Technical Design Report for HYDRUS

Recinto Universitario de Mayagüez (RUMarino Autonomus Underwater Vehicle)

Cesar A. Ruíz Navarro, Aníbal E. Rosado Reyes, Analía Díaz Mercado, Víctor Riefkohl Tirado, Ángel J. Cintrón Martínez, Edyan Cruz Vélez, Diego Quiñones

Abstract – This year, for Robosub 2025, RUMarino brings back Hydrus. Taking the lessons learned from their first participation in 2024, Hydrus arrives with enhancements to materials, design, a reliable electrical stack, and an improved software package. The electrical base on the inside was enhanced to provide better heat distribution throughout the main cabin, and thruster mounts were redesigned to provide greater support. The PCB was redesigned to allow for core features in the submarine to be added, and a voltage monitor was added. Simulation framework was switched to be done on Godot as it does not depend on the operating system of the ROS ecosystem. Finally, extensive testing was performed on the vehicle, making sure all functionalities were capable.

Figure 1: Hydrus

I. Competition Strategy

A. General Strategy

Hydrus has been developed and improved since 2018, competing for the first time at Robosub 2024. As the team prepares their participation in RoboSub 2025, their strategy involves overcoming heat and visibility issues in the Autonomous Underwater Vehicle (AUV) The 2024-2025 design cycle focused on taking the lessons learned in their first RoboSub participation and overcoming previous shortcomings. Overcoming these shortcomings involved rethinking previously established submarine features and increasing the focus on mobility and reliability. For mechanical and electrical systems, it meant redesigning core parts of the electronics system and rebuilding the mounts in which the thrusters rest, adding a battery monitor for safety, and optimizing the board designs further. In terms of software, it meant to create a more scalable and maintainable code, with tools that will let the future development of the autonomous features of the robot be more sustainable in the years.

B. Course Strategy

For RoboSub 2025, our strategy emphasizes leveraging Hydrus' upgraded systems to tackle each mission with accuracy and efficiency. The vehicle is now equipped to respond dynamically to visual cues, physical obstacles and strategies such as:

- *Collecting Data*: The submarine will identify the marine animal it has chosen and pass below the side of the gate with the image which corresponds to the animal. The team is confident in completing the task in style

- *Navigate the Channel:* After going through the appropriate side of the gate based on the chosen marine animal, the AUV will follow the path towards and through a channel of white and red vertical PVC pipes. Thanks to the color coding in the central pipes, the team is confident in completing the task.

- *Tagging:* With the similar color palette and shape of both marine animals, it is unlikely the AUV will correctly identify and fire at the chosen animal first. However, with the bright red border the vehicle accurately detects, the team is confident in the completion of this task.

II. Design Strategy

A. Mechanical Structures

The design of Hydrus, seen in Fig 1. consists of 4 main sections, the hull, camera cabin, low legs, and torpedo system.

1. Hull: The main hull is machined from 6061 Aluminum with a 0.125-inch thickness to allow for long term reusability. The main hull features 16 cable penetrators to allow for safe connections with the gripper system, camera cabin, thrusters, DVL wayfinder, and torpedo system. It is attached to the low legs through bolts fitted below the main hull, ensuring a stable connection between each section. The main hull is enclosed by two 6” diameter Blue Robotics watertight enclosures, each side featuring a double O-ring seal. These watertight enclosures are affixed to the submarine by vacuum sealing the vehicle, ensuring that each end of the cabin has around 800 pounds of force applied to it thanks to Pascal’s law. This design ensures a stable watertight seal while allowing for quick adjustments to electrical systems when needed. One must only repressurize the hull to undo the seal and release the cabins and access the electronics.

Previously, the AUV suffered from electronics overheating inside their cabins, leading to the deformation of the previous 3D-printed carbon fiber mounting stack. In response to this, the mounting stacks were replaced with a new version consisting of VEX Robotics perforated aluminum plates, secured with 3D-printed carbon fiber supports. These perform much better at conducting heat and are connected to the aluminum ends of each cabin. This ensures that the heat flows from the electronics to the much colder ends of the cabin, keeping the electronics safe from overheating.

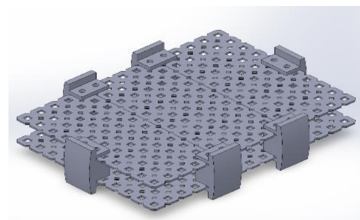

Figure 2. Current Stack Design.

2. Camera Cabin: The camera cabin is a 3” diameter cylindrical enclosure attached to the low legs. Each side is enclosed by double O-ring flanges and held together through a vacuum seal. To ensure visibility within a 90-degree range in the front of the AUV, the camera is held stable inside the cabin.

3. Low Legs and Thruster Mounts: The low legs serve to hold the submarine when lowering and lifting the vehicle from into the water. The low leg structure also serves to hold all the other components that aren’t attached to the main hull such as the thrusters, camera and gripper. Attached to the low legs are 8 Blue Robotics T100 thrusters. Four are mounted on each corner of the AUV, angled at 45 degrees from the face of the low legs. These are responsible for moving the submarine forwards and backwards as well as allowing it to yaw. The last four are closer to the center of the submarine and are oriented in a way that allows the submarine to control its elevation in the water as well as unlocking the ability to pitch and roll.

Previous thruster mount design presented reliability problems during testing and maintenance. When placed through a Finite Element Analysis, the design presented a minimum safety factor of 1.3 when subjected to a 50 lb. force. It is worth noting that this simulation did not take every factor into account, allowing for the possibility of an inflated value for the safety factor. A new mount was created which included a 10 mm base plate to distribute the energy of impacts more efficiently. When subjected to the same conditions, the new mount sports a higher safety factor of 5.3.

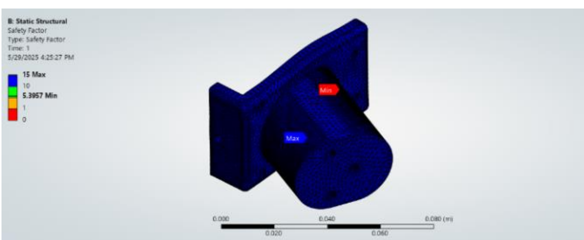

Figure 3. New Generation Thruster Mount.

The final changes to the mount include a switch of filament material from PLA to Hyper series PLA Carbon Fiber.

4. Torpedo System: The torpedo system uses two motors spinning in opposite rotations, allowing for the torpedo to be pushed forwards between the motors up to a meter in distance while staying within the safety parameters outlined in the team handbook.

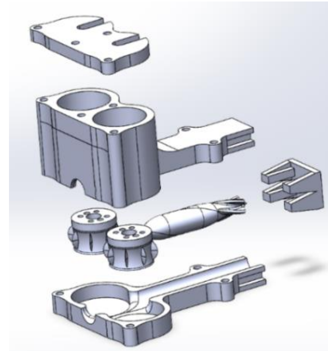

Figure 4: Hydrus Torpedo System.

B. Electrical Systems

1. Power System: The power system is made up of two voltage phases: 22V and 15V. A 22.8V, 23,000mAh battery is utilized to provide power to the PCB. A ZK-12KX voltage regulator is used to lower the voltage to enable the 15V phase that powers the micro-computer. A 22V phase to power a DVL, two DYS 4-in-1 ESCs, and one Blue Robotics Basic ESC for the motors units and the torpedo system. A system of fuses, relays, and voltage monitors was set up to protect important components such as battery, thrusters, and micro-computers.

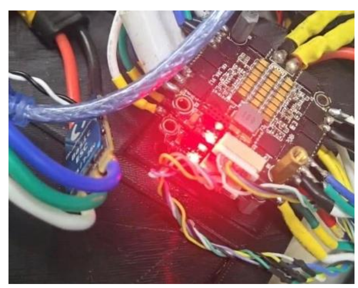

Figure 5. ECSs Implemented in Hydrus

*2. Board Design – Optimizations***:** The team designed one central board from which the whole AUV draws power. The previous PCB design did not have the capabilities to add a DVL. Faced with this problem, the PCB was redesigned to add this key component to the AUV.

Figure 6. Hydrus Board Design.

C. Computer Systems

This year the software team has been concentrating its efforts on evaluating and assessing what is needed for building a complete autonomous vehicle software stack. All the work this year has been concentrated on the official repository. The goal for this year's competition is to have a viable operational autonomous vehicle software package for the robosub competition. One that uses the latest techniques for a resistant and multipurpose autonomous robot.

D. Design, Architecture and Tooling

The biggest problem when building a complete autonomous software stack is to be able to have all the modules enabled and running together, integrated into the same pipeline. It's not only a problem of detecting objects, but also the combination of perception tools, Mission Handling, Path Planning, Sensors Integration, Visual Mapping, Controllers, and Actuators. All this ensures that all the modules perform with a usable framerate and handle the computational limitations of the edge computer inside.

In the strive to make the best product, the team decided to take the long path in a lot of architectural and design decisions in the software. Building things from the ground up, while making sure the team can use and deliver a good, autonomous solution at the end of the year.

The first thing the team strived for was developing tools and ecosystems for fast software development. For that, the team used a self-made orchestration development tool that uses Docker for handling containers and dependencies. The software can support three different devices: CPU-only computers, devices with CUDA and arm64 for the jetsontx2. This tool, known internally as Hocker (Hydrus + Docker), is the main tool for developing and interacting with the software.

The team also made sure to have the highest quality software development practices such as Unit and Integration testing for each part of the pipeline of the autonomous stack. One of the problems when developing the software was to have and test the end-to-end.

E. Computer Vision

For computer vision, the team mainly relied on the ultralytics library for using their YOLO models.

The team has been in the process of releasing a tool for automatic annotations using the latest Video Segmentation Models. Like Sam2, the team has been developing a tool that uses the Cutie model and Mobile Sam. The result is a tool that, with a GUI, can annotate objects using click inputs and custom bounding boxes with higher efficiency than previously.

Object Detection is not enough for creating an autonomous vehicle. The team also needed a way to create and manage a coordinate system and a visual mapping system to tell the robot where to move. For this the team uses Stereolab's Zed Camera that has enabled a depth map solution thanks to stereo camera technology, and an IMU. This information can be used for creating a 3D point sparse map of the surrounding area. Combining this with 2D bounding box detection, we can detect and locate the 3D coordinates of the objects detected. This library enables the coordinate system and visual mapping capabilities that we need to fully express the competition mission's requirements for movements and perceptions.

F. Controllers

The current implementation of the controllers is a very simple custom proportional controller that moves at a constant rate of movement and has predefined thruster commands for moving forward, rotating and going upwards and downwards. The reason for this implementation is to simplify the PID Controller in order to not have to configure the parameters for each individual thruster. For that, it is required to simulate and understand the orientation of the thrusters in a simulated environment.

G. Mission Planning

There are many tools for managing states and missions planning. Many of them are too bloated for the specific type of missions being created, or too integrated into the ROS ecosystem that has made development too complicated in our case, given the hardware limitations. For that reason, the team has created a tree-based mission specification system that interacts with the team's ROS controller directly. One of the plans for future competitions is to integrate an intermediate path planning system that manages obstacles, safety requirements for movement, and more.

H. Simulation

After some work on the simulation side and a lot of failed attempts to implement complicated simulation stacks into the system, the team decided to start over with different designs and technologies. It was decided to use Godot as the simulation framework because it doesn't depend on the operating system of the ROS ecosystem. This creates the foundation of future developments to achieve more mature simulation integration in the system, since the team have plans to use ROS2 for next competition then it's not needed to refactor or reinvent our simulation solution, the plan will be to implement something that doesn't depend on the ROS or ROS2 library ecosystem.

1. Microcontroller Software: After some problems implementing the *rosserial_arduino* package, a decision was made to implement a custom serial communication package. Tools like ports, multiplexers, and virtual hardware devices were used to have a proxy that manages the interactions with the microcontroller. This allows for multiple processes to connect to the Arduino at the same time.

III. Testing Strategy

A. Mechanical Structures

To ensure the submarine could use a vacuum seal to maintain hull watertightness, the submarine was kept in a temperature controlled dry environment with possible areas of failure coated with a mixture of soap and water which could be seen through the vehicle's acrylic cabins. The vehicle was then vacuum sealed and remained in this environment for 36 hours, with routine checks throughout multiple points in the day to verify there was no significant gain in pressure, ensuring the vacuum seal was maintained. To validate the AUV's waterproofing, the submarine was taken to the natatorium while vacuum sealed and remained partially submerged for 2 hours.

B. Electrical Systems

1. Unit Testing with Function Generator: The first testing phase used the HO102S 3-in-1 multimeter in its function generator mode to simulate the PWM signal required by the servo. The configuration was a square wave signal at 50 Hz, with a high-level voltage of 2.50 V—limited by the multimeter but sufficient for testing despite being lower than the ideal 4.6 V. The pulse width was varied from 1 ms to 2 ms, corresponding to the servo's range of 0° to 180°. This setup allowed us to confirm the servo's ability to respond correctly to varying pulse widths and verified its basic functionality.

Figure 7. HO102S Function Generator Mode.

2. System-Level Testing with Microcontroller: In the second phase, the servo was integrated with the onboard Keystudio Mega 2560 R3 microcontroller. A custom test script developed in the Arduino IDE cycled the servo through 0°, 90°, and 180°, verifying accurate response to microcontroller-generated PWM signals. This confirmed both software control and electrical integration within the submarine's system.

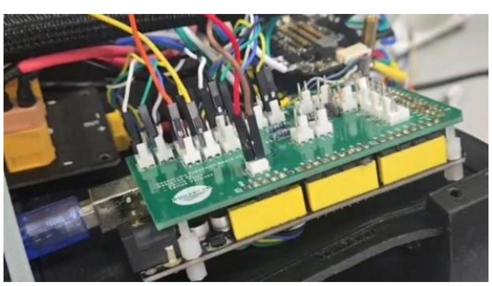

Figure 8. KeyeStudio with Expansion Board.

2.a Results and Observations:

The servo operated reliably during both tests. Even with reduced voltage in the standalone test, it achieved full-range motion—albeit slower and with reduced torque. The microcontroller-driven test validated the servo control code, wiring, and physical setup inside Hydrus. Together, both phases ensured the servo's readiness for system-level deployment.

3. ESC and Motor Testing: To test the ESCs, we used the Keyestudio microcontroller and the Arduino IDE, uploading code to activate each motor briefly and individually. This bench test confirmed that the outputs, motors, and signal cables were all functioning as expected.

Figure 9: Signal Pattern for the Motors.

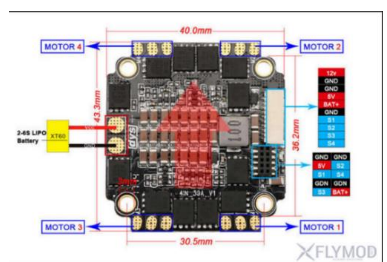

Figure 10: ESC Connection Schematics.

IV. Acknowledgements

We thank our sponsors, advisor Dr. Raúl Torres, IEEE RAS, and UPRM staff for their vital support in making RoboSub 2025 possible. We're also grateful to all past and present RUMarino members whose contributions continue to drive the team forward.

APPENDIX A: Component Specification

	Vendor	Model/Type	Specs	Custom/ Purchased	Cost	Year of Purchase
Frame	King Starboard	3/4in x 48in x 96in Black King Starboard		Purchased and cut	$276.39	2019
Waterproof Housing	Blue Robotics	6"series Cabin, 4"series Cabin		Purchased	$317, $230	2019, 2024
Waterproof Connectors	Blue Robotics, McCartnet	M10 Penetratos Subocnn Wet Pluggables	M10 Thread 6pin connector, 10 pin connector	Purchased	$828.05	2019, 2020
Thrusters	Blue Robotics	T200, T100	Forward Thrust: 5.1 kgf Reverse Thrust: 4.1kgf (16V) Forward Thrust: 3.55kgf Reverse Thrust: 3.0kgf (12V)	Purchased	$38.00, n/a	2019-2020, 2023-2024
Motor Controls	getfpv	DYS F30A 4-in-1 ESC BLHeli_S Dshot	**Continous Current: 30A Input Voltage : 2s-6s Lipo**	Purchased		2022, 2024
Propellers	Blue Robotics	T100	n/a	Purchased	n/a	2019
Actuators		DYS F30A 4in1	continuous current to motor: 30A, peak current: 35A input voltage: 2-6S Lipo BEC output: 5V / 3A, 12V / 1A Size: 43 * 40 * 8mm weight: 12.95g firmware: BLHeli_S supports Dshot150 / 300/600, Oneshot125 / 42, Multishot, PWM processor: EMF8BB21F16G SILABS, 8bit C8051, run 50MHz	Purchased	$58.29	2020
Battery	ShenZhen Grepow	Tattu G-Tech 6S	**Minimum Capacity:** 23000mAh	Purchased	$475	2023

	Battery Co., Ltd	23000mAh 22.8V 25C HV Lipo Drone Battery	**Configuration: 6**S / 23V / 6 cells **Discharge Rate:** 25C **Net Weight(±20g):** 2474g **Dimensions:** 208mm Length x 91mm Width x 62mm Height **Balancer Connector Type:** JST-XHR			
Converter	DROK	Adjustable CC CV Buck Converter, Power Supply Module CC CV Buck Converter DC 5.3V~32V 24v Step Down Voltage Regulator 12A 160W Adapter/Driver	Input Voltage: 5.3~32V Output Current: 8A Output Power: 120W Output Voltage: 1.2~32V Output Ways: 1	Purchased	$12.99	2025
Regulator	DROK	Adjustable CC CV Buck Converter, Power Supply Module CC CV Buck Converter DC 5.3V~32V 24v Step Down Voltage Regulator 12A 160W Adapter/Driver	Input Voltage: 5.3~32V Output Current: 8A Output Power: 120W Output Voltage: 1.2~32V Output Ways: 1	Purchased	$12.99	2025

CPU	NVIDIA	Jetson TX2	GPU: 256-core NVDIA Pascal CPU: Dual 64-bit NVDIA Denver 2 and quad-core Arm Cortex-A57 processors Memory: 8GB LPDDR4 Storage: 32GB eMMC Connectivity: 802.11ac WLAN and Bluetooth	Purchased	$479	2020
Inertial Measurement Unit (IMU)	VectorNav	VN-100	Gyro In-Run Bias: 5°/hr Accelerometer Range: ±16 g Power: 200 mW Gyroscope Range: ±2,000˚/sec Extended Kalman Filter Update Rate: 400 Hz IMU Data: 800 Hz Pitch/Roll: 0.5° Accel In-Run Bias < 0.04 mg	Purchased	$1,075	2020
Doppler Velocity Logger (DVL)	Teledyne	Wayfinder DVL	Max Altitude: 60m Min Altitude: 0.5m Long-Term Accuracy: ±1.15% Velocity Range: 10 m/s Ping Rate: 16 Hz Beam Angle: 30® Depth Rating: 200m Communications: RS-232 Average Power Conssumption: 3W	Donated	$7,500.00	2020
Vision	Stereo Labs	ZED 2i Camera	Stereo Baseline: 120mm Resolution:1080p @30fps Built-in Sensors: IMU, barometer & magnetometer IP: IP66	Purchased		2023
Autonomy	ROS	ROS				
Open Source Software	ROS					
Programming	Python Software	Python, C++				

Language(s)	Foundation					
Internal Comm Network	USB Port			Purchased		
External Comm Interface	Jadaol Cat 6 Ethernet Cable 50 ft, Outdoor & Indoor 10Gbps Support Cat8 Cat7 Network, Flat RJ45 Internet LAN Computer Patch Cable for Router, Modem, Switch, Gaming Consoles, Streaming Devices, White			Purchased		

Appendix B. Outreach Activities

As the pioneering autonomous underwater vehicle in the Caribbean, RUMarino has experienced consistent growth, fueled by the steadfast support of our sponsors and surrounding community. Our initiative has transformed the educational and technological landscape, serving as a catalyst for outreach and innovation. Committed to building meaningful connections, we continually seek opportunities to give back by sharing our expertise and passion. Through interactive workshops and informational booths, we engage students both on campus and from external institutions, sparking interest in robotics and marine technology. Our outreach extends beyond academic circles—RUMarino has also connected with local schools and hosted recreational events such as pickleball, 8-ball pool, and dominoes tournaments. These activities encourage team spirit, wellness, and community involvement, reinforcing our mission to inspire and uplift through inclusive engagement.

A. Campus Outreach

a. Campus Open House

The campus open house is an event where high school students and other interested visitors explore the university, with a focus on the College of Engineering, to learn about the innovative projects and research opportunities available. RUMarino participates annually in this initiative, inspiring future engineers and sparking interest in the fields of autonomy and robotics.

Figure 11: Our team representation in the Open House.

b. "Futuros Colegiales" Event

For this activity, RUMarino was able to present the project to high school graduation candidates from the Antonila Vélez School in Aguadilla and La Academia Interamericana de Arecibo, moving towards the STEM field. Being able to present this students how robotics are implemented in autonomous underwater vehicles.

Figure 12: Our team representation with the students of "La Academia Interamericana de Arecibo".

c. L3Harris Shark Tank

The team participated in a Shark Tank-style competition sponsored by L3Harris, where they were challenged to present why RUMarino deserved sponsorship. The objective was to demonstrate how the team's mission and vision aligned with L3Harris' core values. After submitting a compelling video highlighting the project's impact and relevance to the company's goals, RUMarino advanced to the final stage. In this phase, team leaders presented live in front of a panel of L3Harris employees, ultimately earning third place and securing both funding and official sponsorship for the team.

Figure 13: Our team presenting in the L3Harris Shark Tank.

d. Exploring the Depths of Underwater Robotics

The team organized a dynamic panel discussion featuring fellow participants from the RoboSub 2024 competition. Represented teams included the University of Alberta's ARVP, Embry-Riddle Aeronautical University's Team Unsinkable, and the 2024 champions, Desert WAVE from the Si Se Puede Foundation. This event aimed to engage students and enthusiasts in the fields of autonomy and robotics by offering a unique opportunity to gain insights into the competition, explore the strategies behind each team's success, and understand how these innovative projects have grown and evolved over time.

Figure 14: Day of the activity.

Figure 15: Promotion of the activity.

e. IAP events

The Industrial Affiliate Program is an initiative active learning model that integrates theoretical insights with hands-on industry experience. Multiple companies unite to aid multiple special projects and investigations and RUMarino is part of this program. Yearly the team presents a poster for the upcoming work to be done in the semester and a presentation right before the school year ends to showcase the work done.

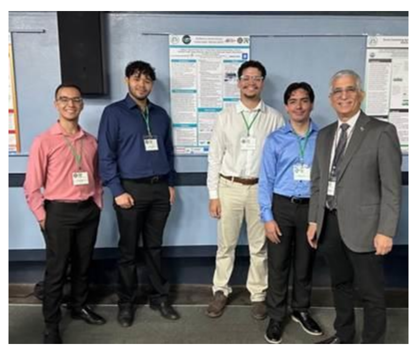

Figure 16: Our team representation with our Dean.

Figure 17: The poster that was presented in this first event.

i. Company Night (IAP Event)

This event provides engineering projects and research initiatives with the opportunity to host informational booths and present their work to the companies participating in UPRM's annual Fall Job Fair. RUMarino showcased its achievements from the RoboSub 2024 competition, outlined its goals for the upcoming year, and introduced its current vehicle, Hydrus. Over 30 companies visited the booth, allowing the team to engage in valuable networking and initiate new sponsorship discussions with several organizations.

Figure 18: Our team representation on the Company Night.

ii. Work Update Presentation at the end of school year

The team had the opportunity to present the work accomplished throughout the academic year, along with the modifications made to our AUV in preparation for RoboSub 2025.

Figure 18: Our team representation on the Work Update Presentation.

B. School Outreach

a. Colegio Sagrado Corazón

The team visited Colegio Sagrado Corazón in Ponce, PR, where they collaborated with the school's SHPE Jr. Chapter to deliver a presentation about RUMarino, its mission, and its impact on both the campus and its members to eleventh grade students. The goal was to inspire the attending students to explore careers in engineering and spark their interest in autonomy and robotics.

Figure 19: Our team representation with the students of "Colegio Sagrado Corazón".

b. Escuela de Matemáticas, Ciencias y Tecnología (EMCT) – San Juan, PR

The team visited the Escuela de Matemática, Ciencias y Tecnología in San Juan PR, (Specialized School in Math, Science and Technology) to participate in the school's Big Mentor program—an initiative that offers special informational sessions to 9th grade students about college opportunities. During the visit, RUMarino presented its mission, goals, and the team's impact on both the campus and its members. The objective was to encourage students to consider careers in engineering and spark their interest in autonomy and robotics.

Figure 20: Our team representation presenting to the students of the "Escuela de Matemática, Ciencias y Tecnología".

Figure 21: Certificate of appreciation for our participation.

C. *Lab Visits*

In this past year the team also received the visit of sponsors, to learn more about how we work in our operations and general updates with our AUV's alonsgside visit from curious students just wanting to learn. We hope to exchange knowledge and build lasting conexions.

Figure 22: Part of team leads and our sponsors

D. Pickleball Tournaments

This academic year, one of our student advisors introduced pickleball to the team after picking up the sport himself. His initiative encouraged members to adopt it as a fun and effective way to stay active, relieve stress, and improve mental clarity. As the team geared up for RoboSub 2025, the idea of hosting pickleball tournaments emerged—not only as a form of team bonding and physical wellness, but also as an innovative way to raise funds and gain visibility within the community. Given the growing popularity of pickleball in Puerto Rico, RUMarino Pickleball Club was created and successfully organized three tournaments that brought together players, supporters, and local enthusiasts. These events allowed the public to engage with the team beyond robotics and generated interest from potential sponsors. For the final tournament, the team proudly secured sponsorships from La Pregunta Pickleball Store and Deporte 24/7, marking a significant step in community outreach and fundraising efforts.

Figure 23: Images of the tournaments and the promotions of the events