Technical Design Report of the Autonomous Underwater Vehicle *Douglas* 2025

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***Abstract*—The McGill Robotics Autonomous Underwater Vehicle (AUV) Team is excited to present Douglas, our fourth-generation AUV, which builds upon the foundation established in the 2023-2024 season. The mechanical team enhanced actuator reliability for both the grabber and the new torpedo system, refined hull geometry to improve control, and increased modularity for easier maintenance. On the electrical side, the internal architecture now includes a redesigned power distribution board, an actuator board supporting additional subsystems, and an entirely new peripheral interface. Meanwhile, extensive physical testing by the software team allowed significant refinement of the vehicle's autonomous capabilities, resulting in enhanced computer vision algorithms, a more responsive controls system, and reliable state estimation. Each modification was thoroughly evaluated based on lessons learned from previous competitions, ensuring continual improvement while retaining the core design that contributed to Douglas' initial success. Our team looks forward to showcasing Douglas at RoboSub 2025, having strategically focused our engineering efforts on enhancing reliability and robust performance, aiming to achieve new milestones and set higher standards in autonomous underwater robotics.**

I. Introduction

Since 2013, it has been the unwavering mission of McGill Robotics to inspire students to build robots and to build robots that inspire students. What began as a small group of passionate engineers has grown into one of McGill University's most dynamic engineering teams, now comprising 300 undergraduate students across four specialized divisions: Autonomous Underwater Vehicles (AUV), Unmanned Aerial Vehicles (UAV), Mars Rover, and Business Team. Our members combine technical excellence with community engagement, advancing robotics education throughout Montreal while developing cutting-edge autonomous systems.

II. Competition Strategy

A. Course Strategy

Task development for Douglas focuses on adding core capabilities that support multiple competition objectives, rather than tailoring behavior to individual tasks. Tasks are analyzed based on functional similarities, allowing shared skills such as path detection, directional decision-making, and precise navigation to be prioritized early in development. This capability-first approach is supported by a modular software architecture that applies the principle of separation of concerns. The decision-making system, referred to as the planner, guides the AUV through the course by interpreting the environment as a discrete set of observable objects, each with defined attributes. High-level behaviors are implemented using a recursive state machine, where states are broken down into simple, testable actions. Actuators are controlled through a unified API, which enables clear interfaces between planning and execution and allows individual systems to be developed and validated independently. This structured approach ensures flexibility and robustness in mission execution, enabling Douglas to effectively adapt to the challenges of the RoboSub course.

1) Heading Out and Collecting Data (Gate)

Douglas begins its run by attempting the coin flip, utilizing the front camera and controlled yaw rotations to survey the area and detect objects of interest, particularly the gate. After determining the gate's precise location, the AUV executes a predetermined rolling maneuver to earn style points, repositions itself, and navigates through the selected side. Using a fine-tuned YOLOv8 model which is known for its "speed and accuracy in real-time applications" [10], Douglas is able to identify the reef shark and the sawfish. By exploiting the central positioning of the front camera and aligning the AUV with the marine animal of choice, moving straight forward allows us to pass under the chosen section of the gate.

2) Navigate the Channel (Slalom)

After navigating through the gate, Douglas approaches the slalom area guided by its front camera. The AUV identifies and differentiates the red and white vertical pipes. Douglas carefully maneuvers in a slalom pattern, weaving alternately around each pipe to complete the course. To minimize chances of collision, we maximize the distance between Douglas and the poles by employing a Voronoi diagram to create the path.

3) Drop a BRUV (Bin)

For the bin task, the dropper mechanism is used to place up to two markers into the appropriate half of the bin (reef shark or sawfish). These halves are assigned positional tags by the perception stack, allowing the planner to center over the correct region and descend to the optimal depth before dropping.

4) Tagging (Torpedoes)

This year, we reintroduced torpedoes with a compact and reliable spring-loaded launcher, fully integrated into the AUV. In competition, our ideal run involves the perception stack identifying the correct openings and aligning the vehicle for close-range launches — maximizing accuracy while minimizing software overhead. The AUV autonomously selects between the reef shark or sawfish based on its initial gate choice and executes the shot with minimal intervention.

5) Ocean Cleanup (Octagon)

Douglas approaches the octagon guided by the acoustic pinger. Upon reaching the table beneath the octagon, the AUV uses its downward-facing camera to identify and differentiate between the two types of trash samples. With a newly designed grabber system featuring integrated current-sensing capabilities, Douglas accurately determines when objects are securely grasped, ensuring reliable pickup and sorting into the appropriate collection baskets. After depositing the trash, Douglas executes rotations matching the number of objects successfully collected in the basket, aiming for bonus points.

6) Return Home, Path, and Pinger

The AUV navigates between tasks using both visual path markers and the bearing calculated from the hydrophones. When a path is expected, the AUV performs a floor scan to lock on to the marker and aligns accordingly. When following a pinger, the AUV updates its heading based on real-time directional estimates. At the end of the mission, the AUV passes back through the start gate to complete the run.

B. Team Success Strategy

The 2023 and 2024 competitions exposed vulnerabilities in our AUV's reliability, including camera failures, power board malfunctions, fuse ruptures, and hull breaches that necessitated reverting to dead reckoning navigation. These failures directly informed our engineering priorities for Douglas. To achieve this, we implemented a protocol beginning with structured design reviews at development milestones, where mechanical and electrical subsystems underwent failure mode and effects analysis (FMEA) before fabrication. Critical components including pressure vessels, power distribution networks, and sensor interfaces were developed through iterative prototyping, with each version subjected to progressively more stringent environmental testing. The software architecture incorporated continuous integration/continuous deployment (CI/CD) pipelines with automated unit and integration testing, ensuring all deployed code met strict validation criteria. This approach to reliability engineering enabled the team to develop a competition-ready platform while maintaining the high performance standards required for RoboSub 2025. The resulting system demonstrates marked improvements in fault tolerance compared to previous iterations, particularly in waterproofing, power system resilience, and software stability under competition conditions.

III. Design Strategy

A. Mechanical Subsystems

McGill Robotics' main design goals this year was to make a compact, modular and agile robot, improve its maneuverability and reliability and add robust actuators for all of the competition tasks. This was done by modifying components of the robot to make it lighter, adjusting the center of buoyancy and center of mass and by rigorously testing components.

1) Hull

The hull is rectangular, with a large opening on the top, allowing easy access to the internal electrical systems (Fig. 4). It is constructed from Aluminum 6061 and protected with an anodized coating. This material was selected primarily for its high thermal conductivity [2], which allows the hull to act as a passive heat sink for internal electronics, reducing the need for active cooling. The anodized coating provides corrosion resistance and non-conductive surfaces.

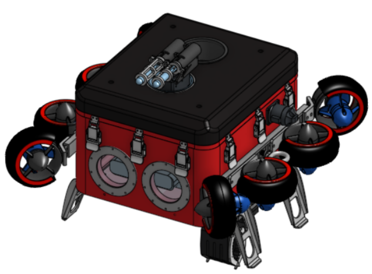

Fig. 1: Douglas Front View

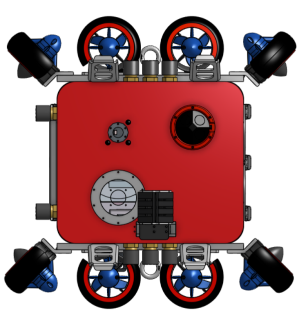

Fig. 2: Douglas Bottom View

2) Thruster Characterization

Considering the thrusters on Douglas are 8 years old, the curve of the force versus the pulse-width modulation (PWM) of each thruster was found experimentally to compensate for any decrease in performance. The true characterization of the thrusters that can be seen in force test curves shown in Appendix Figure 10 allowed us to identify weak thrusters and create a force to PWM matrix that is unique to each thruster.

3) Mass and Buoyancy Optimization

To decrease the distance between the center of mass and the center of buoyancy, the overall weight of the hull and chassis was reduced and the buoyancy foam was spread more evenly across the hull. To reduce the overall weight, the hull lid was modified, the internals were adjusted and the chassis leg structure was optimized. The chassis structure was optimized using finite element analysis to evaluate stress concentrations shown in Figure 7, and designed the leg to compensate using the least amount of material. The inner part of the hull lid was machined to be thinner to reduce weight as well. These changes have reduced Douglas's weight by roughly 1 kilogram, so the actuators can be incorporated with only a small increase in our overall weight.

The buoyancy foam was designed to ensure the AUV meets the requirement of being approximately 5% positively buoyant. The foam components were added in two locations: over the thrusters and on top of the hull. The foam covers for the thrusters also provide a layer of physical protection for the thrusters, shielding them from impact damage during transport, handling or regular usage (Figure 1). All buoyancy foam components were manufactured in-house using extruded polystyrene foam (Figure 9). After machining, the foam was coated first with a layer of liquid rubber to provide water resistance, followed by an outer layer of epoxy resin for rigidity. The foam layout is also positioned so that the center of buoyancy remains slightly above the center of gravity, which improves stability and maneuverability.

4) Grabber

The grabber is mounted next to the downward-facing camera to ensure visibility during object pickup and sorting [11]. Its position was determined through camera field-of-view testing and is offset 2.5 inches from the hull using a 3D-printed rail and bracket assembly (Figure 2). The mechanism is based on a prefabricated claw that was modified with 3D-printed elongated fingers for improved scooping and interlocking [5], shown in Figure 5. A custom spacer introduced a slight offset, allowing the fingers to nest rather than collide [6]. Gear slippage was addressed by designing a thicker replacement gear, while a new motor coupler was added to ensure reliable torque transfer. These changes significantly enhanced underwater gripping consistency during pool testing.

5) Torpedo

The torpedo subsystem was newly introduced this year to complete tagging tasks through reliable short-range projectile launches. The launcher is a spring-powered system designed to meet RoboSub's 2.0" × 2.0" × 6.0" size and 2.0 lb weight constraints as seen in Figure 6. After abandoning an earlier CO_2-based design due to safety and trajectory issues, the team developed a servo-actuated spring launcher featuring internal guide rails and a divider for alignment. The spring's 2.3 kg maximum load allows for manual compression while maintaining consistent launch distance. The torpedo system is fully integrated and positioned to work with the perception stack, enabling close-range, software-guided launches for high accuracy.

B. Electrical Subsystems

The electrical subteam designed, tested, and verified four custom PCBs to support the AUV's subsystems: the Power Board, Display Board, Actuator Board, and DVL Board. Each board was developed with a focus on safety, modularity, and integration with the system's ROS-based architecture. See system architecture diagram in Appendix Figure 16.

1) Power Board

The Power Board manages power distribution, thruster control, and kill switch logic. It includes a Teensy 4.0 microcontroller, dual battery hot-swap controller, voltage and current sensors, water leak detection, and a two-stage kill switch system. Additionally, the board maintains galvanic isolation between high and low voltage domains to protect against surges and ESD events[1]. Moreover, the dual battery system allows for uneven voltage input and prioritizes discharge from the higher-charged battery. Real-time telemetry, including current and voltage data, is published over ROS. Finally, testing confirmed reliable operation under a simulated 100A full-load, with thermal and signal integrity maintained. See PCB in Appendix Figure 12.

2) Display Board

The Display Board monitors key system metrics and publishes depth data using an external pressure sensor. It uses a Teensy 4.0 and an ILI9341 display connected via Serial Peripheral Interface (SPI) protocol, and subscribes to ROS topics to show battery voltages, depth, and status of sensors and actuators; it is positioned beneath a transparent hull window for accessibility. Pressure sensor calibration initially failed due to incorrect fluid density assumptions; after correction in collaboration with the mechanical subteam, the sensor met the required ± 0.2 cm accuracy. See display UI in Appendix Figure 13.

3) Actuator Board

The Actuator Board controls the torpedo launcher and the grabber. It is powered by a 5V Battery Eliminator Circuit (BEC) converter with additional regulation through an onboard Low Dropout (LDO) regulator. It supports up to four servos, each protected by resettable fuses and capacitors. Furthermore, current sensors are used to detect stall conditions, allowing the system to infer object contact [8]. Breakout access points were included to allow protocol changes and additional testing during development. See functional block diagram in Appendix Figure 15.

4) DVL Board

The DVL Board provides Serial and Ethernet communication between the Doppler Velocity Logger (DVL) and the main system. It routes all I/O through an 8-pin connector and includes power protection features such as polarity diodes and filtering capacitors [7]. In addition, a reed switch for the thruster kill system is integrated on this board due to its proximity to the DVL, minimizing wiring and improving reliability. See PCB in Appendix Figure 14.

5) Hydrophone Board

Our team attempted to implement hydrophones, but faced challenges we were not able to overcome. We have been using an STM32 development board and three hydrophones placed in a triangular shape on the underside of the AUV and measuring the difference in phase between each hydrophone. However, our thrusters generate a large amount of high frequency noise and we are still working on a method of Fourier analysis to successfully design a filter to isolate desired frequencies. Eventually, we chose to focus on other electrical development.

6) Testing and Validation

The electrical system underwent structured validation across multiple stages. For instance, the Power Board passed eleven tests, including galvanic isolation, ESD resilience, PWM signal verification, and full-load stress testing. Furthermore, initial failures in current sensing were resolved by correcting soldering issues, and subsequent tests confirmed $\pm$ 0.0125 A accuracy. In addition, voltage sensing circuits met $\pm$ 0.005 V accuracy, and the 5V rail maintained stability during inrush current testing with added capacitive buffering. Finally, pressure sensor accuracy improved significantly after fluid density correction, passing validation points. See Appendix B for the full test plan and results.

In short, the electrical system was designed with an emphasis on fault tolerance, modularity, and integration. Testing confirmed that all subsystems met their design specifications and are ready for operation under realistic operational conditions.

C. Software Subsystems

Software design begins with analyzing mission requirements for various tasks, reflecting upon the performance of previous years, and deriving appropriate software implementations or improvements. These goals are then further defined through testing requirements, which is enforced using continuous integration or mission testing using the software planner. This process is iteratively performed in biweekly sessions as new features or enhancements go through stages of development. The pipeline is simple but strict: static analysis, unit tests, a fast ROS-based simulation, and a short hardware-in-the-loop replay that mimics real conditions.

This strategy is adopted due to hidden failure points from previous iterations. In order to complete mission tasks consistently, formally defined testing requirements must be passed for parts of the software stack until isolated mission tests are passed. These requirements can change dynamically and quickly due to changes from the mechanical and electrical subsystems due to these unknown failure points. Software improvements were made to enforce our existing autonomous system to improve this problem.

With these improvement goals in mind, the team standardized multiple software CI/CD workflows, scripts, graphical interfaces, and virtual Docker containers to enable cross-platform, distributed system, intuitive testing, even on the poolside. Previously, modifications to software during testing were difficult, which made mistakes costly. The testing improvements enforce realistic and testable improvements to the software stack. This overarching design strategy allows the software team to build improvements year after year without discarding previous achievements.

A separate software team works in parallel to provide more abstract improvements on localization and mapping using our application interface. On top of the aim to standardize to create proper testing solutions to software, one of the larger goals for this year was SLAM (Simultaneous Localization and Mapping). The main strategy of this team is research and development (R&D) which is a more technical research-heavy project. A similar design strategy is adopted with a biweekly cycle but with an overarching implementation goal in mind. Algorithmic analysis was performed on relevant SLAM backend algorithms (Extended Kalman Filters, pose-graph optimization) alongside complexity analysis (realistic expectations) through research papers [3] [9]. Relevant tooling (libraries, etc.) is then utilized to implement these algorithms on side branches.

The Extended Kalman Filter was implemented using off-the-shelf EKF implementations from ROS [4]. Mathematical models were derived using common models found in research which can achieve target results [9]. After the mathematical models, these branches are then tested using requirements defined in these cycles, then incorporated back into the main stack after verification. The new EKF-SLAM enhancements were implemented using this strategy. The software team analyzed target requirements for moving within the pool using quantitative measurements (0.1m pose error margin, etc.), and derived minimum viable algorithmic implementations.

See Appendix P for a full software architecture diagram and Appendix Q for our Planner Flowchart.

IV. Testing Strategy

Our team implemented a three-phase testing protocol to systematically validate the AUV's performance and reliability. This structured approach progressed from isolated component verification to full system integration, with each phase building upon the previous one's results.

The initial component testing phase focused on validating individual elements before integration. For mechanical systems, we conducted pressurized leak tests on all hull penetrations, submerging electronic bays for 24-hour periods to verify waterproofing and trial grabber and torpedo tests. Electrical components underwent bench testing - thrusters were characterized for PWM response curves while depth sensors were calibrated against known pressure references in a controlled test tank. Software modules were first verified in simulation with progressively more challenging input scenarios.

Sub-system integration testing began only after all components met their individual specifications. The power distribution network was stress-tested under maximum expected loads while monitoring for voltage sag or overheating. Sensor suites were subjected to cross-validation protocols, comparing IMU orientation data against optical tracking measurements and depth sensor readings against calibrated pressure standards. The navigation subsystem underwent extensive dry testing, with the vehicle attempting predefined waypoint patterns while we logged positioning errors and control responses.

Final system validation occurred in pool environments simulating competition conditions. We designed test protocols that mirrored mission requirements, including timed object retrieval tasks and navigation through obstacle courses. During these tests, we monitored system-wide telemetry including power bus voltages, sensor consistency, and computational load. This comprehensive data collection allowed us to identify and resolve integration issues such as thruster interference patterns and sensor dropout during rapid maneuvers.

Throughout all testing phases, we maintained detailed documentation including procedure and outcomes. This approach enabled us to identify any performance issues to their root causes, whether in component design, subsystem integration, or system-level interactions. The testing strategy proved particularly valuable when diagnosing behaviors that only emerged during full-system operation.

See Appendix B for our full Test Plan and Results.

V. Conclusion

The development of Douglas over the 2024-2025 year was focused on implementing solutions to problems we faced at RoboSub 2024 and continuing to add new capabilities. The mechanical team made small adjustments to the hull developed in the 2023-2024 year and implemented a newly designed grabber and torpedo with the goal of being able to complete more tasks. The electrical team focused on a brand new power board, new peripheral systems, and improved actuator controls with a focus on reliability. The software team utilized new thruster modelling and developed robust PID control to be able to accurately navigate and complete tasks. This year, we've experienced both setbacks and triumphs and we are very proud of all of our work to create a reliable and consistent AUV for the 2025 RoboSub competition.

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Fig. 3: The Team

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This achievement reflects the tireless efforts of our entire team, whose commitment and collaboration made our AUV's development possible. Finally, we thank RoboSub and RoboNation and all its volunteers for creating this competition that fosters innovation and brings together the international underwater robotics community.

Appendix A
Community and Outreach

At McGill Robotics, we live by two core mantras, the first being "Team Before Machine." This reflects our commitment to fostering an internal community within our team. Every few weeks, we host bonding events such as mountain runs, laser tag, and movie nights that strengthen team cohesion. Furthermore, McGill Robotics mission is to inspire students to build robots, and to build robots that inspire students. As an organization, we aim not only to advance the field of robotics but also to nurture a culture grounded in sustainability, collaboration, and education. One of our ongoing outreach initiatives includes a partnership with Trafalgar School for Girls, where we support efforts to integrate STEM into their curriculum. Additional details about all our outreach can be found on our website.These two guiding principles express our commitment to cultivating a close-knit team and making a positive impact in our community.

Appendix B
Test Plan and Results

Based on the testing approach outlined in this paper, the team adopted a multi-phase testing methodology that began in September 2024 and will continue through August 2025. Testing was approached in a systematic manner, with a defined protocol across mechanical, electrical, and software subsystems. For every scheduled pool test, a dry test was first conducted in the engineering building to verify the robot's integrity. A strict clearance hierarchy was enforced: (1) Mechanical hull integrity, (2) Electrical system safety and thruster functionality, and (3) Software simulation validation.

We also wanted transparency by sharing all test outcomes regardless of success or failure. Before each pool test, a log was kept to document test goals, potential risks, and methodologies. After each session, results, videos, and follow-up decisions were recorded and shared with the entire team. This approach enabled rapid iteration, early identification of bottlenecks, and promoted team-wide accountability. The basic plan and outcomes of all major tests conducted throughout the year are documented below.

Scope	Test Date	Environment	Result
Initial Hull Leak Test	Sep 23, 2024	Hull submerged in indoor pool with calibrated weights	Pass - hull cleared for subsequent pool tests
Functional Dry Test	Oct 7, 2024	2023/2024 circuit boards dry test with tether interface	Pass - all thrusters function in air when controlled remotely
Functional Pool Test	Oct 8, 2024	Basic thruster operation in water and thruster orientation check	Partial Pass - heave thrusters need flipping
Grabber Mechanical Validation	Nov 3, 2024	Non-electrical grabber test to determine if design sufficient to grab objects	Pass - grabber able to pick up cups and spoon underwater with manual manipulation
Torpedo Mechanical Validation 1	Nov 4, 2024	Non-electrical test to determine if torpedo powerful enough in water	Fail - torpedo CO canister exploded, redesign required to reduce mechanical force
Simulation Thruster Matrix Test	Nov 11, 2024	Test in simulation to determine if thrusters operate correctly after heave thrusters flip	Pass - simulation abstracts the general movement of AUV, so no effect
New Power Board Test	Jan 7, 2025	Integration of new power board in AUV after PCB validation	Pass - thrusters operate, current and voltage sensing accurate, cleared for pool tests
Torpedo Mechanical Validation 2	Feb 13, 2025	Test of redesigned torpedo system without CO canisters	Pass - torpedo system cleared by electrical and mechanical
Pool Thruster Matrix Test	Feb 15, 2025	Test of new thruster matrix post-simulation	Partial Fail - thruster matrix modified at pool, simulation abstracted behavior
Full Electrical Integration 1	Mar 1, 2025	First full water test of AUV	Fail - tether cannot communicate, requires repotting
Full Electrical Integration 2	Mar 5, 2025	Second full water test of AUV	Fail - tether potting broken on edge, requires repotting
Full Electrical Integration 3	Mar 9, 2025	Third full water test of AUV	Fail - tether potting still failing, new method requested
Grabber and Torpedo Test (electrical)	Mar 10, 2025	Servo control test for grabber and torpedo	Pass - actuator board manipulates servos successfully

Full Electrical Integration 4	Mar 27, 2025	Fourth full integration test in water	Partial Pass - AUV hovering too low, thruster discrepancy noted
Autonomous Navigation in Simulation	Mar 29, 2025	Vision-based autonomy test in sim	Pass - completed all planned competition tasks
Thruster Characterization Test	Apr 28, 2025	Thruster PWM vs force test	Pass - 20% force discrepancy found, software updates required
PID Tuning Software	May 2, 2025	Simulation PID test	Pass - successful data visualization
Raw Sensor Data and Calibration	Jun 12, 2025	Compare sensor output with ruler/tape	Pass - remote calibration successful
State Estimation and Dead Reckoning	Jun 17, 2025	Observe AUV state prediction in 3D	Partial Pass - tuning needed, AUV recovers when moved off course
Pool PID Tuning 1	Jun 24, 2025	In-water PID test	Fail - mechanical help needed, poor performance
Pool PID Tuning 2	Jun 25, 2025	PID test with mechanical team	Pass - AUV moves to target points in water
Official Prequalification Attempt	Jul 5, 2025 (planned)	Prequal attempt (no vision)	TBD
Displacement Recovery	Jul 8, 2025 (planned)	PID recovery test after displacement	TBD
Vision Algorithm Sim Test	Jul 12, 2025 (planned)	Object detection/localization sim test	TBD
Full Integration Test in Simulation	Jul 19, 2025 (planned)	Sim test with full AUV system	TBD
Full Integration Test in Pool	Jul 22, 2025 (planned)	Full AUV test in pool with full team	TBD

APPENDIX C
DOUGLAS VIEWS

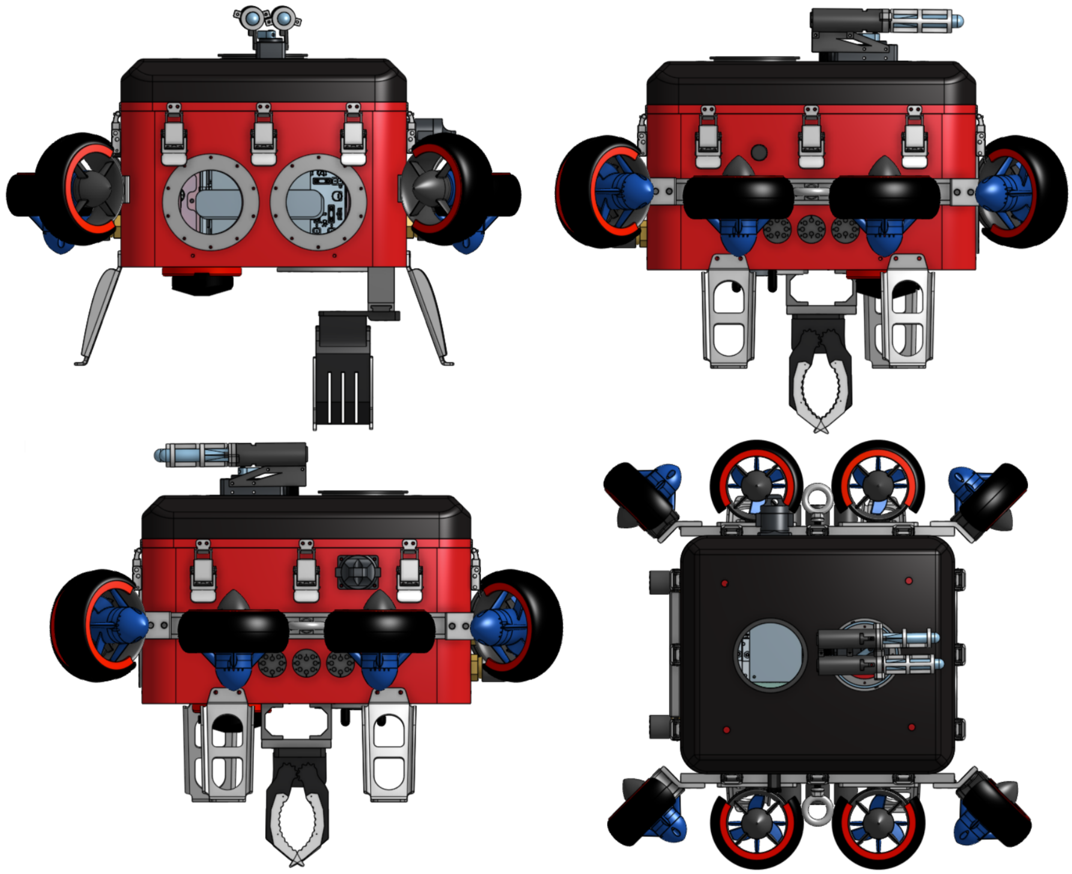

Fig. 4

Appendix D
Grabber

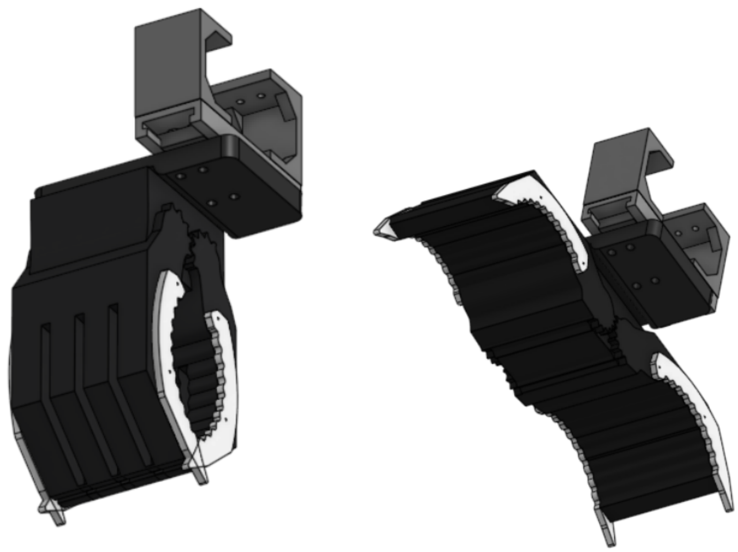

Fig. 5

Appendix E
Torpedo System

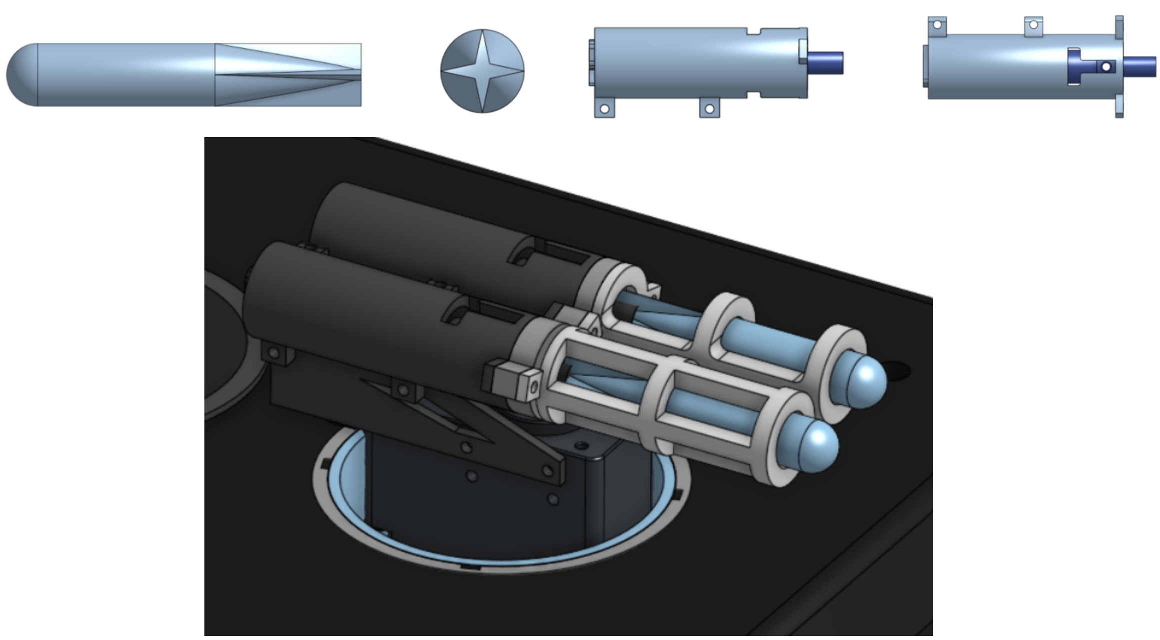

Fig. 6

APPENDIX F
CHASSIS STRUCTURAL ANALYSIS

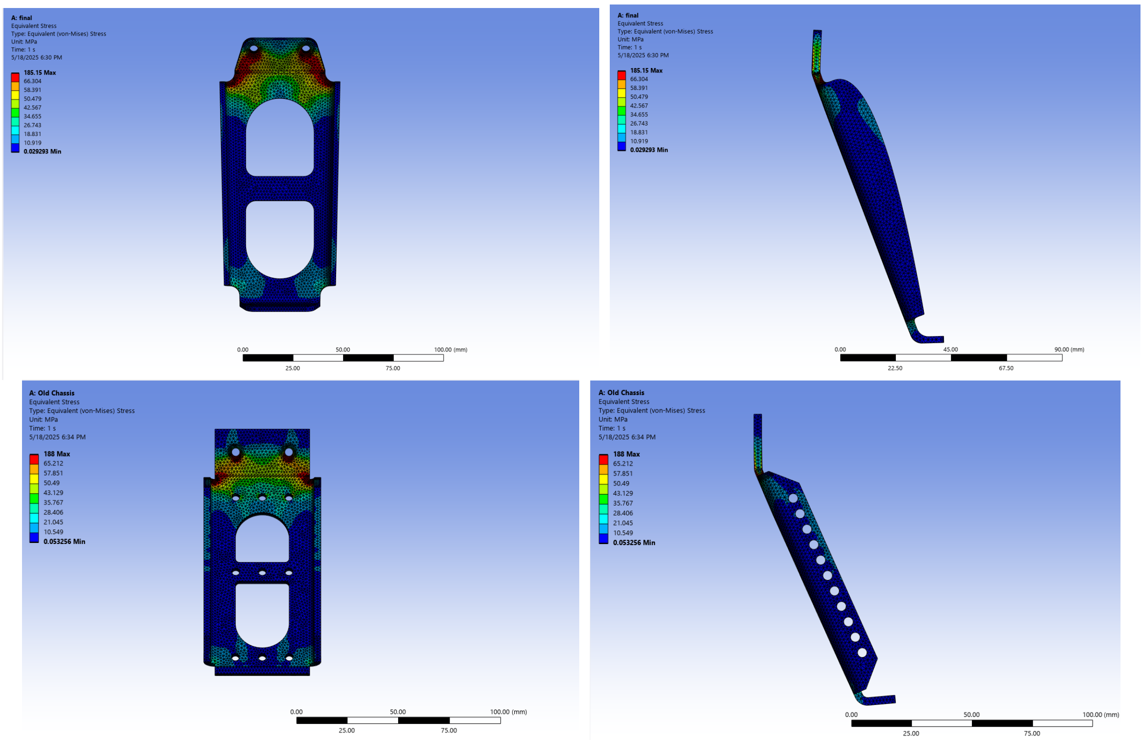

Fig. 7

APPENDIX G
THRUSTER COVER ANALYSIS

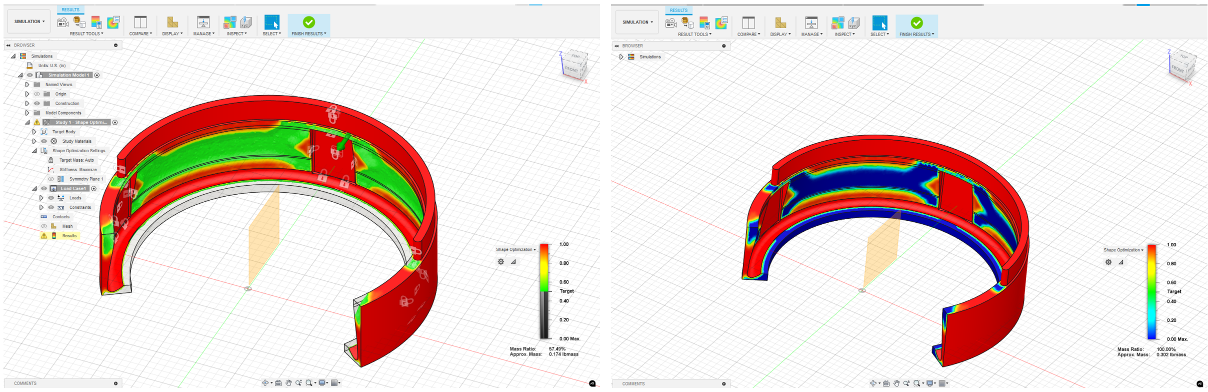

Fig. 8

Appendix H
Buoyancy Foam Manufacturing

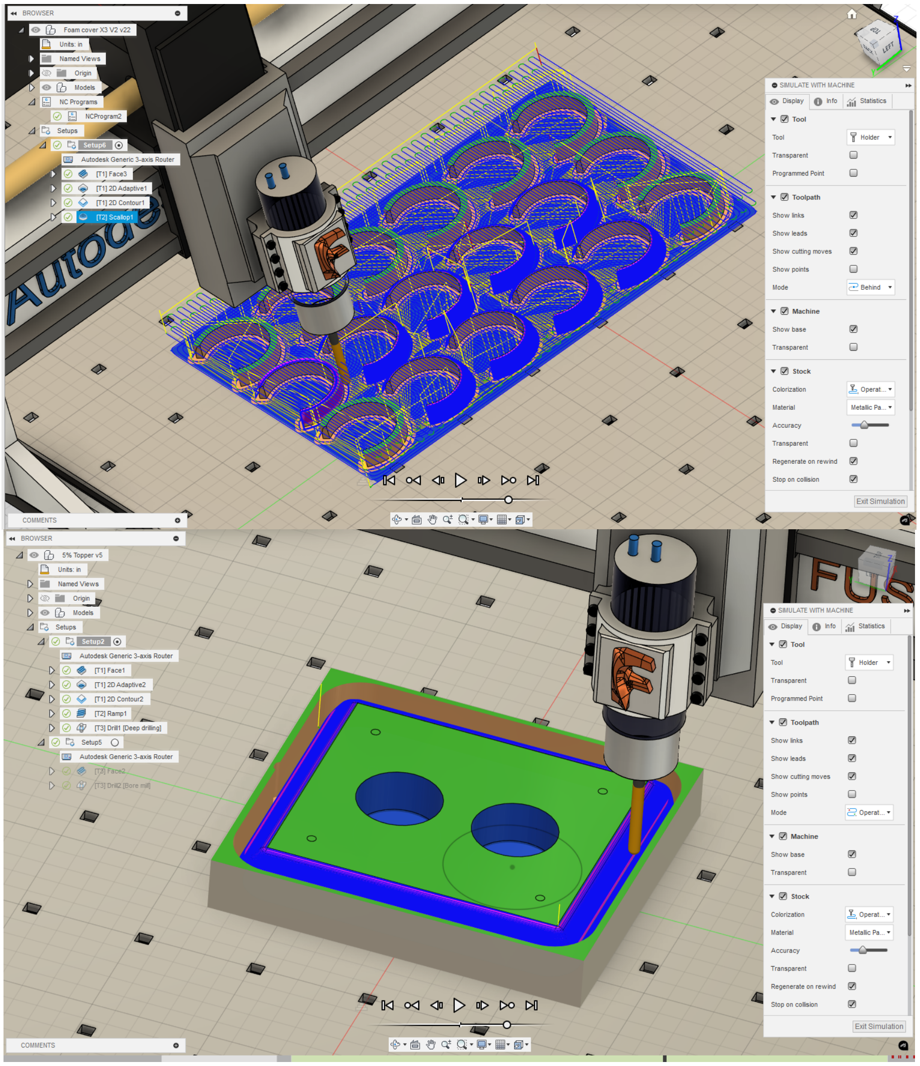

Fig. 9

APPENDIX I
THRUSTER CHARACTERIZATION RESULTS

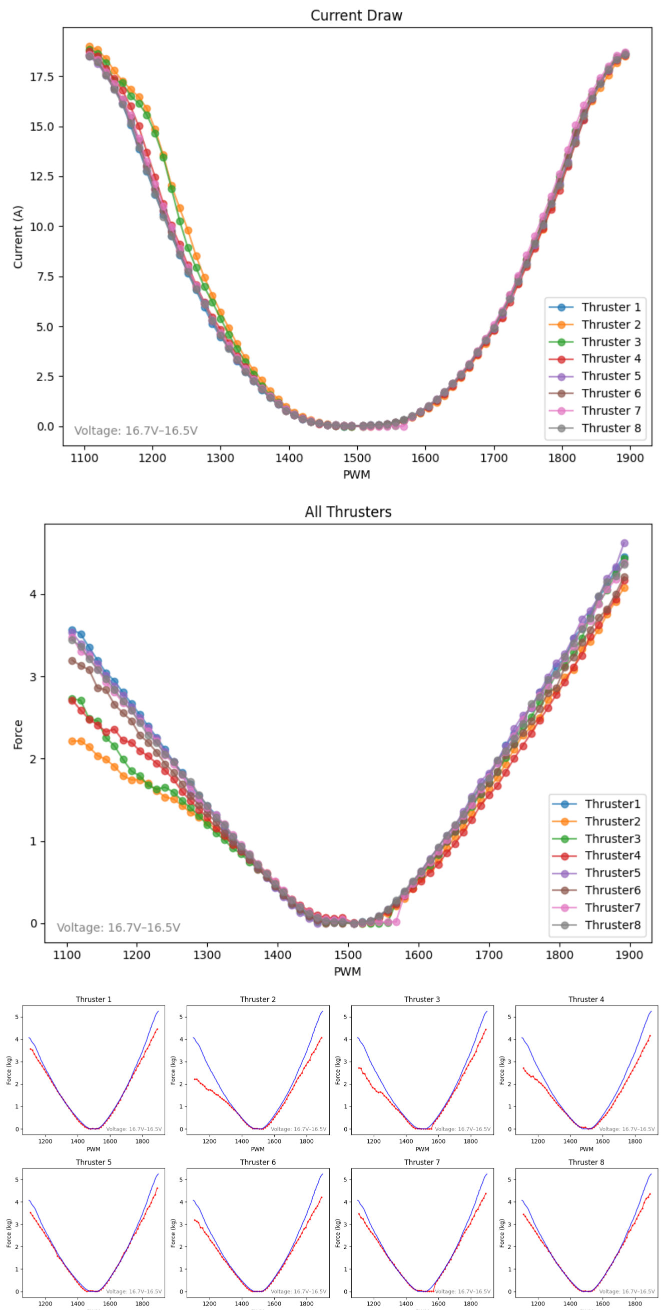

Fig. 10

Appendix J
AUV Internals

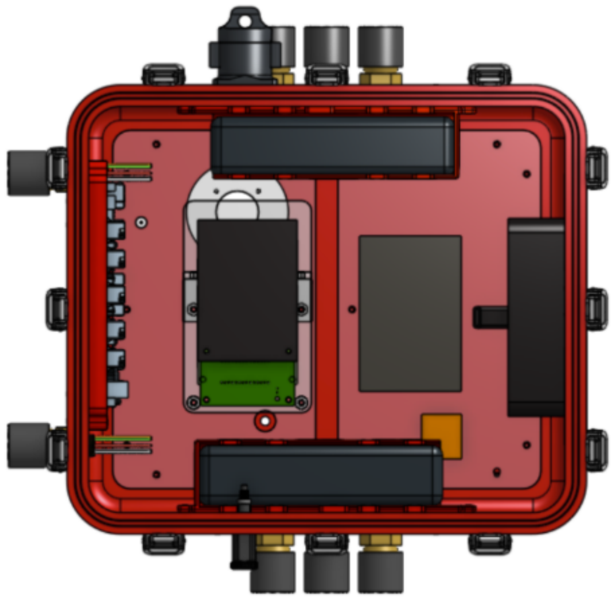

Fig. 11

Appendix K
Power Board

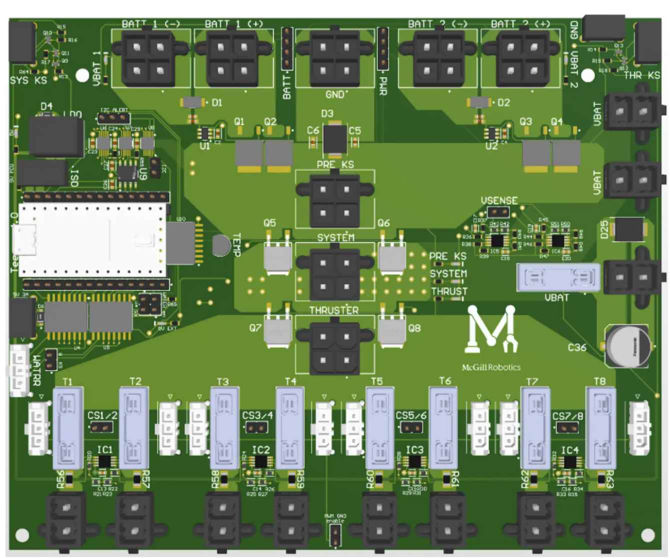

Fig. 12

Appendix L
Display Board

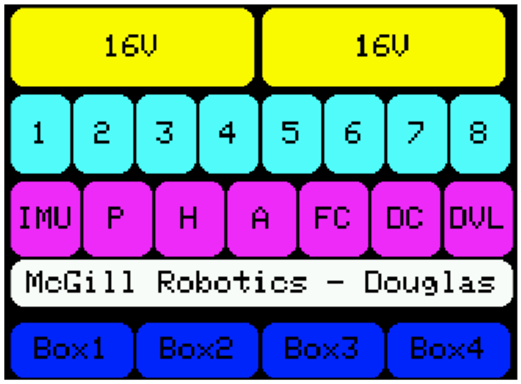

Fig. 13

Appendix M
DVL Board

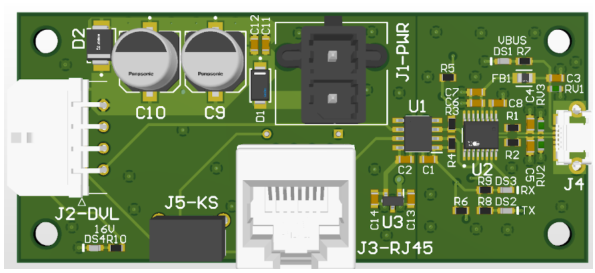

Fig. 14

APPENDIX N
ACTUATOR BOARD

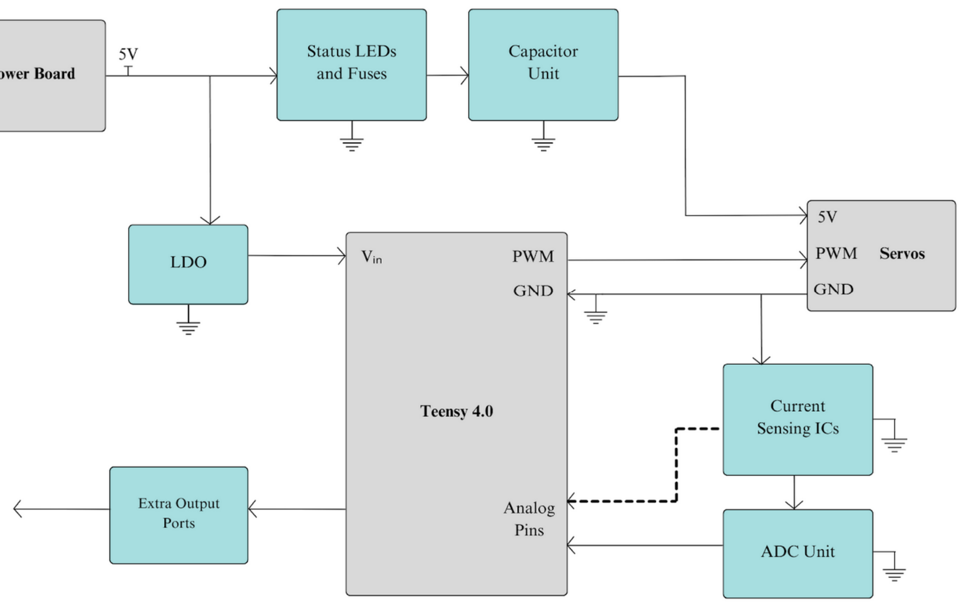

Fig. 15

APPENDIX O
ELECTRICAL ARCHITECTURE

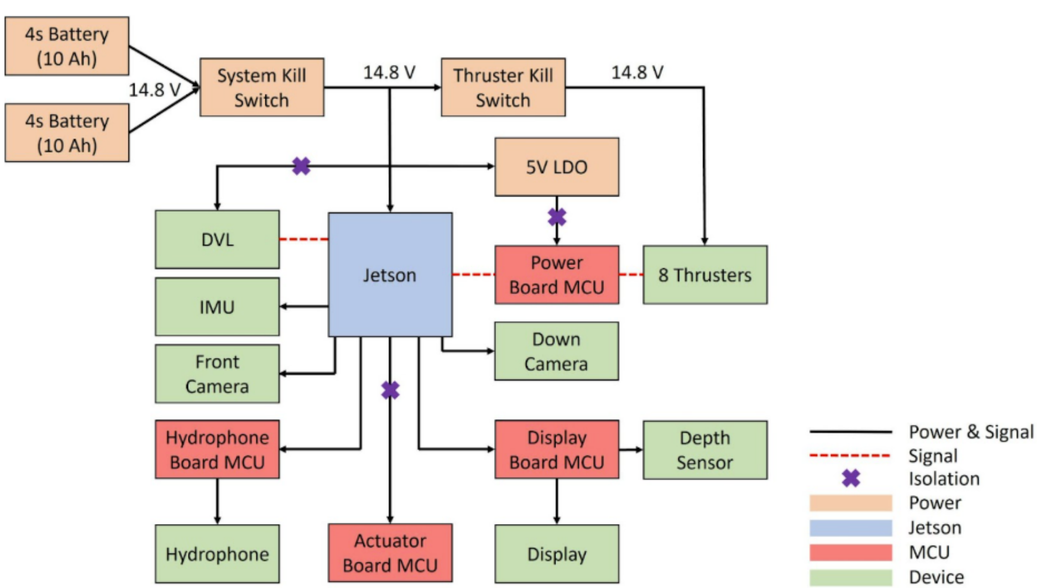

Fig. 16

APPENDIX P
SOFTWARE ARCHITECTURE

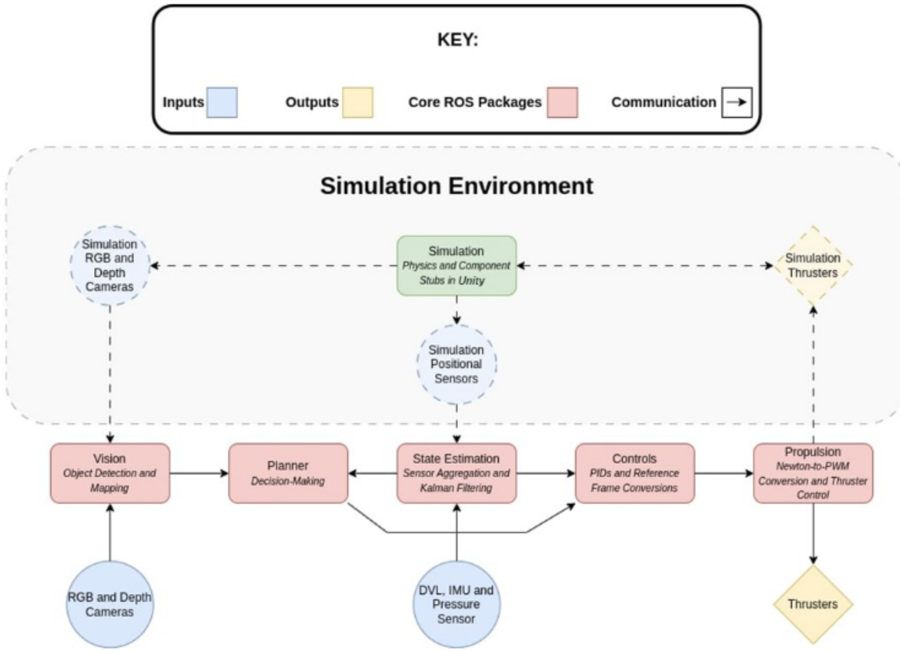

Fig. 17

APPENDIX Q
PLANNER FLOWCHART

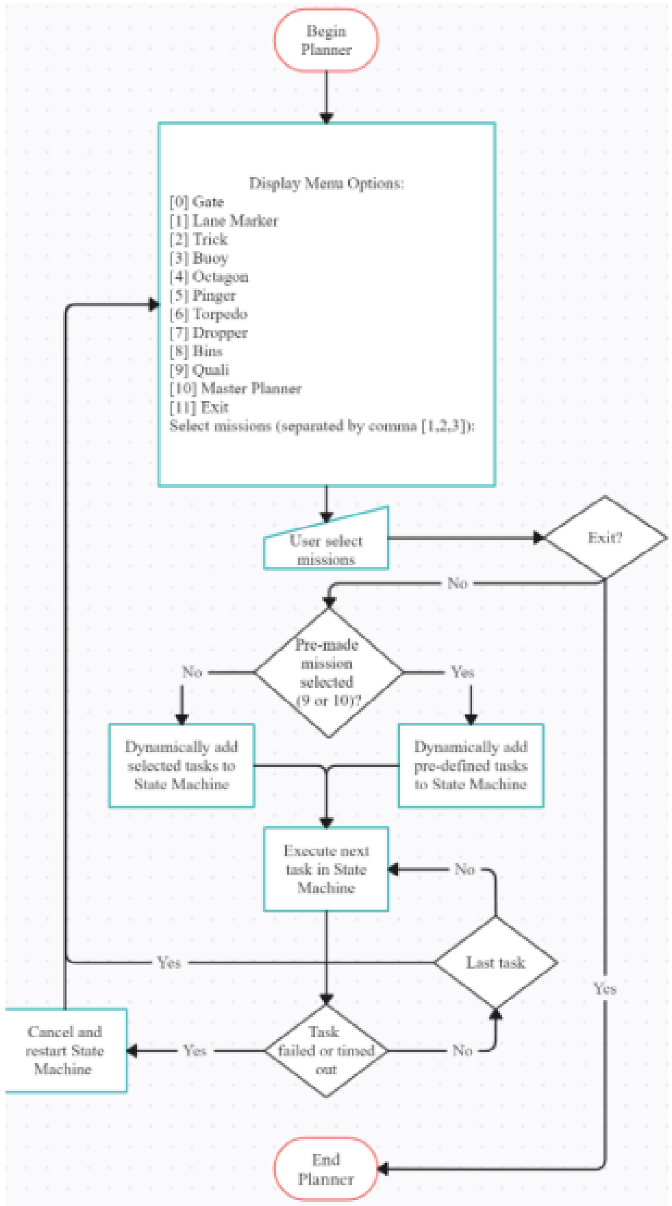

Fig. 18

APPENDIX R
COMPONENT LIST

Components					
Component	Vendor	Model/Types	Specs	Custom/ Purchased	Cost (CAD)
8 Thrusters	Blue Robotics	T-200	4.1 kg f	Purchased	$2400
8 ESCs	Blue Robotics	Basic ESC	Brushless	Purchased	$400
Hull	——	Custom Aluminum Milling	——	Custom	$2,500
Chassis	——	Custom Aluminum Cut and Bent	——	Custom	$140
Internal Electronic Mounts	——	3D Printed	——	Custom	——
Internal Mounting Plates	——	Custom Laser Cut Acrylic	——	Custom	——
Polyurethane Foam	Home Depot	Custom Milled	——	Custom	$20
Rubber Coating	Amazon	——	——	Custom	$15
2 Waterproof Servos	Blue Trail	SER-2020	29.0 kgf-cm	Purchased	$1075
2 LiPo Batteries	Blue Robotics	——	4s,10Ah	Purchased	$650
ECU	NVIDIA	Jetson AGX Orin	——	Purchased	$2000
IMU	SBG Systems	Ellipse-N	GNSS	Purchased	Sponsored
Front Camera	Stereo Labs	ZED 2i Stereo Camera	——	Purchased	$738
Down Camera	Amazon	Camera USB-USB500W02M	——	Purchased	$70

3 Hydrophones	Teledyne Marine	RESON TC4013	170kHz	Purchased	$6800
Pressure Sensor	TE Connectivity	MS5837-30BA	——	Purchased	Sponsored
DVL	Waterlinked	DVL A50	1 MHz	Purchased	$7600
Window Polycarbonate	McMaster Carr	——	Rotary	Purchased	$9.30
System Kill switch	Blue Robotics	——	——	Purchased	$50
O-rings	McMaster Carr	——	——	Purchased	$50
Latches	McMaster Carr	——	——	Purchased	$168
Claw	Amazon	——	——	Purchased	$28
Epoxy	Canadian Tire	——	——	Purchased	$200
Aluminum Window Covers	——	Custom Aluminum Milling	——	Custom	$300
O-ring Grease	Amazon	KEZE	——	Purchased	$18
Internal Component Securement	——	3D printed	——	Custom	——
Main Thruster Kill Switch	——	3D printed	——	Custom	——
Buoyancy Foam	Blue Robotics	——	——	Purchased	$160
Power Board PCB	——	Custom PCB	Thruster Control	Custom	$1200
Pressure Sensor PCB	——	Custom PCB	Depth Sensing	Custom	$25

Hydrophone Board PCB	——	Custom PCB	Accoustic Local-ization	Custom	$250
Display Board PCB	——	Custom PCB	Touch	Custom	$120
Actuator Board PCB	——	Custom PCB	Servo Control	Custom	$250
3 MCUs	PJRC	Teensy 4.0	600 MHz	Purchased	$120
MCU	STMicro-electronics	STM32-L433RC	32 KHz	Purchased	$25
Data Processing	Roboflow	——	——	——	——
Computer Vision Model	Ultralytics	YOLOv8	——	——	——
Open Source Software	——	ROS, PyTorch, OpenCV	——	——	——
Planner Algorithm: Behavior-Tree	——	smach	——	——	——
Software Environment Management	Docker, GitHub	——	——	——	——
Simulation Environment	Unity	——	——	——	——