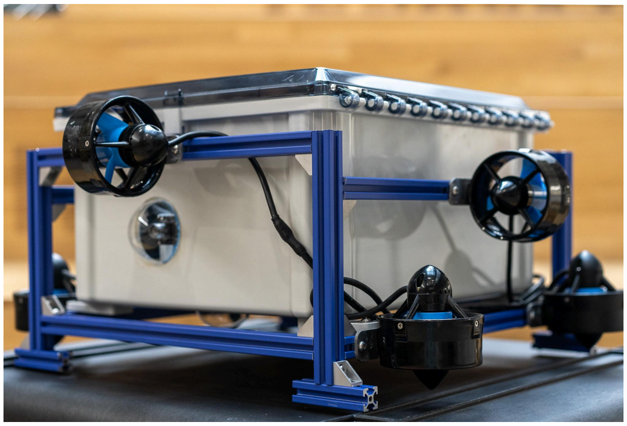
Technical Design Report



I. Abstract

This document details the development process undertaken by the RoboCats at Montana State University to create the Autonomous Underwater Vehicle (AUV) Lynx for the 2024 RoboSub Competition. The project involved designing a mechanical system from scratch, developing a new electrical system, and implementing several software reworks. Comprehensive experimentation and testing procedures were recorded to validate these developments.

II. Competition Goals

Given the significant reduction in human resources following the graduation of many seniors, the RoboCats aimed to develop a straightforward platform that is easy to build and maintain, even with a limited budget. This approach ensures that the team can achieve its competition goals effectively while accommodating the constraints of reduced manpower and financial resources. Because the focus of this year was to simplify the base platform, many features are missing to participate in some of the competition events. The tasks Lynx plans to participate in are listed below.

2.1. Task 1 (Coin Flip)

The first task to be undertaken is the coin flip. The AUV will need to be able to rotate from varied starting positions while searching for the gate, then proceed to approach it after locating it. The capability to turn and move were implemented into previous iterations of the AUV, meaning that the main developmental focus for this task was for vision processing to identify the gate.

2.2. Task 2 (Gate)

Task 2 is to pass through the gate. This is a vital task, as it is required for qualification. Further investment into vision recognition is required, as to identify which side the AUV will pass through. The “Earth” side will be attempted, as the shapes associated with that destination might be easier for the vision system to identify. Style points will be attempted, as 2 full rotations (720°) of yaw will be attempted within the gate. These subtasks require similar capabilities to Task 1.

2.3. Task 3 (Buoys)

The third task to be undertaken by the AUV is contacting the buoys. In order to complete this task, vision recognition will be required to identify the correct buoy location based on the side of the gate passed through in the previous task - previously, this was decided to be the "Earth" destination. When the selected buoy has been found, the AUV will approach and displace the buoy.

III. Design Strategy

The focus of the Lynx AUV is to apply the knowledge gained from previous years to build a completely new, from-scratch design. Lessons learned from earlier models revealed that overambitious mechanical designs, without thorough testing and significant time investment, often result in numerous design flaws such as leakage and poor modularity. Therefore, simplicity, modularity, and reliability were established as the primary design criteria for Lynx.

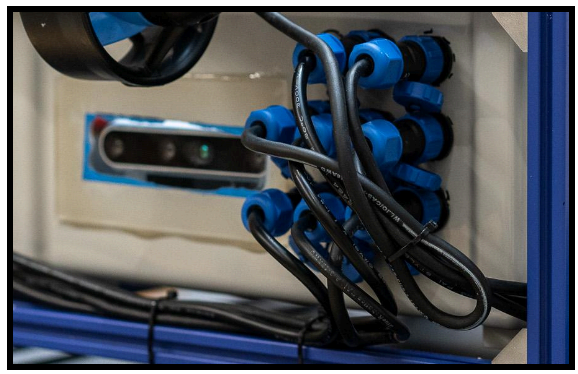
3.1. Enclosure

In previous seasons, numerous issues occurred with leaks in our enclosure. On the first day of the 2023 competition, our primary computer was killed by encroaching water. We also faced problems with feature expansion due to a lack of space to fit additional features. Therefore the mechanical team opted for an off the shelf Nema 68 rated plastic electrical enclosure from manufacturer Attabox. An important decision had to be made on how big of a box we could make neutrally buoyant while staying under the weight limit. Based on preliminary estimates for component weights and space requirements, a 16x14x8" box was selected with the expectation of adding ballast to achieve a near-neutrally buoyant system. Custom steel plates were made to be used for ballast, which are both smaller and easier to mount than standard gym weights and much less expensive than dive weights.

3.2 Thruster Mounting

Design decisions for thruster mounting were mainly driven by previous configurations. Using the same 8 thruster configuration allowed new software to pull from legacy code repositories.

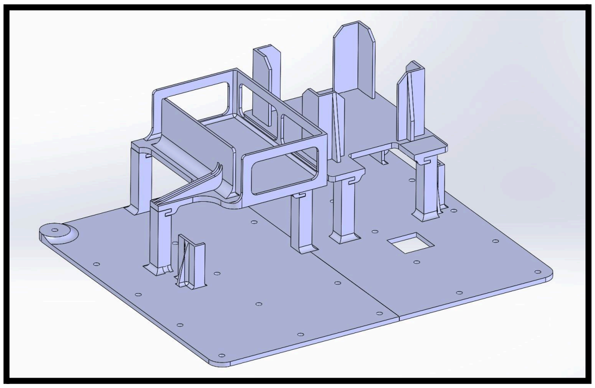
3.3 Electrical Pass-Throughs



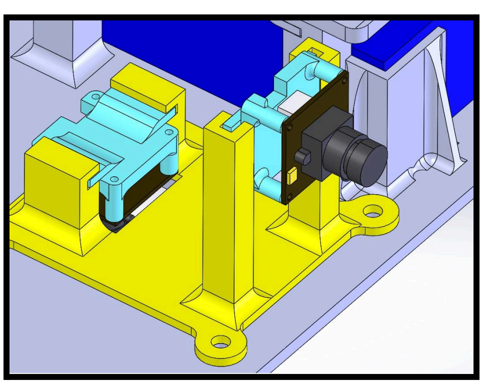
A lot of research took place trying to source ip68 rated passthrough connectors at a reasonable price. Previously, RoboCats had used bluerobotics wire pass-throughs which were great in terms of not leaking, but left a lot to be desired in terms of modularity. After many hours of research we chose the Weipu SP13 series of connectors for their ease of use, cost, and current carrying capabilities.

3.4 Modular Internal System

Previous submersibles housed their electronics in an acrylic cylindrical tube. To access these electronics, most of the components had to be removed. This resulted in added repair time and a lack of overall organization. To address this issue, this year's submersible was designed to utilize a modular internal system. This system allowed the internal assembly to be put together in a way that was easy to access and disassemble without needing to move other components. The system consists of a large 3-D printed base plate. This plate, which consists of the first level of electronics, has predetermined slots to fit into.



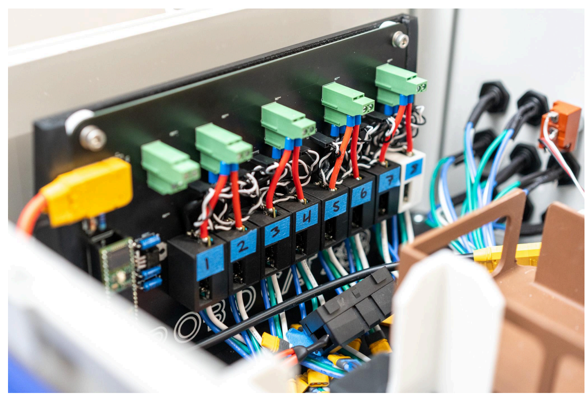
Following that, the base plate has towers with slots, allowing for a second level of modular plates to slide in. This second layer houses the components that would most likely need to be accessed more often than other components. Furthermore, the base plate utilizes a vertical PCB stand that allows a PCB to slide in and out with ease. Lastly, the baseplate contained three camera mounting systems. These cameras used in the sub were attached to a slider that allowed the cameras to slide in and out of the sub but still retain rigidity when attached. When fully assembled, the modular assembly could be slid into the submarine and bolted down with four easily accessible screws. In



the case that a component needs to be removed, its own individual modular section could be removed without anything being in the way.

3.5 Motor Control Pcb

The motor control board is a high current two layer PCB that is being reused from last year until we can design our own ESCs. This board simply connects all the ESCs to power and to the microcontroller. The board also has a voltage regulator to power the microcontroller and utilizes an ADC to measure battery voltage.



3.6 Battery Protection Pcb

After being docked for having no battery protection circuit last year, we decided to go all out on an ideal diode based design. An ideal diode controller essentially utilizes two N-Channel mosfets to act like an ideal diode. The board also implements power switching and fuses. Unfortunately this PCB is still being designed, and will not be ready for this year's competition.

3.7 Central Computer

After killing last year's older x86 based intel pc, a Nvidia Jetson AGX Orin 64GB was chosen for its Robotic Operating System 2 (ROS2) compatibility as well as its sheer processing power that would allow us to run more complex computer vision algorithms. Developer support is also widely available for the platform as it is standard for many robotic applications, aiding in the setup, development, and troubleshooting of the software.

3.8 Sensor Additions

In the 2023 competition all of our processes were accomplished through either open loop control or computer vision. This year we decided to implement many more sensors to help gather more data and in turn improve our subs capabilities. The first and most needed of these sensores was an IMU (Inertial Measurement Unit). The chosen BNO055 will give us both acceleration and rotation data to help improve our positioning algorithms. Temperature, pressure, and humidity measurements were also added to make sure the internals of the sub remain at reasonable temperature and to detect rises in humidity or pressure, indicating a leak.

3.9 Software

As none of the software from previous years was implemented using ROS2, the software was overhauled completely. ROS2 allows the software to be divided into individual nodes with specialized tasks, increasing modularity and allowing for advanced, concurrent systems. Because no code was recycled from previous years, the focus has been on implementing a development environment and establishing basic functionality for this year’s competition that will provide a foundation for more complex tasks and algorithms in the future.

3.10 Torpedos

At the end of 2023, designs of prototype torpedoes began to be made as a proof of concept. These torpedoes use capacitors to store power to comply with rules prohibiting battery operated torpedoes in the water. These capacitors connect to power through two prongs into the sub, which would intern keep them charged. Once released they are propelled forward by a motor in the back. The next version of the design would include a capsule to house the electronics while testing alternative shells to the original as to prevent having to rewire everything for each prototype.

V. Acknowledgements

RoboCats at Montana State University would like to thank all of the people involved in the continued development of the project, including the capstone team involved in developing the hydrophone subsystem. Special thanks to the team's sponsors, NAVSEA and BlueRobotics, for providing necessary resources to allow these developments to continue. The contribution from these sponsors cannot be overstated. Additional thanks to Montana State University, the Norm Asbjornson College of Engineering, and the RoboCats club advisor, Dr. Bradley Whitaker, for all of the continued support.

VI. Resources

[1](2020). Retrieved 12 June 2022, from https://github.com/theAIGuysCode/tensorflow-yolov4-tflite

[2] K. Rust et al., "Robotic Autonomous Vehicle Navigation (RAVN)", MSU EELE, Bozeman, MT., United States, April 2021

[3] X. Xu et al., "RoboSub: Object Recognition and Localization", MSU EELE, Bozeman, MT., United States, April 2021

Appendix A: Component Specifications

Component	Part Number	Cost	Manufacturer	Custom/ Purchased	Year of Purchase
Enclosure	AH14128C	$203.16	AttaBox	Purchased	2023
Batteries	4S 10000Mah	$351.98	Maxamps	Purchased	2023
Power Connectors	XT-90 Series	$96.87	Amass	Purchased	2023
Passthrough Connectors	SP17 Series	$117.70	Weipu	Purchased	2023
Motor Control Microcontroller	Teensy 4.0	$31.50	PJRC	Purchased	2023
Inertial Measurement Unit	BNO085	$29.95	Adafruit	Purchased	2023
Temp and Humidity Sensor	BMP388	$9.95	Adafruit	Purchased	2023
Senor Microcontroller	Metro Mini 328 V2	$14.95	Adafruit	Purchased	2023
Primary Cameras	BR-100126	$99.00	Blue Robotics	Purchased	2023
Thrusters	T200	$1600	Blue Robotics	Purchased	2021
Electronic Speed Controller	Basic ESC	$304.00	Blue Robotics	Purchased	2021
Depth Sensor	BAR02	$85.00	Blue Robotics	Purchased	2023
Primary Computer	Jetson AGX Orin	$1999.99	Nvidia	Purchased	2023
Various Electronic Components and Wires	N/A	~$400.00	Digikey	Purchased	2023