NYU RoboSub 2025 Technical Design Report

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Abstract—The NYU RoboSub team, AUViolets, have developed Kelpie, a principal autonomous underwater vehicle (AUV), for the 2025 RoboSub competition. Designed for simplicity and reliability, Kelpie aims to perform its core tasks, namely navigation and image processing, using stereoscopic vision, inertial sensing, and PID control. It features a modular aluminum frame, an acrylic pressure vessel, and a ROS-based software stack running on an NVIDIA Jetson Orin platform. As a first-time competition team, the AUViolets aim to succeed at the chosen tasks and intend to use the competition to further validate the performance of key systems.

I. INTRODUCTION

The AUViolets [5] is a competition-based vertically integrated project (VIP) [6] team at the Tandon School of Engineering at New York University (NYU) dedicated to building an autonomous underwater vehicle (AUV) to participate in the annual RoboSub competition [1]. Team members are given the opportunity to develop hands-on robotics skills through experience on the following subteams: admin, electromechanical, motion, and vision. For the 2025 competition, the AUViolets team consisted of 20 members dispersed across these subteams, including 19 students and one academic advisor.

NYU AUViolets are set to debut their first functional AUV prototype, Kelpie (Figure 1), in the 2025 RoboSub competition. The design and construction of Kelpie began in August of 2024 and finished in early May of 2025. The team was originally founded in August of 2022, with the first few years dedicated to R&D, including: research of previously successful designs, universal parts sourcing, laying the foundations for the software development, initial mechanical concept design, and the prototyping and testing of varying subsystems.

Figure 1: Photographs of Kelpie, the AUViolets first functional prototype.

Within this technical design report, we discuss the strategy planned for Kelpie's debut competition, highlight key features of the principal design, detail testing strategies for both the software and the electromechanical components, and list future possible design upgrades.

II. COMPETITION STRATEGY

A. GENERAL STRATEGY

Since Kelpie is the first AUV designed by the NYU AUViolets, the complexity of the system, and consequently the choice of tasks, was kept to a minimum. This was to ensure that the robot could be finished within limited student working hours and to maximize the reliability of the AUV, as fewer subsystems typically leads to fewer possible sources of error. With this in mind, the AUV only contains the systems necessary for navigation and image processing; however, the design allows for future implementation of added functionality.

B. COMPETITION GOALS

Without a robotic arm, torpedoes, or the means for completing various complex tasks, the goal for the 2025 RoboSub competition is the completion of the following three tasks: (i) coin flip, (ii) data collection, and (iii) navigating the channel. The highest priority tasks are coin flip and data collection, as similar tasks are used for pre-qualification.

C. TASK EXECUTION

COIN FLIP

For the "coin flip" task, Kelpie's orientation with respect to the competition start gate is determined by a coin flip [1], as seen in Figure 2. Heads means the AUV is oriented near parallel with the gate, while tails has the back end facing the gate.

To complete this task, Kelpie will rotate until the front-facing camera captures each pole of the gate using computer vision. The robot's angle at each of these moments will be recorded using the altitude and heading reference system (AHRS). The difference between the angles for the gate poles is used to determine which side is facing the gate and properly orient Kelpie toward the gate.

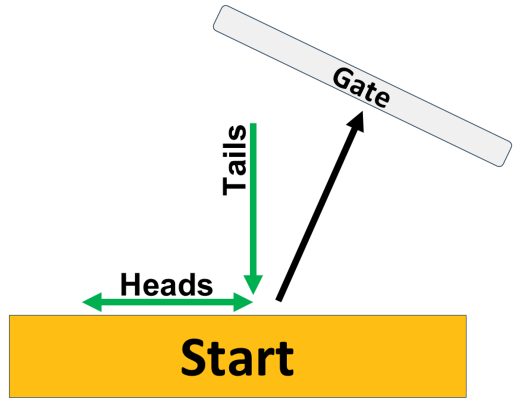

Figure 2: Schematic representation of the "coin flip" task [1]

COLLECTING DATA

The "collecting data" task requires the AUV to pass through the start gate, which is divided into two sides, with a swordfish and a shark each representing a side. For this year's competition, Kelpie will pass through the side represented by a shark. It should be noted that this decision would affect the completion of some of the more complex tasks that will not be completed by Kelpie at this year's competition.

The PID controller and AHRS are used to ensure Kelpie maintains control while passing through the gate. Kelpie will attempt to pass through the gate with style by completing a barrel roll in order to gain extra points. Kelpie will then rotate until it is perpendicular to the gate.

FOLLOWING THE PATH

In order for Kelpie to move to the navigating the channel task, it is necessary to complete the "following the path" subtask. This will require the use of the bottom-facing camera and computer vision to detect and follow markers placed at the bottom of the pool (Figure 3).

Kelpie will move in a zig-zag fashion after exiting the gate to ensure it can find the orange path. Next, Kelpie will rotate until the width of the bounding box is minimized, since this indicates Kelpie is pointing in the same direction as the path. Then, Kelpie will move forward until it reaches the navigating channel task.

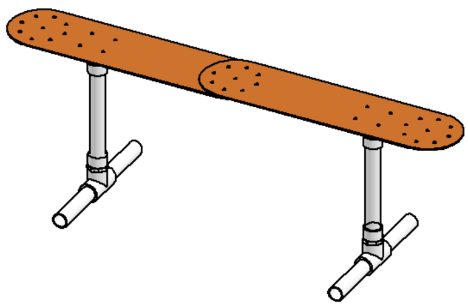

Figure 3: Schematic of a typical path mark found on the bottom of the pool [1].

NAVIGATING THE CHANNEL

For the “navigating the channel” task (Figure 4), similar to a slalom, Kelpie will rotate 180 degrees to find all the white and red poles and record their angle with the AHRS and distance using the Zed’s depth map. It will then use the distance measurement to determine the three poles that form the closest set. Kelpie will pass on the left of the set and then correct the angle to ensure it is perpendicular to the line formed by the three poles. It will then repeat the previous steps until it passes all three sets.

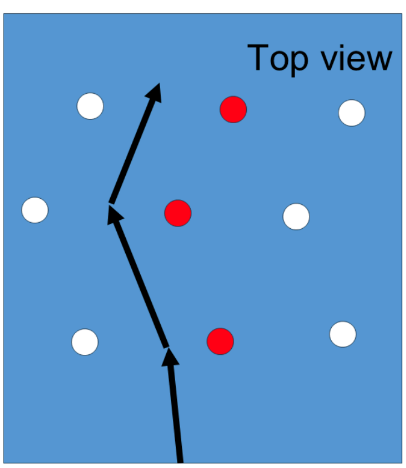

Figure 4: The “navigating the channel” task [1].

III. DESIGN STRATEGY

A. DESIGN OVERVIEW

The electromechanical design of Kelpie consists of the hull and frame, while the software refers to both the vision and motion aspects that control the AUV. Kelpie can operate autonomously or be controlled through the neutrally buoyant tether purchased from Blue Robotics; Kelpie will operate fully autonomously during the 2025 RoboSub competition. The overall dimensions of the AUV are 18.5″ × 18.2″ × 12.0″. with a dry weight of 32.2 lb including the tether. Kelpie was designed to be positively buoyant without ballasts, so that future modifications, such as torpedoes, would not require additional buoyancy devices. Detailed component descriptions can be found in Appendix A of the report.

Kelpie utilizes Zed stereoscopic cameras facing both forwards and downwards to detect distance and collect image data while leveraging the computational power of the NVIDIA Jetson Orin to process the visual feedback and feed the motion logic through real-time image recognition. The onboard AHRS is also used to ensure that the AUV can be maintained in the desired orientation at all times. In order to control the Blue Robotics thrusters and lights, two onboard Arduinos are used for pulse width modulation (PWM) output at speeds determined by the custom motion software. Additionally, the Arduinos are used for data acquisition from the following sensors: hull leak and air temperature. All systems are powered using a single 14.8 V 12000 mAh Li-Po battery.

The hull (Figure 5, 1) of the AUV is defined as the pressure vessel enclosure that houses the majority of the electronic systems. The frame (Figure 5, 2) seats the hull, and mounts the water-side electronic subsystems, which currently consists of the thrusters and lights. The eight thrusters allow for movement in all degrees of freedom in both translation and rotation. Both the hull and frame consist of a combination of bent sheet metal aluminum (gray in the CAD), 3-D printed ABS components (white in the CAD), and off the shelf components. Manufacturability and compatibility with potential future modifications was prioritized throughout the design process. As movement speeds are low, hydrodynamics were not considered.

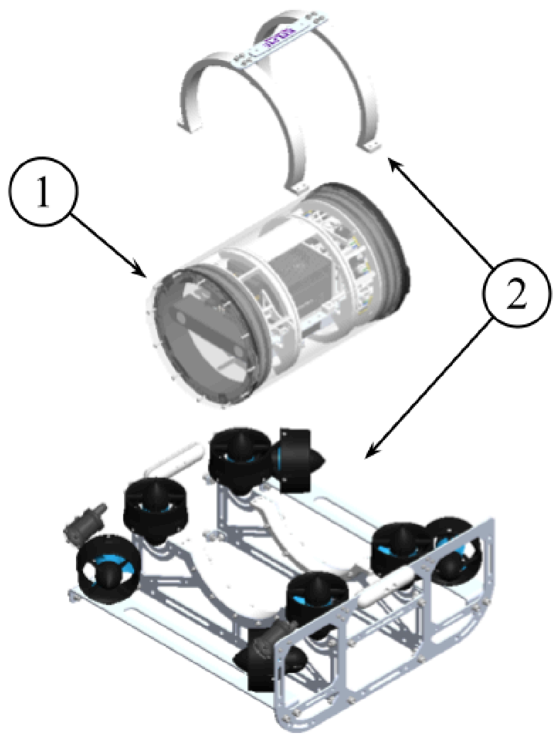

Figure 5: Kelpie CAD exploded view showing the hull (1) and the frame (2).

B. FRAME DESIGN

The frame of Kelpie (Figure 6) was designed to be rigid, lightweight, modular, and easy to manufacture. The subsystems mounted to the frame for the 2025 competition included the eight AUV thrusters (Figure 6, 1) and two lights (Figure 6, 2).

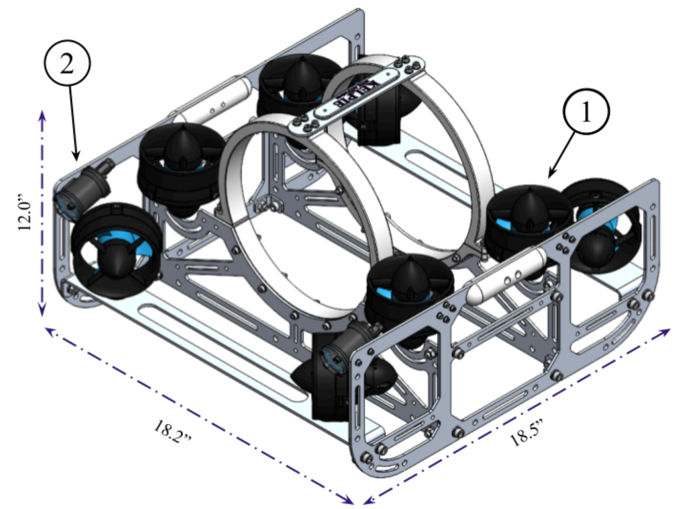

Figure 6: CAD of Kelpie's frame showing the outer dimensions along with the location of the thrusters (1) and the lights (2).

Sheet metal (5052 aluminum) was used for the main frame components, while the hull clamps and various other components were 3-D printed using ABS plastic. Aluminum 5052 was chosen as the primary frame material as it is not only easy to machine and bend, but it is also lightweight and corrosion resistant–a key feature for a vehicle operating in an underwater environment.

In order to further decrease the weight and allow for future modifications, the frame has various slots sized for both M4 and M6 bolts, which would allow for self-contained systems, such as a torpedo launcher, to be mounted on various locations on the frame. A static finite element analysis was run to ensure that the slot sizes would not affect frame rigidity.

C. HULL DESIGN

MECHANICAL SUBSYSTEMS

The hull of the AUV (Figure 7) consists of two subassemblies: the pressure vessel (Figure 7, 1) and the electronics mounting rack (Figure 7, 2) inside.

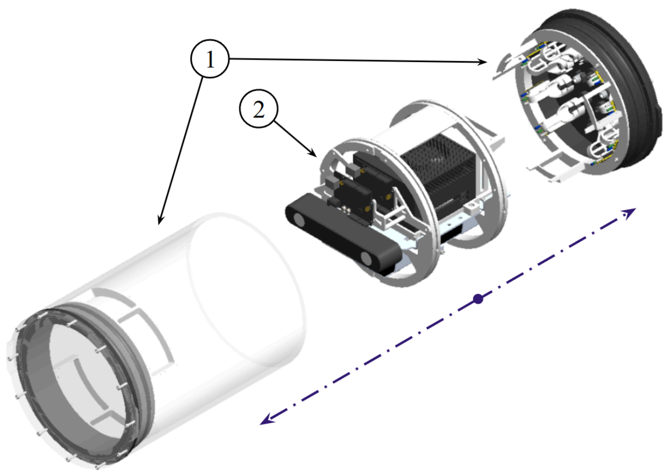

Figure 7: CAD of Kelpie's hull subassembly, showing the pressure vessel (1) and the mounting rack for the onboard electronics (2).

The pressure vessel is comprised of an acrylic tube with two end caps (one acrylic and one aluminum) bolted to aluminum flanges that are sealed with o-rings. The aft end cap has non-permanent waterproof penetrators to connect the interior electronics to external subsystems. Acrylic was chosen for the stern end cap and main pressure vessel tube due to the reliance on cameras for navigation and shallow depth requirements during operation.

The electronics mounting rack is designed for ease of maintenance, allowing for the external hull tube to be slid off for easy access to the electronic systems. ABS centering rings hold the mounting plates for all electronic components. ABS spacers bolted to the flanges keep the mounting rack centered to create space for wiring in the rear of the hull. The mounting rack is designed in a way that allows for the battery to be quickly swapped out by removing the front acrylic faceplate.

ELECTRICAL SUBSYSTEMS

The electrical subsystem (Figure 8) consists of a single 14.8 V Li-Po battery running to a combination of voltage regulators to power the AHRS, Jetson unit, Arduinos, thrusters, and lights. These voltage regulators ensure that the sensitive electronics both receive the required input voltage and are not at risk of damage due to overvoltage. The cameras are directly powered by the Jetson unit and the onboard sensors from the Arduinos. A water side kill switch shuts off power to the Jetson unit, effectively killing all submarine motion.

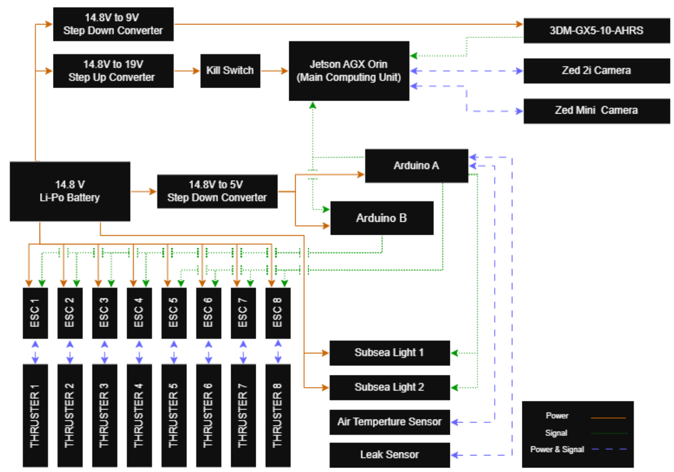

Figure 8: Diagram showcasing how Kelpie's electronic components are interconnected.

Each thruster is equipped with an electronic speed controller that takes power directly at the battery voltage and PWM signal from the Arduinos. XT60 style connectors, which are rated for 60 A of continuous current [2] (far exceeding the maximum draw of 32 A for each T200 style thruster [3]), are used throughout the wiring harness in case components need to be replaced quickly. XT30 connectors are used for the lower current components.

While not entirely necessary for the competition, the Jetson unit can communicate with an external computer through a tether that penetrates the aft end cap, which is useful for testing. A Cat5 GB ethernet connection is used, as the tether has four twisted pairs. A signal booster may be required in the future to increase signal transmission through harsh underwater environments.

D. SOFTWARE

The software stack consists of four main components: Arduino code for reading sensor inputs and controlling the speed of the thrusters, Python code for handling the AHRS, Python code for the computer vision, and Python code for the main controller. ROS is used to handle interprocess communication with the publisher subscriber paradigm.

The Arduino code and Python code for the AHRS is for interfacing with the sensors and thrusters. Input is read from the sensors and published with ROS, and the thruster speed is updated with a ROS subscriber that receives the value published by the main controller.

For the computer vision portion, a YOLOv8 model was pre-trained and fine-tuned with manually labelled images relevant to the competition such as underwater gate. The computer vision code takes image input from the two Zed stereoscopic cameras, one facing forward and one facing downward. The computer vision code also publishes a depth map that is generated by the Zed stereo cameras.

The Python program governing the main controller plans for each task sequentially. This approach is taken as it is easier to implement and only two tasks are being attempted. To make the code easier to maintain, a separate function was created for each task. There are 4 PID controllers that are used for controlling the movement of Kelpie, including one for each axis of rotation and one for moving forward and backward.

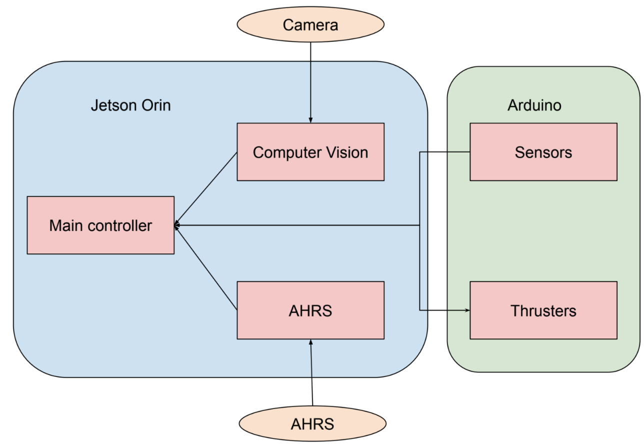

Figure 9: Diagram showing different components of the software

E. FUTURE MODIFICATIONS

As Kelpie is the first prototype from the AUViolets, it is necessary to include future plans for modifications and design changes. As mentioned in section *IIIC*, the frame was designed with modularity in mind, allowing for the mounting of both non-explosive torpedoes and a grabber to complete more complex tasks during future RoboSub competitions.

Another key potential design change is related to the battery. While all electrical components are currently contained within the same pressure vessel, in case of catastrophic failure and for waterproofing concerns, it can be desirable to have the battery in a dedicated pressure vessel. Catastrophic failure of the Li-Po battery due to a current overdraw, water leak, or overheating could lead to the destruction of all key components from a lithium fire. Additionally within the current design, it is necessary to open the pressure vessel each time the battery is replaced. This significantly increases the risk of potential leaks or damage to the acrylic faceplate. By adding a separate battery hull, these risks could be mitigated, battery swaps would be faster, and additional batteries could be added for longer operational time.

We will also explore whether the power from the battery can be complemented by onboard solar power via flexible thin-film modules placed on the inside of the hull which is currently made from visibly transparent acrylic. This would allow for full autonomy and longer operational times. [4]

It could also be beneficial to move the cameras to external pressure vessels, creating more flexibility in mounting location with potential for pointing actuation. With these modifications, the hull itself could be manufactured from aluminum, allowing for better heat transfer with the surrounding water than the acrylic version and lowering the ambient air temperature inside the AUV.

Additionally, various improvements can be made to the electronics discussed in section IIIB. Custom PCBs for sensors and PWM control will be implemented to save valuable space inside the hull and replace generalized components, such as the Arduinos. Various additional safety mechanisms, such as fuses will also need to be incorporated for future versions in order to protect sensitive components such as the electronic speed controllers. In order to circumvent this in the current version, it was deemed that the thrusters would be hard capped at half maximum speed, to minimize the risk of over current. However, this is not desirable for both performance and efficiency.

IV. TESTING STRATEGY

A. HARDWARE TESTING

WATERPROOF TESTING

In order to ensure the safety of the hull electronics, waterproof testing of the pressure vessel was essential. This was done prior to the assembly of the inner electronics hull to minimize risk. However, the hull was attached along with the thruster penetrators to test all potential leak points. For the test, the AUV was first submerged for five minutes. After no leaks were detected, the front faceplate was removed and replaced to simulate a battery replacement. The same submersion process was followed. No changes were made, as the hull remained completely waterproof.

ELECTRONICS TESTING

Various electronics tests were performed to verify the functionality and datasheets of various electronic components.

Thruster bench testing was performed to verify battery safety and actual power draw. The thrusters were run at 50 μs PWM intervals, and it was determined that half speed had the best balance between safe current draw and efficiency. The need for a safe current draw is described in section *III* of the report. Testing of the lights followed a similar process.

Additionally, voltage outputs from each of the voltage converters off of both power supply and battery power were tested prior to integration with the remaining components. Once the correct output voltages were verified, electronic components were each plugged into the wiring harness on battery power one by one until their functionality could be verified.

B. SOFTWARE TESTING

Due to time constraints, rather than building a testing simulator, the software components of Kelpie were tested with manually crafted sensor input. The main controller was tested by adding a 1 minute sleep to every step of the PID controller to give enough time for manually passing in the hypothetical sensor input and computer vision input. These inputs are what we think are realistic values given the motion of the robot based on the thruster signal. The thruster signal sent by the main controller at each step was assessed to determine whether it was behaving as expected. For the computer vision program, it is tested by passing in images and checking whether the bounding box is correct.

C. INTEGRATED TESTING

Integration testing is planned for the summer of 2025 before the competition takes place. The testing plan includes a combination of in-pool testing along with various image recognition tasks.

V. ACKNOWLEDGMENTS

The AUViolet's team would like to thank and acknowledge the efforts and support of the NYU VIP administration.

VI. REFERENCES

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VII. APPENDIX A: COMPONENT SPECIFICATIONS

Table A1: Kelpie Components

Components	Vendor	Qty.	Purchased/ Custom	Unit Cost	Specs
Frame	-	1	Custom	$247.10	-
Pressure Vessel	-	1	Both	$927.00	-
NVIDIA Jetson Orin	-	1	Purchased	$1,999.00	link
3DM-GX5-AHRS	Mouser	1	Purchased	$2,045.38	link
Thrusters	Blue Robotics	8	Purchased	$220.00	link
Subsea Light	Blue Robotics	2	Purchased	$170.00	link
Misc. Mounting Prints	-	12	Custom	-	-
ZED 2i Stereo Camera	Stereo Labs	1	Purchased	$519.00	link
ZED Mini Stereo Camera	Stereo Labs	1	Purchased	$399.00	link
Arduino Uno	Amazon	2	Purchased	$27.60	link
Battery	Hobby King	1	Purchased	$95.14	link
Misc. Voltage Converters	Amazon	3	Purchased	$28.48	link
Tether	Blue Robotics	1	Purchased	$400.00	link