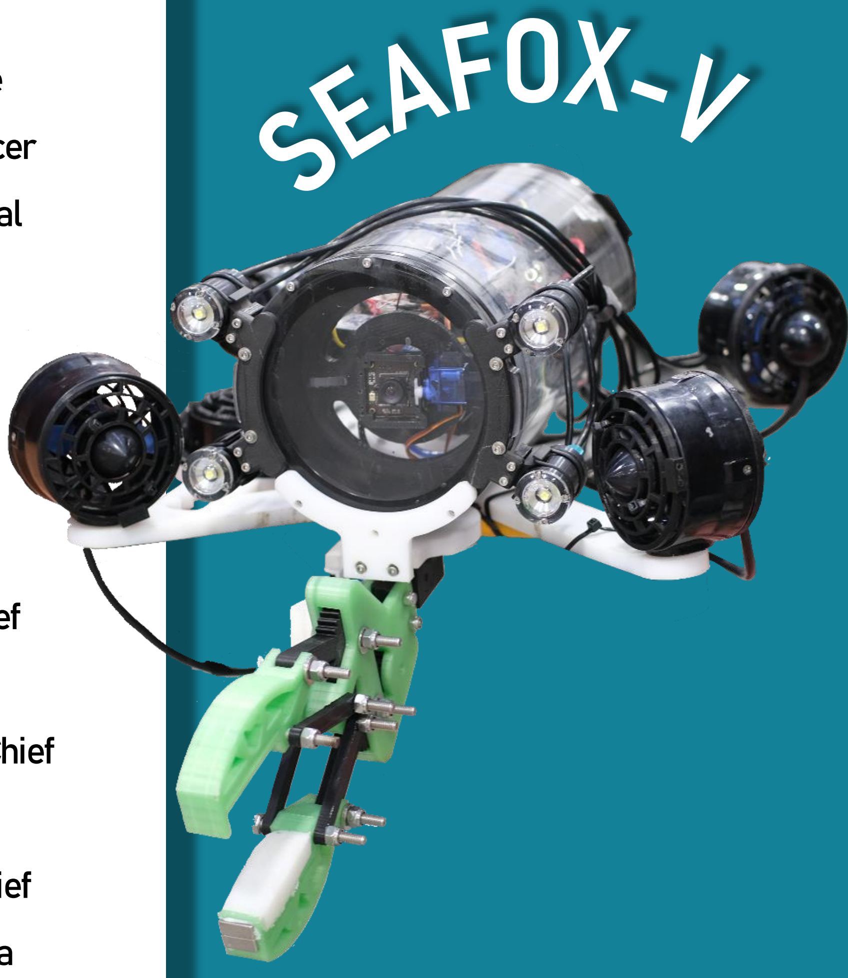
CETYS University
Mexicali, Mexico
MATE 2022



TEAM MEMBERS

'22 Carlos Maytorena, Software
'20 Carolina Flores, Safety Officer
'21 Chantal Mendoza, Mechanical
'21 Daniel Orduño, Electronics
'22 Diana Bentley, Mechanical
'22 Dimas Trejo, Electronics
'23 José Beas, Documentation
'22 Juan Romero, CTO
'22 Marco Leal, Electronics Chief
'21 Marian Meza, CEO
'21 Miguel García, Mechanical Chief
'22 Misael Anaya, Mechanical
'22 Saúl Mendoza, Software Chief
Head Coach: Luis Carlos Básaca

INTRODUCTION

Abstract

This document is an overview of the design and manufacturing of the ROV prototype that Sea Fox inventive is presenting at the MATE 2022 competition. This ROV is designed to carry out missions in environments such as rivers, lakes or dams. This will be the 5th generation in CETYS University in which a team of students meets to design and build an ROV. The last competition was canceled due to the COVID-19 pandemic.

Now, the team is eager to compete and prove that the knowledge gained from past iterations of the Sea Fox Inventive team and their missed opportunity to show their hard work will provide great results. The mistakes learned in the past years and the effort and good organization have made it possible for SeaFox Inventive to proudly announce its new ROV: 'SeaFox-5'. (The name comes from the previous models of ROVs that have been built and from which we learned a lot).

Fig. 1. SeaFox team members

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DESIGN RATIONALE

DESIGN PROCESS

SeaFox-5 is the result of working as a team for over a year, with some previous experience from two prototypes that could not reach the competition and one that could with a lot of room for improvement.

This ROV is greatly different from the last ones, due to complications during the design and manufacturing process of it, the SeaFox Inventive Team as a project was delayed and stopped because of the external circumstances everyone knows (pandemic). But going through this major event, and making it through it helped the team to start relying on their own time, so from the beginning of the season, when the team returned to work, the team's own deadlines were always a big topic inside the laboratories.

The SeaFox-5 defines a new generation for the SeaFox Inventive team, not only because of the conditions it was made under, but because it is the upgraded version of an ROV that could finally make it after three years to the competition. Then, having the opportunity to go there, and learn from other teams was indispensable for the development of this vehicle.

Once the season started, the team was immensely excited about experiencing what they already had again, so they started working.

The main objective of the SeaFox Inventive team was going to the competition, so they already knew what they had to do in order to pursue and get to that goal.

First, the team read the manual for the competition individually and understood the problems that needed to be solved more than the tasks by themselves, then, with the previous feedback from the last competition, the team brainstormed ideas of what they could design in order to solve the tasks from the manual. And finally with these meetings, the team decided that they wanted a lighter, more manageable, and less difficult to repair ROV. With the tasks in the manual, and the design ideas and goals decided, the team could start working.

Fig. 2. Team first meeting

After these meetings, the team began to look for economical support and activities that could raise funds for this project. After getting the money, they started ordering the vehicle components and as soon as they arrived, everyone went ahead manufacturing, designing and coding the SeaFox-5.

Finally, after months of work, the SeaFox-5 was already built, prepared to go into the water and ready to finish his tasks, so it did in the qualification video.

In addition to what each team does (mechanical, electronics and software), project management has become one of the main components of the team itself, letting the project flow smoothly as the time passes by instead of looking for brute force solutions.

MECHANICAL DESIGN

This year's ROV design is focused on versatility, simplicity, and ease of manufacturing. Hence, modifying its design, if needed, would be a simple task. It is intended to strive for a sleeker frame, and a smaller overall weight of the mechanical components.

The initial design was made taking weight distribution into consideration, carefully arranging the different subsystems and actuators in a way that the center of mass remained centered and balanced, and that minimum ballast would be required, only to achieve neutral buoyancy.

Once an initial design was chosen, flow simulations were ran, and design modifications were made, prioritizing ease and cost of manufacture, while also optimizing the fluid mechanics performance of the ROV. When the final mechanical design revision was ready, blueprints were made, and a manufacturing plan was put into action, starting with the generation of G-code for CNC manufacturing of the HDPE plates, leaving as little manual manufacturing as possible. Finally, the electronics capsule was installed and secured in place.

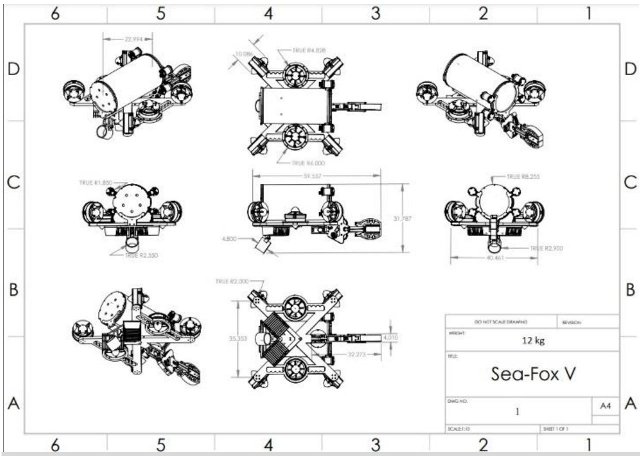

Fig. 3. SeaFox-5 mechanical design drawings

Frame

Logically, among the components with a higher priority there was the matter of the physical structure. In past years, the material used for the structures of the ROV consisted of metallic parts, usually aluminum for being a lighter material. However, after studying the composition of the structure of commercial ROVs and other equipment in past MATE competitions, it was concluded that high-density polyethylene (HDPE) is a good frame material, due to the balance in lightness and the strength that it would provide to the structure; additionally, due to the mass properties of the material, which has positive buoyancy, it helped with achieving neutral buoyancy without having to add many floaters. Also, because of how easy it would be to machine this material. It was finally decided to use 1 cm wide plates.

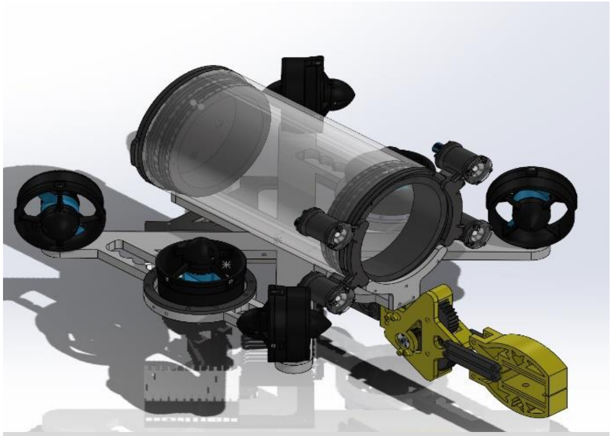

Fig. 4. SeaFox-5 design development

Buoyancy and stability

This ROV does not require additional floating elements thanks to the capsule, the 3D prints, the encapsulation of the lights and the material of which the frame is composed. All of this components add a lot of positive buoyancy. The highest concentration of air volume is in the capsule, this is an advantage because the capsule is in a higher position in the vehicle, therefore it helps to stabilize it.

Fig. 5. Weights made out of iron.

In order to neutralize the huge amount of positive buoyancy SeaFox-5 uses a static ballast system which consist only in 4 weights made out of iron bars attached to the bottom of the vehicle.

Fig. 6. T100 thruster with basic ESC

Propulsion

SeaFox-5 is able to move thanks to the BlueRobotics T100 thrusters. These are very popular in commercial ROVs, because they are easy to install and do not need meticulous maintenance unlike the brushless motors adapted to be used underwater.

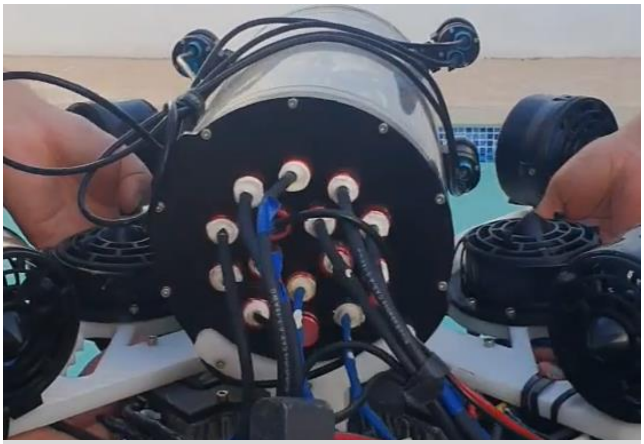

Fig. 7. Back lid of SeaFox-5 with penetrators

Enclosure and sealing

To encapsulate the electronics of our ROV, it was preferred to use an 8" enclosure from BlueRobotics. This was due to the fact that the previous teams had a lot of troubles sealing their enclosures. Consequently, there was something reliable to learn from. The aluminum cap from the enclosure was drilled with 15 bores allowing connections from the electronics panel to thrusters, sensors and servos. All cables coming through the enclosure are sealed using a penetrators and marine grade epoxy.

ELECTRICAL COMPONENTS

Power distribution

The Seafox-5 ROV prototype is powered by a 48 VDC and 30 A power supply. There is a voltage conversion from outside to inside the capsule. The ROV has two regulators attached outside the capsule and another two regulators inside, all these converters are divided mainly into two sections. The converters that are outside regulate from 48 V to 12 V and the other two converters regulate from 12 V to 5 V. The first section is responsible for energizing the thrusters, the lamps and the other two regulators, everything requires a 12VDC power supply and can consume a significant amount of current.

The other section of converters is used to power the control section and communication systems, composed of the PCA9685 controller, the Jetson Nano controller, and the Arduino. All these devices are powered by 5 VDC. This section of converters consists of two stages, the first is responsible for lowering the voltage from 48 VDC to 12 VDC, and the second stage is responsible for lowering the voltage from 12 VDC to 5 VDC.

Communication

The advantage that the SeaFox 5 has is an ethernet cable in the tether, which allows the team to communicate between the control station's computer and the vehicle computer (Jetson Nano). This communication 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 makes use of several electronic sections for the manipulation of the vehicle and its functions. One of them is the Jetson Nano controller, a minicomputer used frequently for object detection, segmentation, and speech processing, it has 4 USB ports, 2 HDMI ports and 1 Ethernet port. The 4 ports of the Jetson Nano were used to supply power to 3 cameras and the Arduino.

The Jetson Nano receives information from the PC through an Ethernet cable, also the device works in conjunction with the Arduino Uno, which establishes a connection within a USB cable to control the system remote by sending data in I2C protocol to the PCA9685 in order to control the ESCs. The cameras send the video information to the PC passing through the Jetson Nano via an Ethernet cable.

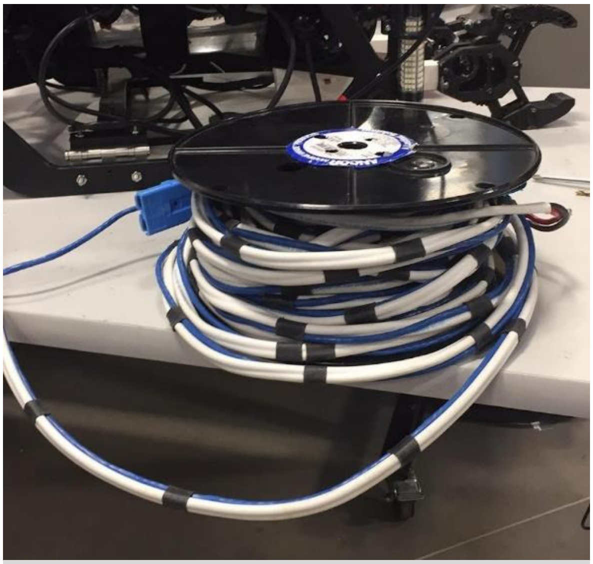

Fig. 8. Rolled Tether

Tether

For the tether design the team agreed that the ROV needed at least the power supply cable and one communication channel, in this case the Ethernet. Once the maximum current value going through the power cable was calculated, 27.42 A, wire gauge charts were reviewed to evaluate the appropriate one to endure the current. It was decided that 10 AWG anchor marine grade duplex cable could do the job and one twisted pair Cat 5 for communication. To maintain the two cables together, pieces of heat shrink were used all along the tether.

To supply the correct amount of voltage to the ROV, it was needed to weld the cables that connect the regulators outside the capsule with the power supplies and isolate the welders with pieces of heat shrink, to ensure the isolation, epoxy was applied to every piece of heat shrink.

For more security a special part was designed to protect the main connection of the power supply with the two regulators and the piece was filled with epoxy. Finally all the isolated cables were tested underwater with a multimeter to verify that they are waterproof.

Vision System

SeaFox-3 has 3 cameras. The first one is pointing forward and is mainly used for navigation and objectives localization underwater. The second one is also pointing forward but with a slight angle downward. This is one is preferably used when manipulating objects with the frontal grippers.

Fig. 9. Camera for downward vision

The last one is pointing downward; this point of view is useful when the SeaFox-5 is required to get aligned in a certain position. All cameras are capable of being connected via USB and each one is attached to the Jetson Nano. The first camera is mounted inside the capsule of the ROV, and the second one goes below the vehicle, inside a different capsule which is waterproofed.

Control Station

The control station consists of a single computer or laptop where the videos of the 2 cameras are displayed, in the screen the main program is also available for the full manipulation of the ROV. If it is a desktop computer, keyboard and mouse are required. A gamepad is the main way to control the vehicle, using an Xbox One controller is one of the better ways to read from a personal computer due to compatibility with Microsoft hardware so that's what the team did.

Fig.10. Control Station

The control station consists of two parts even though it’s the exact same page running in the same computer.

First, the driver needs to see the camera’s streaming so he can control what the vehicle is doing.

On the other side of the control station the thruster control page is almost always opened, allowing the teammates of the driver to modify the parameters of the thrusters so the ROV can be controlled easily.

Fig.11. Electronics Enclosure

SOFTWARE

Topside Software

Most of the software used to control the vehicle is developed by the team. Instead of using an existing application the team prefered developing their own whole control system due to the restricted availability to use the graphical user interface and the control system for our specific tasks.

Developing their own control system, including both the graphical user interface and the control system inside the Jetson Nano from scratch provides the team much more flexibility when implementing it.

The resilience of the control system is based in allowing the team to change everything they want to. The GUI grants the capability to see and change some parameters of the vehicle from the control station, and the scripts that run inside the Jetson Nano lets the team send data to the thrusters and the servo motors to control the vehicle itself.

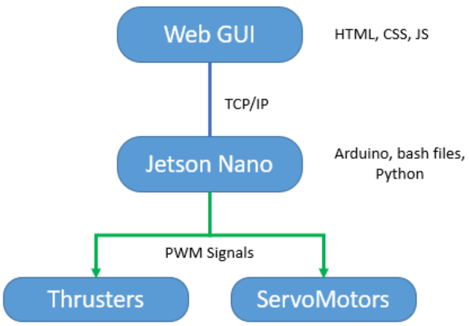

Fig. 12. Software system control

Through the GUI they can see the cameras, see the buttons and how they are mapped and control the parameters of the thrusters, such as the maximum and minimum PWM value and set the PWM value that sets the thruster steady.

The GUI consists of two basic parts, the navigation bar at the left and the display of the page on the right side of the screen as shown in the picture below:

Fig. 13. GUI Cameras

Each button of the navigation bar changes to a different page inside the application, the first icon shows the cameras in the GUI, in here the team can only see what the cameras of the vehicle are sending to the control Station following the path mentioned earlier in the document, it can also show some basic indicators which mark a green or red light if a component is either active or inactive respectively.

The second icon changes the application to the gamepad page, this page shows an image of the gamepad in which the driver can see how the buttons are mapped. It is basically just an image the driver can use as an aid in case he forgets what each button does as shown in the image below:

Fig. 14. GUI Control

In the last page, the application shows the thruster control site, in which the team in the control station can change via the GUI the maximum and minimum PWM levels of each thruster, follow up the levels at which every thruster is working and send the data to the Jetson Nano. Also, the GUI runs with the live-server extension for visual studio code, which allows the team to debug and modify the code instantly in case of any problem.

Finally, this application allows the team to control the vehicle graphically, this is one of the major advantages of using a GUI because the driver and the people working at his side can watch what is happening with their vehicle during the competition.

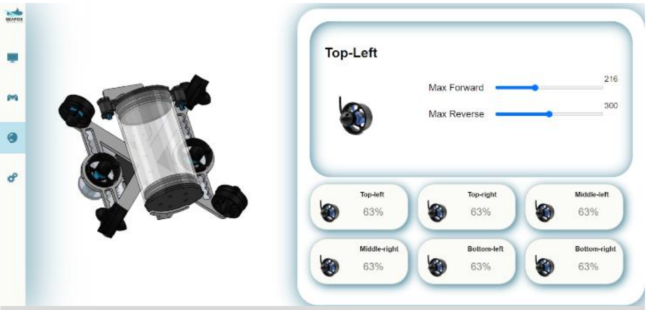

Fig. 15. Thrusters

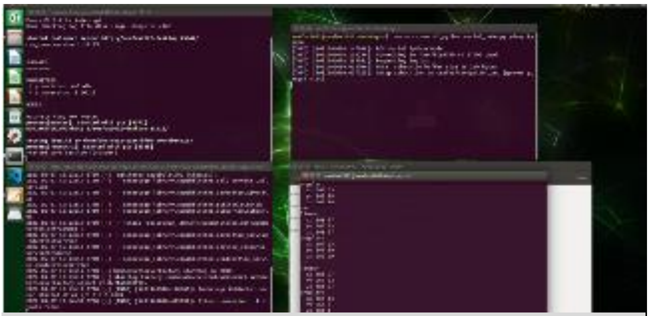

Fig. 16. Jetson nano terminals

Onboard Software

Inside of the vehicle, the main controller is the Jetson Nano, this developer kit allows the team to have a full running computer inside the ROV capsule. Having the processing power of a computer inside the capsule lets the team process every task at high speeds. Also using the Jetson Nano, which uses Ubuntu as operating system, gives the team the opportunity to modify bash files, processes of the computer and design, integrate and use the outputs of this development kit to send and receive data to the components on the vehicle so they can have better communication between them. The programs inside the Jetson Nano run as processes at startup or by commands using SSH, they appear as the image shown below in the Jetson Nano.

The Jetson Nano runs python scripts using TCP/IP libraries to work as a web server so the control station's computer can connect to it via TCP/IP protocol. It also creates different processes to create and read from topics, which is the way TCP/IP protocol sends and receives data.

The arduino scripts are run in the Jetson Nano also, these scripts use the usb outputs of the development kit to send serial data to the arduino, and the arduino sends the data through two cables to the pca (thrusters and servo motors controller).

This development kit also reads the usb cameras, and sends their image through TCP/IP protocol through the ethernet cable to the control station's computer as shown in the diagram below.

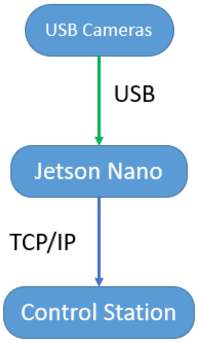

Fig. 17. Connection diagram.

PAYLOADS

Gripper

The SeaFox-5 has just one robotic gripper, this gripper can move its arm to point downwards or to the front of the vehicle. This was designed and 3D printed to achieve an optimus grip and the capability of being powered with waterproofed servos, adding a mix of materials to produce malleable plastic so it can grab the props with more .

Fig. 18. Frontal Gripper design

Gripper mobility

For the mobility of the gripper 2 servos were attached, the first servo was used to allow the gripper to open and close the hand, and the second servo was used to move all the arm in a complete range of 90°.

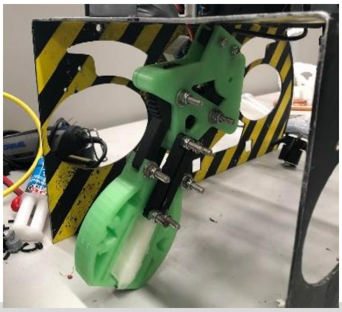

Fig. 19. Gripper mobility

TROUBLESHOOTING & TESTING TECHNIQUES

As every system was completed, it was tested to determine if it worked. For example, when the voltage converters were installed, they were tested with a multimeter to check voltage levels at the outputs. Each electronic system was also tested separately, the Jetson Nano was reviewed by means of a monitor and it was ensured to fulfill its operation of capturing video signals.

Fig. 20. SeaFox-5 being tested underwater

A problem noted during testing of the operation of the SeaFox-5 was the difference of the current draw of the ROV when above water and underwater. The team had a hypothesis that this issue occurred due to water leakage into the capsule even though the operation of the ROV was successful, and the trial runs of the mockup trials were also successful.

Given that this issue had occurred previously, the team decided to analyze the electrical diagram of the ROV and determined that the power consumption was not justified given that the thruster current required was correctly calculated for underwater use.

Another indicator of this was the fact that one of the voltage regulators stopped functioning. During those test runs the team decided to use only one regulator as opposed to two but, the ROV will use two when it comes to the competition as well as making sure that no water enters the chamber housing the electronics.

SAFETY

Company Safety Philosophy

Seafox Inventive has it clear that security in our workspace, safety when using any tools and correct use of PPE are our highest priorities. We are aware that these precautions allow us to produce neat and reliable work. That is why none of the common protocols and warnings are ever compromised for any reason. The security measures are also reflected in the construction of our ROV, either in electrical systems when waterproofing them, or in mechanical systems and chassis, by avoiding any sharp edges that could harm our staff or surrounding components.

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:

- At all times there must be a responsible teacher overseeing the work that is being done.
- Before performing any task or modification, this must be consulted with the team's CEO for security reasons.
- The laboratory must be locked up when no one is working.
- Each tool has its corresponding place.
- The use of PPE is mandatory when necessary.
- Everyone should be instructed on how to use an extinguisher.

Fig. 21. Safety signs at laboratory entrance

Training

Every member of Seafox Inventive was gathered in an initial meeting where the project was explained and the roles distributed. After this, everyone was trained in regards to using the laboratory and its tools as well as the correct use of PPE for different activities. A survey was conducted to know the schedules of all the members to determine the hours of work at the laboratory, making it easier to have a responsible teacher supervising student activity.

Vehicle Safety Features
*See more at our Safety Company Review

Our ROV design pays attention to many safety features in order to avoid causing damage to the user or to the ROV itself.

- The structure was designed on ABS plates that were cut with rounded corners to avoid filing.
- All electronics are placed in a waterproof enclosure.
- Any bondable external system or mechanism was designed or abraded with the intention of avoiding sharp edges.
- The six thruster motors were mounted with their safety guard.
- The tether is supported with a strain relief to avoid damage to the capsule penetrators.
- The ROV tether has the indicated fuse according to calculations as required for the competition.

Operational and Safety Checklists

i. Pre power check

- Check connections and ensure that no cable is damaged or loose.
- Confirm that the electronic systems enclosure is sealed correctly.
- See to it that the area surrounding the ROV is clear and the tether is unobstructed and untangled.

ii. Vacuum test

- Connect the manual vacuum pump to the vent penetrator.
- Pump until 10 in Hg is reached, and then set the timer for 15 minutes.
- Once the time has passed and pressure inside the enclosure remains above 9 in Hg, remove the pump and tighten the vent plug.

iii. Power up check

- Connect tether to the power source.
- Verify connection to the Graphical User Interface.
- Ensure that there are people monitoring the ROV before and during the tests.
- Establish a safe connection between the control and the thrusters.
- Test external systems and mechanisms beforehand, including the vessel, and the gripper.
- Check the cameras' functionality.

iv. In water check

- Submerge the ROV with care, preferably with the help of two members of the team.
- Make sure that the amount of bubbles present is normal.
- Check the leak detector on a regular basis.

v. In case communication is lost

- If communication is lost, disconnect the ROV from the power source and bring unit to the surface by the tether.
- Initiate reboot process.

LOGISTICS

Scheduled Project Management

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 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.

As shown in the diagram below:

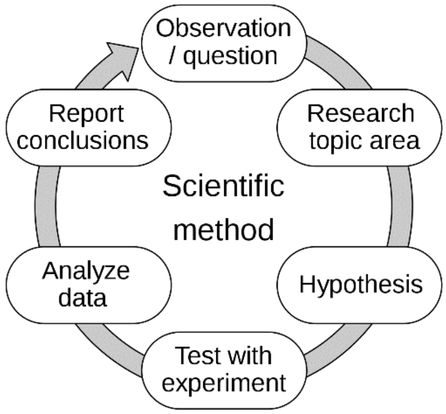

Fig. 22. Scientific method

On the other hand, the team needs organizational skills in order for the project to be completed in a timely manner. 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 really well for the team was taking stand up meetings from 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.

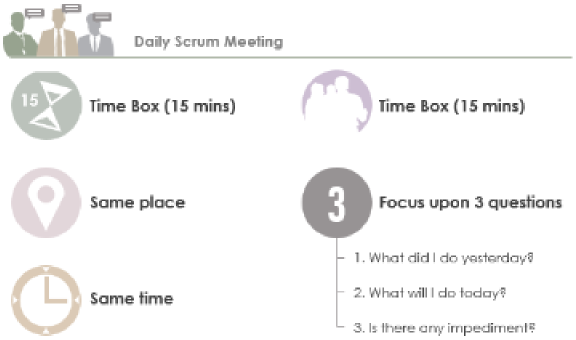

Fig. 23. Daily SCRUM Meeting

Also, the Kanban Board methodology helped the team define their deadlines and individual tasks to complete.

The Kanban Board is a brilliant visual tool that gives an overview of the current work status and simplifies team communication.

It helps optimizing, continuously improving, boosting productivity and eliminating 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 itself by having a CEO and three managers for the main areas, those being: mechanics, electronics and programming. There were very few new members meaning that the vision of the new ROV was made very clear to all members specifically because the timeframe to build the SeaFox-5 was very short compared to previous years. The managers were the best at each area from the previous competition. Most of the team members had assignments set in various areas. Other areas not listed above include props, image, and documentation.

Mechanics	Electronics	Software
Marco Leal	Marco Leal	Juan Pablo Vázquez
Carolina Flores	Miguel García	Carlos Maytorena
Chantal Mendoza	Daniel Orduño	Marian Meza
Miguel García	Carlos Maytorena	Diana Bentley
Misael Anaya	Dimas Trejo	Saúl Nehemias
Diana Bentley		
Mariana Castro		

Props	Documentation	Image
Carolina Flores	Daniel Orduño	Chantal Mendoza
Chantal Mendoza	José Beas	
Dimas Trejo	Diana Bentley	
Saúl Nehemias	Saúl Nehemias	
	Marian Meza	

Fig. 24. First division of labor in SeaFox Inventive

Workspace

Almost all work is carried out in an area designated by our university. This area is a work cell, 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 material, tables with power distribution and computer equipment. This section is restricted only to members who are working on the project.

Fig. 25. SeaFox Inventive work cell

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 in 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 as well as in the case that working on the designated workspace is not viable. That is why we value the files stored in Google Drive very much and we take care by backing them up.

Budget and Project Costing

Given that the SeaFox-4 never got to compete because it was meant to go to the 2020 Competition, most of the resources already acquired for it were utilized for the 2022 Competition. Most of the components from the SeaFox-5 were reutilized from the previous ROV when it comes to motors, regulators, and the capsule given that they were still in proper working conditions but the frame pieces that are 3D printed are new since the design of the ROV has changed. This meant that a cost projection for this year's competition with the previous fundraiser activities was comparatively very low.

The fundraiser activity for the remaining expenses was the sale of baked bread, it was an activity that took place throughout 2 weeks.

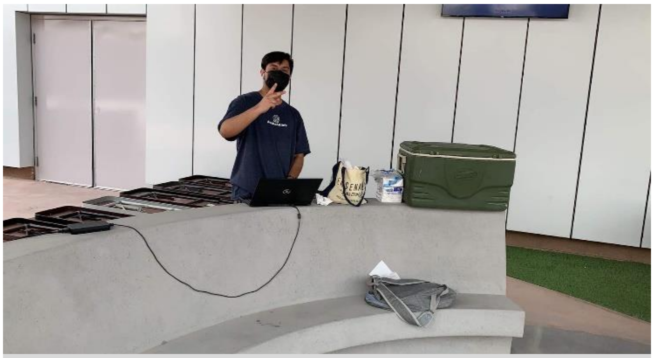

Fig. 26. Baked bread selling event

Fig. 27. Baked bread flyer

CONCLUSION

Challenges

During the whole process of both designing and implementing the vehicle there were a lot of challenges in the team's path. Some of them were solved easily and fast, but some others took more time and effort than expected to be solved.

During the design section, one of the major challenges was working from home, and developing software or integrating the hardware with less time available than before due to the school's availability for the use of the laboratories was more difficult than ever.

Also, during the implementation phase, the team encountered a new problem. Due to the pandemic, the team was not growing in members (strictly speaking about quantity of members), and the students who were working in the SeaFox Inventive team were mostly from last semester, this meant they were already in internships, with part time or even full time jobs, then, availability to work having not only the school weight but their jobs also was limited.

Finally, during the day the team tested the vehicle and recorded the video for the qualification phase of the competition, there were three major challenges which affected more than the team could ever expect.

First, two of the three 3D printers available stopped working, this meant everything the team had to print (which was a lot) was delayed because of the long printing times.

Then, the camera's streaming and the communication between the control station's computer stopped working, so the software team had to find a way to communicate with the Jetson Nano and solve the camera streaming problem, this took almost 12 hours to be solved.

Finally, when everything was looking great, after the first water leaking test procedure, the vehicle was taken out and the team proceeded to measure voltage and current in the regulators. Everything worked well, but after less than an hour, one of the 48v-12v 30A regulators stopped working, this meant the team had to change the design of the electronics circuit, to take the current for every component from just one regulator instead of two, this also meant the vehicle would not be able to function at a high speed, and the cameras and servo motors had a worse performance than expected.

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, there's some things that cannot be expected, such as the pandemic for example.

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 the members in their life as engineers.

Finally, teamwork, working with well-structured methodologies for planning the project has been proved to work every single time, and using methodologies like SCRUM or applications like the Kanban inside Microsoft Teams taught the SeaFox Inventive Team tools that almost every company is using at the moment. Therefore, finding a team that helps each one of the members apply the knowledge from classes, giving them the workspace to do it and showing them methodologies to be more productive which are used in the engineering world is the main lesson learned during this season.

FUTURE IMPROVEMENTS

Part replacements

One of the main problems that we encountered for this competition was the lack of extra parts or components required to continue our progress including the 3D printers as well as the voltage regulator. The delays were truly evident and they cost valuable time that could've been spent doing more trial runs. Even though the cost would elevate substantially, the benefit far outweighs the cost, and another benefit of having extra parts is that they can be used for research purposes for upcoming SeaFox models that future teams create.

Waterproofing

An area of opportunity that we found was that of waterproofing or at least repelling water from the circuitry and electronic components inside the capsule in the future whether it be by utilizing better penetrators, changing the pressure inside the capsule, utilizing better pressure measuring equipment or rethinking all together a way to house electronic components underwater, and allowing the electric signals to reach the motors. Making an underwater vehicle that relies on electronics to operate is a clear challenge in itself but having to deal with fried circuitry is a big way to demoralize the team, especially given that the parts are not cheap, which is why this occurrence needs to be remedied.

SENIOR REFLECTIONS

Saul Nehemías Mendoza

During the design and implementation of this project my mood never went down.

Working with such a great team, learning not only how to implement what we learn from school to a project but also learning new things such as working with planning methodologies has been one of the major learnings

I can take for my professional experience. More than thinking about what the team could do to make the ROV work make this project one of the most complete projects I have ever been.

I think the effort is shown not only in the competence but in every meeting and in every day in which we had to go work in the laboratory because persistence is what I call a real job, and understanding that big projects are not finished by only developing the solution but also planning the way everyone is going to work.

Finally, I believe that big companies' work experience cannot be taught, but this kind of project is actually pretty similar to what most of the companies are doing right now.

Daniel Orduño

I think that during the realization of this project I put my skills as an engineer to the test, despite being focused on a single area of work such as electronics, I was able to learn a lot from the other areas by working with my teammates.

In many situations some problems were presented to me, these gradually became challenges that motivated me to move forward so the project could continue on its course and accomplish our goals.

Something that I really appreciated from having worked on an engineering project of this magnitude was that I was able to put the knowledge that I learned theoretically during my career into practice by completing the tasks that the ROV needed. It is also worth mentioning that I learned the importance of each calculation that was made, whether it is to design a circuit, a piece, the material that is being used, etc.

Marian Alondra Meza

The experience as one of the team leaders will always be pleasant for me, from the coordination of the activities, the assignment of the teams, the planning of time, the calculation of our budget, decision making, etc., will always be aspects that become complicated since sometimes responsibility can be very stressful.

Maintaining a positive attitude during the execution of the project was key so that if it did not work on the first try, the team would never consider giving up at any moment.

Another essential part of being one of the people who coordinates the team is always maintaining trust in the members that conform it, since good results will always depend on the performance of each one of the members and the person who coordinated them.

I can proudly say that the performance of the team always exceeds my expectations and the learning obtained during the project was without a doubt one of the experiences that will support me in my formation as an engineer.

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- Miguel Bravo, Luis Manuel Torres & Marco Espinoza - His time and support
- Our Families - Their continued support and encouragement

Fig. 28. SeaFox Inventive member with Underwater Robotics book

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APPENDICES

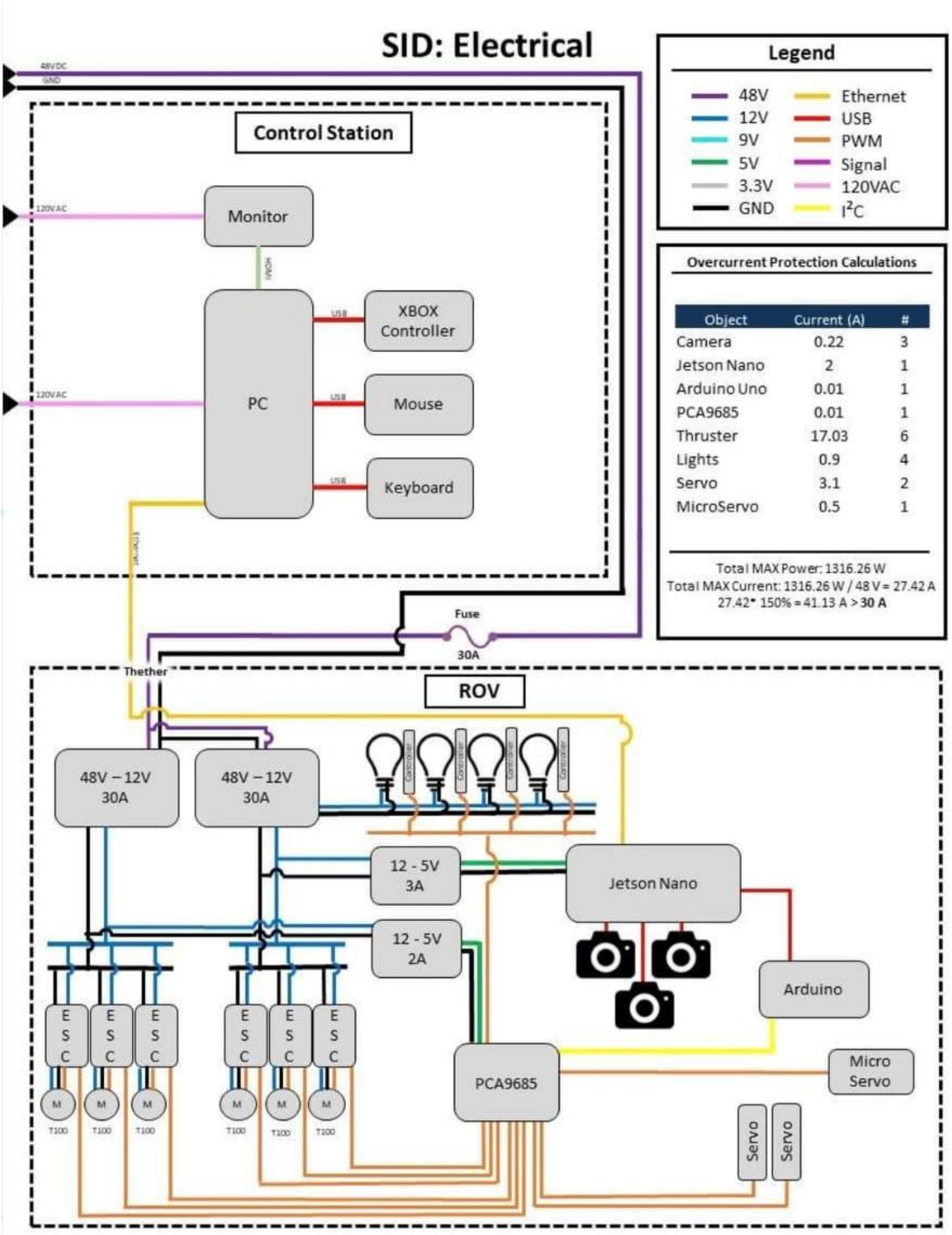
POWER BUDGET

Object	Voltage (V)	Current (A)	Quantity	Unit Power (W)	Total Power (W)	Total power brushless motors (W)
Camera	5	0.22	3	1.1	3.3	3.3
Jetson Nano	5	2	1	10	10	10
Arduino	5	0.01	1	0.05	0.05	0.05
PCA9685	5	0.01	1	0.05	0.05	0.05
Thruster	12	17.03	6	204.36	1226.16	
Lights	12	0.9	4	10.8	43.2	43.2
Servo	5	3.1	2	15.5	31	31
MicroServo	5	0.5	1	2.5	2.5	2.5
				Total Power	**1316.26**	**90.1**
MAX current		27.42208333				

The table shows how 27.42 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: 1316.26 W

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

SID


SID: Electrical
Legend
48V
12V
9V
5V
3.3V
GND
Ethernet
USB
PWM
Signal
120VAC
I²C
Overcurrent Protection Calculations
Object | Current (A) | #
Camera | 0.22 | 3
Jetson Nano | 2 | 1
Arduino Uno | 0.01 | 1
PCA9685 | 0.01 | 1
Thruster | 17.03 | 6
Lights | 0.9 | 4
Servo | 3.1 | 2
MicroServo | 0.5 | 1
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
Control Station
Monitor
PC
XBOX Controller
Mouse
Keyboard
USB
120VAC
Fuse
30A
Thether
ROV
48V – 12V
30A
48V – 12V
30A
12 - 5V
3A
12 - 5V
2A
Jetson Nano
Arduino
Micro Servo
PCA9685
Servo
Servo
ESC
M
T100

BUDGET AND PROJECT COSTING

Part description	Quantity	New/Reused	Unit cost	Total Cost
Tether				
Heat shrink 3/4 1 meter	5	reused	$2.48	$12.40
Anchor Marine Grade Duplex and Triplex Wire 100ft	1	reused	$118.17	$118.17
Cable UTP CAT 5e 21m	1	reused	$9.76	$9.76
Plug RJ45	2	reused	$0.26	$0.52
Anderson connector & terminals	1	new	$30.00	$30.00
Thrusters				
T100 Bluerobotics Thrusters	6	reused	$119.00	$714.00
Sealed enclosure				
M10 Cable penetrator for 6mm cable	14	new	$4.00	$56.00
M10 Cable penetrator for 8mm cable	1	new	$5.00	$5.00
Watertight Enclosure for ROV/AUV (6" Series)	1	new	$425.00	$425.00
JB Weld Marine Weld 20 min	4	new	$4.76	$19.04
Syringe 100ml	4	new	$1.00	$4.00
Silicone based lubricant	1	reused	$7.76	$7.76
Electronics				
Voltage converter regulator DC/DC 48V DC descending DC 12V 30A 360W	2	reused	$42.34	$84.68
Connection blocks	1	reused	$9.27	$9.27
Screws and bolts	6	new	$0.80	$4.80
Jetson nano	1	new		$0.00
Web USB Camera	2	reused	$45.00	$90.00
16 channel PWM PCA9685 for Arduino	1	reused	$8.99	$8.99
Arduino UNO	1	reused	$25.00	$25.00
Basic ESC	6	reused	$25.00	$150.00
Frame				
High density polyethylene 0.375"*18"*24" white	2	new	$14.99	$29.98
screws M3 x 12mm 100 pcs	1	new	$8.49	$8.49
Resine crystal 1kg & catalyzer	1	new	$18.62	$18.62
screws to fix frame	20	new	$0.39	$7.80
screws to fix clamps	8	new	$0.31	$2.48
Illumination				
Lights	1	reused	$325.00	$325.00
Printing filament 3D PLA 1.75mm 1kg	2	reused	$22.29	$44.58
Zip ties 100pcs	1	new	$8.00	$8.00
			Total	**$2,048.49**

Travel expenses	Quantity	Unit cost	Total Cost
Transportation (380km)			
Team members with VISA (van transportation provided by school)	12	NA	$0.00
Accomodation			
2 Queen w/refrigerator room rate	3	$219.00	$657.00
Food & drinks	12	$100.00	$1,200.00
Total			**$1,857.00**

EARLY GANTT DIAGRAM FOR DIFFERENT TEAM AREAS