Triton Robosub Technical Design Report
2023 University of California, San Diego

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Abstract—Triton Robosub's Nu is the result of a col laboration among undergraduate students from the Uni versity of California - San Diego. We present the design and development of the "Nu" underwater vehicle, which boasts significant improvements over its predecessor. The vehicle features a custom-designed frame with 6 degrees of freedom. Our new modular power distribution board optimizes space utilization. Nu also incorporates software to utilize high-precision sensors for velocity, underwater imagery, and underwater acoustic sensing. Nu represents a fully-realized vehicle with an efficient electrical system and versatile software.

I. Competition Strategy

For the upcoming 2023 competition, our team finds itself in an intriguing position. Although our team is not new to the competition, the individuals comprising it are participating in Robosub for the first time ever. This gives us a sense of embarking on a new venture, akin to a freshly formed organization, and fuels our eagerness to compete in what feels like our "inaugural" tournament.

Our preparation for this year's competition has been centered around a vehicle that has been a work in-progress since 2020. The competition presents us with several objectives that we must accomplish. Given the customized nature of our vehicle and the limited testing time available, our aim is to achieve a level of performance equal to or surpassing our founding year in 2019.

Considering the time, hardware, and experience constraints of our team members who are relatively new to this environment, we carefully evaluated the objectives and made a strategic decision to focus on the tasks we accomplished in 2019: successfully navigating through the gate and identifying images on the buoys. By setting these goals, we obtained a clear understanding of the additional components and code that would be necessary to achieve them.

Given that this is somewhat akin to our first year, we made a deliberate choice not to attempt the other challenges. Our intention is to concentrate our efforts and ensure success in the initial tasks we have selected. Establishing our team and maximizing our learning potential have been our primary goals for this year, and we firmly believe that we will accomplish them.

II. Vehicle Design

A. Mechanical Design

Our vehicle has undergone a significant transfor mation, transitioning from the Ra (2019) BlueROV to our meticulously designed "Nu" vehicle. Every aspect of the design and component selection has been carefully considered to leverage the strengths of our team and the available hardware.

Nu features a custom-designed frame capable of housing multiple enclosures, sensors, and thrusters. The frame is CNC-machined from High-Density Polyethylene (HDPE), providing excellent corrosion resistance and an optimal cost-to-weight ratio. Ad ditionally, our custom CNC'd end cap enhances functionality by enabling the connection of more ex ternal sensors and thrusters to our 8-inch electronics enclosure.

Enhancing maneuverability and control, Nu in corporates a new 6 degrees of freedom system. With our eight (T200) thruster formation, the vehicle can now perform more complex tasks and navigation than was previously achievable with Ra.

To ensure efficiency and reliability, our sub in corporates three waterproof enclosures. The pri mary 8-inch enclosure houses our main electronics rack, while the two additional 3-inch enclosures are dedicated to our parallel battery system, which integrates seamlessly with our custom power distri bution system. By distributing the batteries into two

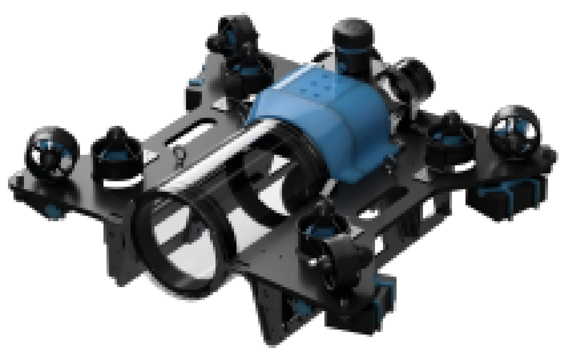

Fig. 1. Top Isometric View of our AUV

enclosures, we have improved stability and weight distribution in our new design.

We have also introduced Blue Robotics Wetlink penetrators to enhance the vehicle's functionality. These specialized connectors establish watertight seals without the need for epoxy, significantly re ducing the occurrence of leaks in our vehicle. With this implementation, we eliminate the risk of water ingress and guarantee uninterrupted operation.

The mechanical design of our AUV represents our first fully realized attempt at creating a customized, robust, and efficient underwater vehicle.

B. Electrical Design

The electrical section of our underwater vehicle encompasses a range of advanced components care fully selected to enhance its capabilities. Internally, we have integrated a powerful Jetson Xavier NX that handles mission planning and computer vision; we also have a Raspberry Pi 4 that is used as an interface for sensors and motor control.

We also developed a new power distribution board (PDB) that addresses specific problems with our previous vehicle. First and foremost was to optimize space utilization; to achieve that, we use custom PCBs used to fit more components in a smaller footprint. This arrangement also facilitates logical grouping of components and efficient routing of traces on the board, contributing to a well organized system layout, resulting in much better reliability over time.

Secondly, the component layout is designed for efficient heat management; one such example is our electronic speed controllers (ESC) and buck

converters being positioned across two adjacent sides to facilitate effective heat dissipation. We also utilize buck converters, which provide greater efficiency compared to traditional linear regulators, which dissipate heat to convert power.

To drive the eight thrusters, we have integrated eight BlueRobotics ESCs directly onto our PDB which allows us to connect them to our Pixhawk 1 flight controller with relative ease.

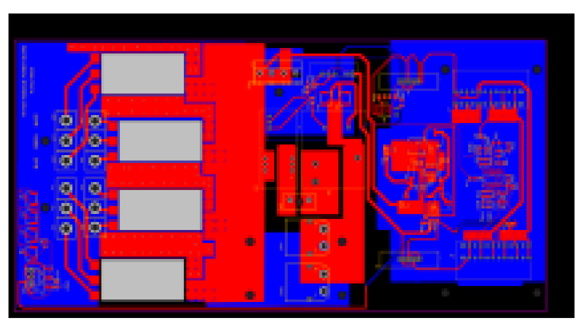

Fig. 2. Power Distribution Board

Externally, our vehicle is equipped with the Teledyne Explorer DVL (Doppler Velocity Log), a high-precision sensor that provides accurate velocity measurements. To capture high-definition underwa ter imagery, we have included two DeepWater Ex ploration (DWE) exploreHD cameras, which were the only well-designed fully submersible cameras (up to 400m) at an extremely affordable price. Both cameras are used for computer vision tracking, one forward facing and one downward.

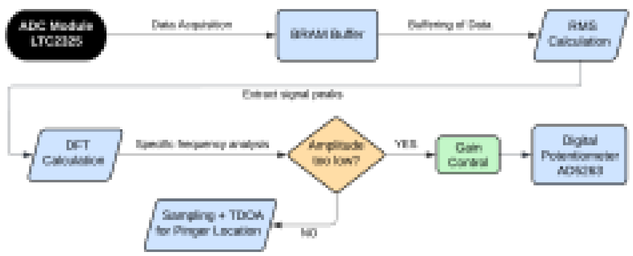

Fig. 3. Hydrophone array signal processing path

Additionally, our vehicle incorporates a hy drophone array, enabling underwater acoustic sens ing. The array captures analog signals from the environment, which are then converted into dig ital values through an Analog-to-Digital Conver sion (ADC) module. The digital data undergoes

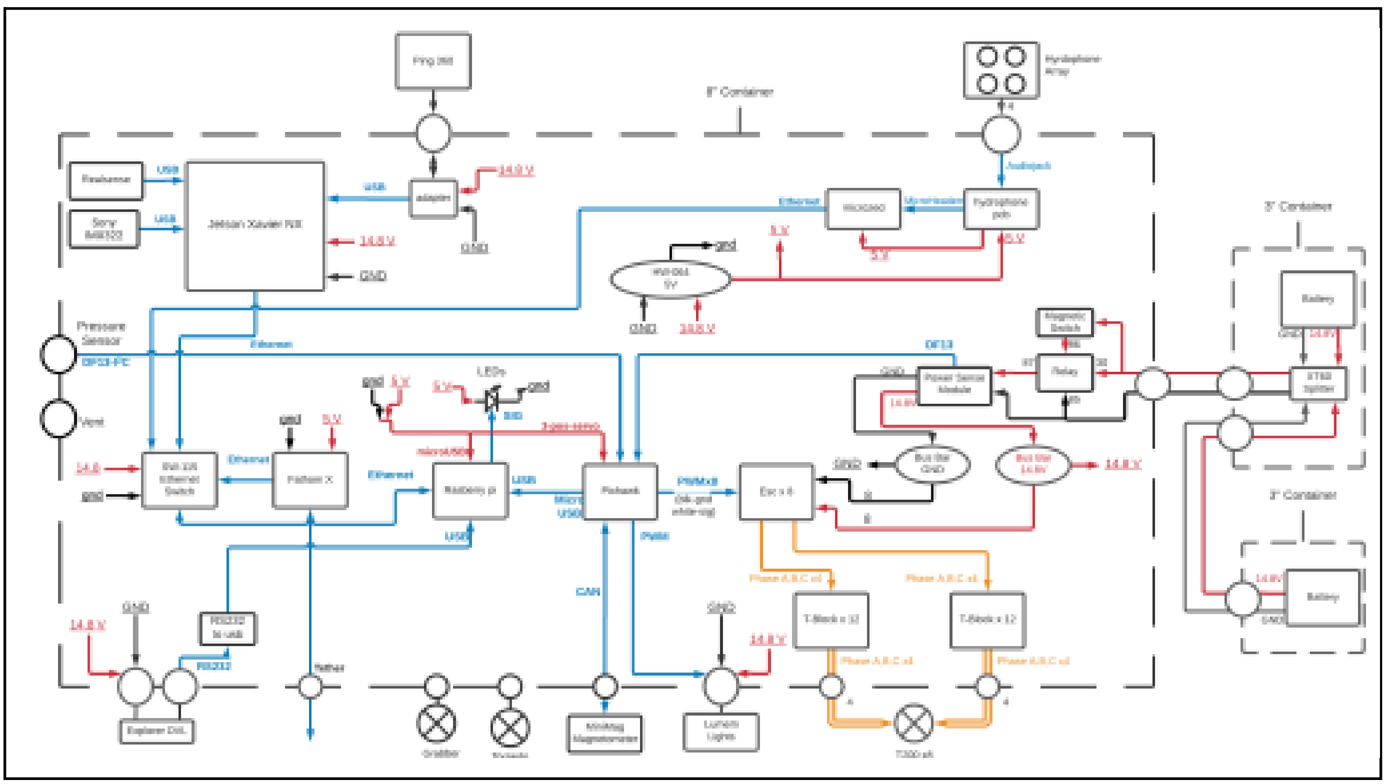

Fig. 4. Electrical Block Diagram

Root Mean Square (RMS) calculation to assess the signal magnitude, followed by a Discrete Fourier Transform (DFT) to analyze frequency components. The system then focuses on a specific frequency of interest and performs a Time Difference of Arrival (TDOA) computation to determine the pinger’s rel ative heading location.

All in all, the electrical system in our vehicle is designed to ensure reliable and uninterrupted oper ation in challenging underwater environments. By integrating cutting-edge components and carefully considering the electrical design, we have created a sophisticated and efficient electrical system that complements the mechanical design, resulting in a fully-realized, customized, and capable underwater vehicle.

C. Software

Our team has developed a versatile software stack that supports a wide range of functionalities and interactions within our system. Our strategic decision to adopt a Python-based architecture has proven beneficial in facilitating the onboarding of new team members and promoting collaboration between different subteams, including mechanical and electrical. By utilizing Python as our primary programming language, we ensure that developers from diverse backgrounds can quickly understand the codebase and make effective contributions.

The Jetson Xavier NX, as mentioned earlier, is configured to run ROS (Robot Operating System), an open-source framework that serves as the foun dation for our software stack. Our focus has been on creating a comprehensive ROS workspace that encompasses our control system, high-level mission planner, and sensor interfaces. Among these inter faces, we take particular pride in the following:

, Camera node: This node publishes Image mes sages from an RTSP stream, allowing us to integrate visual information into our system.

, DVL node: Designed to parse RS232 data from our DVL (Doppler Velocity Log), this node publishes the data in a usable format, enabling us to utilize precise velocity information.

, Pixhawk controller node: Responsible for re ceiving information from other nodes and publishing relevant processed data. This node leverages the Pixhawk Ñ ROS bridge to facil itate seamless communication.

Fig. 5. DWE.ai exploreHD 400m computer vision camera

This past year, the team faced a challenge due to a lack of familiarity with the codebase from previ ous years. Consequently, we made the decision to embark on a rewrite of the codebase, accompanied by thorough documentation. This approach ensures that our progress is steady, albeit somewhat slow. Initially, we achieved controlled movement of the submarine through open-loop path-following, which involved executing sequences of motor commands based on predictable predictions. Subsequently, we tested our DVL and implemented a closed-loop control system that utilized the DVL data stream.

To enhance the accuracy of 3D pose estimation, we fused the DVL data with gyro information from the Pixhawk. This controller enables relatively precise navigation using its built-in algorithms, al lowing our team to focus on higher-level control logic, and leave the A-to-B navigation to the Pix hawk. This improved estimation capability enabled us to perform advanced path following by utilizing a list of setpoints and implementing PID control between those setpoints.

Furthermore, we integrated basic object detec tion on the camera stream, employing closed-loop control to center the system on detected objects. This capability enhances the system's perception and its ability to interact with the surrounding envi ronment. Additionally, we have plans to utilize our downward-facing camera for floor mark tracking, employing non-machine learning techniques.

III. Testing Strategy

Our submarine has had limited time in the water, with several in-water vehicle tests remaining unfin ished. Following its assembly, the robot construction has been in an unusual state for the past two years. Our initial water test took place at the pool in UCSD campus rec center and served as a leak and buoy ancy assessment. The purpose was to determine the amount of additional weight required for the sub to maintain neutral buoyancy and identify any leaks in the enclosures. The test revealed that approximately 10 pounds needed to be added in various areas to achieve neutral buoyancy, and minor leaks were detected in the second battery enclosure.

Due to initial budget constraints, we had to em ploy creative solutions to address the leaks instead of outright replacing the parts. For instance, we designed battery latches to securely fasten the end caps, effectively stopping the leak in the battery containers. Meanwhile, the electrical team took the opportunity to enhance the power distribution sys tem in terms of modularity and user-friendliness.

During the second water test held at the Canyon view Aquatic Center, the submarine remained leak free, and we completed the first revision of the power board. The software team also had the chance to test motor control functionality and properly con figure the motors in the QGroundControl software. After a few hours, the motors were successfully mapped.

Unfortunately, this test turned out to be our last due to unfortunate timing. However, we are eagerly looking forward to conducting further experiments in the upcoming weeks, as we strive to make more improvements. We are excited about showcasing our performance at the competition.

IV. Acknowledgements

We extend our sincere gratitude to our esteemed faculty advisors, Ryan Kastner from the CSE de partment and Curt Schurgers from the ECE de partment, for their invaluable support and guidance. Their mentorship played a vital role in our decision making process and ensured our unwavering focus on achieving our goals. Additionally, we would like to express our appreciation to Nathan Hui for his continuous assistance and advice throughout the year. Under his expert guidance, we gained exten sive knowledge in the areas of design, manufactur ing, and testing. We would also like to acknowl edge the Kastner Research Group for generously providing us with the base BlueROV2 and a cutting edge laboratory facility, which served as an ideal workspace for our team.

We would also like to extend our heartfelt thanks to the companies, Deepwater Exploration, Brain Corp Inc, Lockheed Martin, and Teledyne Marine, for their valuable support. Their sponsorship and assistance have been instrumental in our progress, enabling us to fulfill our goals and participate in competitions.

We would like to express our sincere appreci ation to Alice Grgas, the Associate Director of the Corporate Affiliates Program at Jacobs School of Engineering, for her invaluable assistance in organizing networking events and facilitating con nections with industry partners. Alice's support has been instrumental in the success of Triton Robosub, and we are grateful for her dedication to our team.

We would also like to extend our heartfelt thanks to Alejandra Arguelles, Program Coordinator at Ja cobs School of Engineering. Her invaluable support in navigating our financial challenges and providing guidance has been instrumental to our success.

Our heartfelt thanks to the Canyonview

Aquatic Center for their invaluable support, allowing us to conduct vital tests in their pool.

We would like to extend our gratitude to Jennifer Truong and Jacqueline Le for their invaluable assis tance in the procurement of parts and supplies.

We extend our sincere gratitude to the Jacobs School of Engineering IDEA Center and the Tri ton Engineering Student Council for their generous support.

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Appendix A

Component List

Component Vendor Model/Type Specs Custom/Purchased Cost Year of Purchase

ASV Hull Form/Platform Blue Robotics Enclosure Diameter: 8” Purchased 343.00 2019 Waterproof Connectors Blue Robotics WetLink link Purchased 50 2023 Propulsion Blue Robotics T200 link Purchased 200 2021 Power System Blue Robotics Li-ion Battery link Purchased 289 2021 Motor Controls Blue Robotics Basic ESC link Purchased 36 2021 CPU Nvidia Jetson Xavier link Purchased 429 2021 Teleoperation Blue Robotics Fathom-X link Purchased 85 2019 Compass N/A N/A N/A N/A N/A N/A IMU Pixhawk Pixhawk 1 link Purchased 219.90 2019 DVL Teledyne Explorer link Sponsored 15759.00 2019 Camera(s) DWE.ai exploreHD 2.0 link Sponsored 300 2023 Hydrophones Aquarian H1C link Sponsored 139.00 2020 Algorithms N/A N/A N/A N/A N/A N/A Vision Open Source Object Detection YoloV4 Custom 0 2020 Localization/Mapping N/A N/A N/A N/A N/A N/A Autonomy N/A N/A N/A N/A N/A N/A Open-Source Software ROS Melodic Ubuntu 18.04 Custom 0 2022