RoboSub 2026 Technical Design Report

Université de Sherbrooke – Team Nautilus

Emile Aimez, Guillaume Dostie, Océanne Hardy, Vincent Labrecque, Xavier Lefebvre, Catherine Marcoux, Aryel Morin-Mercier and Félix Tremblay

Abstract – Team Nautilus presents PIGEON, its first-generation autonomous underwater vehicle for RoboSub 2026. The system integrates newly developed mechanical, electrical, and software components, focusing on a reliable and modular design to enable the execution of key competition tasks. It relies on a robust vision system and a state-machine-based autonomy architecture for real-time perception and decision-making. A full-system validation strategy is employed to ensure component robustness and reliable mission performance in real-world conditions.

I – Introduction

Team Nautilus is a student-led capstone project at the Université de Sherbrooke. Nautilus developed custom mechanical, electrical, and software systems tailored to mission requirements, with a strong emphasis on in-house design and system integration. Through the diversity of its technical backgrounds, the team draws on strong interdisciplinary expertise to transform a first-generation concept into a fully functional autonomous submarine.

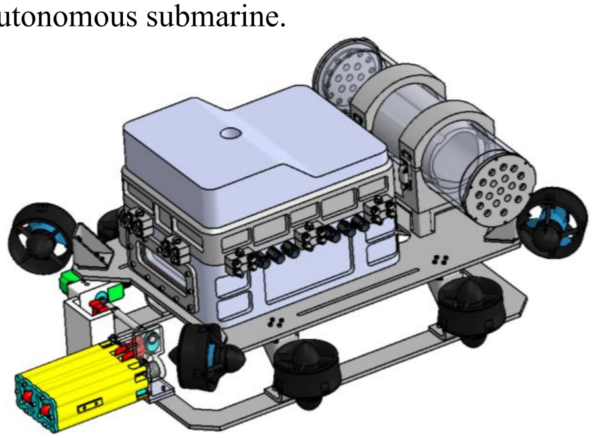

Fig. 1 : PIGEON AUV

II - Competition Strategy

A. Core Strategy

As a first-year team, our strategy is centered on building a reliable vehicle that can successfully complete a set number of tasks. Our development approach followed a step-by-step progression, where the vehicle first completed basic tasks before tackling increasingly complex missions. Tasks were prioritized based on their technical feasibility and point value [7].

The Begin Assessment (Gate) and Return Home task were given the highest priority because they are essential mission tasks and can be completed reliably with limited complexity. Then Avoid Debris was given the second priority as it mainly relies of maneuverability. Next, the Recon (Bins) task was implemented as its complexity increase due to the addition of actuation mechanism while remaining simple. The Deploy (Torpedoes) task received the lowest priority due to its high complexity, requiring precise maneuverability, advanced vision processing and accurate actuation simultaneously. For the Octagon task, the object manipulation portion was intentionally set aside to reduce system complexity. However, the surfacing portion was still integrated into the competition strategy since it provides additional points while requiring minimal added complexity to the vehicle.

Task	Complexity (*)			Points (**)	Evaluation	
	Maneuverability	Vision	Actuation	Point valuation	Score	Priority
Gate	2	1	0	2	5	1
Slalom	3	1	0	2	6	2
Bins	1	2	2	1	6	3
Torpedoes	2	3	2	1	8	5
Octagon (surfacing only)	2	2	0	3	7	4
Return Home	2	2	0	2	6	1

***Complexity** : 1=Easily done, 2=moderate, 3=Complex
**** Point valuation** : 0-749 pts =3; 750-1000pts = 2,1000 pts + = 1

Fig. 2 : Task prioritization

This strategy relies on a robust vision system for real-time detection, a finite state machine for mission sequencing and reliable actuation mechanisms for manipulation tasks.

B. Competition Task Execution

1) **Heading Out (Coin Flip):** At the start of the run, a coin flip will be requested. *PIGEON* will use its vision system to localize the gate relative to its current position. If the gate is not immediately detected, the vehicle will execute a yaw rotation sweep until the gate enters the field of view of the camera.
2) **Begin Assessment (Gate):** After detecting the location of the gate, PIGEON's vision system identifies the three structural legs — left, center, and right. A YOLO-based object detection model is then used to classify the symbols displayed on the gate. Then, the AUV center itself with the sign of choice. Once aligned, *PIGEON* will move forward to pass through the gate.
3) **Avoid Debris (Slalom):** After navigating through the gate, *PIGEON* will identify and approach the debris *(slalom).* Using its front camera, the AUV can identify and differentiate the red and white vertical pipes. The AUV then executes a series of arcing maneuvers to navigate through the slalom course.
4) **Recon (Bins):** For the Recon (Bins) task, the downward-facing camera is used to locate and identify the desired bin. A centering algorithm within the vision pipeline aligns the dropper mechanism above the identified bin. Once aligned, the AUV descends to the optimal depth and releases both markers sequentially.
5) **Deploy (Torpedoes):** For the Deploy task, PIGEON detects the vertical board and its openings using its vision system. The AUV first centers itself with the larger opening and launches its first torpedo using the spring-loaded launcher, before realigning with the smaller opening to deploy the second torpedo.
6) **Resupply (Octagon):** Following torpedo deployment, PIGEON attempts only the surfacing portion of the Octagon task, intentionally scheduled last to minimize the risk of premature mission termination.
7) **Return Home:** Finally, using its forward-facing camera, *PIGEON* will re-navigate the course to get to the gate and pass through it to complete the Return Home task.

III - Design Strategy

A. Mechanical systems

The AUV mechanicals systems include the propulsion system, the frame, the watertight enclosure and the deployment systems, as shown in Appendix B

1) Propulsion system

PIGEON's propulsion system consists of four horizontal thrusters angled at 45° at the frame's corners and four vertical thrusters centrally positioned. The horizontal thrusters are positioned at the extremities to maximize the moment arm for yaw control. Their 45° orientation allows combined thrust vectoring to achieve longitudinal, lateral, and rotational motion. The four vertical thrusters are symmetrically placed to ensure balanced pitch and roll control while providing uniform vertical thrust to compensate for buoyancy, see Appendix B for more details.

2) Frame

PIGEON's frame consists of a dual-level anodized aluminum structure. The lower level forms a ring that provides ground support while housing the dropper and torpedo launcher. The upper level serves as the primary mounting platform for the thruster configuration, battery tube and watertight enclosure.

3) Watertight Enclosure

The electronics enclosure was designed to house and protect all onboard electronics with a rated depth of 10m. Watertight integrity is achieved with the use of axial O-rings [6] and clamping brackets applying a uniform torque to ensure adequate compression. Blue Robotics Wetlink Penetrators are used for sealed cable routing, while vision system viewpoints are integrated directly into the enclosure walls.

The enclosure was fabricated from aluminum, via CNC machining, for its favorable strength-to-weight ratio. Finite element analysis was performed to identify regions of excess material, enabling targeted weight reduction while maintaining structural integrity, as shown in Appendix C.

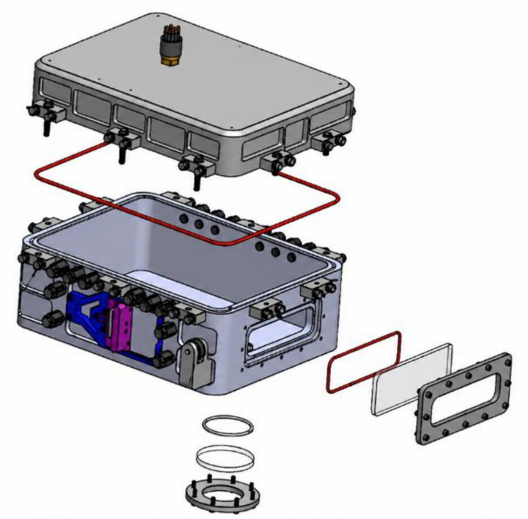

Fig. 3 : Watertight enclosure

4) *Deployment Systems*
The dropper and torpedo launching system integrates both subsystems into a compact camshaft-driven mechanism featuring four independent cams: two dedicated to marker deployment and two to torpedo firing. As the camshaft rotates, each cam sequentially actuates its corresponding subsystem at predefined angular positions, enabling controlled deployment while reducing actuator count and improving overall system reliability.

The dropper mechanism uses spring-loaded inclined locking hooks combined with a tubular guiding structure to ensure stable and repeatable marker release. The 3D-printed markers incorporate internal ballast for negative buoyancy and a 2° inclined geometry that improves hydrodynamic stability and minimizes disturbances caused by vehicle motion and local currents.

The torpedo launcher operates using a spring-driven propulsion system with a guided launch piston that efficiently transfers elastic energy to the projectile. To maximize underwater range and accuracy, the torpedo geometry was optimized using a Myring [4] hydrodynamic body profile with rear stabilizing fins based on a NACA 0012 airfoil [1]. The 3D model was then subjected to computational fluid dynamics (CFD) simulations in Ansys Fluent software to confirm its hydrodynamic behavior. The projectiles were manufactured using UV resin 3D printing to achieve high dimensional accuracy and improved surface finish, reducing friction during launch. The overall assembly was primarily manufactured through 3D printing with interchangeable tolerance-adjustment components, enabling rapid design iteration, simplified maintenance, and reliable integration on the vehicle. Appendix D presents the dropper and Torpedo launching system.

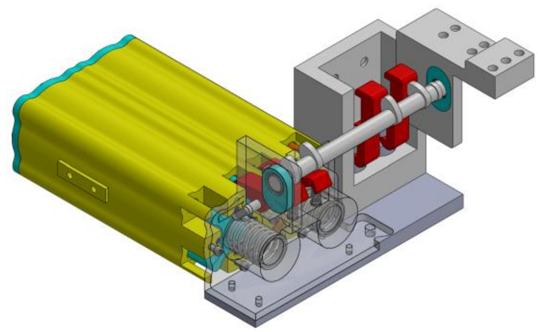

Fig. 4 : Dropper and Torpedo Launching System

B. *Electrical systems*
PIGEON's electrical systems ensure the vehicle's power distribution, system control, environmental monitoring and embedded telemetry.

1) *Component selection*
The NVIDIA Jetson was selected for its high computational throughput, enabling real-time vision inference and sensor fusion within the vehicle's power budget. Low-level attitude control is handled by a Cube Orange+ flight controller, chosen for its ArduSub compatibility [2]. For localization, a DVL provides velocity measurements to the state machine, while the Bar02 barometer handles depth estimation.

2) *Power supply and distribution*
The vehicle is powered by a 14.8V/15,6 Ah Blue Robotics lithium-ion battery, providing enough capacity for over 2 hours of continuous operation. Battery temperature is continuously monitored via a thermistor integrated into the battery pack. The signal is routed through a dedicated PCB to the Cube

Orange+, ensuring the system remains within safe operating limits.

The battery feeds the thrusters directly through a safety circuit, while DC-DC converters generate three regulated voltage rails for the remaining subsystems. A 5 V rail powers the Cube Orange+ and the emergency stop circuit. A 12V rail supplies the DVL and the front facing lights. Finally, a 19 V rail powers the onboard computer exclusively, providing a clean, low-noise supply. Low-power sensors, such as the leak detector and barometer, are powered by the Cube Orange+, while the vision cameras are powered directly by the onboard computer.

The voltage levels were selected based on component requirements and a desire to optimize current levels throughout the system, minimizing resistive losses and thermal dissipation.

Finally, components were strategically positioned within the watertight enclosure to separate high-power motor drive circuitry from sensitive low-power electronics, minimizing electromagnetic interference and simplifying cable routing. See Appendix E and F for more details on the electrical schematic and layout.

3) *Kill Switch*

The vehicle features a hardware kill switch that cuts motor power independently of software, ensuring a safe shutdown in the event of a communication loss or system failure. It is triggered by removing a magnet detected by a Hall effect sensor and re-armed manually using a second sensor. The circuit controls the 14.8 V motor supply through a MOSFET pair, with RC filtering to suppress noise and pull-up/pull-down resistors to ensure stable logic levels.

C. *Software systems*

PIGEON's software systems ensure the vehicle's autonomous decision-making, mission execution, sensor processing, navigation control, and real-time behavioral logic.

1) *Autonomy Strategy*

Given pool-time limitations, the autonomy architecture is designed to be highly modular, testable in high-fidelity simulation environments and responsive to real-time sensor feedback.

i) *Simulation Environment*

To bypass physical testing constraints, the software pipeline is validated using a digital twin environment in Gazebo Harmonic [3]. This environment simulates underwater physics, hydrodynamics and the exact RoboSub obstacle layout. The vehicle's physical setup is integrated with ArduSub SITL (Software-In-The-Loop) [2] running on an Orange Cube+ flight controller. This allows the team to simulate exact sensor outputs, tune propulsion responses and verify autopilot behavior directly from a ground control station using QGroundControl before deploying code to the physical submarine.

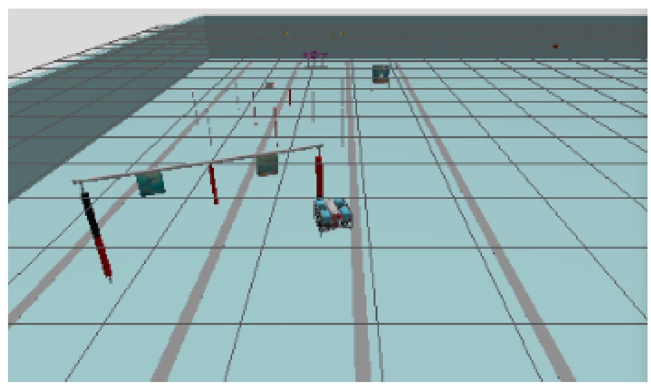

Fig. 5 : Simulation in Gazebo Harmonic

ii) *High-Level Software Architecture*

The high-level intelligence of the AUV is powered by ROS2 [8]. ROS2 coordinates a network of concurrent, specialized nodes that handle perception, navigation and control. To bridge the gap between ROS2 and the Orange Cube+ flight controller, the system utilizes the MAVLink protocol via a custom-coded Python *pymavlink* wrapper. This wrapper simplifies complex maneuvering commands, such as absolute position holding, origin resetting and parameter initialization. A critical component of this architecture is real-time sensor fusion which continuously mitigates drift and merges disparate sensor inputs to establish the definitive vehicle state required for closed-loop navigation.

iii) Task Management

The decision-making layer relies on a multi-tiered state machine that organizes and sequences each task on the course, as shown in Appendix G.

1) **The Search State**: The vehicle initiates an environmental scan using a neural network vision model via the onboard camera. If the target is not detected, the AUV executes a 360-degree yaw rotation to locate it. A built-in timeout safeguard handles error states if the target remains unfound within a set threshold.
2) **The Alignment State:** Once an object is detected, dedicated ROS2 nodes calculate the error vector between the object's position and the camera's center. A localized PID controller continuously adjusts thrust to minimize this error, dynamically centering the AUV on the target.
3) **The Task Execution State:** Upon reaching a precise target distance, a task-specific state machine takes control to score points. These sub-states execute specialized behaviors: Mechanical Interaction (torpedo launching and marker dropping), Path Navigation (gate crossing and slalom), Path Markers (Orientation) and Surfacing (Octagon).

2) Perception systems

The perception suite uses two Luxonis OAK cameras with onboard processing to reduce computational load on the main computer [5]. An OAK-1 is mounted downward for dropper and floor marker detection, while a forward-facing OAK-S2-D stereo camera provides object detection and depth estimation for control.

The vision system provides four key outputs for control: object class, distance, object angle relative to the vehicle and relative angle between objects. A two-stage pipeline is used, where a YOLOv8n [9] network performs detection and classical vision algorithms extract geometric information from stereo depth and camera intrinsics.

Models are trained on datasets from previous competitions and real in-water captures. Separate networks are used for simulation and real deployment due to domain differences. YOLOv8n was selected primarily for its high inference speed, enabling real-time performance.

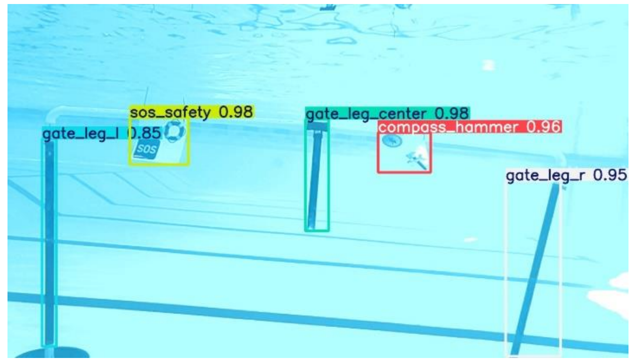

Fig. 6 : Real Time Vision Detection

IV – Testing Strategy

Testing and validation were conducted iteratively at both the subsystem and vehicle levels to reduce integration risks and ensure reliable operation. Mechanical, electrical, and software subsystems were first validated independently before full system integration, simplifying debugging and accelerating issue identification throughout development. See Appendix H for our full Test Plan.

A. Pressure testing and Leak Detection

Initial pressure and leak testing was first conducted on the empty enclosure, without electronics installed, to validate structural watertightness. Vacuum immersion tests equivalent to a 10 m water depth were performed while monitoring internal pressure and visually inspecting for leaks using an internal camera. After integrating the electronics, repeated leak-free vacuum tests were used to characterize the normal pressure decay behavior of the enclosure over time and establish an acceptable pressure-loss threshold for pre-dive verification. Before deployment, enclosure pressure decay is checked against reference curves to verify system integrity.

B. Actuation Systems

The actuation systems were validated through both simulation and experimental testing. Pool tests of the dropper mechanism confirmed the linearity, stability and repeatability of marker deployment during a 2 m descent. For the torpedo launcher, CFD simulations in Ansys Fluent evaluated hydrodynamic performance and passive stability, while MATLAB/ Simulink trajectory simulations validated projectile range and trajectory rectitude under representative launch conditions.

C. Electrical Systems

Electrical validation was conducted iteratively to minimize integration risks. A dedicated testing protocol defined procedures and safety measures for hazards like short circuits, overheating, and malfunctions. Subsystems were first verified independently via continuity checks and controlled bench-top power-ups using a laboratory power supply. Subsequently, progressive system integration was performed using the lithium-ion battery.

D. Vision Testing and Validation

The vision system was validated using both simulation and real-world underwater testing. YOLOv8n models were evaluated using confusion matrices generated from dedicated test datasets to measure object detection and classification accuracy. Additional in-water and out-of-water experiments were conducted to validate distance estimation, angular measurements, and robustness under varying lighting conditions and object orientations.

E. Pool Testing

Pool testing was conducted to validate the integrated behavior of the vehicle in representative underwater conditions. These tests evaluated propulsion, localization, control stability, vision integration, and actuation performance during autonomous mission execution. Pool experiments also provided real-world data to refine control algorithms and validate the reliability of subsystem interaction under operational conditions.

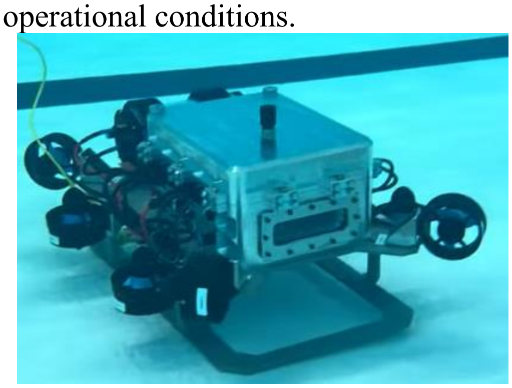

Fig. 7 : Pool Testing

V – Conclusion

As a first-year team, Team Nautilus successfully developed PIGEON, a modular autonomous underwater vehicle capable of completing key RoboSub 2026 mission tasks. Despite the technical complexity and limited development time, the project provided valuable experience in robotics, systems integration and autonomous systems engineering. Team Nautilus is proud of what was accomplished and hopes this work will serve as a strong foundation for future underwater robotics development at Université de Sherbrooke.

VI - Acknowledgement

The Nautilus Team extends its sincerest gratitude to everyone who has supported the development of PIGEON. Nautilus's accomplishments would not have been possible without the generous contribution made by our sponsors: CTA, Usinage CMO, Modelage Simon Inc., Fonds d'appui à l'engagement étudiant (FAEE), Cal Construction, Xsens, LOJIQ and EBM Laser. We are particularly grateful to the Université de Sherbrooke for providing essential facilities and institutional support throughout our project development. Finally, we would like to thank RoboSub, RoboNation and all associated volunteers for their efforts in organizing an international competition that promotes innovation, technical excellence and collaboration within the underwater robotics community.

VI – References

[1] Airfoil Tools, "NACA 0012 airfoil (n0012-il)." [Online]. Available: http://airfoiltools.com/airfoil/details?airfoil=n0012-il

[2] ArduPilot Development Team and Community, "ArduPilot: Open-Source Autopilot for Autonomous Vehicles", Available : https://ardupilot.org

[3] Gazebo, "Gazebo Documentation," *GazeboSim.org*. [Online]. Available: https://gazebosim.org/home

[4] F. Liu, Z. Sun, H. Quan, and P. Zhu, "Multi-objective optimization of the Myring-style shape considering direct sailing resistance and flow induced noise," *Applied Ocean Research*, vol. 164, p. 104785, Nov. 2025.

[5] Luxonis, "DepthAI Documentation," Luxonis Docs. [Online]. Available : https://docs.luxonis.com/softwarev3/depthai/

[6] Parker Hannifin Corporation, *Parker O-Ring Handbook*, Catalog ORD 5700. Lexington, KY, USA: Parker Hannifin Corporation, 2024. [Online]. Available: https://www.parker.com/content/dam/Parkercom/Literature/O-RingDivisionLiterature/ORD-5700.pdf

[7] RoboNation, *RoboSub 2026 Team Handbook*, 2026. [Online]. Available: https://robonation.gitbook.io/robosub-resources

[8] ROS, "ROS Documentation," *ROS.org*. [Online]. Available: https://www.ros.org/

[9] Ultralytics, "Ultralytics Documentation," *Ultralytics Docs*. [Online]. Available: https://docs.ultralytics.com/

Appendix A: Community Outreach

At Nautilus, we believe strong teamwork is the foundation of a successful team. Collaboration, innovation, and knowledge sharing guide both our technical development and team culture.

Beyond competition, Nautilus is committed to sustainability, outreach, and community engagement. Over the 2025 summer, the team volunteered at the Fête du Lac des Nations, collecting cans and bottles throughout the event to help reduce its environmental footprint while raising funds for the project. The initiative required significant effort but strengthened team cohesion and reinforced our commitment to sustainable engineering practices.

The team also presented its project during the Université de Sherbrooke open house, where members showcased their work and introduced first-year college students to engineering and robotics. This experience helped inspire future engineers while highlighting the real-world impact of autonomous systems.

In December 2026, Nautilus will further present its work at MégaGÉNIALE, Canada's largest engineering fair, providing an opportunity to demonstrate its technical progress and engage with the broader engineering community. These initiatives reflect Nautilus' commitment to developing high-performance systems while fostering education, sustainability, and innovation.

Fig. 8 : Sustainability Volunteer Initiative

Appendix B: PIGEON's Structure

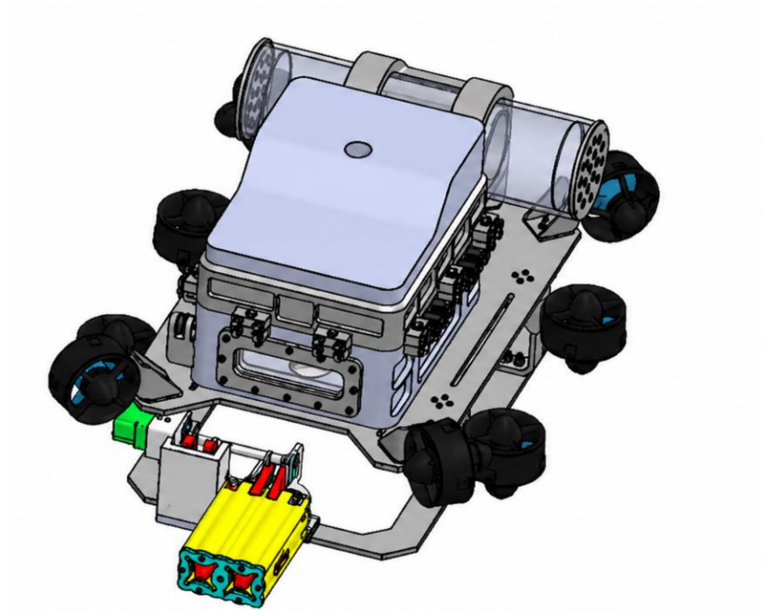

Fig. 9 : PIGEON Mechanical Assembly

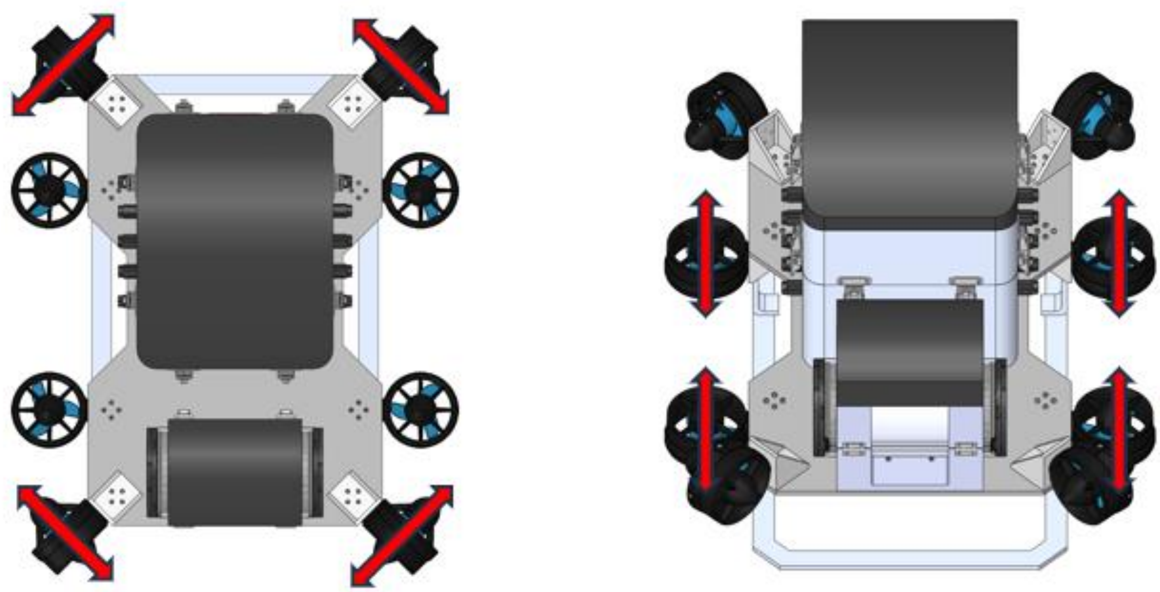

Fig. 10 : Propulsion Architecture

Appendix C: Watertight Enclosure FEA

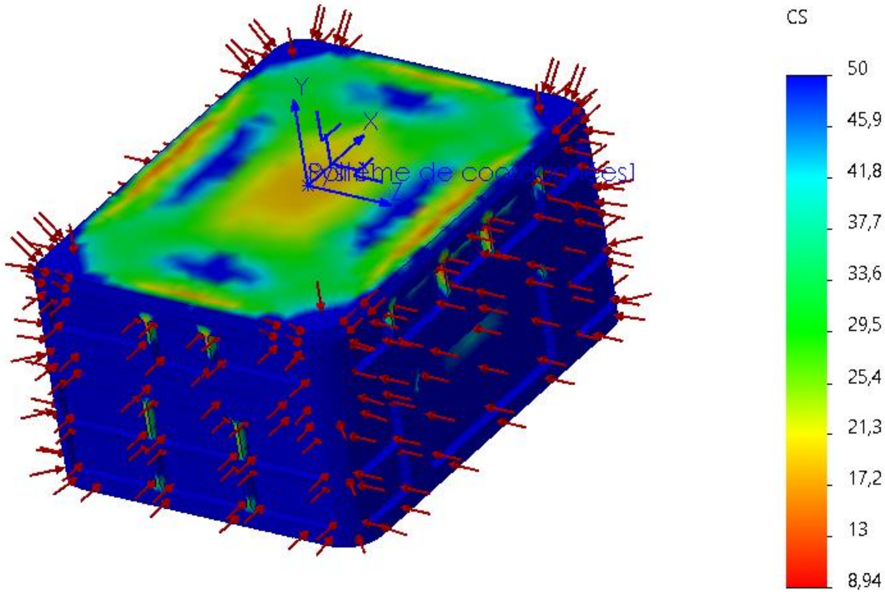

Fig. 11 : Weight Optimization

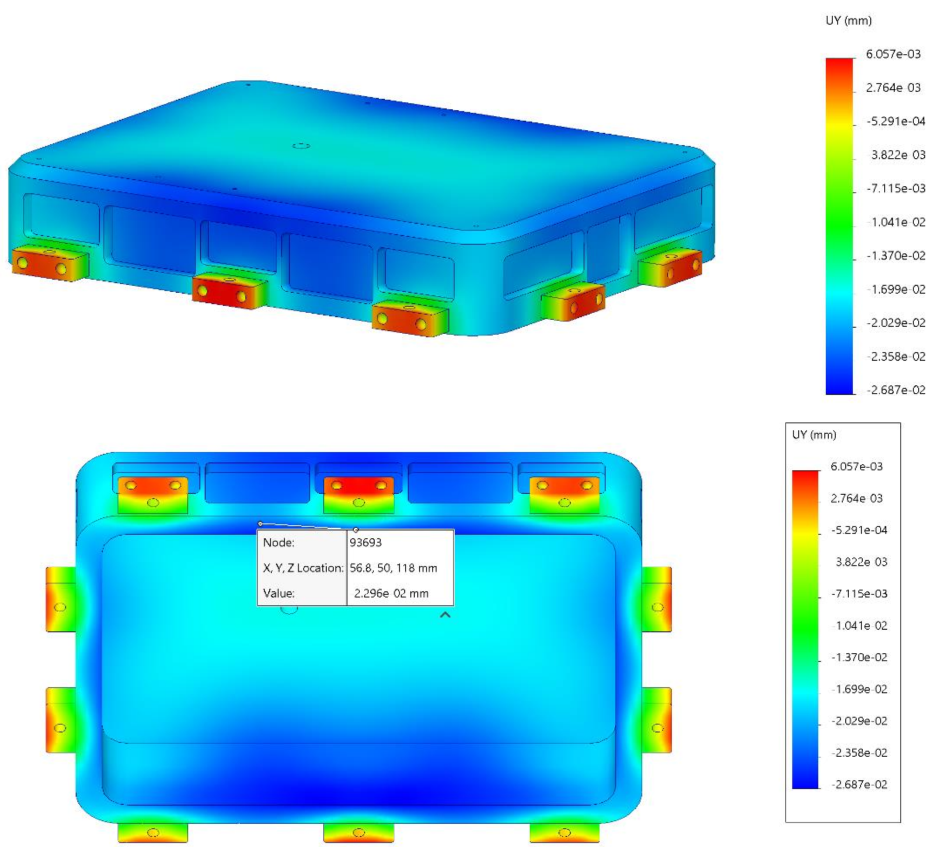

Fig. 12 : Clamping Load Distribution

Appendix D: Dropper and Torpedo Launching System

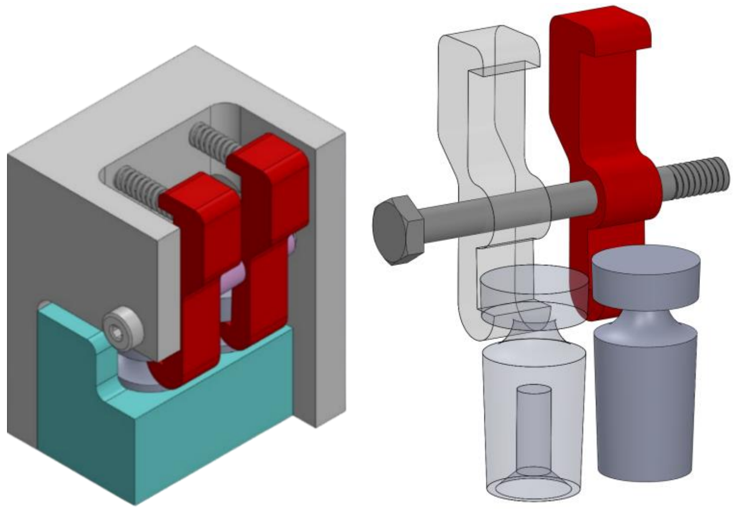

Fig. 13 : Dropper Mechanism

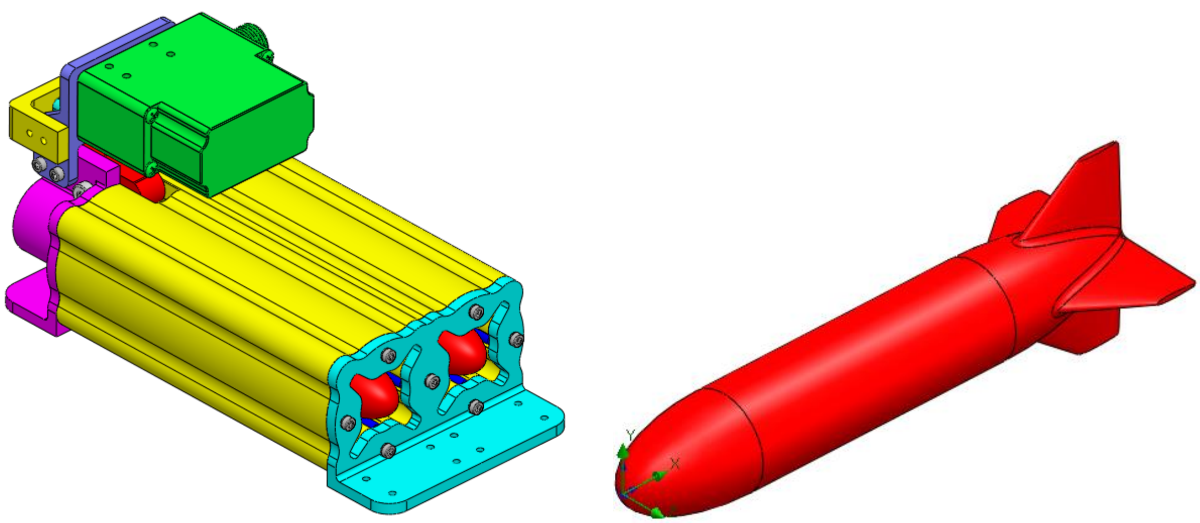

Fig. 14 : Torpedo Launcher Mechanism

Appendix E: Electrical Schematic

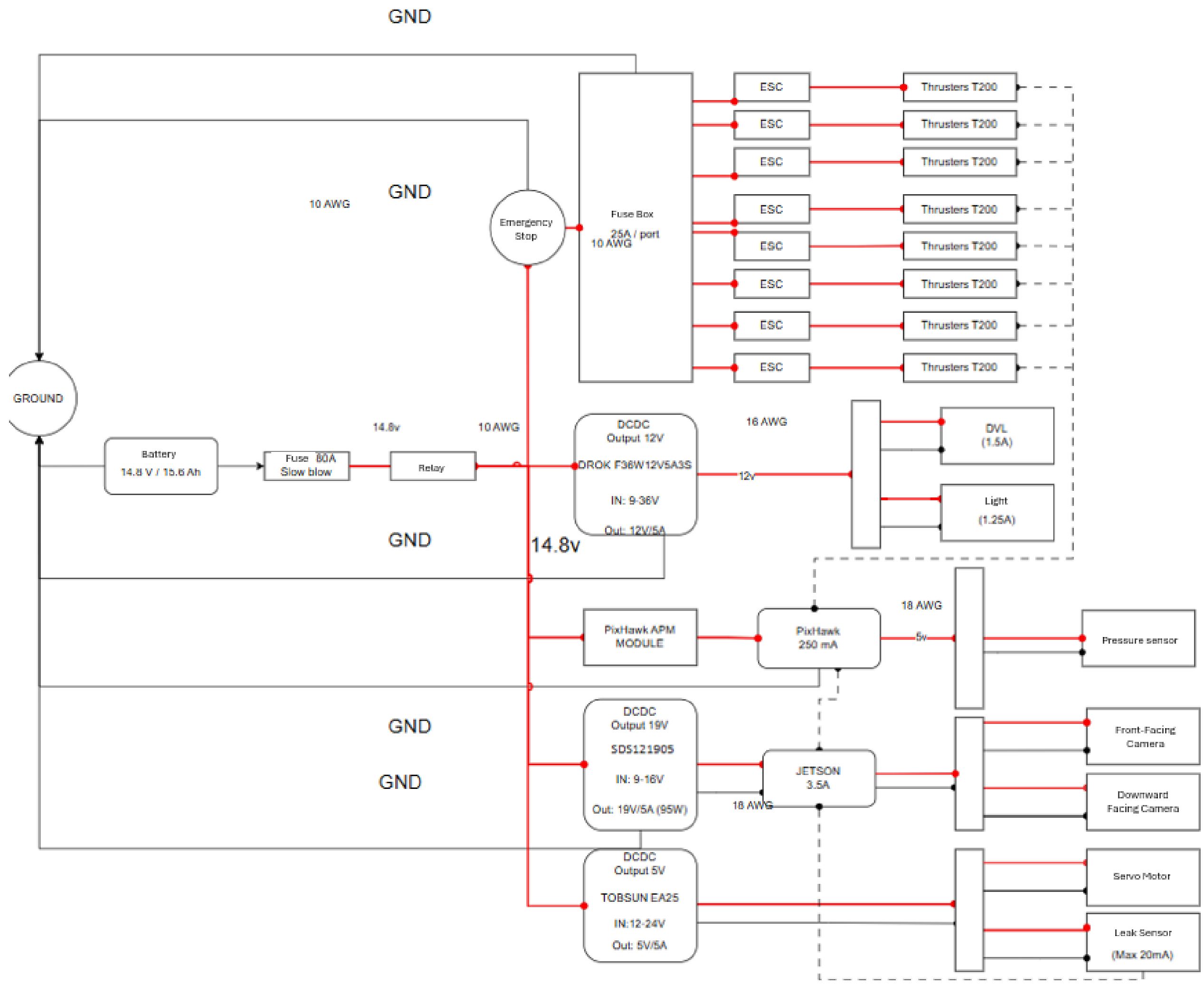

Fig. 15 : Electrical Schematic

Appendix F: AUV Internal Layout

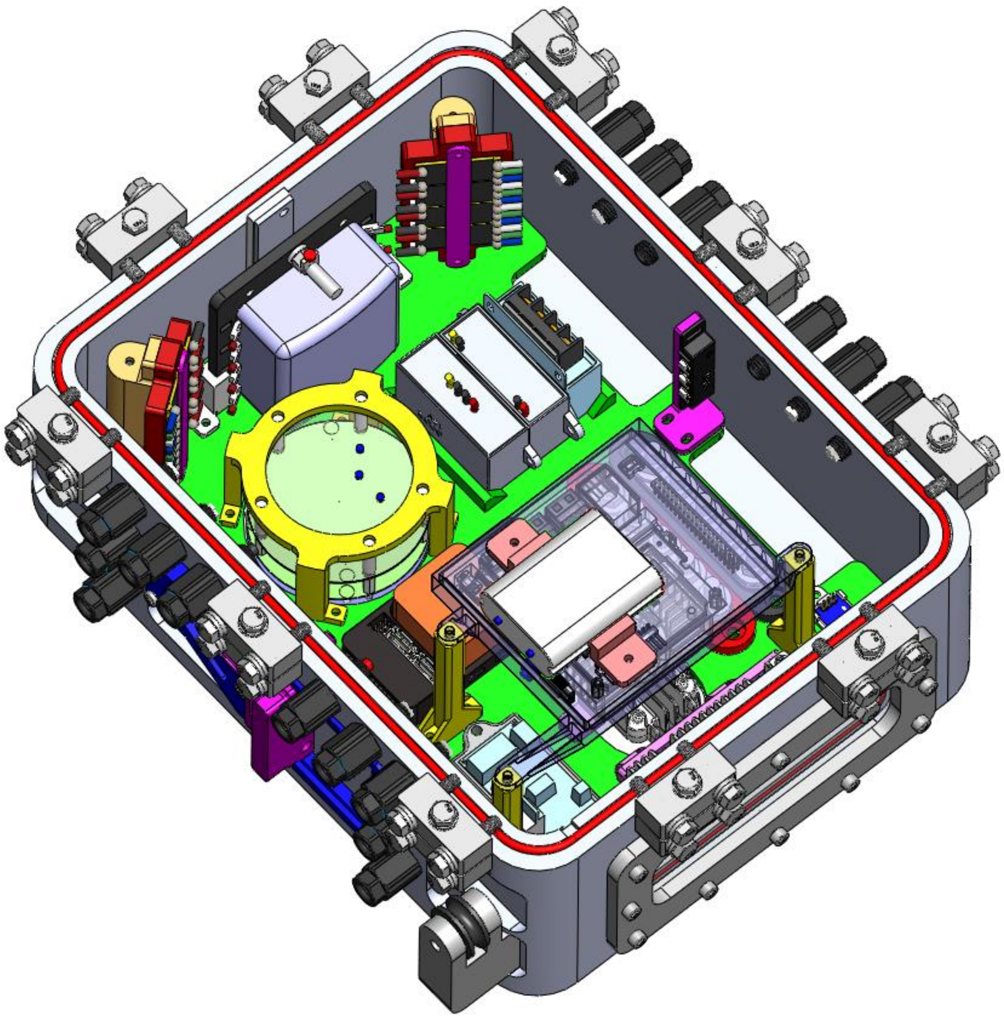

Fig. 16 : AUV Internal Layout

Appendix G: Vehicle's Logic

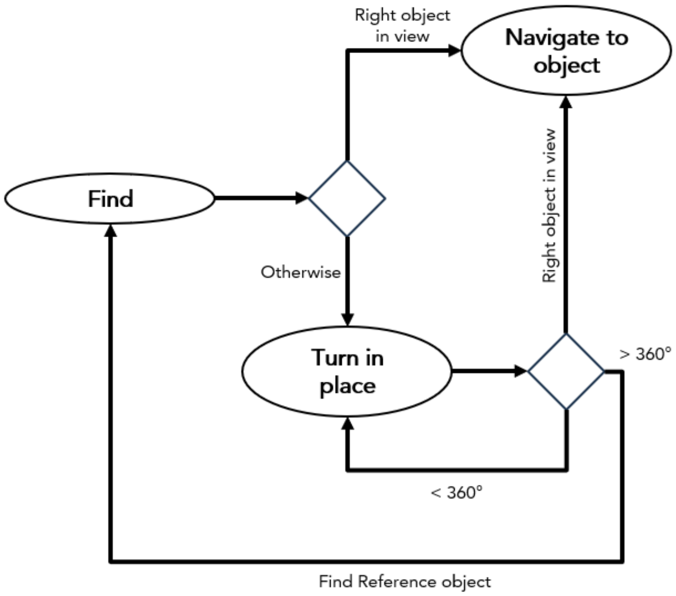

Fig. 17 : Object detection logic

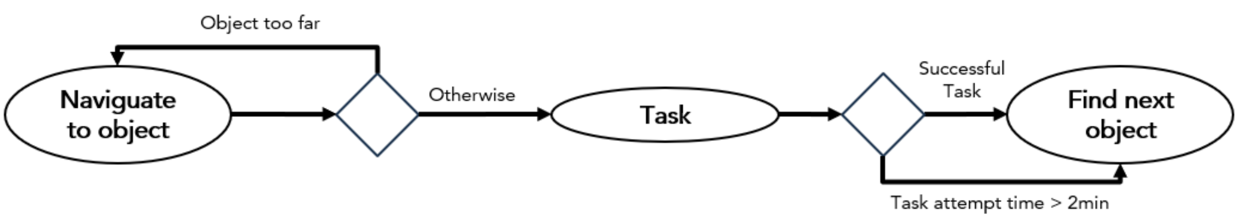

Fig. 18 : Vehicle movement logic

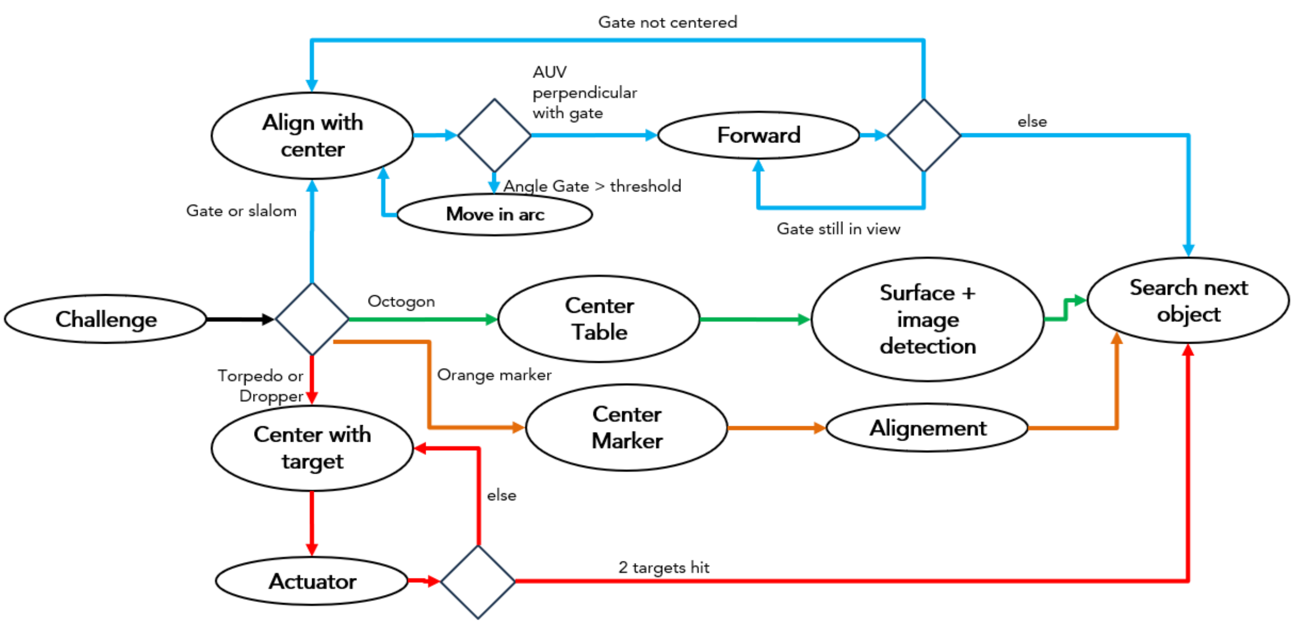

Fig. 19 : Vehicle's global state machine

Appendix H: Test Plan

Date	Test Category	Objectives
January 19th 2026	Electrical	Validate electrical circuit operation, power distribution, telemetry, and thruster control under bench conditions.
February 2nd 2026	Vision	Validate image acquisition and video transmission.
February 15th 2026	Mechanical	Verify watertight integrity of the battery tube.
March 12th 2026	Mechanical	Validate watertight integrity of the main electrical enclosure and all penetrators.
March 20th 2026	Mechanical	Validate reliable operation and repeatability of the dropper and torpedo launcher systems.
March 24th 2026	Software	Validate depth sensor accuracy and stable PID-controlled depth hold performance.
April 4th 2026	Software	Validate localization, position hold capability, waypoint navigation, and position transmission.
April 14th 2026	Software	Verify reliable real-time position transmission.
April 22nd 2026	Software Vision	Attempt prequalification tasks while validating autonomous gate approach and image recognition capabilities.
April 30th 2026	Software Vision	Attempt prequalification tasks while validating autonomous gate approach and image recognition capabilities.
May 9th 2026	Software Vision	Validate autonomous gate traversal and slalom navigation
May 23rd 2026	Software Vision	Validate marker deployment accuracy and autonomous alignment with target bins.
May 30th 2026	Software Vision	Verify torpedo launcher reliability, targeting consistency, and vehicle stability during launch.
June 6th 2026	Software Vision	Validate octagon localization and autonomous surfacing behavior within the target area.
June 20th 2026	Software	Execute the complete autonomous mission sequence to evaluate subsystem integration and reliability.
June 30th 2026	Software	Repeat full mission testing under competition-like conditions to validate robustness and mission timing.
July 5th 2026	Software Vision Mechanical Electrical	Perform final pre-competition validation, safety inspections and full vehicle readiness checks.

Appendix I: List of Components

Component	Supplier	Specification	Custom/ Purchased	Total Cost
Frame	EBM Laser	Anodized Aluminium dual level frame	Custom	1 500 $
Watertight Enclosure	Usinage CMO Modelage Simon	CNC-machined Aluminum 6061-T6 enclosure	Custom	3 000 $
O-rings	Parker	Axial O-rings for main enclosure and windows	Purchased	30 $
Thrusters	Blue Robotics	8 x T200 thrusters	Purchased	3 000$
ESC	Blue Robotics	8 x ESC	Purchased	400 $
Waterproof Connectors	McArthney	SubConn underwater connectors	Purchased	700 $
Waterproof Penetrators	Blue Robotics	Wetlink Penetrator of different sizes	Purchased	500 $
Waterproof Servos	Hitec	Servo motor: HSB-9360TH	Purchased	250 $
Waterproof servos enclosure	Blue Trail Engineering	Servo Kit SER-200X	Purchased	200 $
Battery	Blue Robotics	Lithium-ion Battery (14,8V, 18Ah)	Purchased	450 $
Battery Tube	Blue Robotics	4″ Watertight Enclosure	Purchased	400 $
DVL	Cerulan Sonar	DVL-75	Purchased	3 000$
IMU	Xsens	Xsens Sirius IMU	Purchased	3 750 $
Front Camera	Luxonis	OAK-D S2	Purchased	700 $
Down Camera	Luxonis	OAK-1	Purchased	300 $
Lights	Blue Robotics	1500 lumens subsea LED light	Purchased	500 $
Onboard Computer	NVIDIA	Jetson Orin Nano 8GB	Purchased	400 $
Controller	Cube Pilot	Orange Cube+	Purchased	500 $
Pressure sensor	Blue Robotics	Bar02	Purchased	75 $
Leak Sensor	Blue Robotics		Purchased	20 $
Converter DCDC	Amazon	5V, 12V, 19V	Purchased	100$
Electrical Components	Amazon	Wires, cables, connectors, fuses, etc.	Purchased	1 200$
3D Printed structure	-	Electrical mounting, Dropper and Torpedo Launcher	Custom	250 $
Fasteners	Boulons de l'Estrie	Screws, nuts, standoffs, inserts, washer, etc.	Purchased	250 $
Programming Language	-	Python	Custom	-
Software Frameworks	-	ROS2	Custom	-
Vision Algorithms	-	YOLOv8n	Custom	-
Testing Time: in Water	Université de Sherbrooke	80 hours of testing in a pool	Purchased	1 200 $