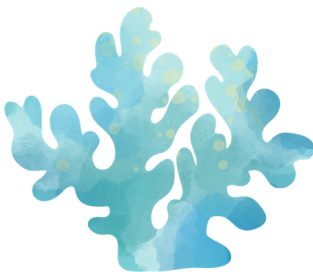


G.U.S.T.A.V.

Global Underwater Survey & Task Assistance Vehicle

Weinberg-Gymnasium
Kleinmachnow, BB, Germany



Florian Theile '27

David Chobe '26

Julius Kaestner '26

Sebastian Fröhlich '27

Lenn Rüdemann '27

Dr. Andreas Trippo

Jörg Sirisko-Theile

CEO & Engineering Lead

Head of Marketing

Mechanical Engineer & Tether
Operator

Mechanical Engineer & Pilot

Tether Operator

Mentor

Mentor

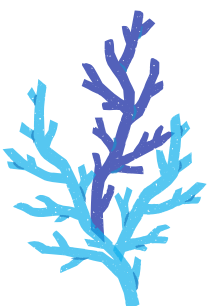


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1. Abstract

Weinberg Robotics is a first year, student-run company and started this year with four members, who all share the passion for engineering and underwater exploration. Our company followed a structured and collaborative engineering process to design and build a remotely operated vehicle (ROV) for the MATE ROV Ranger Competition. By analyzing the mission requirements, we identified a key conclusion: effective underwater operations depend on precise and adaptable movement.

Based on this insight, we defined mobility as our central design priority. Our team worked together across different roles to develop, test, and refine a solution that maximizes maneuverability and control. This resulted in an eight-thruster propulsion system that enables full six-degree-of-freedom movement.

Through iterative development, problem-solving, and continuous improvement, we transformed a core design idea into a functional and mission-ready ROV. This process reflects our company's ability to combine engineering thinking, teamwork, and practical implementation to meet complex real-world challenges.



Figure 1: Weinberg Robotics Team Photo

Front Row (l-r): David Chobe, Julius Kaestner, Florian Theile, Lenn Rüdemann
Back Row: Sebastian Fröhlich

2. Project Management

Every member of Weinberg Robotics has a role according to their skills and interests. The team was under the leadership of Florian Theile as CEO, engineering lead, and Co-Pilot. Head of marketing was David Chobe, responsible for laying out the documentation structure and for capturing the most important moments of the construction process. To help with manufacturing parts and design decisions, Julius Kaestner and Sebastian Fröhlich were on the engineering team, where they also had effective input as the tether operator and pilot. A last-minute recruitment was Lenn Rüdemann who joined the team as new tether operator to support our rather small team

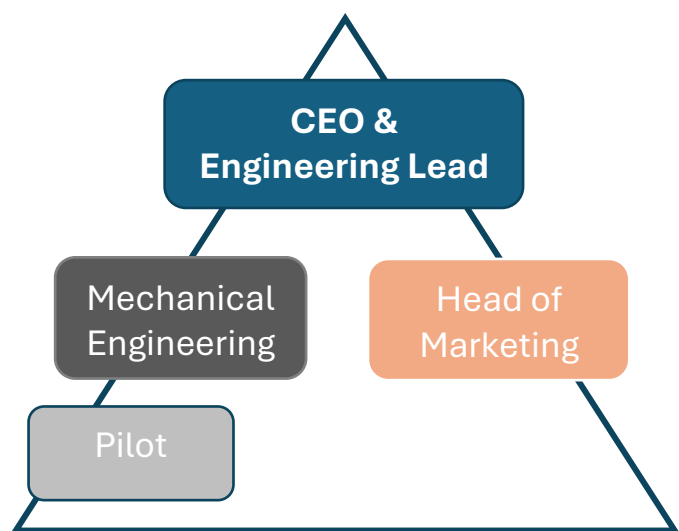


Figure 2: Weinberg Robotics team structure - Made by Florian Theile

To keep track of the project in the short time, the schedule was split into three phases. The design phase, prototyping & build phase and testing phase. Before anything else started, the team brainstormed about different design options for the ROV. When the design idea was set, the design process started in Onshape. From the point on when the raw frame was ready to be built, design and build phase overlapped to optimize the time needed for new iterations. During build sessions the team often discussed current prototypes and improvement ideas.

2.1. Operational Challenges

Weinberg Robotics only received approval for founding and funding at the beginning of March 2026. This created a lot of time pressure for the design and build phase and changed the schedule drastically. Because of the short time, the team decided to use meetings to build the ROV. The CAD modelling and adaption of design ideas was done by the engineering lead. Because of this structure we were able to build a functioning ROV within the deadline.

Another major challenge was that because of our small team, advancing to the World Championship brought many new tasks that had to be done in a short amount of time. In the meeting to distribute those tasks we decided to recruit and train two new students. As the new students were missing the experience from the regional practice run, they were assigned assisting tasks and gradually took on more responsibility. This resulted in a reduced time for them to get familiar with the project.

3. Design Rationale

GUSTAV was designed to provide a highly maneuverable, reliable, and mission-focused solution for complex underwater operations in the 2026 MATE ROV Competition. Throughout the development process, our team focused on balancing functionality, stability, safety, and cost efficiency while maintaining a highly modular structure that allows quick repairs and future upgrades.

3.1. Engineering Design Rationale

The ROV measures 60 cm × 42 cm × 42 cm and weighs 12.5 kg. While the overall design follows proven standard ROV concepts commonly seen in professional and competition systems, every structural, electrical, and software-related integration was individually designed and adapted to meet the mission requirements of the Ranger class.

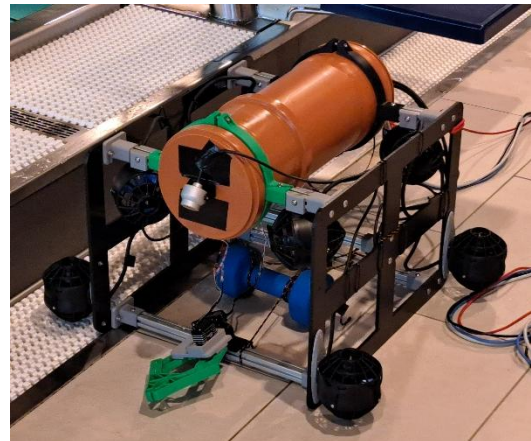


Figure 3: Gustav - Photo taken by Jörg Sirisko - Theile

The main design objective was to optimize maneuverability in underwater environments. This was achieved by designing the frame side panels as open as possible. The panels have big cutouts to significantly reduce drag on lateral movement which improves responsiveness during precise movement. However, increasing the openness of the overall structure reduces structural rigidity and stability. To address this trade-off, we reinforced the frame with extended mounting brackets for the aluminum extrusions.

3.2. Innovation

One innovative aspect of the vehicle is its modular and adaptable design philosophy. The ROV combines CNC-milled structural elements with 3D-printed custom components, allowing rapid prototyping and efficient redesigns during testing phases. Multiple critical structural parts were redesigned several times after stress testing identified weaknesses. In particular, the enclosure mount repeatedly showed a point of failure during movement tests and recovery out of the pool. By modifying the CAD



Figure 4: Design iteration with structural failure - Photo taken by Florian Theile

model and switching to stronger materials, the team can increase the durability of the entire frame system significantly within a short time.

Having a highly modular Slide-On-System for the frame is another innovation we made. The frame is made from 2020 aluminum extrusions with HDPE side panels. This made it possible to create our own 3D printable Slide-On-System for thrusters, enclosure, frame mounts, cameras, and the claw. The Slide-On-System is easily adjustable in CAD to fit new parts and can be screwed in place everywhere on the ROV. This makes it possible to quickly adjust a components position e.g. if it is noticed during testing, that a different camera angle would give a better view.

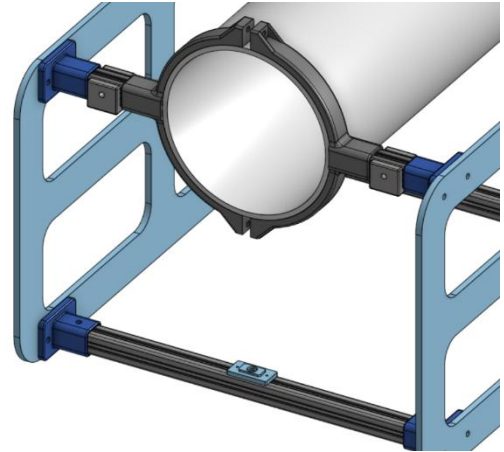


Figure 5: Slide-On-System - CAD made by Florian Theile

3.3. Systems Approach

The ROV was designed as an integrated system in which propulsion, buoyancy, control systems, cameras, and manipulators support each other to maximize operational performance. Three deep-sea HD cameras provide overlapping viewing angles, including a direct view on the gripper, improving operator awareness during precision tasks. Camera-based tasks became one of the strongest operational capabilities of the vehicle due to the high image quality and intuitive pilot interface. The modular buoyancy system makes it possible to balance the ROV, allowing the propulsion system to operate more efficiently.

3.4. Vehicle Structure

The vehicle structure is a balance of manufacturability, durability, and adaptability. The main electronics enclosure uses a waterproof PVC pipe because it is inexpensive, widely available, easy to machine, and reliable under pressure. We decided against an aluminum enclosure because at the depth where our ROV is intended to operate, the higher waterproof rating does not make up for the higher weight and cost of aluminum. CNC-

milled HDPE side panels for the frame provide rigidity and dimensional accuracy, while 3D-printed parts allow fast iteration and mission specific customizations. HDPE was used because of its easy manufacturability and light weight while still maintaining high structural support and rigidity. Alternatives such as aluminum were considered, but rejected due to higher cost, more weight and more complex manufacturing requirements. During early testing phases of mounting brackets, PLA was primarily used for waste reduction in prototype development and rapid iteration. Final structural components were later printed from ABS to improve long-term durability and impact resistance. The team learned that even small material changes could significantly improve system reliability. Several structural failures during testing directly influenced later redesigns and material choices.

The vehicle has been successfully tested at depths of up to 4 meters and is structurally designed for greater depths based on the specifications of the propulsion and enclosure system.

The modular structure improves serviceability and future expandability. Aluminum extrusions distribute structural loads between both frame sides while also providing versatile mounting points for additional systems and upgrades. This modular design proved essential after repeated stress failures in earlier prototypes.

3.5. Electrical System

The electrical systems on board GUSTAV are all housed in a watertight enclosure. The onboard systems are powered using a 12 V surface power supply with current protection of 25 A through integrated fuses. A 12 V to 5 V converter supplies stable power to the Raspberry Pi, cameras, and auxiliary electronics. The surface laptop and the Raspberry Pi are connected via an Ethernet cable.

The tether connects the topside system to the ROV. It consists of two 6 mm² wires (10 AWG) for positive and negative, an Ethernet cable and a

rope as tether base. Having two 6 mm² wires leaves room for future upgrades to higher voltage systems. The wire size was selected based on a calculation of the voltage drop. The ROV has an average current consumption of 15 A with a drop of 2 V and output voltage of 10 V. Bigger wires would make the tether too stiff and limit the ROV in its maneuverability.

All critical electrical systems are protected using waterproof housings, waterproof connectors, and a tether strain relief. The tether management system is operated by a dedicated tether operator to reduce drag and prevent entanglement during missions. The 25 m long tether was intentionally designed to ensure a large operational range while maintaining maneuverability for the ROV. Future improvements include adding buoyancy elements along the tether length except near the vehicle itself to reduce drag while preserving diving capability.

To minimize wiring errors during assembly and maintenance, the electrical system follows a clearly defined polarity convention using color-coded connectors and cables. Additional protective covers around the thrusters improve operator safety and reduce the risk of mechanical damage during operation.

3.6. Control System

The control architecture was intentionally kept compact and efficient to minimize unnecessary complexity. It is a two-part system written by the team in Python. A flight joystick provides intuitive control for the pilot across all axes of movement while simultaneously controlling the claw system. The surface control computer and Raspberry Pi are communicating over Ethernet (TCP). The raw joystick data is passed to the ROV where it is processed. The -1 to 1 values are translated into

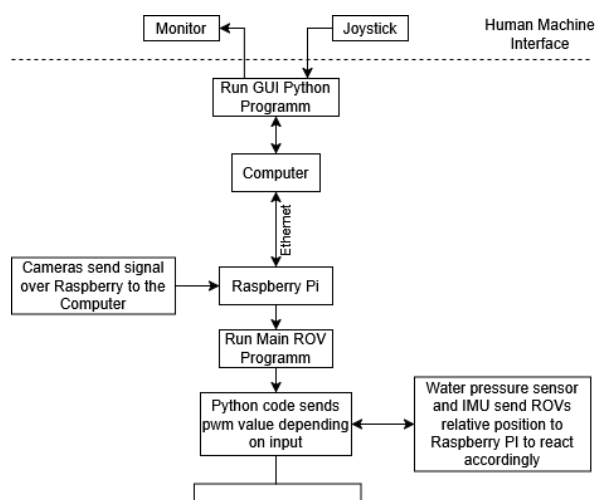


Figure 6: Flow chart of the ROV - Made by Florian Theile

PWM values based on the control algorithm. The algorithm can be adjusted with a variable power limit for each thruster to enable stabilization.

The team also experimented with additional stabilization sensors, including an IMU system intended for future automatic thrust adjustment and stabilization features. Due to time limitations before competition, these systems could not yet be fully integrated. Nevertheless, the hardware architecture already supports future expansion toward autonomous stabilization systems.

Although the team currently does not use a formal version-control workflow due to its small size, members already gained experience with GitHub in private projects and plan to integrate structured version control into future development cycles.

3.7. Propulsion

To meet the requirement of precise and adaptable movement, the propulsion system of GUSTAV was designed using eight T200 thrusters. These thrusters were chosen by Weinberg Robotics for their known reliability, good online documentation and thrust to weight ratio. An eight-thruster configuration was chosen over a six-thruster design, to enable full six degrees of freedom. This enables one additional degree of freedom compared to the six-thruster design, without the need for a more complex stabilization algorithm.

The two front and rear motors are angled 45 degrees to enable omnidirectional horizontal movement and allow the ROV to rotate 360-degrees on the spot. The four vertical thrusters are mounted at each corner of the ROV to maximize the rotational force in roll or pitch and ensure balanced thrust distribution.

This configuration minimizes the interference between thruster streams, while providing stable and precise control for inspection or manipulation tasks.

3.8. Buoyancy and Ballast

The buoyancy system was designed around a high inherent buoyancy concept. The main waterproof PVC enclosure contains a large internal air volume that naturally generates positive buoyancy by 4.1kg. The buoyancy was calculated in Onshape by assigning materials to the components. Neutral buoyancy is then achieved with adjustable ballast rather than relying on heavy structural materials. Initial testing used temporary external weights like dumbbells, while future iterations are planned to use modular screw-mounted ballast systems for faster adjustment and improved consistency. Adjustable ballast was chosen over fixed ballast because it creates the option to move the ROV's center of mass closer to the bottom and increases neutral stability. If new tools are added the buoyancy can then be easily edited.

The team intentionally rejected lead ballast solutions due to environmental concerns regarding heavy metals.

3.9. Payload and Tools

GUSTAV's camera system consists of 3 identical underwater HD cameras. This allows for options like our Slide-On-System to have the same mounting bracket for every camera and reduces the need for different replacement parts. Camera 1 is placed under the watertight enclosure with the view out front. This was selected to provide the pilot with better situational awareness. Camera 2 is placed at the front of the watertight enclosure facing down on the gripper to aid with precision movements. Camera 3 is placed at the bottom of GUSTAV facing the ocean floor providing a clear view of the crab samples for the crab counting computer vision program. Adding a fourth camera for rear view was considered by the team but rejected due to possible confusion of too many camera windows on the GUI.



Figure 7: Camera 3 facing the ocean floor - Photo taken by Florian Theile

Instead of developing multiple specialized grippers with higher mechanical complexity and failure risk, the team designed a single versatile manipulator capable of rotating from -90° to $+90^\circ$. This approach reduced mechanical complexity while still enabling a wide variety of mission tasks such as coral interaction, valve manipulation, and measurement operations. During practical testing, the team discovered that the precision control of the vehicle itself could compensate for some mechanical limitations of the manipulator. Even when the manipulator temporarily failed during testing, we discovered that several tasks could still be completed by balancing and positioning the ROV and using the stationary claw as a hook.

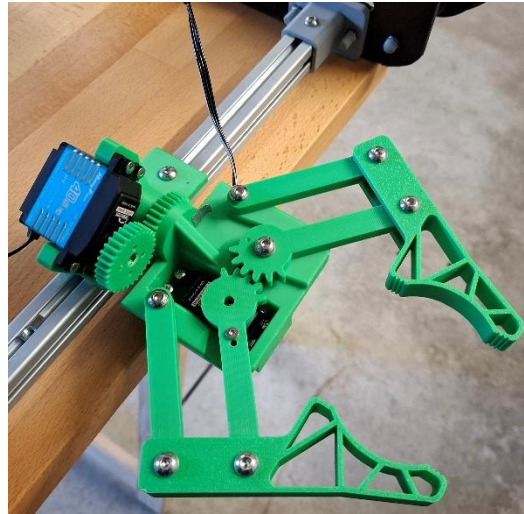


Figure 8: Claw - Photo taken by Florian Theile

3.10. Vertical Profiling Float

Weinberg developed a vertical profiling float known as Rüdiger. Its mission is to complete two vertical profiles while collecting pressure data, maintaining fixed depth of 2.5 meters and then transmitting that data back to a surface station for analysis.

The design consists of a lead screw driven buoyancy engine to control the internal volume of a 500ml syringe. A water pressure sensor and an Arduino R4 WiFi are used for processing and wireless communication with the surface station. The Arduino microcontroller was selected because of its user-friendly C++ programming language and the built in WiFi module.

The Arduino is connected to a stepper motor driver, which controls a Nema 17 stepper motor, driving the buoyancy engine. When receiving a dive command the stepper motor initiates the descent. To calculate the precise position of



Figure 9: Rüdiger - Photo taken by Florian Theile

the plunger inside the syringe, the Arduino reads real-time depth data from the water pressure sensor and feeds this data into a PID loop. The PID loop calculates the ideal descent speed based on the relative position to the target depth. The pressure sensor also stores the depth data every 5s on an onboard SD card. During the

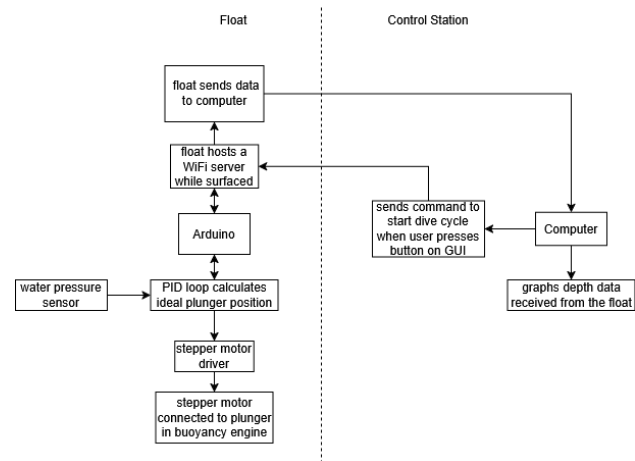


Figure 10: Float flow chart - Made by Florian Theile

whole diving process, the floats status is continuously displayed by an LED matrix. Because the float stays under the surface after finishing the two dive cycles, it activates a bright blinking LED to visually signal the ROV for retrieval and to increase surface visibility.

The system is powered by eight 1.2V NiMH AA batteries in series, creating 9.6V in total. All internal components are housed in a 50cm acrylic tube ensuring easy visibility for quick on-site inspections of the system.

3.11. Build vs. Buy

Because Weinberg Robotics is competing for the first time in 2026, many decisions were based on reliability and longevity. When it comes to Buy vs. Build, we were lucky to have access to multiple Bambu Lab X1C's and a H2C, that greatly decreased our expenses for buying encasing, mounting brackets or anything small made of plastic. When it came to the decision to buy or build a part, building was chosen more often to reduce the waiting for delivery times and still having the flexibility to fully customize parts.

For other things like the frame or enclosure we bought the raw material and worked with our CNC mill and saws to rely on the already tested draft and still have a unique and practical fit for our build.

When it comes to electrical equipment and more complex parts like the Cameras, Raspberry Pis or the thrusters we relied on companies with great experience and commercial intent, saving us massive amounts of time while keeping the quality.

4. Testing and Iterative Development

Testing played a critical role throughout the engineering process. The ROV underwent repeated dry runs, pool trials, buoyancy tests, maneuverability evaluations, and official product demonstration testing sessions in Göppingen. Real-world testing revealed a few weaknesses that could not have been predicted through theoretical planning alone.

One major issue involved manipulator servo failures caused by water exposure and mechanical stress. In response, the team implemented improved cable protection, servo shielding, and gear protection measures to increase long-term reliability. Structural failures during buoyancy testing also resulted in redesigned connectors and stronger reinforcement strategies.

These iterative improvements significantly increased the overall robustness of the system and demonstrated the importance of practical testing and rapid design adaptation.

5. Problem Solving

The development process also required solving major organizational challenges. Temporary loss of team members significantly increased the workload for the remaining students. To maintain progress, new contributors were quickly integrated into the project through collaborative problem solving and hands on learning. This strengthened the team's ability to adapt under pressure and maintain development efficiency despite limited personnel. Throughout each stage of this project, we followed a structured and logical approach to solve problems (Figure 11).

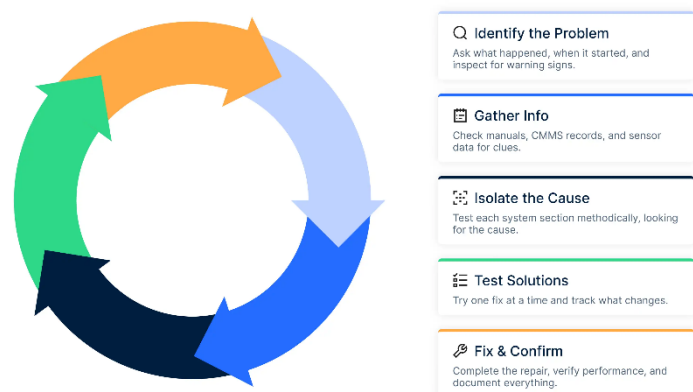


Figure 11: Trouble shooting flow chart - MaintainX

This five-step approach has proven effective in overcoming a variety of technical challenges. For example, during a testing phase, temporary issues with camera signal processing required the use of off-the-shelf camera software solutions. However, the underlying problem was later resolved, eliminating future software licensing costs and improving system independence.

6. Budget and Accounting

Income				
Source				Amount
School District				\$7,900
Expenses				
Category	Type	Description	Budgeted Cost	Spent
Hardware	Purchased	Frame, Aluminum Extrusions	\$440	\$220
Hardware	Purchased	PVC Pipes	\$175	\$165
Hardware	Purchased	Acrylic Tube	\$55	\$63
Electronics	Purchased	Thruster	\$2,740	\$2,235
Electronics	Purchased	Cameras	\$1,190	\$1,265
Electronics	Purchased	Control boards, wires	\$810	\$310
Electronics	Purchased	Servos	\$190	\$190
Electronics	Purchased	Stepper Motor	\$45	\$25
Sensors	Purchased	Pressure, Humidity, Amp	\$100	\$45
Registration			\$450	\$450
Travel			\$9,100	\$8,950
		Total Cost	\$17,195	\$15,415
		Fundraising needed	\$9,265	\$7,515

7. Conclusion

The Weinberg Robotics ROV demonstrates a balanced engineering approach focused on maneuverability, modularity, reliability, and operational safety. The design process emphasized practical problem-solving, iterative improvement, and efficient integration of mechanical, electrical, and software systems. Through extensive testing and continuous redesign, the team developed a versatile underwater vehicle capable of performing complex mission tasks while maintaining adaptability for future development and technological expansion.

8. Acknowledgments

A special thanks goes to MATE for letting us compete at this unique event with an amazing value and experience for everyone and to our variable supporters; namely our teacher Dr. Trippo and accompanying mentor Jörg Sirisko-Theile, for travelling with us and supporting our project with all their capability. But none of it would have been possible without the incredible financial support from our school's administration and we are very thankful for the great collaboration!

9. Appendix

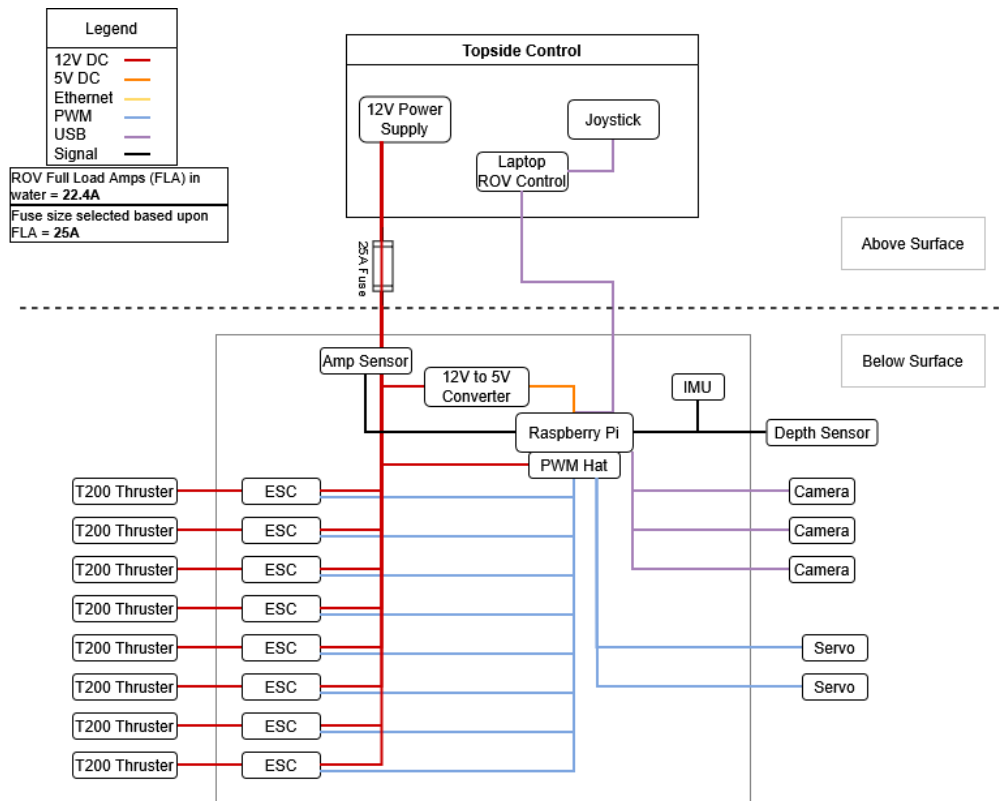


Figure 12: ROV SID - Made by Florian Theile

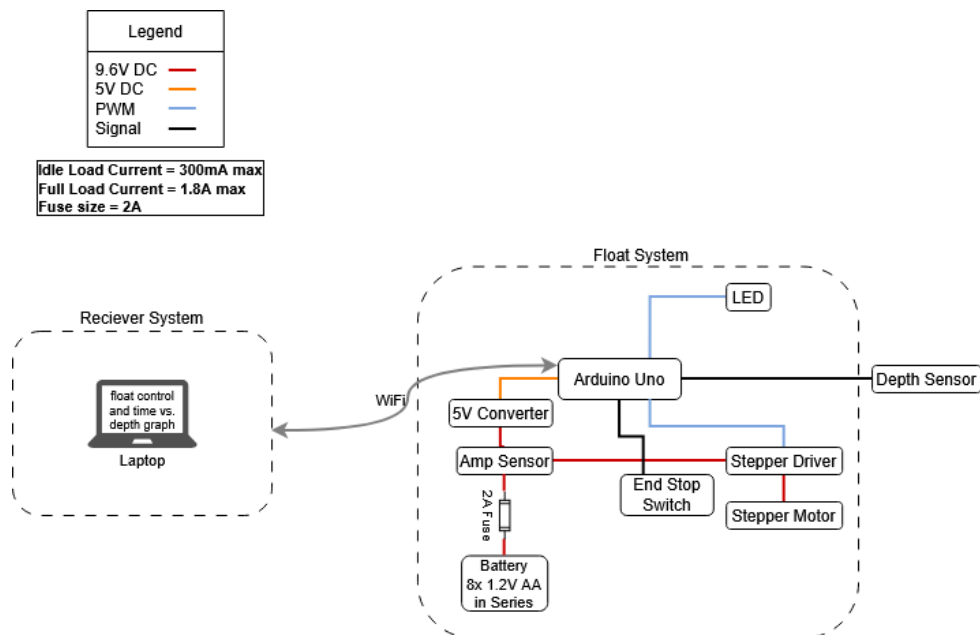


Figure 13: Vertical Profiling Float SID - Made by Florian Theile

10. References

Figure 11: Trouble shooting flow chart – MaintainX

<https://www.getmaintainx.com/blog/maintenance-troubleshooting-techniques>

Omni Calculator, used as an all-around calculation tool.

<https://www.omnicalculator.com/>

Blue Robotics, Voltage drop calculator.

<https://bluerobotics.com/learn/voltage-drop-calculator/>

Onshape

<https://www.onshape.com/>