TECHNOLOGY REPORT

Cougar Robotics Incorporated and ROV Pavona

Clarenville High School, Newfoundland and Labrador, Canada

Team Members:

Isaiah Dalton
Company CEO

Natalie Poole
Assistant CEO

Mark Spurrell
Chief Designer

Nathan Fillier
Accounting Manager

Nicholas Reid
Human Resources

Mentors
Jenna Blagdon
Michael Spurrell

Using sub-sea ROV technology to support and enhance ocean quality globally

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ROV Panova placing the irrigation system at the Mate Regional Competition.

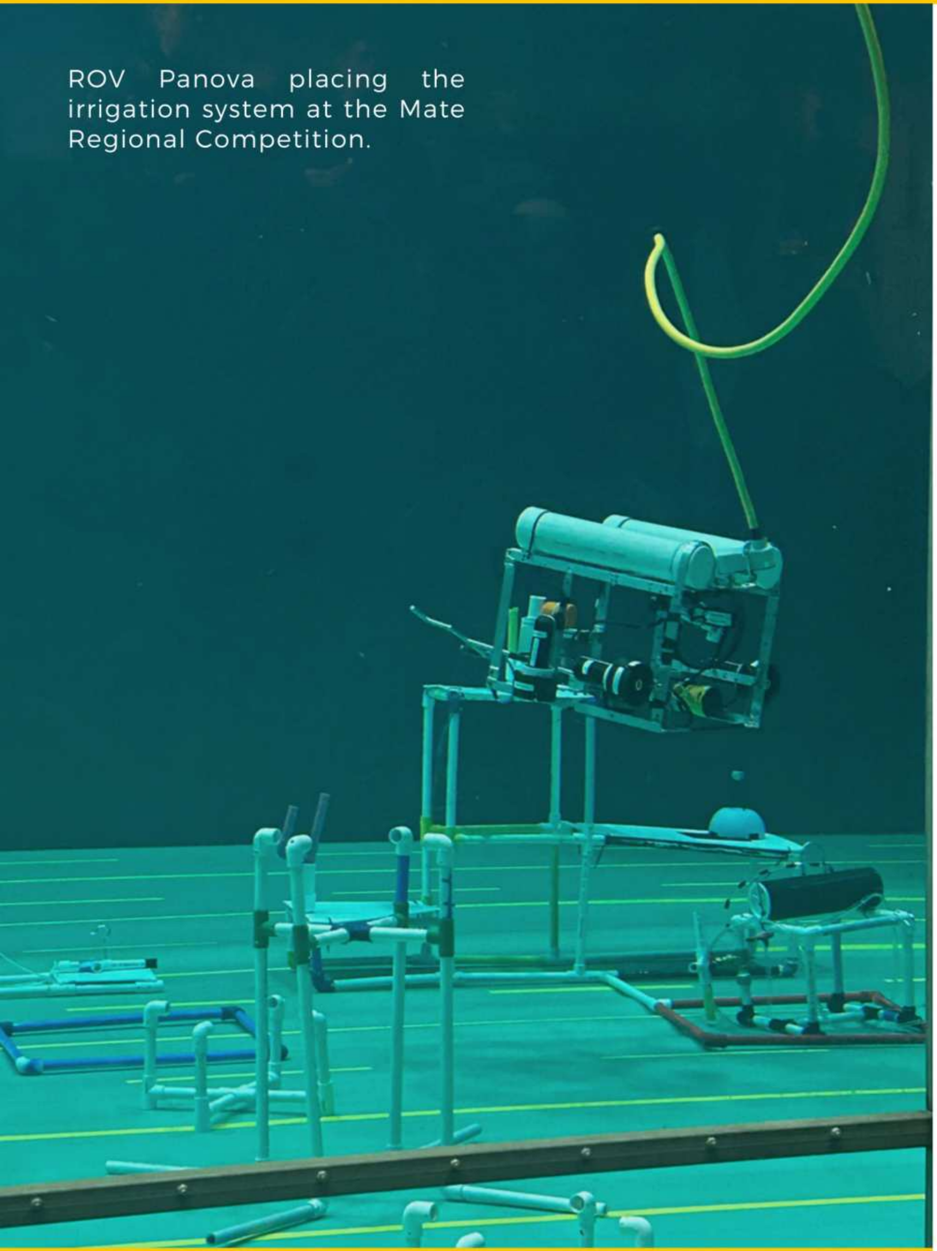


Figure 1: ROV Panova (M. Spurrell, 2024)
Mission Attempt 1, Task 2. May 4, 2024

Mate International Technology Report - 2024

Cougar Robotics Incorporated

Clarenville High School, Clarenville, NL, Canada

https://cougarrobotics.my.canva.site

Abstract

Beneath the ocean surface lies an expansive network of invertebrates, known as corals, which constitutes at least 25 per cent of all known marine species (United Nations, 2021). They provide important cultural, economic, recreational and social benefits to hundreds of millions of people, but they are dying (Jones, 2024). Remotely Operated Vehicles (ROVs) play a crucial role in the race to save the reefs. Cougar Robotics Incorporated has built a simple, yet reliable ROV, known as Pavona. This ROV has been carefully constructed and is designed to take a variety of underwater samples, measurements and images, in order to support research and conservation efforts. The ROV is neutrally buoyant and is designed to ensure minimal drag and responsive movement. In addition, there is an 80 degree feild of view camera that functions well in the ocean environment, even in low light, which makes it ideal for deep water exploration. Pavona was strategically designed and constructed with cost, function, and environmental concerns at the forefront; resulting in a product that is cost-efficient, speed-efficient, and environmentally friendly. The success of ROV Pavona is a clear indicator of the improvements that have been made in ROV technology with regards to accessible and affordable underwater exploration. This technology is vital to the protection and preservation of the world's coral reefs.

Nomenclature

v = The speed of ROV [m/s]

Fd = Drag Force on ROV [N]

P = Pressure [Pa]

V = Voltage [V]

A = Reference Area [m^2]

Cd = Drag Coefficient

P = Mass Density of Fluid [kg/m^3]

W = Vehicle Weight [N]

m = Mass of Vehicle [Kg]

I = Current [A]

Fg = Force of Gravity [N]

T = Temperature [^{o}C]

R = Resistance [Ω]

Figure 2: ROV Pavona: Side, top and isometric view. (M. Spurrell, 2024)

Teamwork and Project Management

Cougar Robotics Incorporated is a company specialized in the design and construction of ROV's. Originating from Clarenville High School in Clarenville, Newfoundland and Labrador, Canada. The company consists of five student team members and two teacher mentors (Organization Chart: Appendix A). The team was tasked with the construction of a ROV to complete three distinct missions focused on developing innovative solutions to help replenish and regrow the ecosystems of coral reefs, to activate recovery floats, and to deploy cables in a marine environment. Every team member played a vital role, sharing in the design, construction, and testing of the ROV. The company adopted an unique and ambitious approach to constructing the ROV and completing mission goals. The goal was to design a passive 'mission-based, multi-tool' vehicle that was void of any programming, servos or grippers. This resulted in an ROV design that is dependable, efficient, repairable and marketable. A system of basic switches, simple tools and low level electronics would be the mandate to ensure that the product was reliable, repairable and marketable to the common consumer. These simplistic robust attributes were also considered when determining a name for the ROV. Inspired by the Coral Reefs, the ROV was coined *Pavona* after a remarkably easy to grow, and reliable species of coral. The company's success can be attributed to the strict schedule followed by the team. Deadlines were set, and members agreed to meet at least four times a week. Every meeting began with a safety moment (Appendix B); then announcements and tasks were discussed and distributed. Dedication and teamwork are a critical component in the construction of a successful ROV. The company is proud of ROV *Pavona* and is confident in its ability to complete the tasks presented by the Marine Advanced Technology Education (MATE) Center at The World Mate ROV Competition.

Figure 3: Team Photo (Y. Fillier, 2024)
Back Row (L to R): Mark Spurrell, Natalie Poole, Isaiah Dalton, Nathan Fillier, Nicholas Reid
Front Row (L to R): Jenna Blagdon (Mentor), Michael Spurrell (Mentor)

Design Rationale

During the development of ROV *Pavona*, constructing a reliable and repairable ROV was the main objective. A conscientious effort was made to use common materials that would allow clients to easily repair the ROV. The team procedures followed strict safety guidelines as outlined by the Canadian Occupational Standards and Policies (COSP) to ensure the safety of all team members. All ROV features were constructed to accomplish mission goals that replicate real-life tasks. Inspiration was taken from coral reef marine life by designing tools that mimic their natural abilities. To maximize productivity, all tools were developed using 3D modelling software. Testing was performed using COSMOS Floworks to reduce drag and improve the overall design. The unique custom quick connection feature allows tools to be interchanged with ease, decreasing transition time between tasks. All tools are displayed in detail under the payload and tools section (page 10-12). The team formulated a six-step design process (figure 4) developed entirely by Cougar Robotics Incorporated. The process was effective and was used throughout the construction of ROV *Pavona* and its tools. Although linear by design, steps could be reorganized and revisited at any time during the design process.

Six-Step Design Process

- **Define**: Describing the problem in detail; analyzing all resources, specifications and limitations.
- **Research**: A studious inquiry in order to establish facts and learn as much as possible from others
- **Solutions**: Ideating possible solutions. Generate and formulate numerous options.
- **Prototype**: Construct a scaled model or operational version of a solution.
- **Test**: Test the solution and identify new problems. Determine if there were faulty assumptions.
- **Improve**: Make changes and test new solutions before settling on a final design.

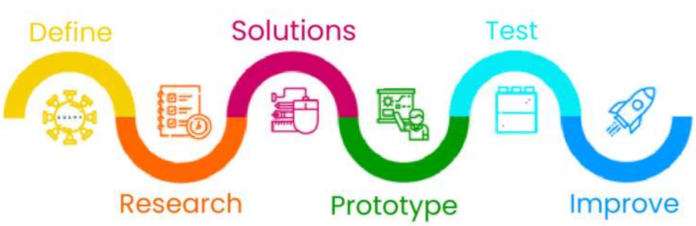


Figure 4: Design Process (N. Poole, 2024)

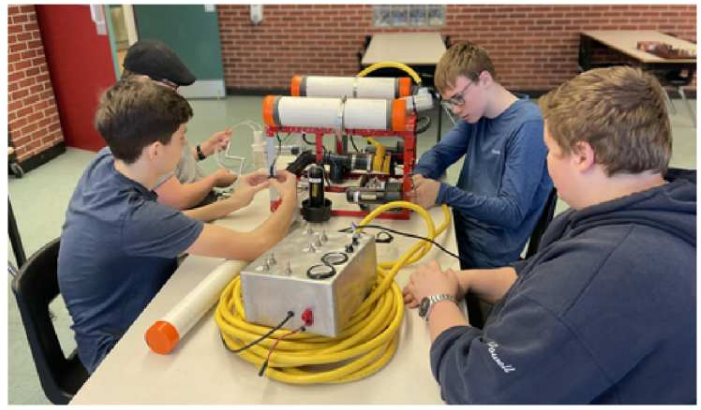


Figure 5: Brainstorming (N. Poole, 2024)

Innovation

During the construction phase of ROV *Pavona*, the company strived to embrace innovation and simplify tools wherever possible. At the beginning of every meeting, the team discussed ideas and made an effort to '***Think outside the box***'. For instance, when considering how to pull a metal pin, the team opted for a more simple approach such as a magnet attached to a stick. This forward-thinking mentality significantly boosted the success rate during testing and design phases. The company collectively tackled challenges with creative solutions, which ensured that each was versatile and tailored to specific mission requirements.

Problem Solving

Every problem was susceptible to the company's **Six Step Design Process**. Brainstorming became a major part of the developmental process. This was most evident when designing tools to complete mission tasks. After defining the problem and researching solutions, the team would brainstorm ideas. These ideas were turned into prototypes that would be tested. when testing commenced, the company would reevaluate and decide how the end effector could be improved to complete the task more effectively. One of the largest challenge the company faced was designing a tool that could effectively transport the power connector. Due to the props starting position and design it was difficult to grasp and manipulate. A variety of prototypes were constructed using hooks, latches and arms. Through testing and redesigning the company was able to successfully construct the Mandarin Fish (page 12). This tool has the capability of grasping the power connector, rotating it and mating with the smart cable.

Figure 6: ROV Frontal View and tools (N. Reid , 2024)

Systems Approach

ROV Pavona was designed as simplicity and reliably as possible. The company made an effort to produce tools that were readily repairable and replaceable. Every part of the ROV adhered to strict standards focusing on reliability and reducing the risk of malfunctions. This was a critical factor across the entire vehicle. The control systems operate solely through switches, guaranteeing full functionality without depending on any software. All tools were tailored for specific mission tasks and using a straightforward mechanical system.

Vehicle Structure

In designing the ROV Pavona, the primary focus was on reducing weight, size, and cost. The company aimed to create a vehicle that was easy to handle, highly functional, and cost-effective. This involved selecting materials that met company standards while also staying within budget (Appendix C). Special attention was given to choosing lightweight, affordable, and durable materials. 6061 aluminum emerged as the preferred option due to its high corrosion resistance, good workability, and machinability. At a total weight of only 8.6kg and dimensions of less than 0.5m, ROV *Pavona* would be classified as a mini-class Rov.

Frame Material: Aluminum	**Mass:** 8.6 kg
Propulsion: 12V Thrusters	**Speed:** 1.1m/s
Height: 0.31m	**Width:** 0.38m
Buoyancy: 4.1 N	**Voltage:** 12 V
Length: 0.48m	**Drag:** -0.184 N

Figure 7: ROV Materials (I.Dalton, 2024)

Vehicle Systems

Cougar Robotics took a unique approach to the construction of ROV Pavona by focusing on the development of task specific tools. The team analyzed each mission and developed a unique tool that would accomplish each task. Through the design approach and analysis of each mission task it was determined that it would be the most efficient and effective to construct task specific tools. During the refinement process, it was determined that a modular based system would best meet the needs of the mission. The system is unique in design as it utilizes a quick connect system which allows users to adjust or replace tools at surface level in seconds (see page 11). Before construction of tools, careful consideration was given to the overall construction of Pavona. A house is only as good as its foundation. This led Cougar Robotics to begin with frame design and construction.

ROV Frame

The ROV frame was a critical decision as it serves as the basic building block of the entire system. The choice of frame design was dependent on its susceptibility to tool placement, but, most importantly, its resistance to drag and reduced water flow. Three options were considered for the frame's material and design. The first option was a square frame constructed from 0.031m ID (1.25 inch) polyvinyl chloride (PVC) pipe and fittings. The second option was a similar design made from 0.002m x 0.025m aluminum flat bar. The third option was a U-shaped frame fabricated from 0.0047m thick polycarbonate resin thermoplastic.

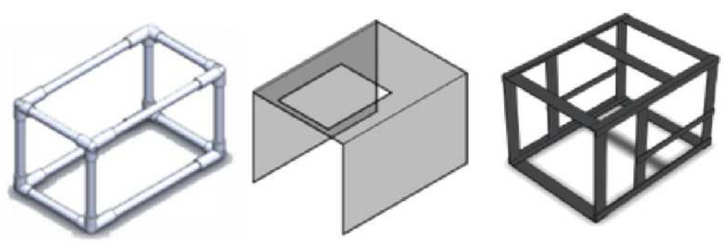


Figure 8: ROV Frame design (I. Dalton , 2024)

All frames were drafted in SolidWorks and underwent a fluid flow analysis using COSMOS FloWorks. COSMOS FloWorks simulates complex 3D fluid flow analysis providing insight into how a fluid flows through each frame. From the data it was determined which model exhibited less drag, to make it as streamline as possible.

The aluminum flat bar reported a horizontal translation drag of nearly half of the polycarbonate resin thermoplastic and a quarter of the PVC.

Frame	Drag
0.025m Aluminum Flat Bar	-0.1846N
0.031m ID Polyvinyl Chloride (PVC) Pipe	-0.8465N
0.0047m Polycarbonate Resin Thermoplastic	-0.2984N

Figure 9: Drag Data (N. Poole, 2024)

After testing, the company decided to construct the frame from aluminum flat bar. The box-shape frame measures 0.46m x 0.35m x 0.30m (L x W x H) and is open on all sides. The open-ended design provides sufficient space to easily mount thrusters, tools, and buoyancy.

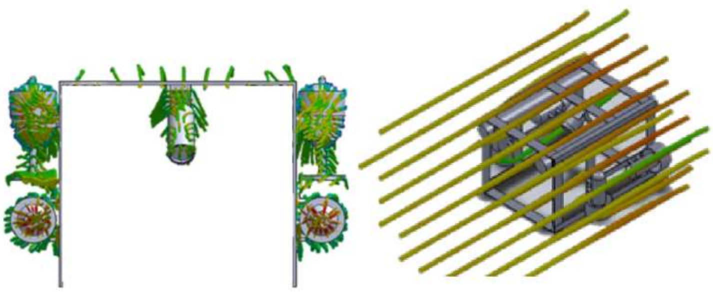


Figure 10: SolidWorks Drag Analysis (I. Dalton, 2024)

Aluminum flat bar proved to be lightweight, corrosion resistant, durable, and easy to cut and bend. In addition it combines high tensile strength, hardness, and temperature resistance with low water absorption. Once the basic shape was chosen, a complete model including thrusters, buoyancy, and the camera was drafted in SolidWorks. Further drag analysis was performed to see how fluid flow would be affected. It was discovered that the entire model would yield a drag of -11.49N.

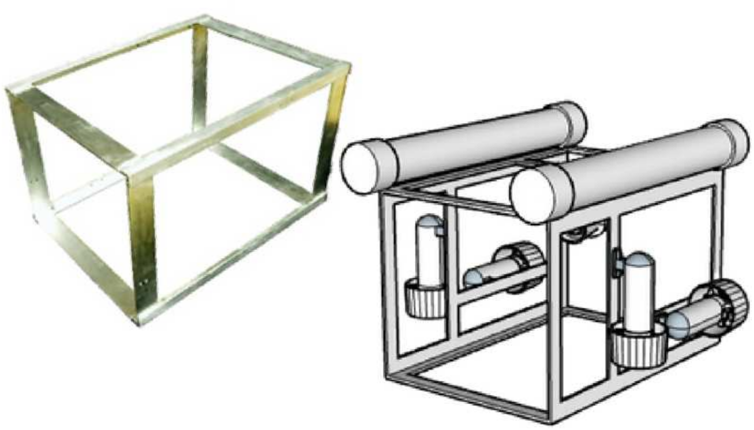


Figure 12: Frame Design (N. Fillier, 2024)

Control and Electrical Systems

The electrical system of ROV Pavona was entirely custom-designed and assembled by the company. It consists of the controller, power cable, tether, camera, and tools. All systems have a 12 volt DC rating and satisfy the MATE competition safety guidelines.

Controller

The company opted for a manual system comprising only mechanical switches. This choice aligned with the company's focus on simplicity and also facilitated troubleshooting in case of any issues during operation. Multiple control designs were created using SolidWorks and equipped with necessary components.

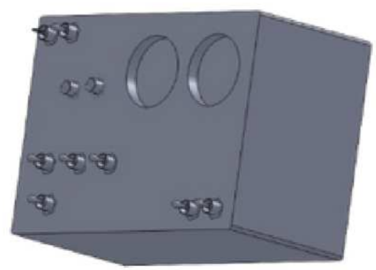


Figure 11: CAD Design (M. Spurrell, 2024)

Once the main design was determined, an aluminum box-shaped shell was welded to house the controls. Switches were strategically placed on the top and all wiring was secured within the controller. Two ten terminal brass busbars were placed inside to act as connection points for the positive and negative terminals. An ammeter and voltmeter was added to allow monitoring of the system's current and power supply voltage. A single dipole kill switch was added to shut down power immediately in case of an emergency. To maneuver the ROV, three two-way momentary switches were utilized. One switch controls the vertical motors, while two separate switches were used to control forward motion and turning.

Figure 13: Controller (N. Poole, 2024)

Additionally, several momentary switches were included to activate various tools. A dual-directional DC motor controller, model K-166, was installed on the panel. It offers users the flexibility to replace any momentary switch on demand. The K-166 motor control enables enhanced management of end tools in two directions. Rotating the potentiometer results in the DC motor rotating. The central position on the potentiometer signifies OFF, causing the motor to and stop prior to changing direction.

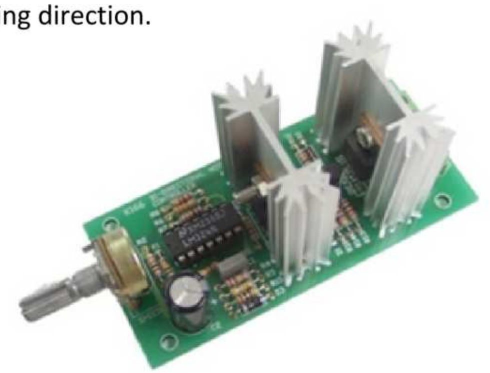


Figure 14: motor controller (N. Fillier, 2024)

Extreme measures were taken to ensure MATE safety standards were followed. All wiring was well protected and neatly organized. Submersible cables and connectors were waterproofed and properly sealed.

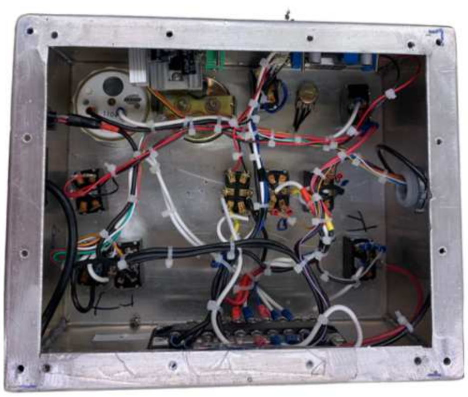


Figure 15: Power cable and Inside controller (I. Dalton, 2023)

The power cable has been assembled using a 12-2 copper wire, an Anderson connector, and a fuse. The cable can be disconnected from the controller for convenient storage. A 25-amp blade fuse has been installed on the positive side of the cable close to the power source. In the event of excessive current flow caused by a short circuit, overload, or device malfunction, the fuse will blow, safeguarding both the operators and the ROV from harm. A comprehensive Electrical SID (page 8) has been devised in accordance with CSA C22 standards and symbols to enhance clarity and precision.

Figure 16: Fuse (N. Poole, 2024)

Tether

The tether is "one of a kind" and was entirely designed by our company in conjunction with Leoni Limited. The minimum number of wires was chosen to decrease weight and maximize flexibility. The tether measures 13.5 meters, consists of six pairs of 24 gauge insulated wires to control tools, a coaxial video cable, and three pairs of 20G insulated wires to power the thrusters. This provided us with a sufficient number of paths to transmit and receive signals to and from the ROV. The wires were enclosed with buoyant filler and a polyurethane shell to provide neutral buoyancy and waterproofing up to 100 meters. Keeping the tether in operation condition was of utmost importance to ensure user safety. A tether management protocol (appendix C) and safety procedures were developed (Appendix B) and adhered to all times.

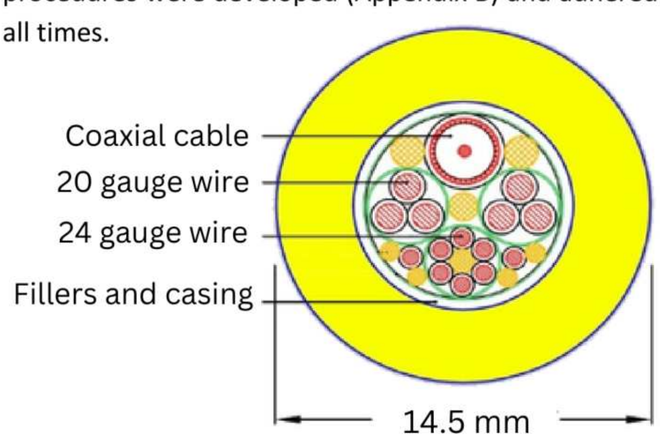


Figure 17: Tether Diagramme (N, Fillier, 2024)

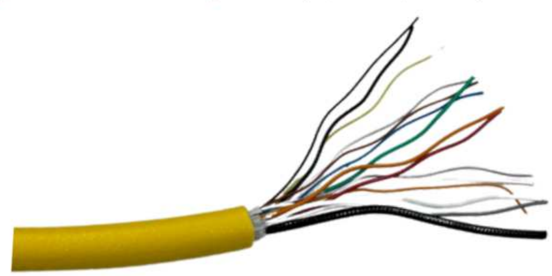
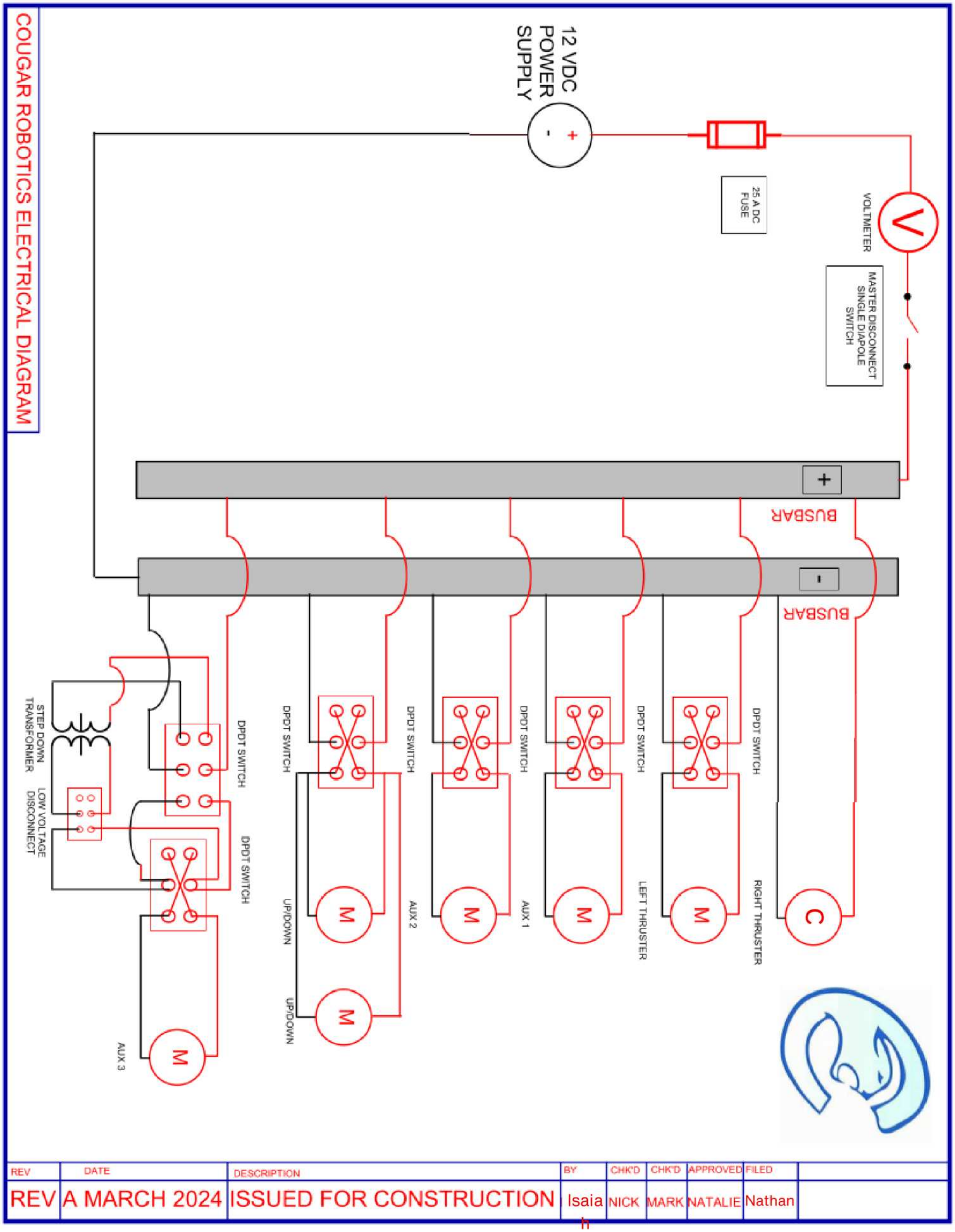


Figure 18: Tether Cross Section (N, poole, 2024)

ROV Pavona - System Integration Diagram



Tether Mounting

To improve maneuverability, a free-form attachment system was developed to connect the tether to the ROV. Constructed using a system of rings and a carbiner the apparatus allows the ROV to rotate and make finite movements without twisting the tether. The system permits a loose, but firm connection between the ROV and tether.

Figure 19: Tether Connection (N. Poole, 2024)

Propulsion

The propulsion system is one of the most critcal components of any submersible ROV. In the early stages of construction the team developed and designed a custom thruster from bilge pump a 12 volt - 500GPH bilge pump. The motors were extracted from the bilge pump housings and dismantled. Mechanisms originally used to pump water were removed and replaced with a brass hub and a 40mm 4-Blade propeller.

Figure 20: Bilge Pump (N. Reid, 2024)

After considerable practicing, the company decided that the ROV lacked the speed need to complete the mission tasks. It was expected that the bilge pump thrusters were inefficient and could not provide the required propulsion. The company required thrusters that were more powerful and energy efficient. After much research and deliberation a second set of thruster was purchased from SeaBotix Incorporated. The SeaBotix BTD-150 thrusters are equipped with a 12V Brushed DC motor, 76mm, 2 blade prop and kort nozzle. They also meet the IP20 safety standards and restrictions set my MATE.

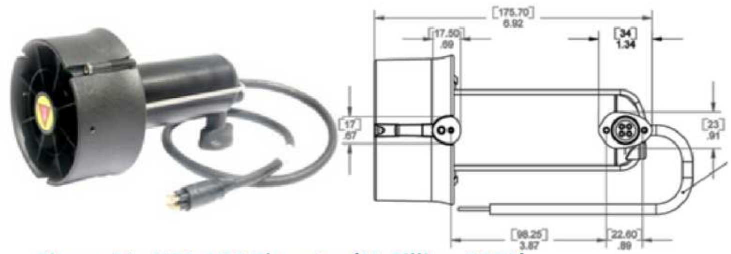


Figure 21: BTD-150 Thruster (N. Fillier, 2024)

To compare each model of thruster a series of small scale bollard tests consisting of a spring scale and lever were used to determine the force. As well, an ammeter was used to measure the current drawn in air and while under a load in water. It was found that the BTD-150 would draw double the current of the bilge pump system (figure 22). However, the SeaBotix thrusters produced significantly more force, being almost three times more powerful.

Current Comparison		
Thruster	**Current in air**	**Current in water**
BTD-150	1.8 Amps	2.6 Amps
Bilge Pump	0.9 Amps	1.3 Amps

Thruster	Bollard Test: Force
BTD-150	21.5N
Bilge Pump	5.2N

Figure 22: Thruster analysis (N. Poole, 2024)

Using the data collected it was determined that the SeaBotix Thruster outperformed the bilge pump motors and would be the preferred choice. The thrusters were attached to the sides of the ROV to provide vertical and horizontal motion.

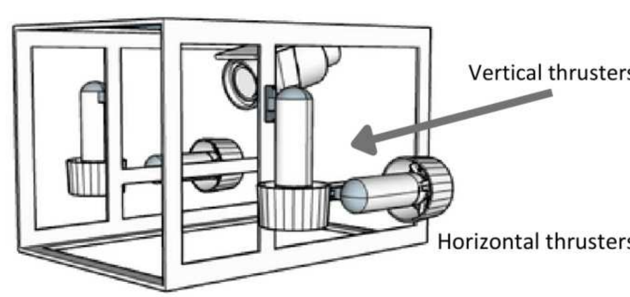


Figure 23: CAD Model (I. Dalton, 2024)

Positioning of Thrusters

A test of the electrical devices on ROV Pavona indicated that powering any more than four thrusters, camera and tools at one time would be close to 70% of the 25 amp limit. So, four thrusters (two for vertical translation, one for turning left, and one for turning right) were used to propel the ROV. The positioning of the thrusters was crucial to provide stability and straight-line motion. The thrusters were positioned as low as possible to obtain a low center of gravity and to direct propeller backwash away from other sensors and tools. Two thrusters were placed on either side of the ROV to obtain vertical lift, and two thrusters were placed horizontally to provide forward motion.

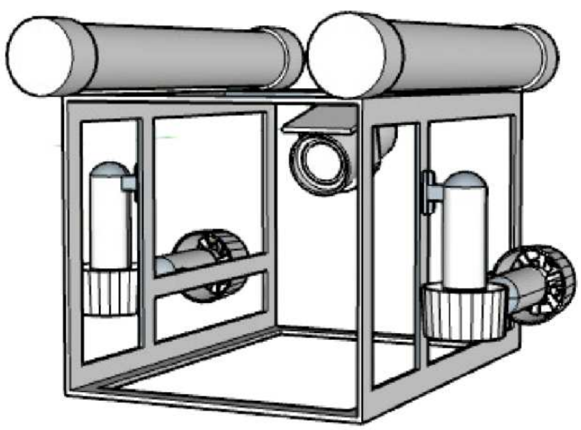
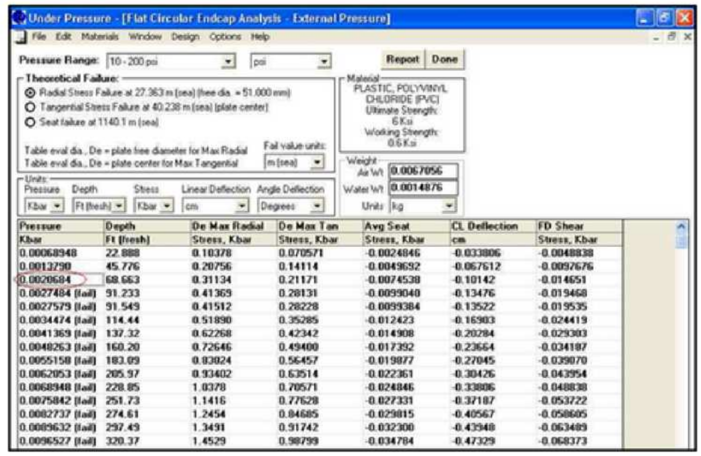


Figure 24: CAD software (N.fillier, 2024)

Buoyancy System

To control the vertical motion of the ROV, the company decided to use a system of buoyancy and thrusters. The thrusters provide vertical movement and the buoyancy would provides stability. The company explored several possibilities for the buoyancy. Initially, foam was considered, but it was found that the foam would compress and lose buoyancy as the ROV dived to deeper depths. Common polystyrene, for example, yields 10% deformation at 100 kilopascals of pressure. (Figure 38) This deformation would compromise the buoyancy of the ROV. As an alternative, the company decided to use a hollow pipe for floatation as it is more resistant to compression. To test this theory a we used a software called Under Pressure 4.5, which is Commonly used as an engineering design tool to aid in the design of pressure housings and pressure vessels in the marine industry. The software evaluates structural capabilities, deflections and weights of common pressure vessels.

The data reported (figure 25) that a radial stress failure would occur at the endcaps if exceeding 0.0021013 kbar (plate center) of pressure. This force and subsequent failure would occur at 21 meters (69 feet) below sea level, which is deeper than the operating capabilities of the ROV.



Pressure Kbar	Depth Ft (fresh)	De Max Radial Stress, Kbar	De Max Tan Stress, Kbar	Avg Seat Stress, Kbar	CL Deflection cm	FD Shear Stress, Kbar
0.00068948	22.888	0.10378	0.070571	-0.0024846	-0.033806	-0.0048838
0.0013790	45.776	0.20756	0.14114	-0.0049692	-0.067612	-0.0097676
0.0020684	68.663	0.31134	0.21171	-0.0074538	-0.10142	-0.014651
0.0027484 (fail)	91.233	0.41369	0.28131	-0.0099040	-0.13476	-0.019468
0.0027579 (fail)	91.549	0.41512	0.28228	-0.0099384	-0.13522	-0.019535
0.0034474 (fail)	114.44	0.51890	0.35285	-0.012423	-0.16903	-0.024419
0.0041369 (fail)	137.32	0.62268	0.42342	-0.014908	-0.20284	-0.029303
0.0048263 (fail)	160.20	0.72646	0.49400	-0.017392	-0.23664	-0.034187
0.0055158 (fail)	183.09	0.83024	0.56457	-0.019877	-0.27045	-0.039070
0.0062053 (fail)	205.97	0.93402	0.63514	-0.022361	-0.30426	-0.043954
0.0068948 (fail)	228.85	1.0378	0.70571	-0.024846	-0.33806	-0.048838
0.0075842 (fail)	251.73	1.1416	0.77628	-0.027331	-0.37187	-0.053722
0.0082737 (fail)	274.61	1.2454	0.84685	-0.029815	-0.40567	-0.058605
0.0089632 (fail)	297.49	1.3491	0.91742	-0.032300	-0.43948	-0.063489
0.0096527 (fail)	320.37	1.4529	0.98799	-0.034784	-0.47329	-0.068373

Figure 25: Under Pressure screenshot (N. Poole, 2024).

Buoyancy

To achieve vertical stability and a state of neutral buoyancy, the gravitational force (Fg) experienced by the ROV had to be equal to the buoyant forces (Fb1 and Fb2). At a mass of 8.6 kg when in water it was calculated that Pavona needed a vessel consisting of 0.0083 m_3 volume. This is achieved by using two 0.51m long, 12cmO.D. schedule 40 PVC pipe and endcaps. The pipes were secured atop of the vehicle. With the bulk of the vehicular mass hanging below the buoyancy makes the ROV very stable.

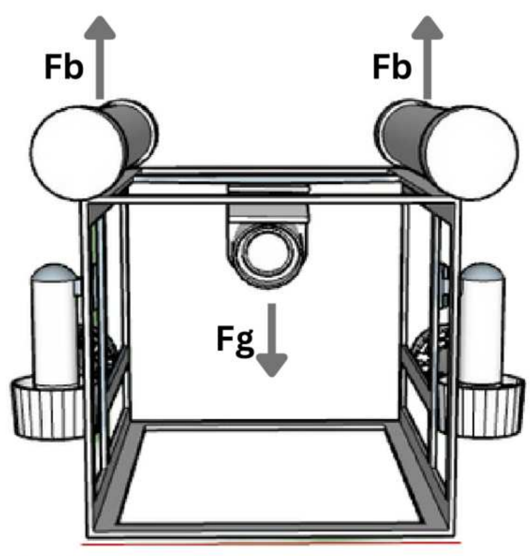


Figure 26: Cosmos Flow Works (N. Reid, 2024)

Camera

A high quality camera system is a vital requirement of any ROV. The company worked closely with a local ROV camera production company, SubC Imaging, to select the perfect camera for Pavona. An added bonus was that SubC Imaging, would be available to provide immediate tech support and assistance if needed. The Angler model camera entails digital noise reduction, back light compensation and highlight compensation which result in a clear and sharp image. The camera has an underwater view angle of 80 degrees and the ability to operate in low light conditions of 0.0001 Lux. It boasts a resolution of 1020 x 580 pixels, a sapphire lens, and waterproof to depths up to 500m.

Figure 27: Camera (Sub C Imaging, 2024)

Camera Positioning

Given the 80 degree field of view, simple trigonometry was used to determine an equation for camera position (L) and optimal viewing. $L=x\cdot\cot\theta$, where W is the width of the ROV, $x=1/2W$, and L is the distance from the lens to the front of the ROV and θ is the field of view. It was calculated the the camera would be placed, L= 0.32m from the front edge of the ROV.

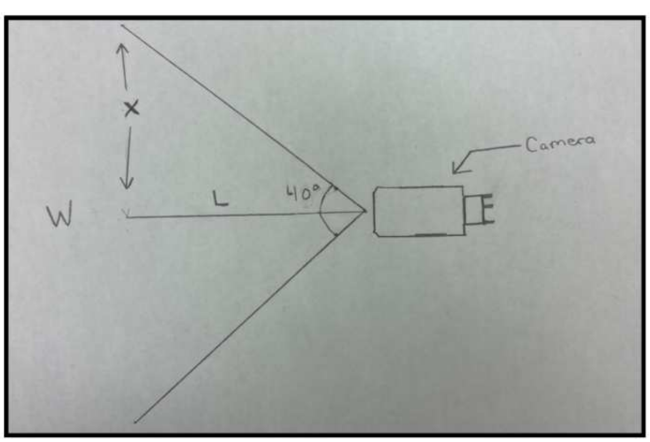


Figure 28: Feild of view sketch (N. Reid , 2024)

Tools (Payload Tools)

The company was challenged by the MATE to develop a specialized ROV for coral restoration and preservation. Cougar Robotics adapted a very unique approach to accomplishing mission tasks.   While most ROVs commonly feature a gripper for handling tasks, Cougar Robotics decided to take adapt a **Task-focused, Payload** strategy. Instead, designing a specific tool to complete each task.   This involved developing distinct tools tailored to each specific task. Inspiration was drawn from the diverse marine life found in the ocean and coral reefs. The following pages showcase these unique tools.

Quick Connect System

To compliment the task focused, payload approach, the company designed and constructed a quick-release tool attachment system. This system allows the ROV to be completely modular. Within seconds a user can interchange or reposition tools with ease.

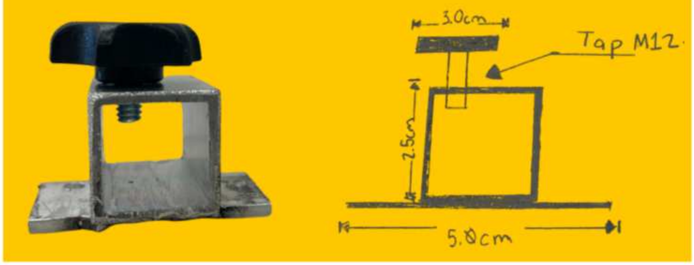


Figure 29: Quick Connect (I. Dalton, 2024)

Manta Ray

The Manta Ray is an ingenious tool that is used to connect the multifunctional node to the recovery line. It was important to create a tool that could both guide the attachment system and connect to its target. The company took inspiration from the aquatic creature of the same name. The Manta Ray has a unique feeding

Figure 30: A Manta Ray (UIG via Getty Images, 2024)

technique, where it uses its large cephalic fins, to guide food towards its mouth. This feeding technique became an inspiration for the ROV end effector. A carabiner and an alignment rod would provide the perfect solution. Just as the manta ray uses it's curved fins to guide prey, the curved carabineer and attached rod would allow easy connection to the node. The oversized 10cm carabiner, was attached to two sections of 30cm aluminum flat bar. The tool is attached to the ROV using the companies quick connection system.

Figure 31: The Manta Ray (N. Fillier, 2024)

Reef Lobster

Living amongst the coral in warmer climates, the Reef Lobster is a remarkable creature. Measuring less than 13cm , these lobsters only hunt at night. Unlike other lobster they have claws only on the first pair of pereiopods. They use these claws to capture food and tightly hold their prey with an extreme force giving its small size.

Figure 32: A Reef lobster (Candy Corals, 2024)

As a part of the competition mission the company was tasked with transporting a sample of coral. The coral was constructed from a piece of PVC pipe. The challenge would be to both collect the coral and hold it tightly for transport. A tool was constructed from an inverted funnel which acts as an alignment mechanism to guide itself onto the coral. Taking inspiration from the reef lobster, a claw mechanism was added to secure the sample. The claw was constructed from a 12 V dc motor and pivoting latch. Once the metal arm is rotated into position, the coral is fully supported from underneath. Using these mechanisms, the Reef Lobster makes the attachment, transportation, and implantation a trivial task. Once the desired location is reached, pilots simply need to lower the coral into the desired area of implantation and open the latch. This frees the coral safely implanting it into its new home.

Figure 33: The Reef Lobster (M.Spurrell, 2024)

Mandarin Fish

The Mandarin fish, named for its extremely vivid coloration is a remarkable species and lives along the coral reefs of Australia. Also, know has the coral reefs 'bottom feeder' it uses its large pelvic fins to 'walk' along the seafloor. Through slow and precise movements it has developed an highly efficient feeding technique. Its stealthy approach and capacity to sweep prey off the ocean floor inspired the construction of one of the ROV's tools.

Figure 34: A Mandarin Fish (Two Fin Divers, 2024)

The ‘Mandarin FIsh’ is tasked with transporting the power connector and to effectively plug it into the SMART cable repeater. To complete this task the company constructed a tool from a PVC Tee, 12 V DC motor and a sheet-metal catch mechanism. The top of PVC tee was carved into an intricate design. It’s shaped in such a way that it can perfectly catch the hook on the power connecter. Once the tool and power connector have mated the locking mechanism is rotated 180 degrees, using a geared motor to secure the power connector. One of this mission’s challenge, is that during competition setup the power connector is facing in the opposite direction of its insertion direction. A second DC motor was added to this tool which is capable of rotating the power connector to match the desired insertion direction.

Figure 35: The Mandarian Fish (N.Reid, 2024)

Yellow Tang

The yellow tang is a species of marine ray-finned fish. Its natural habitat is among shallow reefs within the pacific ocean. Due to it’s astonishing bright yellow appearance the yellow tang has become a very popular fish in home aquariums. One of it’s most interesting features is it’s moderately protruding snout. Using its powerful suction technique, the yellow tang is able to ‘suck’ up its prey,

Figure 36: A Yellow Tang (Waikīkī Aquarium, 2024)

which consist of algae and marine plant material. This characteristic inspired the company to produce it’s own yellow tang with very similar features but a vastly different diet! The mission requires teams to capture a sediment sample in the form of Mexican beach pebbles. To accomplish this task a vacuum comprised of a bilge pump and PVC pipe was constructed. This powerful tool can easily capture and transports its contents of pebbles to the surface. This tool was subject to a series of revisions. Many different profiles for the opening, using different angles of pipe, were tested. It was determined that a 90 degree elbow and a flat opening parallel to the ocean floor maximized successful capture. The company also experimented with different ways of containing the pebble inside the yellow Tang. The company tested a one-way valve and catch bag. After testing these “capture” devices, a simple discovery was made. Keep the pump running!

Figure 37: The Yellow Tang (N. Poole, 2024)

Mimic Octopus

One of the most versatile marine creatures is the Mimic Octopus of the Indopacific coral reef. With its eight tentacles, the mimic octopus is truly versatile and capable of interacting with its surroundings. It is also

Figure 38: A mimic octopus (TFH Magazine, 2024))

also inspired our most versatile and valuable tool. The mimic Octopus found on ROV Pavona is multifunctional and capable of completing many mission tasks. The tool is comprised of a length of aluminum rod, a 12V DC motor, section of rope and magnet. The aluminum rod as been welded into a fork-like design and attached to the

The magnet and rope have been cleverly attached to the ends of the rod. When the motor is rotated the tools becomes very capable of pulling metal pins, turning the irrigation valve pulling levers, and carry various pieces of marine equipment. The tool represents everything that is unique about Cougar robotics. It's simple, creative, innovative and effective.

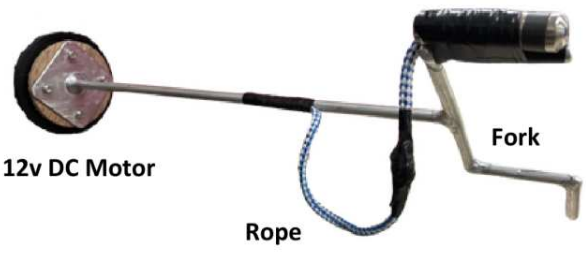


Figure 39: The mimic octopus (M. Spurrell , 2024)

Critical Analysis

Testing

The team performed numerous tests on ROV Pavona, to guarentee its safety and effeciency. The vehicle underwent numerous assesments before entering the water to ensure the protection of the team and the ROV. The electrical wiring was tested before anything else, to guarantee the ROV could be handled safely. When issues occured, the team shut off all power and resolved the problem in a safe and effective manner. Once all electrical work was approved, the end effectors were then evaluated in a dry environment, to confirm that all tools were working as intended. After the ROV was determined to be in perfect working condition, the team tested it in a water tank. First, all tools were verified to be functioning properly. To test the effeciency of the vehicle and the pilots, the team created the props that would be used in the MATE competition. The team then observed as the ROV completed all of the missions required. If any problems arose, all team members had a perspective on the situation, and could each offer different solutions. Once all tools were perfected, the team adjusted the buoyancy of the ROV. The initial discussion was to determine the type of buoyancy. It was decided that the optimal method would be schedule 40 PVC pipe to add buoyancy. A basic calculation was performed to determine the approximate length of PVC pipe needed, and then the vehicle was tested in the water to make microadjustments.

Troubleshooting

Team meetings would commence with a discussion of current problems with ROV Pavona. The exact challenge being faced would be diagnosed, and the entire team would brainstorm possible solutions. Once viable solutions were determined, the team members most skilled in the area would analyze, then conclude and implement the best solution. Then, the ROV would be retested and the prototype would either be adjusted or permanently fitted.

Prototyping

Before anything was built, multiple sketches were made to determine the best ideas. To design the end effectors, the team considered each mission individually and sketched multiple possible tools that could perform the task. Each sketch was peer reviewed by the team, and the best contenders were made as prototypes. All prototypes would then be brought before the team as a proof of concept, and the best tool would then be developed further by team members. Once the permanent utensil was crafted, it was attached to the ROV and tested on land, and then the team would observe it in the water tank. Each team member would observe different issues, and then adjust the tool.

Accounting

Cougar Robotics knew that a competitive budget would be essential for success. It was also important to create an itemized list of all materials used, to guarantee transparency with clients. To start, the team researched the fair market value (FMV) of all the materials which would be needed for the construction of the ROV. This included the framework, control box, motors, tether, camera, and end effectors. It was also considered if materials were purchased, reused, or donated. Then, the values were added to find the total amount the ROV would cost. This provided a comprehensive total for the project, which was then set as the budget. The team constructed a ROV that cost less than this estimate, building a very affordable vehicle. The travel expenses were thoroughly researched before any plans were committed to. Multiple estimates were obtained to determine the most cost effective form of travel. All forms of travel were considered, and the estimated travel expenses were $15000.00. All expenses associated with the ROV and travel were accurate to the estimates determined, and there were no large unexpected charges. The team purchased many items to suit the ROV, but some materials were reused, such as the switches and motors, and some were donated, such as the camera. Refer to appendix C for a comprehensive list of all material used and their source. The expenses of the vehicle were covered by the company's income. Team members hosted a bake sale, recycling drive, and canteen to raise funds for the ROV. Estimates of donated materials were accurate with the current FMV. Overall, our budget reflects an accurate and effective use of our resources.

Safety

Cougar Robotics prioritizes safety above all else and maintains a philosophy that safety is the top priority. The company has adhered to the MATE safety standards and constructed ROV Pavona to meet all safety requirements. Cougar Robotics also developed strict safety protocols and procedures (appendix B) to be followed when constructing and operating the ROV. When constructing the vehicle, many tools were used. Before any work was completed with these tools, a thorough safety discussion and demonstration was provided to guarantee that all team members knew how to operate the machinery in a safe manner. The development of ROV Pavona also required electrical wiring. The team was taught by a professional to ensure maximum safety and knowledge when wiring. All electrical work was verified by a supervisor before being tested on land or in water. Whenever the team was constructing the vehicle, the appropriate PPE was used, most commonly safety glasses and hearing protection. When operating the vehicle, all Cougar Robotics members knew the flight plan of the ROV, and their role. To avoid any tripping hazards, one team member is designated to manage the tether and keep it neatly out of the footpath. The tether manager is also responsible for keeping the tether safe in the water, making sure it is not damaged by the ROV itself. In the case of an emergency in the water, the control box is equipped with an emergency shutdown switch to immediately turn off the ROV, mitigating any risks. Although the team at Cougar Robotics is highly trained, ROV Pavona itself has vehicle-specific safety features. The team guaranteed that the ROV has no sharp edges, and the thrusters are shrouded with guards to protect the team. Any potentially dangerous components, such as the thrusters, are clearly marked with caution labels.

Conclusion

The survivability of our coral reefs has massive global effects with potentially fatal outcomes for many species of coral and other marine life. Designing an ROV that could help mitigate the effects of climate change would be a challenge. Six months ago our team was developed when five grade ten students answered the call. At that time, our team had limited knowledge and no experience with ROV's. Constructing and building an ROV from start to finish requires hard work, determination and teamwork. During the next few month we worked tirelessly every day after school, and late into the weekend nights. Our passion and love for what we wanted to accomplish grew into something very special.

Our team had to overcome various hardships, challenges, and innovations to produce an effective product. In the the end, we did it by winning our regional competition!

The sense of pride and accomplishment that comes with completing such a feat has been very satisfying.

The main focus of the company was to not only design an ROV that was functional, but one that was efficient and reliable. ROV Pavona was constructed from common items that are readily available. The switch based controls and systems of nuts, bolts, pins and levers was built entirely by students. Through the use of simple devices, the company has created a product that with a reduced chance of failure and satisfies company standards of safety, reliability, and marketability. We have shown that hard work and innovation conquers all. We are extremely proud of ROV Pavona; and even prouder of the friendships we built. We have loved every moment. The entire process has been extremely rewarding and fulfilling. Thanks for following our journey. See you in Tennessee! *Cougar Robotics*

Figure 40: Robotics Team (M. Spurrell, 2024)

SAFETY CHECK LIST

Cougar Robotics aims to protect its employees by implementing a safety first mentality that will be implemented by all employees

Figure 42: Wearing PPE (M. Spurrell. 2024)
Safety Personal Protective equipment was worn at all times.

Construction Safety Checklist

- Controller power switch is in the off position
- ROV is disconnected from power source
- All Personnel working on the ROV have proper qualifications for shop
- Team members are using safety glasses/other appropriate safety equipment
- Propeller guards are securely fastened
- No corrosive materials or exposed wiring

Operational Safety Checklist

- Controller power switch is in off position
- Fuse is in place (correct amperage)
- ROV is disconnected from power source
- Check ROV for hazards (loose bolts, cracks, buoyancy check)
- No exposed wiring
- Tether is neatly laid out
- Complete resistance check
- Ensure guards are securely fastened
- Check tools for damage
- Step away from ROV and connect to power supply
- Check all switches are working
- Designated personnel to place ROV in water and release
- Turn on power

COUGAR ROBOTICS INC.

CLARENVILLE

Company Information

Cougar Robotics Inc. is an environmental focused company, committed to the U.N Ten challenges - Ten years, one ocean philosophy.

Isaiah Dalton - Company CEO
Grade: 10
Job Roles: Deck Manager & Designer
Career Goal: Mechanical Engineering
Pet Saying: " Don't step on the tether!"

Nathan Fillier - Accounting Manager
Grade: 10
Jab Roles: Pilot & Quality Control
Career Goal: Marine Engineering
Pet Saying: " Are we hitting the wall?"

Natalie Poole - Assistant CEO
Grade: 10
Job Roles: Tool Manager & Graphics
Career Goal: Mechanical Engineering
Pet Saying: "Where's my safety glasse

Nicholas Reid - Human Resources
Grade: 10
Job Roles: Quality Control & Safety
Career Goal: Marine Engineering
Pet Saying: "No, it's your other left!"

Mark Spurrell - Cheif Designer
Grade: 10
Job Roles: Pilot & Electrical Manager
Career Goal: Marine Engineering
Pet Saying: "Which way do I spin it!"

ROV: Pavona

Description of overall vehicle

Frame Material: Aluminum
Mass: 8.6 kg
Propulsion: 12V Thrusters
Speed: 1.1m/s
Buoyancy: 4.1 N
Voltage: 12 V
Length: 0.48m
Width: 0.38m
Height: 0.31m

TETHER MANAGMENT PROTOCOL

The tether management system (TMP) is followed to protect and manage the tether when operating or deploying the ROV

Figure 42 ROV Panova (M. Spurrell. 2024)
Mission 2 Attempt, Task 1. May 4, 2024

- Tether is stored in a safe location
- Tether is neatly coiled to prevent kinks and twisting
- The tether manager is mindful of loose tether while transporting
- Tether is always carried and transported by a sufficient number of people
- Ensure the tether is free of knots and kinks
- Ensure the tether is safely and securely attached to the ROV
- Refrain from stepping on tether to avoid injury and damage
- Always straighten tether prior to mission to improve maneuverability
- Release sufficient tether at the start of the mission to help the speed of the descent
- Make sure there is some slack, but not enough to result in tangling
- Do not pull on the tether
- After the mission is finished, carefully collect the tether and neatly coil it.

BUDGET

SCHOOL: CLARENVILLE HIGH
INSTRUCTOR: MICHAEL SPURRELL

REPORTING PERIOD: 1/12/2024 5/3/2024

DATE	TYPE	CATAGEORY	EXPENSE	DESCRIPTION	NOTES	AMOUNT	BALANCE
1/12/24	Purchased	Hardware	PVC pipe	PVC 12 foot schedule 20 pipe	Used for bouancy	$60.99	$60.99
1/16/24	Purchased	Hardware	Aluminium	6 foot aluminium flat bar	Used for frame	$30.99	$91.98
1/18/24	Donation	Eletronics	Tether	Leoni 45 foot tether	Main tether	Donation	$91.98
1/26/24	Purchased	Hardware	Aluminium bar	8 feet Aluminium angle iron	Used for the reef lobster	$40.99	$132.97
2/9/24	Purchased	Hardware	Sodering wire	sodering wire	Sodering camera	$6.99	$137.96
2/11/24	Purchased	Tools	Heatgun	Lincion eletric Heat gun	Used for heat shrink	$65.99	$202.95
2/14/24	Reused	Eletronics	Thrusters	BTD 150 12 volt thrusters	For ROV propulsion	Reused	$202.94
2/18/24	Purchased	Hardwre	Camera	Subc imaging 90 deg. camera	Main Camera	$5099.99	$5301.93
2/29/24	Purchased	Hardeare	End Caps	3 inch end caps	Cover for bouancy	$8.99	$5210.92
3/1/24	Purchased	Hardware	PVC tee	PVC tee reducer	Construction of props	$2.99	$5212.91
3/4/24	Purchased	Hardware	Silica Gel packets	100 silica gel packets	Used for soaking water	$15.99	$5227.90
3/5/24	Purchased	Hardware	Foam	ROV marine foam	Used for bouancy	$310.99	$5527.89
3/12/14	Reused	Hardware	Solid works Program	Cosmos flow works	Drag anyalis	Reused	$5527.88
3/13/24	Purchased	Hardware	Magnets	Cow magnet	Used as an end effector	$20.99	$5547.87
3/17/24	Purchased	Hardware	Epoxy	Plastic weld epoxy	General construction	$12.99	$5558.86
3/30/24	Purchased	Hardware	Tape	Electric tape	General construction	$6.99	$5565.85
4/13/14	Purchased	Hardware	temperature sensor	Temperature senor	Measuring temperature	$15.99	$5580.84
4/19/24	Purchased	Eletronics	U-brackets	#3 U-brackets	Teather mounting	$9.99	$5589.83
4/19/24	Travel	Hardware	Travel	Cost to drive to St Jhons	Used for camera mount	$35.99	$5624.82
4/23/24	Purchased	Travel	Bildge pump	500GPH	used for end effctor	$50.99	$5674.81
4/28/24	Purchased	Elertonics	Switches	4 single dipole switch	Used for controler	$20.99	$5694.80
5/1/24	Purchased	Hardware	PVC pipe	6 foot 3inch schedule 20 PVC	Used for bouancy	$30.99	$5724.79
5/3/24	Purchased	Hardware	Epoxy	Plastic weld Expoxy	General construction	$12.99	$5736.78
5/4/24	Cash donated	General		Funds donated by parent support	For travel cost	$550.99	$6286.77

Total raised ($550)USD
Total spent ($6285) USD
Final Balance ($5735)USD

GRAND TOTAL **$185 USD**

Cougar Robotics

https://cougarrobotics.my.canva.site
709-466-2713
Clarenville, Newfoundland Canada

PROJECT COSTING

SCHOOL: CLARENVILLE HIGH
INSTRUCTOR: MICHAEL SPURRELL

REPORTING PERIOD: 1/12/2024 5/3/2024

TYPE	CATAGEORY	DESCRIPTION	AMOUNT (USD)	BALANCE (USD)
Purchased	Hardware	PVC pipe	$140	$140
Purchased	Hardware	Epoxy	$50	$50
Donated	Electronics	Camera	$5000	-
Purchased	Hardware	Lexan	$80	$80
Purchased	Hardware	Aluminum	$70	$70
Purchased	Tools	Soldering Iron	$120	$120
Reused	Electronics	Motor	$60	-
Purchased	Hardware	Controller	$50	$50
Purchased	Hardware	Angle iron	$25	$25
Purchased	Hardware	Foam	$80	$80
Purchased	Hardware	Sheet metal	$85	85
Donated	Donation	Nuts & Bolts	$550	$25

Total income ($550) USD
Total spent ($5700) USD
Reused ($5060) USD

GRAND TOTAL $90 USD

Cougar Robotics

https://cougarrobotics.my.canva.site
709-466-2713
Clarenville, Newfoundland
Canada

FLIGHT PLAN

To efficiently, and reliably protect ocean ecosystems.

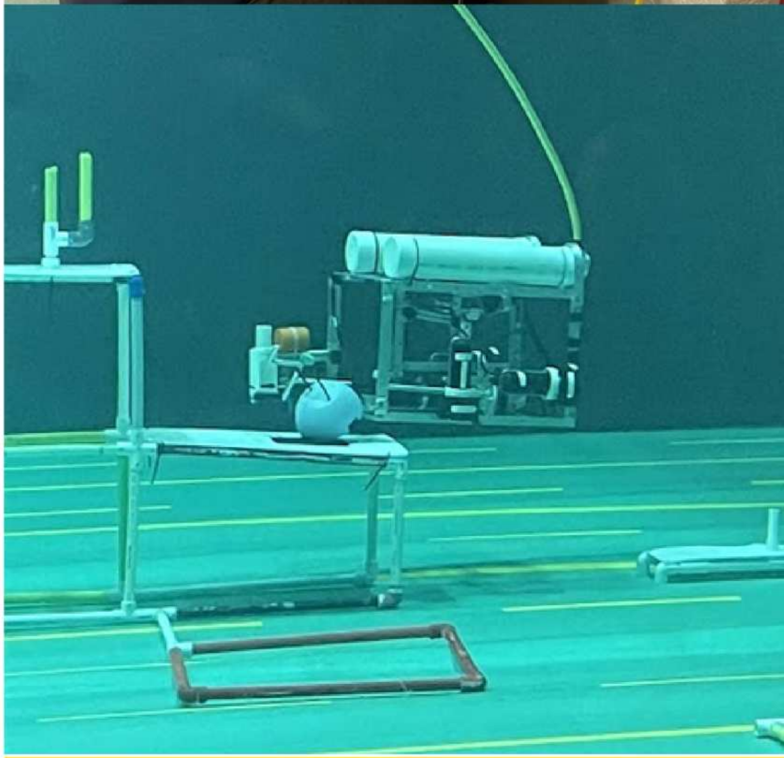


Figure 43: ROV Panova (M. Spurrell. 2024)
Mission 2 Attempt, Task 2. May 4, 2024

Descent 1

- ROV Pavona will deploy Mate Floats and the measuring tool
- Using the Mimic Octopus the first pin will be pulled on the multi-functional node and note the failed node
- Using the magnet attachment, Pavona will pull the second pin
- Using the measuring tool, Pavona will take photos for on deck calculation, then move the branching and brain coral to correct spots.
- Pavona will then collect the measuring tool, acoustic receiver and mate floats before returning

Descent 2

- Pavona will drop the acoustic doppler and irrational system in correct place
- The hose will be placed around branching coral and then the ROV will turn the valve.
- Pavona will use the yellow tang to collect the Mexican beach pebbles

Descent 3

- Reef Lobster will be swapped with Mandarin Fish
- Pavona will drive through the waypoints and deploy the smart repeater
- Temperature will then be taken
- The power connector will be placed

Appendix F: Photo Credits

Figure 1: ROV Pavona at Regionals (M. Spurrell, 2024) Page 2
ROV Pavona completing Task at Regional Competition

Figure 2: ROV Side Top and isometric view (M.Spurrell, 2024) Page 3
ROV pavona with all tools.

Figure 3: Team Photo (M. Spurrell, 2024) Page 3
Group Photo of Cougar Robotics.

Figure 4: Design Process (N. Poole, 2024) Page 4
The teams 6 step Design Process.

Figure 5: Brainstorming (N. Poole, 2024) Page 4
Picture of the team at a late night brainstorming session.

Figure 6: ROV frontal veiw and tools (N. Reid, 2024) Page 5

Figure 7: ROV materials (I. Dalton, 2024) Page 5
Materials that ROV Pavona is built with

Figure 8: ROV Frame design (I.Dalton, 2024)Page 5

Figure 9: Drag data (N. Poole, 2024) Page 5

Figure 10: SolidWorks Drag Analysis (I . Dalton, 2024) Page 6
ROV Pavona placed into Fluid Flow Anyalisis to calculate drag.

Figure 11: CAD Design (I. Dalton, 2024) Page 6
A CAD design of ROV Pavona's controller.

Figure 12: CAD Frame (M. Spurrell, 2024) Page 6

Figure 13: Controller (N. Poole, 2024) Page 6
Picture of ROV Pavonas Controller

Figure 14: Motor Controller (I. Dalton, 2024) Page 6

Figure 15: Power cable and Inside controller
(I. Dalton, 2024) Page 7
The inner Workings of ROV Pavona's Controller

Figure 16: Figure 15: Fuse (N. Poole, 2024) Page 7

Figure 17: Tether Diagramme (N. Fillier, 2024) Page7

Figure 18: Tether Cross Section (N. Poole 2024) Page 7

Figure 19: Tether Connection (N. Poole 2024) Page 9

Figure 20: Bilge Pump. (N. Reid 2024) Page 9

Figure 21: BTD-150 Thruster (N.Fillier, 2024) Page 9

Figure 22 : Thruster analysis (N. Poole, 2024) Page 9

Figure 23: CAD Model (I. Dalton, 2024) Page 9
Sketch of ROV Pavona frame

Figure 24: CAD software (N.fillier, 2024) Page 10
CAD model of ROV Pavona's frame.

Figure 25: Under Pressure Screenshot (N. Poole, 2024) Page 10

Figure 26: Cosmos Flow Works (N. Reid, 2024) Page 10
Drag simulation of ROV Pavona.

Figure 27: Camera (Sub C Imaging, 2024) Page 11
3d model of camera

Figure 28: FIeld of view sketch (N.Reid, 2024) Page 11

Figure 29: Quick Connect Design Process
(I. Dalton, 2024) Page 11

Figure 30: A Manta Ray (UIG Via Getty Images) Page 11

Figure 31: The Manta Ray (N. Fillier, 2024) Page 12
The manta is a tool that connects the recovery line to the multi function node

Figure 32: A Reef Lobster (Candy Corals, 2024) Page 12

Figure 33: The Reef Lobster (M.Spurrell, 2024) Page 12
Allows The company to easliy transport the branchng coral

Figure 34: A Mandarain Fish (Two Fin Divers, 2024) Page 12

Figure 35: The Mandarian Fish (N.Reid, 2024) Page 13
Allows the company to transport the power connector

Figure 36: A Yellow Tang (Waikiki Aquarium, 2024) Page 13

Figure 37: The Yellow Tang (N. Poole, 2024). Page 13
Allows the company to transport sediment samples

Figure 38: A mimic octopus (THF Magazine, 2024). Page 13

Figure 39: The Mimic Octopus (M.Spurrell, 2024) Page 14
The Mimic Octapus is our most versitle tool

Figure 40: Robotics Team (M.spurrell, 2024) Page 15

Figure 41: Pavona Coral (M. Spurrell, 2024) Page 15
Type of coral ROV Pavona is named after

Figure 42: Robotics ROV Pavona (M.Spurrell, 2024) Page 15
ROV Pavona during mission attempt.

Figure 43: ROV Panova (M. Spurrell, 2024) Page 20
Mission 2 Attempt, Task 1. May 4, 2024

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