.85	Reused
TOTAL	(33404.88)	$477.67	Actual Cost: $398.24

Acknowledgments

Firstly, we would like to thank our heartfelt gratitude to our mentors- Mr. White, Mr. Samnani & Mr. McClain for introducing us to this concept and encouraging us to push our limits and aim for the sky.

We would also like to thank- • MATE India for organizing this challenging competition

All sponsors of MATE India as well as the Internationals

Kingsport Aquatic Center for hosting the Competition

American School of Bombay to support our ROV financially and providing extended support always.

ASB Pool for allowing us to carry out our testing rigorously.

All electronics shops in Lamington Road, Mumbai, for catering to our requirements.

All workshops in Jogeshwari for allowing us to work on their machines for various fabrications

We would also like to thank our family members, friends, team volunteers and well-wishers for extending their warm wishes and support during this journey.

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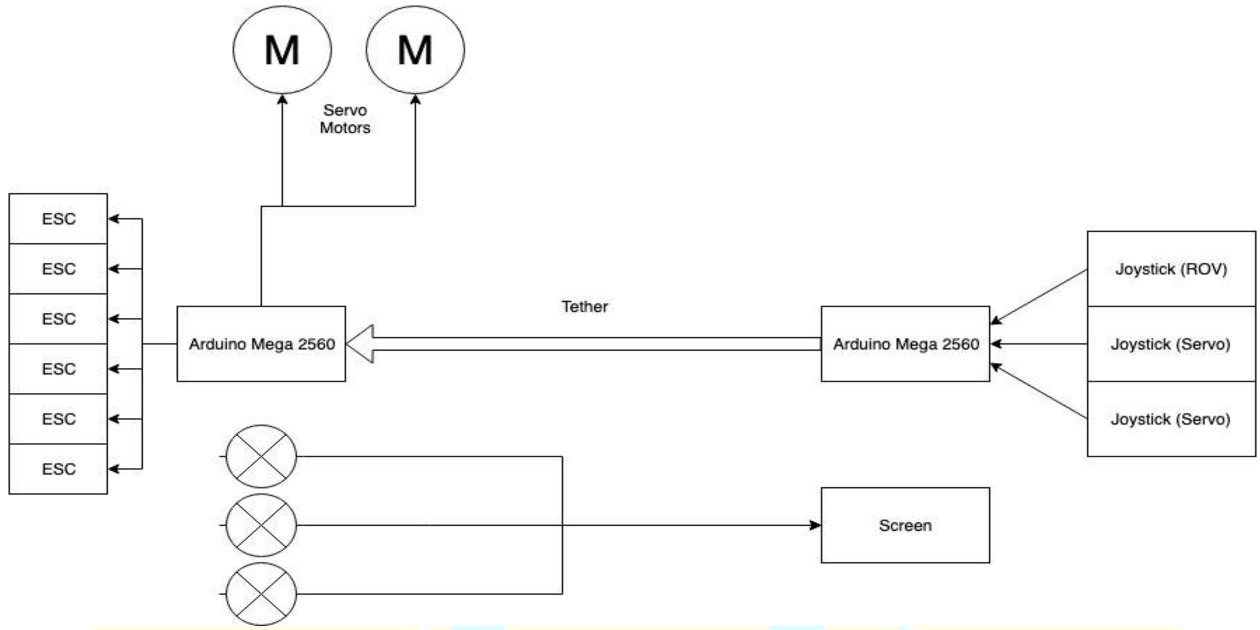
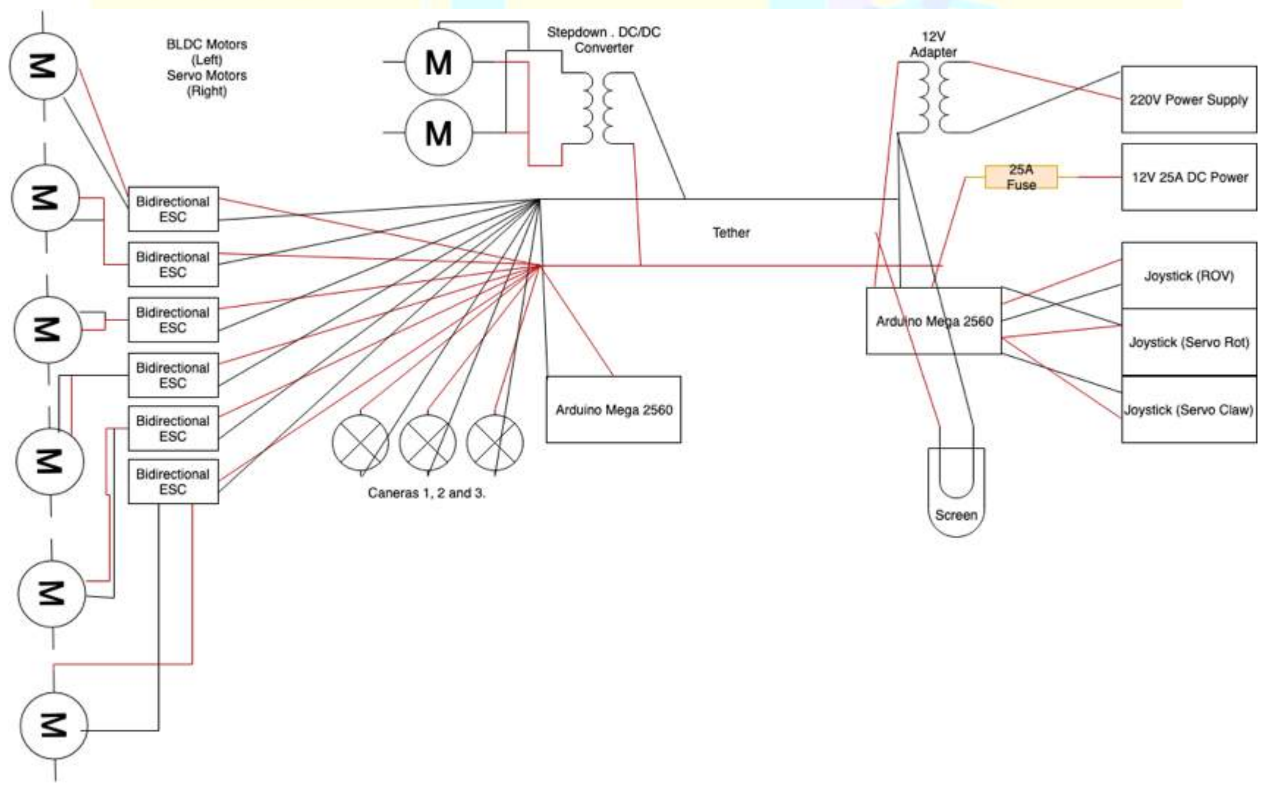
Appendix 1 SIDs

SYSTEM INTEGRATION DIAGRAM

Communication SID



Power SID



Appendix 2 Safety

Workshop Safety:

Required Training	Required Protective Equipment
1. Use of Soldering Iron 2. Use of Heavy/ Power tools 3. Using epoxy	1. Protective Gloves 2. Respirators 3. Earplugs or muffs

Operational Safety:

Required Training	Required Protective Equipment
1. Transporting the ROV 2. Assembling the ROV 3. Setting up wiring and voltage 4. Launching the ROV 5. Retrieving the ROV	1. Transporting the ROV 2. Assembling the ROV 3. Setting up wiring and voltage 4. Launching the ROV 5. Retrieving the ROV