SEAFOX INVENTIVE
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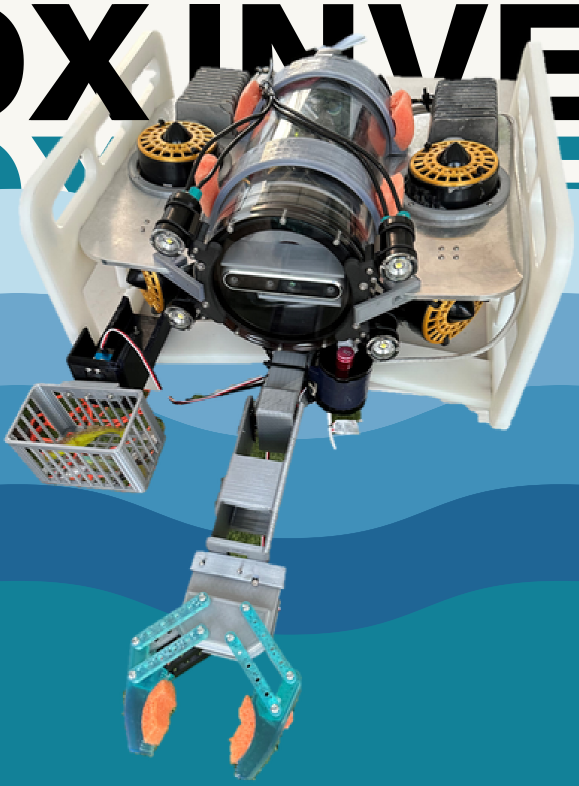

CETYS UNIVERSITY
MEXICALI, BAJA CALIFORNIA, MEXICO
MATE 2023

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INTRODUCTION

ABSTRACT

This document is an overview of the design and manufacturing of the ROV prototype that SeaFox Inventive presents for the MATE 2023 competition. This ROV is designed to carry out missions in environments such as oceans, rivers, lakes or dams. This will be the 6th generation at CETYS University in which a team of students meets to design and build an ROV, in addition to working with social responsibility. The social responsibility activity that we carried out during this season was to design a course to promote STEM culture and innovation in young people from low-income high schools.

The team is eager to compete and show that the knowledge gained from previous iterations of the SeaFox Inventive team and demonstrating their hard work will yield great results. The lessons learned in recent years, the effort and good organization have made it possible for SeaFox Inventive to proudly announce its new ROV called: 'SeaFox-JSL'. In memory of Dr. Jorge Sosa Lopez, a beloved professor and mentor who passed away at the end of 2022.

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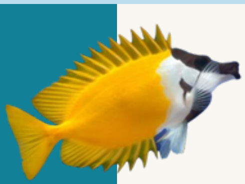


DESIGN RATIONALE & DESIGN PROCESS

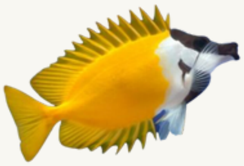
Fig. 1. SeaFox-JSL mechanical design review

The SeaFox-JSL prototype defines a new generation for the SeaFox Inventive team, since it is a fresh team with new members, including some who have been involved in this project for a while, but mostly because the new members had not previously had the opportunity to be in contact with ROVs, making their contribution even more remarkable.

This motivated us to attend to the competition of this new season and work as hard as possible. Having the opportunity to go there again last year, and learn from other teams was indispensable for the development of this year's prototype. Once the season started, the team was immensely excited about experiencing again what they already had, so they started working. The main objective of the SeaFox Inventive team was to assist to the competition, so we already knew what we had to do in order to pursue and achieve our goal.

First, each team member individually studied and read the competition manual and understood the problems that needed to be solved. Then with the previous feedback from the last competition, the team brainstormed ideas of what they could design to solve the tasks from the manual. Finally, with these meetings, the team decided that they wanted a more manageable, versatile, simple, and efficient ROV, and that any necessary design modifications would be easily implemented for all the members using their creativity and knowledge in the design area. Equipped with the task descriptions from the manual and a clear design direction, the team commenced their work.

After the design stage, the team began to look for economic support and activities that could raise funds for this project. After getting some seed funding, they started ordering the vehicle components and as soon as they arrived, the team started manufacturing, designing, and coding the SeaFox-JSL. Finally, after months of dedicated effort, the SeaFox-JSL was born, fully constructed, poised to be submerged in water, and ready to complete its assigned tasks, as demonstrated in the qualification video.



Mechanical Design

The main goals of this year's ROV design are versatility, simplicity, and efficient manufacturing. Any necessary design modifications can be easily implemented. The focus is on creating a sleeker frame and reducing the overall weight of the mechanical components.

During the initial design phase, careful attention was given to weight distribution to maintain a centered and balanced center of mass. This approach minimized the need for additional ballast to achieve neutral buoyancy.

Flow simulations were conducted after selecting the initial design, leading to modifications that simplified manufacturing processes and improved cost efficiency. Efforts were also made to optimize the ROV's fluid mechanics performance. Precise blueprints were created once the final mechanical design was revised, and a meticulous manufacturing plan was executed.

The manufacturing process began with generating customized G-codes for CNC manufacturing of the HDPE plates, reducing the need for manual labor. Finally, the electronics watertight enclosure was securely installed, ensuring seamless integration into the system.

Frame

One of the most important components is the frame. In past years, the materials used for the physical structure of the ROV would either be mostly metallic parts or components made of high-density polyethylene (HDPE). After carefully analyzing different materials and determining the optimal combination, it was concluded that using both HDPE and aluminum 6061-T6 was the best choice for this year’s ROV.

HDPE offers a great balance in weight and strength, while aluminum has low density, high durability, and can be easily machined. Aluminum 6061-T6 was used to create two plates that could support the thrusters’ weight and the watertight enclosure, one in each bumper. HDPE was used to create the rest of the framework; this included the two side bumpers and the lower base of the ROV, where a robotic arm was installed.

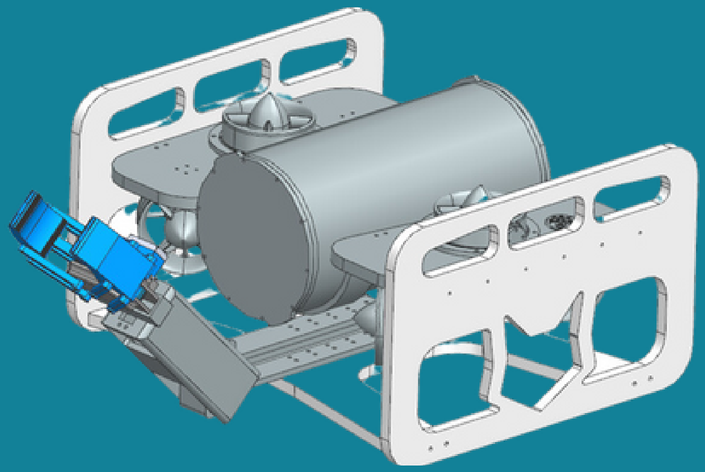


Fig. 2. SeaFox-JSL Mechanical Design

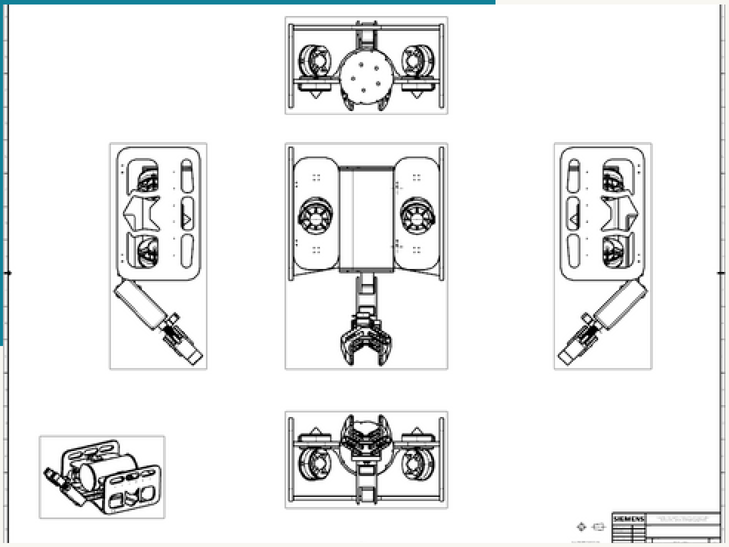
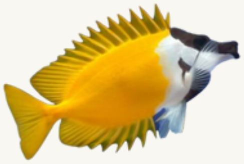


Fig. 3. SeaFox-JSL Mechanical Design Drawing



Buoyancy and Stability

As an underwater ROV, we need to be sure that the watertight enclosure remains free of leaks to maintain water outside, far from our electronic components. This creates a lot of positive buoyancy which is reduced by the weight of each component we added to the ROV. We took into consideration how the headlights, frames, thrusters, grippers, and electrical components affected our buoyancy.

Even with everything assembled, we needed to add weight on the front of the ROV since we had to reduce the positive buoyancy left in that area. These added weights are made out of iron and located at the front of our ROV, having enough buoyancy to complete our tasks efficiently.

Propulsion

The SeaFox-JSL vehicle utilizes the BlueRobotics T100 thrusters known for their exceptional performance, ease of installation, and low maintenance requirements compared to modified brushless motors.

These thrusters offer reliable maneuverability, streamlined integration, and optimal operational efficiency due to their robust construction and specifically designed components. By incorporating the T100 thrusters, we have achieved a propulsion system that delivers dependable performance while simplifying the deployment and maintenance processes of underwater ROVs.

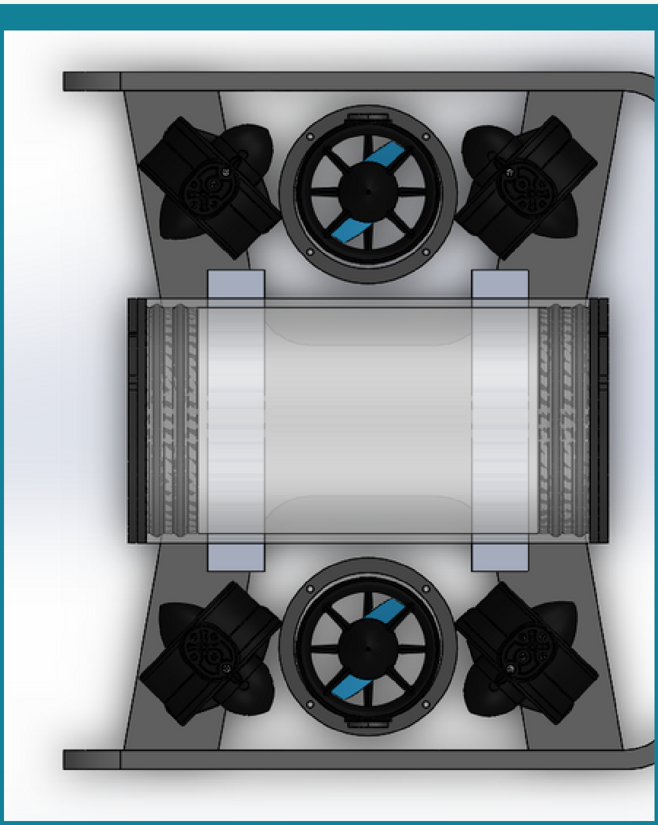


Fig. 4. SeaFox-JSL Mechanical Design Top View

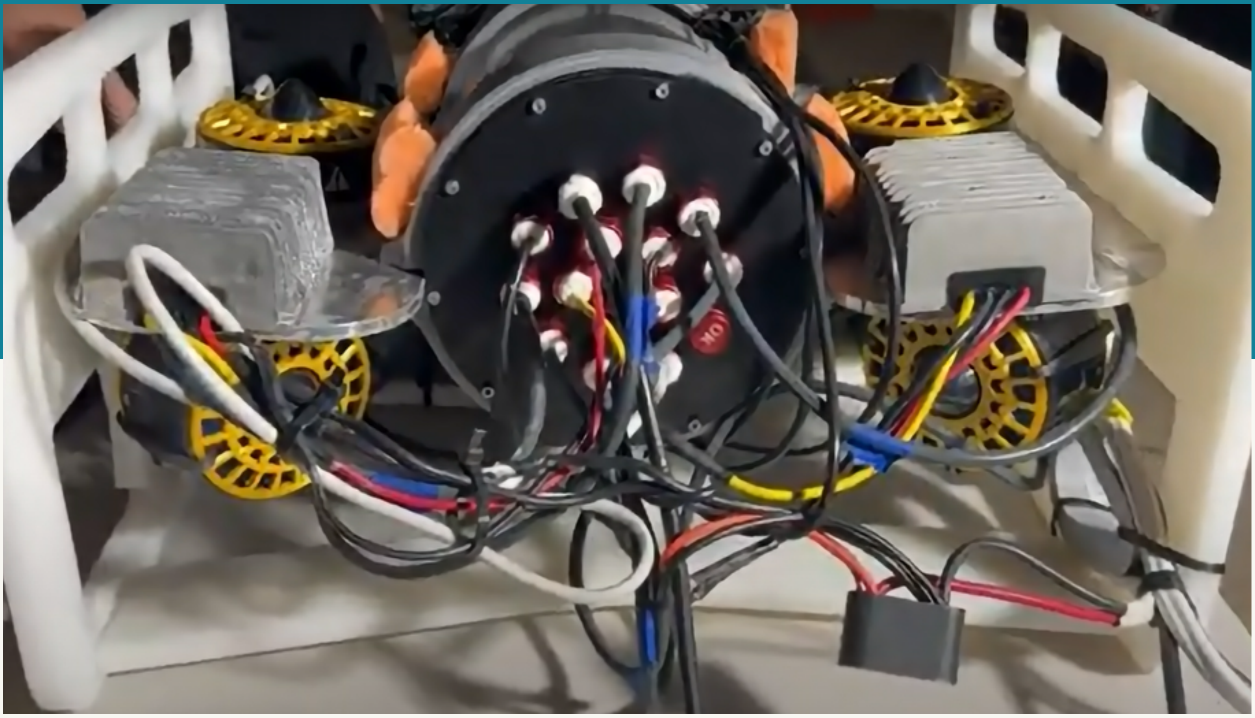


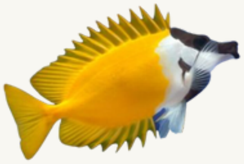
Fig. 5. Watertight enclosure and sealing

Enclosure and Sealing

To ensure proper encapsulation of the electronics within our remotely operated vehicle (ROV), we opted to utilize an 6" enclosure manufactured by BlueRobotics. This decision was made based on the challenges encountered by our team in previous years in effectively sealing their enclosures, thus prompting us to seek a reliable solution.

To facilitate the integration of the electronics panel with the ROV's thrusters, sensors, and servos, a series of 15 bores were meticulously drilled into the aluminum cap of the enclosure. These bores serve as connection points for the various cables associated with these components.

To maintain the integrity of the enclosure and prevent any water ingress, all cables that pass through the enclosure are meticulously sealed using penetrators and marine-grade epoxy. This meticulous sealing process ensures that the electrical connections remain protected from moisture and other external elements that could compromise the functionality and reliability of the ROV's electronics system.



Electrical Components

Power Distribution

The Seafox ROV-JSL functions with a 48VDC and a 30 A power supply. There is no voltage conversion in the tether from the surface source until the enclosure in the backside of the ROV. Two 48VDC to 12VDC regulators power the six thrusters (T100), providing the ROV with its movement options, the ESC (Electronic Speed Controllers) and the Lumen Subsea Headlights, using a considerable amount of the current flow. There are two other 12 VDC to 5VDC regulators that supply energy through the main chamber to the control section and communication systems. These systems include servomotors, a microcomputer NVIDIA Jetson Nano and a microcontroller Raspberry Pi Pico, with its proper SKU15275 shield that organizes signals properly.

Communication

The Seafox JSL conveniently has an ethernet cable running through its tether, which allows the team to communicate the Jetson Nano vehicle computer with the control system computer at the surface.

The communication system lets the scripts and the GUI send data over TCP/IP protocol, previously creating topics through scripts in the Jetson Nano and sending data to those topics from the control station's computer.

Control System

The control system uses an NVIDIA Jetson Nano, a microcomputer that has four USB ports available, used to power the two cameras installed in the ROV and the Raspberry Pi Pico, two HDMI ports, and 1 ethernet port. The two cameras send the video information to the PC in the surface control station through the Jetson Nano via the ethernet cable, similarly, this cable is used to communicate with both computers and to control the ROV's movement with the use of a Raspberry Pi Pico to send control signals to the ESCs, thus controlling the thrusters.

Tether

The tether used by this prototype consists of a power supply cable and one communication cable, the ethernet cable. The wire gauge charts were reviewed to evaluate the power cable that was most suited for the 30 A current needed.

Fig. 6. Rolled Tether

An ANCOR Marine Grade 10 AWG CAT6 power cable was selected due to its high endurance and performance. To maintain the two cables together heat shrink tubing was used all along the tether. To supply the correct amount of voltage to the ROV, **the cables that connect the regulators outside the watertight enclosure needed to be tin soldered with the power supplies** and isolate the soldered cables with pieces of heat shrink, epoxy was applied to every piece of heat shrink to ensure waterproofing.

Vision

Seafox ROV JSL operates with two cameras, one that is pointing forward, allowing visibility of the gripper, also used for navigation. The second one provides the pilot with an ample view of the basket servo extension, All cameras are connected to the Jetson Nano via USB.

The first camera is mounted inside the watertight enclosure of the ROV, and the second one goes below the vehicle, inside a different and smaller watertight enclosure.

Control Station

In this iteration of the Seafox ROV, a PlayStation 5 controller is used due to its increased sensibility and better precision when controlling the vehicles' movement. The control station consists of a laptop computer with an attached PS5 controller and a secondary monitor where the two cameras' video is shown. A timer starts when the ROV starts moving and an s-curve acceleration system is used to limit the current and prevent drastic voltage changes and current spikes.

Fig. 7. Control Station

Onboard Software

Our system employs the Nvidia Jetson Nano microcomputer as the primary computational unit due to its exceptional compatibility with the Robot Operating System (ROS). The Jetson Nano operates on Ubuntu 18.04, serving as the central node in our network. It accepts messages relayed from the graphical user interface (GUI), facilitated by roslibjs, a core JavaScript library that enables browser-based interaction with ROS.

These messages are subsequently processed and dispatched to the Raspberry Pi Pico, powered by the RP2040 microcontroller, which serves as a bridge between the Jetson Nano's software and the physical hardware components like servos, thrusters, lights, and leak detectors.

The choice of RP2040 is strategically based on its speed, cost-effectiveness, and impressive number of available PWM pins. This microcontroller is equipped with a robust dual-core ARM Cortex M0+ processor operating at speeds up to 133 MHz, and it features a built-in PWM module capable of managing up to 16 independent PWM outputs.

The provision of these functionalities significantly streamlines the electronic design process and augments the complexity of operations the software can handle.

We've developed custom classes using the RP2040's C++ SDK, thus enabling direct control over the thrusters, servos, lights, and leak sensors. Communication between the RP2040 and the Jetson Nano is handled via the serial port, and we have integrated rosserial to ensure seamless communication with ROS.

Our onboard software is designed to receive and process geometry twist messages from the GUI, which express velocity as two distinct vectors: linear and angular. Upon receiving these messages, the software computes the requisite speed for each thruster to attain the specified velocity.

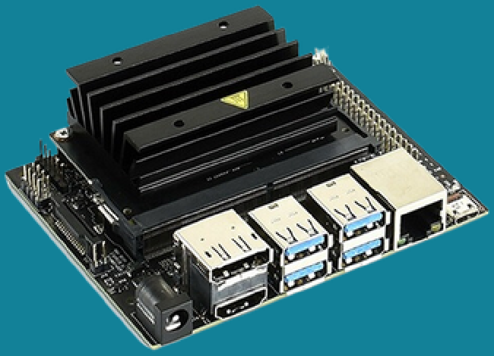


Fig. 8. Nvidia Jetson Nano

To ensure the smooth operation of the ROV, it incorporates an s-curve algorithm before dispatching these speed commands to the RP2040. This algorithm ensures smooth acceleration and deceleration, which effectively minimizes current spikes, thereby safeguarding the hardware from potential damage. This careful management of velocity transition also enables us to operate the ROV at significantly higher speeds while maintaining the system's overall safety and reliability.

We use Intel's RealSense camera D435 for capturing images in our system. These images are processed using the usb_cam package, which is a ROS driver specifically designed for USB cameras. The package reads images from the camera and publishes them using image_transport. This ROS package offers a simplified interface to subscribe to and publish images within the ROS ecosystem.

To facilitate access to these messages via the GUI, we implement rosBridge and the web_video_server. These tools create a bridge between ROS and web applications, effectively providing a video stream accessible via HTTP. This setup allows for real-time, web-based monitoring of the images captured by the Intel RealSense camera.

Graphical user interface

We devised a sophisticated graphical interface (GUI) providing comprehensive access to all the requisite elements for task fulfillment. At the inception of this interface, there is a capability to capture multiple perspectives via integrated cameras. Additionally, the interface is equipped with a precise timing mechanism to monitor time allocation for individual challenges, alongside an error notification system for proactive fault detection.

VIDIOC_S_FMT error 5, Input/output error

Fig. 9. Control Station

In the settings segment of the interface, we established pathways to manipulate motor speed, adjust the ROS IP, and modify control settings to enhance adaptability across varied tasks.

Our technological solution was developed employing React JS. Our decision to adopt this library was predominantly due to its array of reusable components, fostering consistent design throughout the interface. As previously mentioned, we utilize roslibjs to handle the transmission and reception of messages between the GUI and ROS, enabling real-time interaction with the system.

To harness the functionality of a PS controller, we employ the Gamepad API. This API allows us to read input from the controller, which is then processed into a geometry twist command. This command represents the desired movement direction and speed for the ROV. Once processed, these commands are sent directly to the Jetson Nano.

Software Diagram

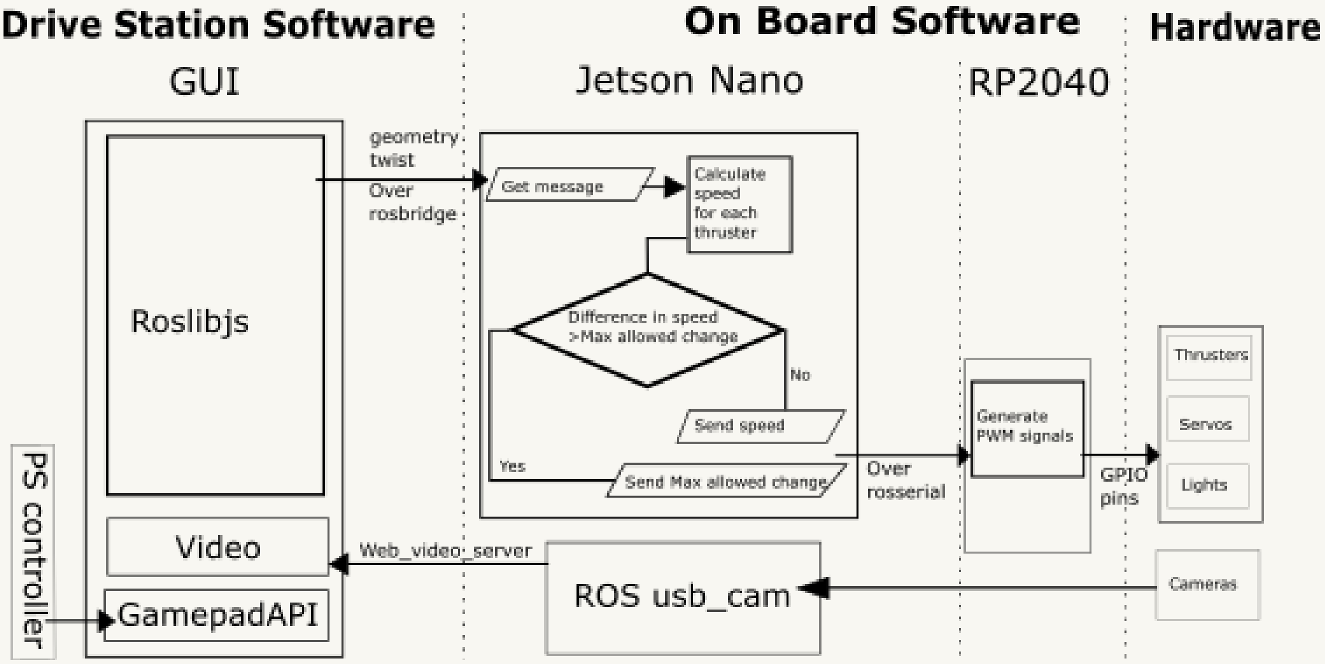
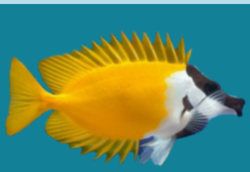


Fig. 10. Software Diagram

Payloads



Robotic Arm

The SeaFox-JSL has an articulated robotic arm with two links and a gripper, this arm can move to point the arm down or towards the front of the vehicle and has the option to move the gripper with the wrist. This was designed and 3D printed for optimum grip and the ability to be powered with waterproof servos, adding a mix of materials to produce malleable plastic so it can grip objects more easily.

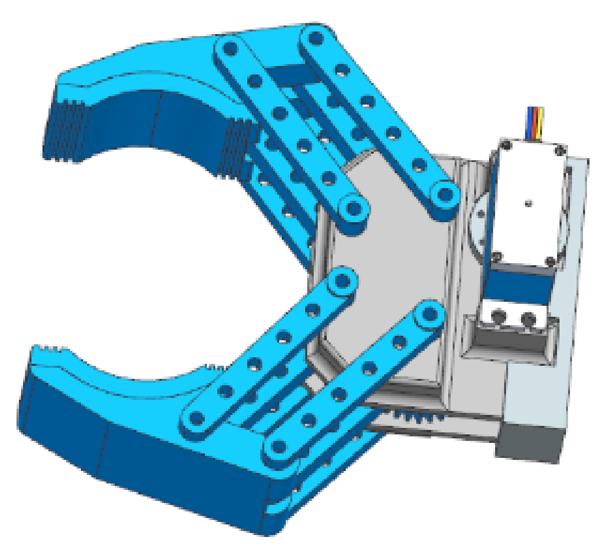


Fig. 11. Gripper

Degrees of freedom

For the mobility of the gripper, 3 servos were coupled, the first servo was used to allow the gripper to open and close the hand, the second was used to rotate the wrist 180° and the third servo was used to move the arm in a full 90° range.

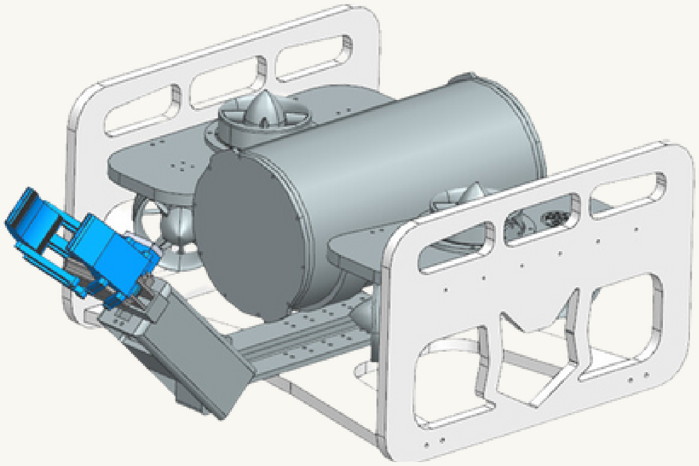


Fig. 13. ROV JSL - Robotic Arm

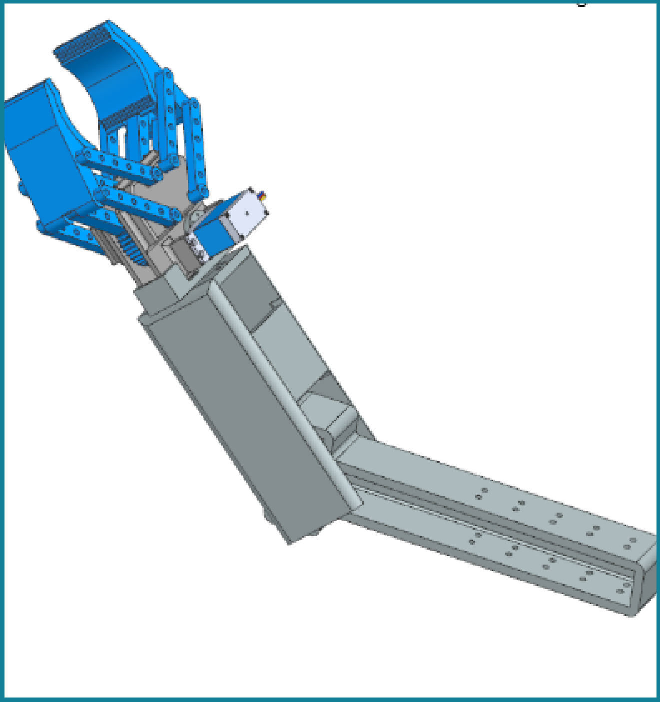


Fig. 12. Degrees of freedom

TROUBLESHOOTING & TESTING TECHNIQUES

During the testing phase of each system, it was noticed that everything was in order. To obtain a broader test of the entire ROV, which was already assembled and ready to enter the water, there were concerns regarding the different mechanisms that would be utilized. In this case, modifications were made to elements such as the gripper since it uses 3 servo motors. It was crucial to verify that these servos would not be affected by water contact, as they are water-proof motors. However, it was noticed that they exhibited unusual behavior, and upon analysis, it was confirmed that they had been affected by water.

Consequently, sealing modifications had to be made, and the team decided to find materials compatible with the small openings that these motors contain, ensuring that this issue would not pose a problem in the future, considering that these motors are essential components for the ROV's operation.

Another issue that was analyzed in greater detail was buoyancy. Although load distribution analyses indicated stability, upon immersion, the ROV would tilt and lose stability, making tasks more challenging to perform. Another analysis was conducted to identify potential factors affecting the ROV's movement. Additional loads were distributed strategically to achieve complete stability and make control more effective and manageable.

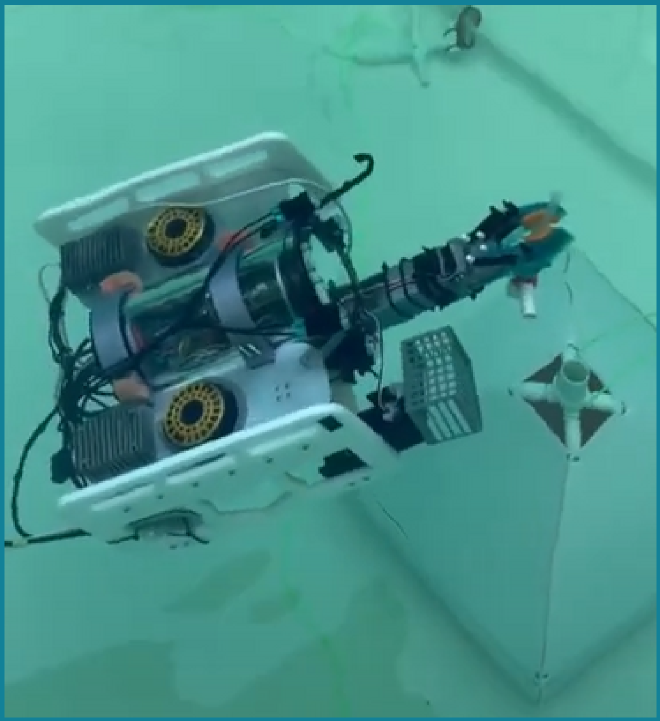


Fig. 14. ROV JSL doing task 3

Fig. 15. ROV JSL doing task 1

SAFETY

Company Safety Philosofy

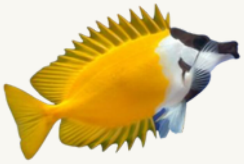
Seafox Inventive prioritizes workspace security, tool safety, and proper PPE usage. These measures ensure reliable work without compromising protocols. Our dedication to security is evident in the design and construction of our ROV. We take meticulous care in waterproofing our electrical systems and ensuring that our mechanical systems and chassis are free from any sharp edges that could potentially cause harm to our staff or other components in the vicinity.

Fig. 16. Safety Philosofy

Lab protocols

Our work area must follow certain conditions to be usable and safe. All team members know what these requirements are. Here are our laboratory rules:

- Continuous supervision by our professor/mentor is mandatory during all work activities.
- Wearing appropriate PPE is compulsory whenever deemed necessary.
- Before performing any task or modification, this must be consulted with the team's CEO for security reasons.
- Each tool has its corresponding place.



- Everyone should be instructed on how to use an extinguisher.
- The lab should be securely locked when it is not used.

Training

SeaFox Inventive convened an initial meeting, where project details were shared, and roles were assigned to each member. Subsequently, comprehensive training was provided on laboratory usage, tool handling, and the proper utilization of PPE for various activities. To facilitate effective supervision, a survey was conducted to gather member schedules, enabling the determination of laboratory work hours by our professor/mentor who supervised student activities.

Vehicle Safety Features

Our ROV design prioritizes safety and incorporates various features to prevent harm to both the user and the ROV itself:

- The structure utilizes ABS plates with rounded corners to eliminate the need for filing.
- All electronics are housed in a waterproof enclosure.
- External systems and mechanisms are either designed or treated to eliminate sharp edges.
- Safety guards are installed for the six thruster motors.
- The tether is supported with a strain relief mechanism to prevent damage to the watertight enclosure penetrators.
- The ROV tether is equipped with the appropriate fuse as per competition requirements.

Operational and Safety Checklists

Pre-power verification:

- Verify cable connections for any damage or looseness.
- Ensure proper sealing of the electronic systems enclosure.
- Clear the area around the ROV and ensure the tether is free from obstructions and tangles.

Vacuum testing:

- Connect the manual vacuum pump to the vent penetrator.
- Pump until reaching 10 in Hg, then set a 15-minute timer.
- After 15 minutes, if the pressure remains above 9 in Hg, remove the pump and tighten the vent plug.

Power-up verification:

- Connect the tether to the power source.
- Confirm connection to the Graphical User Interface.
- Ensure continuous monitoring of the ROV by team members.
- Establish a secure control-thruster connection.
- Before testing, verify the functionality of external systems and mechanisms, including the vessel and gripper.
- Check the cameras for proper operation.

Water immersion check:

- Submerge the ROV cautiously, preferably with assistance from two team members.
- Verify the presence of normal bubble levels.
- Regularly inspect the leak detector.

Lost communication procedure:

- In the event of communication loss, disconnect the ROV from the power source and surface it via the tether.
- Initiate the reboot process.

LOGISTICS

Project Management and Work Methodology

During the development of the vehicle, the team had to use different work methodologies to get to their goals. Because of the complexity of the project, including engineering skills to design, build and implement the vehicle, the tests planned to go through the scientific method. This method includes 6 basic steps which are:

1. Asking a question about something you observe
2. Doing background research to learn what is already known about the topic
3. Constructing a hypothesis
4. Experimenting to test the hypothesis
5. Analyzing the data from the experiment and drawing conclusions and
6. Communicating the results to others

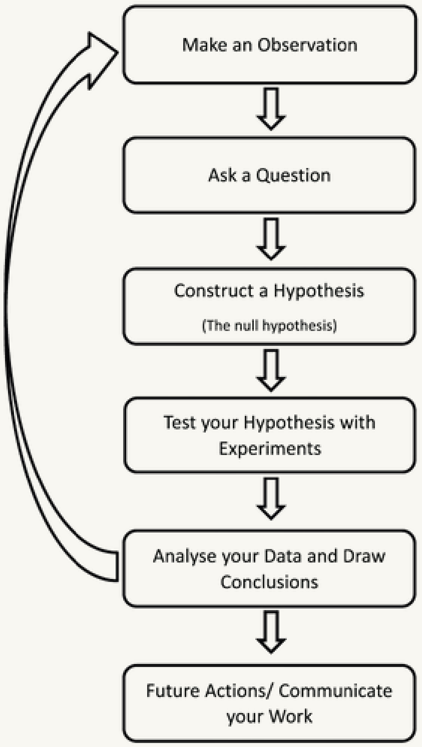


Fig. 17. Scientific Method

On the other hand, the team needs organizational skills for the project to be completed promptly. It is important to follow a methodology that ensures that the organization of daily activities is adequate, which is why the team has decided to use different tools that have worked for them in previous projects (the last participation in the MATE competition is included in those previous projects).

One of the methodologies that worked well for the team was taking stand-up meetings from the SCRUM methodology. The Daily Standup meetings are usually time-boxed to between 5 and 15 minutes and take place with participants standing up to remind people to keep the meeting short and to the point. The meeting should take place at the same time and place every working day. All team members are encouraged to attend, but the meetings are not postponed if some of the team members are not present.

One of the crucial features is that the meeting is a communication opportunity among team members for them to keep advancing on their individual and team topics. To manage these meetings the team used the Scrum Poker Tool App.

Another method implemented is the Kanban Board which is a brilliant visual tool that gives an overview of the current work status and simplifies team communication. It helps optimize, continuously improve, boost productivity, and eliminate chaos. They work by mapping individual work items to sticky notes placed into columns on a large board. Board's columns represent a sequence of specific steps that tasks or products must go through from the start of work to finish. Work items are written down on cards and placed into their respective columns. To manage all the activities in a Kanban Board the SeaFox Inventive Team uses Microsoft Teams Tasks Planner.

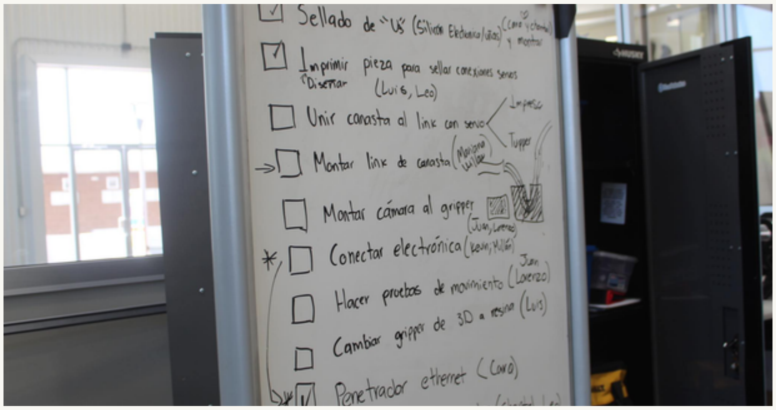
Finally, one of the most important if not the most important planning tool for the ROV is using a Gantt Diagram as shown in the appendix section.

Company Organization and Assignments

SeaFox Inventive had to restructure with an experienced CEO and a new team. There was a great impact on the students, so the number of new members increased, which meant that the vision of the new ROV had to be defined for all members. The chiefs were the best in every area showing great skills to do the best job possible. Most of the team members had established assignments in various areas. Other areas not mentioned above include promotional articles, company image, and documentation.

Workspace

Almost all work is carried out in an area designated by our school. This area is a work cell / laboratory, one of several located in the Integration and Testing Laboratory of the Innovation and Design Center building in CETYS University Mexicali Campus. It is equipped with mechanical and power tools, lockers to store materials, tables with power distribution, and computer equipment. This section is restricted only to members who are working on this project.



☑ Sellado de "Us" (Silicón Electrónica/uñas) (Caro y chente) y montar
☑ Imprimir pieza para sellar conexiones servos (Luis, Leo)
Diseñar
☐ Unir canasta al link con servo — Impreso / Tupper
→ ☐ Montar link de canasta (Mariana Villa)
☐ Montar cámara al gripper (Juan, Lorenzo)
* ☐ Conectar electrónica (Kevin; Millán)
☐ Hacer pruebas de movimiento (Juan Lorenzo)
☐ Cambiar gripper de 3D a resina (Luis)
☑ Penetrador ethernet (Caro)

Fig. 18. Assignments

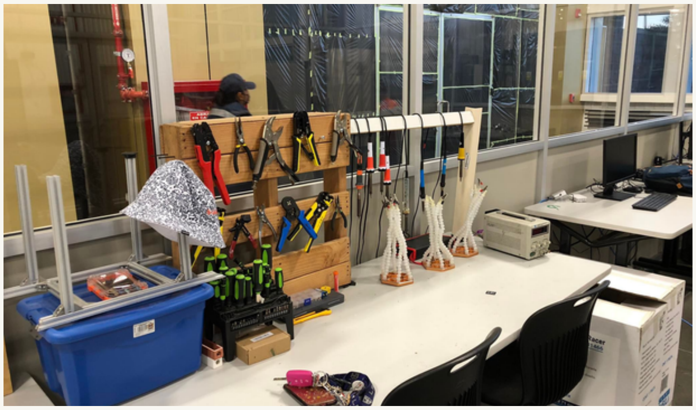


Fig. 19. Workspace

Shared Media

Likewise, all current members of the project have access to a shared Google Drive. In that location are all files utilized by every generation of engineering students who have tried to consolidate the project of building an ROV. We have learned a lot from all the information contained and we are proud to think that this year we have refined the technical documentation aspect of the competition. We feel that all the acquired knowledge will be very useful to future generations for the development of better prototypes and more interesting functionalities. That is why we value the files stored in Google Drive very much and we take care by backing them up.

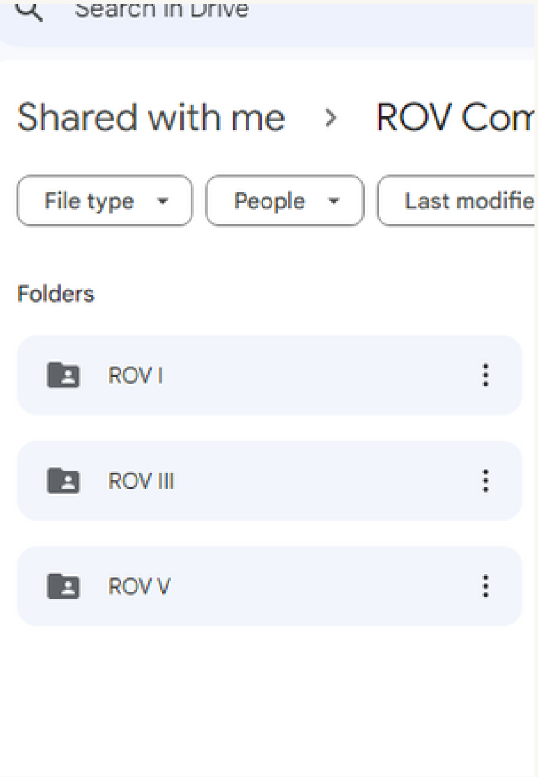


Fig. 20. Google Drive

Budget and Project Costing

Some parts of this ROV were reused from past prototypes with new parts being purchased and implemented. For the budgeting process, several activities were conducted during the semester, which provided us with cost savings on the necessary components, allowing us to focus the proceeds on travel costs and other necessary expenses. Among the fundraising activities were a weekly bread sale, a television raffle, and a raffle for a trip to Ensenada, which allowed for a large amount of profit.

Fig. 21. Budget

CONCLUSION

Challenges

Throughout the process of designing and implementing the vehicle, there were many challenges within the team. Some of them were resolved easily and quickly, but others took more time and effort than expected to resolve. During the design section, one of the main challenges was working from scratch with a new team, since most of the team were new in the team but senior students, it was possible to rapidly overcome. Software development or hardware integration was a challenge, but we managed to solve it with teamwork and organization of the integration process.

Fig. 23. SeaFox Team

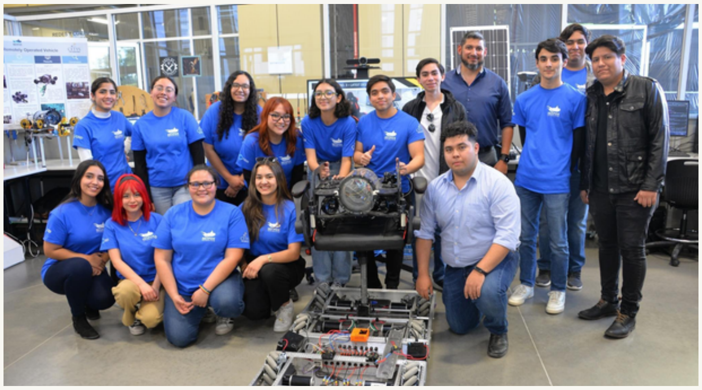


Fig. 24. SeaFox Team

Fig. 22. Waterproofed servo motors

Finally, during the day the team tested the vehicle and recorded the video for the qualifying competition, two big challenges affected more than the team could expect. First, the organization of working in parallel, since one sub team had their part ready, while another was not finished, caused a delay in the pre-testing process. Then, the servomotors had communication problems since they were not completely waterproof, the mechanical team had to manage to make the mechanisms work without motors to carry out tests and to be able to record the demonstrative video optimally.

Lessons Learned and Skills Gained

Each challenge encountered and solution taught the team various lessons. The team looked for an organized and effective structure for everything since the beginning of the season, but as always, some things cannot be expected. Even though the team encountered an immense amount of challenges throughout the whole season, the solutions were always found and implemented.

The main lesson learned during this season is that persistence can change the outcome of most of the events. Also, thinking outside the box with a calm mind to find a solution when everything seems like it will not work is one of the lessons that will help and have already helped our team members in their life as engineers.

Future Improvements

One of the main problems we found for this season was the lack of additional parts or components needed to continue our progress, including 3D printers, as well as material that did not arrive on time for implementation.

Although the cost would increase substantially, the benefits far outweighs the cost, and another benefit of having additional parts is that they can be used for research purposes for future SeaFox prototypes.

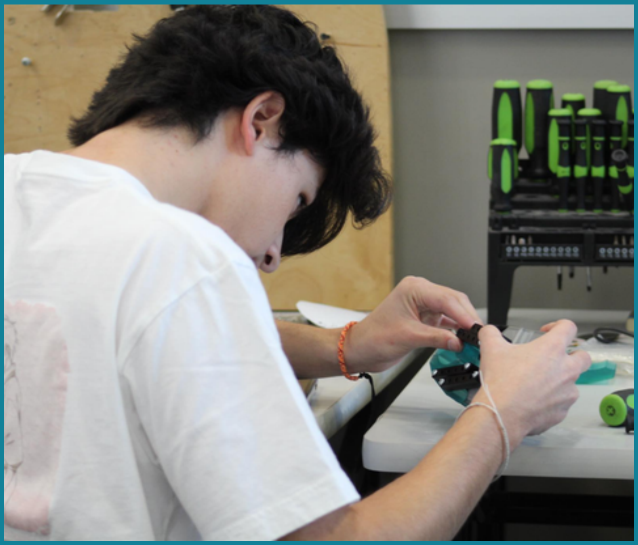


Fig. 25. Mechanical testing

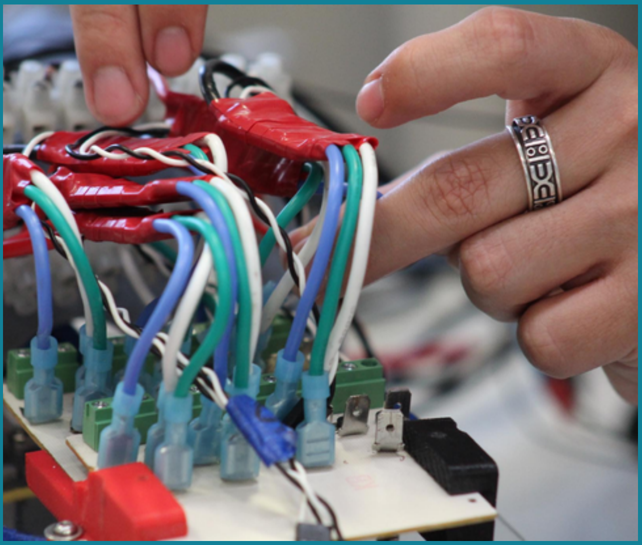


Fig. 26. Electrical testing

Another possible improvement would be the implementation of pneumatic or hydraulic systems to activate the mechanisms. With this system, the prototypes could be controlled more efficiently and reliably to meet the challenges set in the competition. This would help to stop using motors that claim to be waterproof and are not.

Senior Reflections

Mariana Yael Castro Figueroa (Mechanical member)

As a member of SeaFox Inventive since 2019, I must admit that year after year I'm surprised by the great leap that it takes to be a stronger team and eager to go far, both within the competition and in life.

Being a young team with only three years of competing, our capability to reach a higher level year by year is denoted by making new proposals and ideas to overcome adversities.

As I'm the most experienced member this year, I had to lead the group. I consider this to be mainly a challenge due to the number of talented students joining the team. They have so many ideas to do for the SeaFox project that I'm sure they will get very far.

I'm fully confident that they will be in excellent hands. I'm grateful for the opportunity that SeaFox and MATE have given me to enhance my knowledge and skills as an engineer. To my colleagues for always being with me inside and outside the workspace, and finally to the Head Coach for not leaving us alone and trusting in each one of us.

Fig. 27. Company presentation to Tesla, Inc.

Fig. 28. Mechanical testing

Acknowledgements and References

- MATE Center and Marine Technology Society - Sponsoring this year's competition
- All of 2023 MATE Sponsors - Their support of the MATE competition
- CETYS University and CEID - Their support and provided facilities to SeaFox Inventive
- Dr. Luis Basaca, Head Coach - His knowledge and guidance
- Our Families - Their continued support and encouragement

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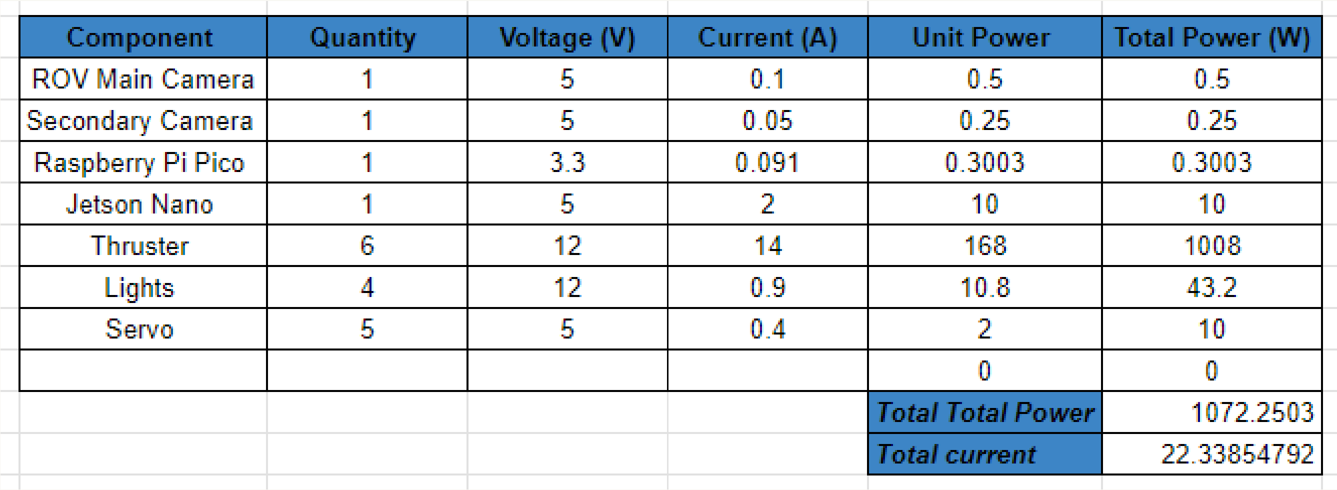
APPENDICES

Power Budget

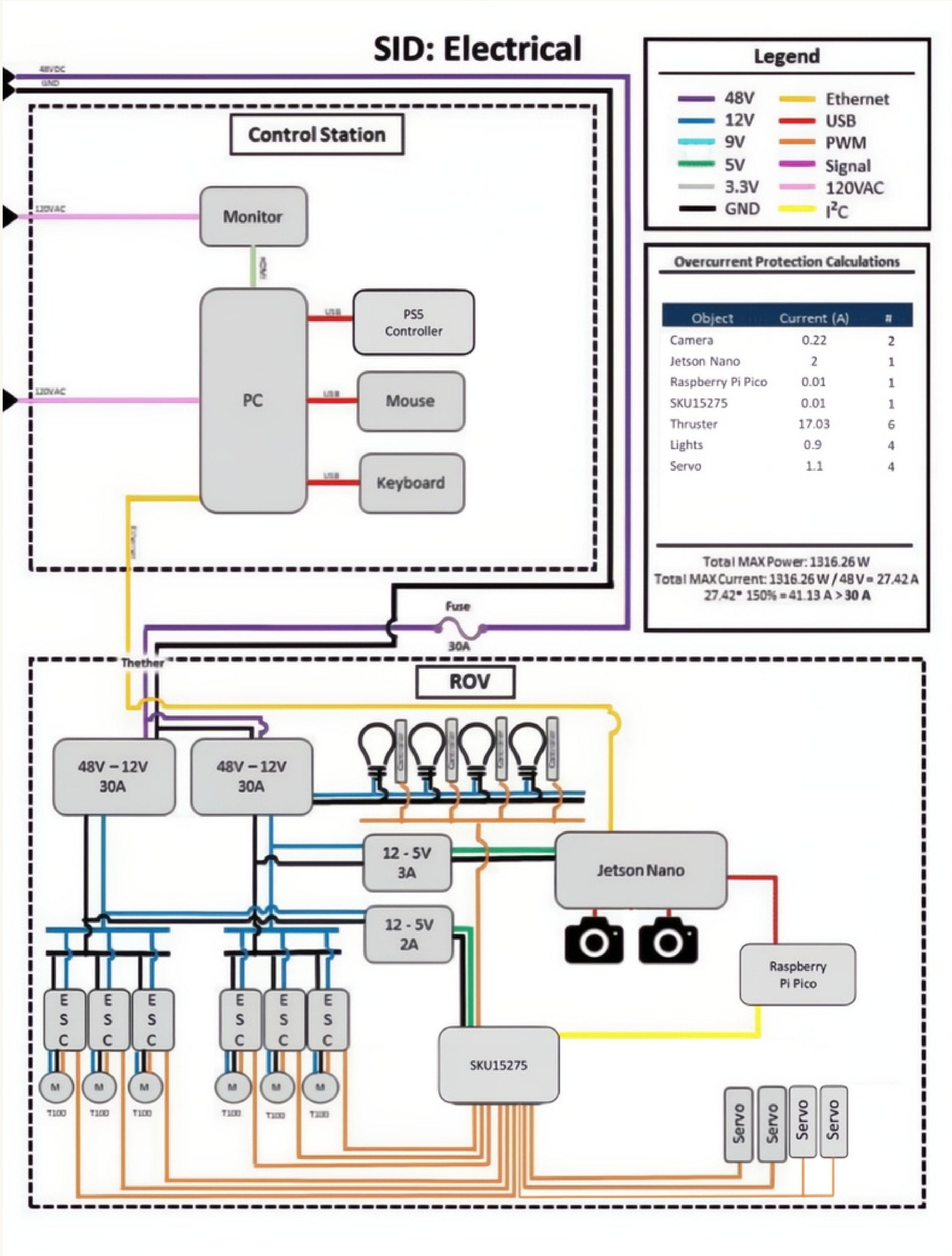


Component	Quantity	Voltage (V)	Current (A)	Unit Power	Total Power (W)
ROV Main Camera	1	5	0.1	0.5	0.5
Secondary Camera	1	5	0.05	0.25	0.25
Raspberry Pi Pico	1	3.3	0.091	0.3003	0.3003
Jetson Nano	1	5	2	10	10
Thruster	6	12	14	168	1008
Lights	4	12	0.9	10.8	43.2
Servo	5	5	0.4	2	10
				0	0
				Total Total Power	1072.2503
				Total current	22.33854792

Fig. 29. Power Budget

The table shows how 22.34 amps are required to power the ROV at max power. This means a 30 amp fuse perfectly fits the needs of power security. Total MAX Power: 1072.25 W. Total MAX Current: 1072.25 W / 48 V = 22.34 A, 22.34 * 150 % = 33.51 A > 30 A.

SID



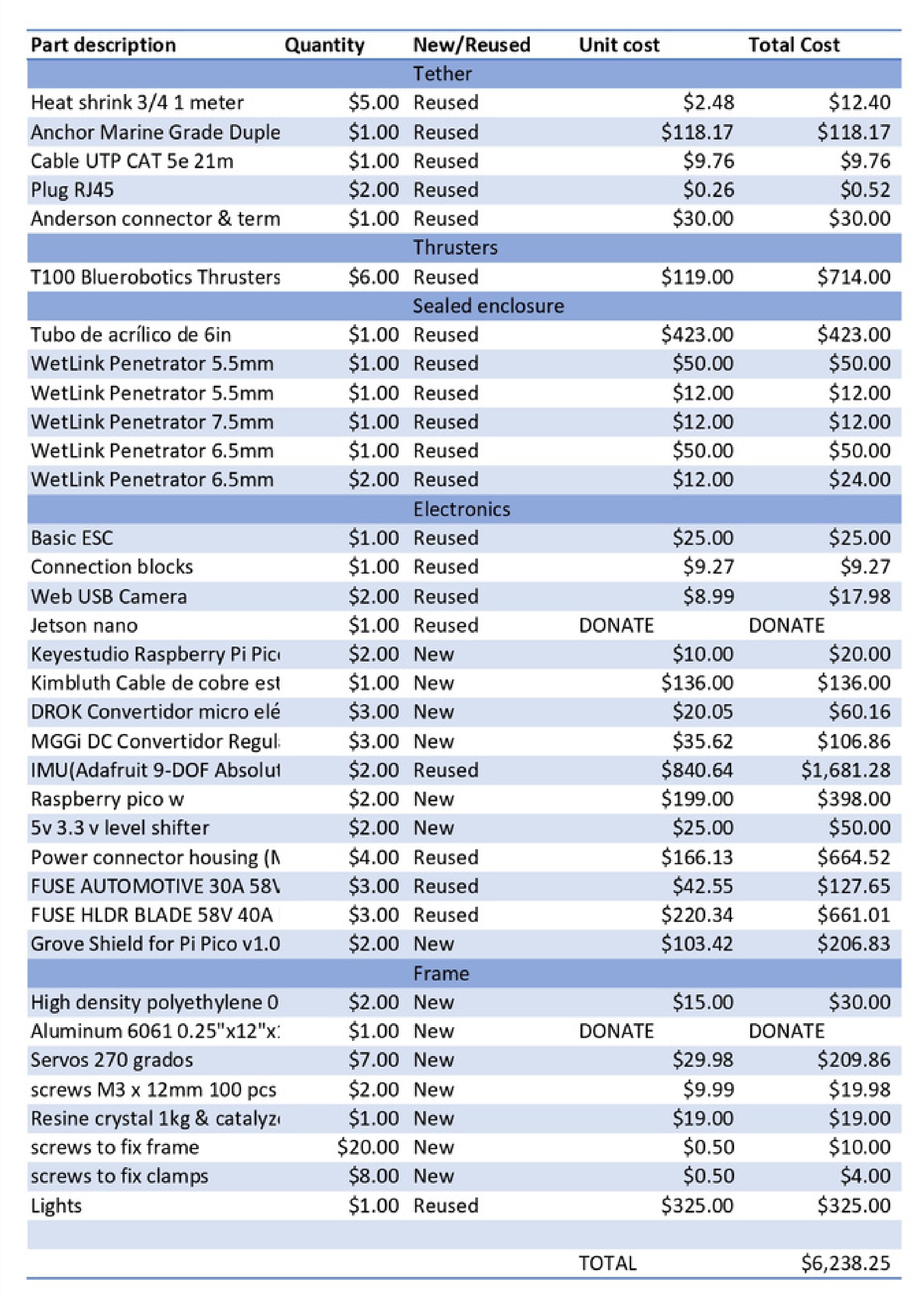
Overcurrent Protection Calculations

Object	Current (A)	#
Camera	0.22	2
Jetson Nano	2	1
Raspberry Pi Pico	0.01	1
SKU15275	0.01	1
Thruster	17.03	6
Lights	0.9	4
Servo	1.1	4

Total MAX Power: 1316.26 W
Total MAX Current: 1316.26 W / 48 V = 27.42 A
27.42* 150% = 41.13 A > 30 A

Fig. 30. SID: Electrical

Budget and Project Costing



Part description	Quantity	New/Reused	Unit cost	Total Cost
		Tether		
Heat shrink 3/4 1 meter	$5.00	Reused	$2.48	$12.40
Anchor Marine Grade Duple	$1.00	Reused	$118.17	$118.17
Cable UTP CAT 5e 21m	$1.00	Reused	$9.76	$9.76
Plug RJ45	$2.00	Reused	$0.26	$0.52
Anderson connector & term	$1.00	Reused	$30.00	$30.00
		Thrusters		
T100 Bluerobotics Thrusters	$6.00	Reused	$119.00	$714.00
		Sealed enclosure		
Tubo de acrílico de 6in	$1.00	Reused	$423.00	$423.00
WetLink Penetrator 5.5mm	$1.00	Reused	$50.00	$50.00
WetLink Penetrator 5.5mm	$1.00	Reused	$12.00	$12.00
WetLink Penetrator 7.5mm	$1.00	Reused	$12.00	$12.00
WetLink Penetrator 6.5mm	$1.00	Reused	$50.00	$50.00
WetLink Penetrator 6.5mm	$2.00	Reused	$12.00	$24.00
		Electronics		
Basic ESC	$1.00	Reused	$25.00	$25.00
Connection blocks	$1.00	Reused	$9.27	$9.27
Web USB Camera	$2.00	Reused	$8.99	$17.98
Jetson nano	$1.00	Reused	DONATE	DONATE
Keyestudio Raspberry Pi Pic	$2.00	New	$10.00	$20.00
Kimbluth Cable de cobre est	$1.00	New	$136.00	$136.00
DROK Convertidor micro elé	$3.00	New	$20.05	$60.16
MGGi DC Convertidor Regul	$3.00	New	$35.62	$106.86
IMU(Adafruit 9-DOF Absolu	$2.00	Reused	$840.64	$1,681.28
Raspberry pico w	$2.00	New	$199.00	$398.00
5v 3.3 v level shifter	$2.00	New	$25.00	$50.00
Power connector housing (	$4.00	Reused	$166.13	$664.52
FUSE AUTOMOTIVE 30A 58	$3.00	Reused	$42.55	$127.65
FUSE HLDR BLADE 58V 40A	$3.00	Reused	$220.34	$661.01
Grove Shield for Pi Pico v1.0	$2.00	New	$103.42	$206.83
		Frame		
High density polyethylene 0	$2.00	New	$15.00	$30.00
Aluminum 6061 0.25"x12"x	$1.00	New	DONATE	DONATE
Servos 270 grados	$7.00	New	$29.98	$209.86
screws M3 x 12mm 100 pcs	$2.00	New	$9.99	$19.98
Resine crystal 1kg & catalyz	$1.00	New	$19.00	$19.00
screws to fix frame	$20.00	New	$0.50	$10.00
screws to fix clamps	$8.00	New	$0.50	$4.00
Lights	$1.00	Reused	$325.00	$325.00
			TOTAL	$6,238.25

Fig. 31. Budget and Project Costing