Technical Design Report for Type-X

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***Abstract*— With interdisciplinary cooperation between team members, the Kennesaw State University Autonomous Underwater Vehicle Team (KSU AUV) has built a new design from the ground up. The AUV Type X platform has been designed to be our most lightweight, cost-effective, and robust design yet for the 2025 RoboSub competition. The motor configurations and new control systems allow for absolute control and flexibility. This vehicle utilizes a custom electrical and software architecture to allow for ease of modifications and control of movements within the water. This paper discusses the 2025 KSU AUV competition strategy and highlights the technical attributes of the Type X.**

Keywords—autonomy, underwater, vision, machine learning

I. Competition Strategy

A. Preface

The KSU AUV team is a 20-member student organization sponsored by Kennesaw State University that competes yearly in the RoboSub competition. For the 2024-2025 competition season, Kthe SU AUV team has built a new design from the ground up. The Type X is a versatile platform developed during the 2025 season. Our team consists of three major sub-groups - mechanical, electrical, and software - which collaborate to design and integrate the necessary systems required to form a working autonomous architecture. The technical attributes of the Type X are found in Sections II and III of this report, in addition to the hardware and software specifications provided in the appendices. The team has collaborated for design work, integration, and testing while meeting appropriate safety guidelines.

B. Competition Strategy

Post-RoboSub 2024, the team identified numerous potential improvements from the Hope platform. Notable examples would be a drastic decrease in the designed weight and materials used. For the 2025 season, we have decided to utilize primarily 3D printed designed parts, drastically reducing our weight from approximately 42 kgs to approximately 25 kgs. Since we are utilizing FDM printing, most of our parts will be cheaper since we are buying rolls of filament instead of aluminum, making this year’s AUV cost-effective. For the 2025 RoboSub competition, the team identified three primary challenges to pursue:

1. Easier to assemble open-frame designs.
2. Modular in-house designs for the new electrical system.
3. Improved accuracy of autonomous control software.

To meet these objectives, the team sub-groups focused efforts on improving movement-critical and task identification systems from the 2024-2025 season and developing a new AUV ground up.

II. Design Creativity

A. Mechanical Design

1) Outer Structure and Component Housing

After the 2024 competition, team leadership identified several issues with the current submarine frame that required attention. Through in-depth discussions and proposals, it was decided that designing a new frame would be more efficient than adjusting the current frame. This would also allow the team a secondary backup submarine if needed. The main issues that required attention were: difficulty of access to the main electrical enclosure, the large amount of time and difficulty in assembling the sub after shipping, and the design of the battery housing, which prevented access for inspection.

To address the first design concern, the mechanical team made a new design for the electrical enclosure. We kept the box-shaped enclosure from last year, but changed the closure method from bolts to latches. A completely removable top was kept, but was replaced with polycarbonate to allow a greater view of the internals.

The second issue was solved by removing the aluminum t-rail extrusions and making the two main side panels out of a large sheet of CNC-cut HDPE. This lets us still have the large side frames for structure, but allows for easier flat packing and assembly.

The third issue was solved by going back to the previous sub-design of acrylic tubes with machined end caps for each battery. This was done because the old design was tested and trusted.

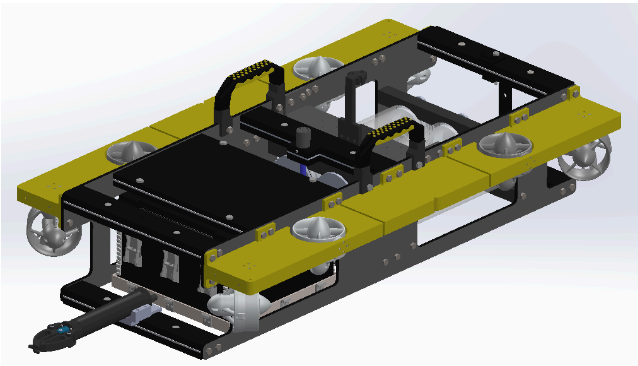

Figure 1. Type-X Structural Assembly

2) Control Electronics Housing:

All of Hope's control electronics are located in the central housing. The components are mounted on a non-conductive base plate that is then mounted to the inside roof of the housing. Mounting of components to the roof of the housing was chosen because when the AUV is being maintained, it is upside down, allowing for easy access to all components. This design choice also keeps the electrical boards suspended in case of a leak in the main enclosure. The electrical team worked on schematics and wire management, which is discussed further in the *Electrical Design* section.

All of the components are mounted onto a plastic plate, which is then itself mounted to the roof of the main housing. Having all of the electronics located on one board allows for easy removal of all components for troubleshooting without a lengthy disassembly process. This mounting plate also helps to ensure all electrical components are electrically isolated from the metal housing.

3) External Battery Packs

The purpose of the External battery packs was to allow for more of the weight to be placed on the rear of the frame to make the weight distribution more balanced and to allow easy change-out of low-power batteries with fully charred batteries without needing to open the main electrical enclosure. This also isolates the heat the batteries produce during operation from the main electrical housing. Through several rounds of testing, we have verified that the battery housing itself provides more than adequate cooling to all the batteries to prevent them from overheating during operation.

4*) Robotic Arm and Torpedo Design*

The mechanical team spent many months researching and designing various iterations of sub-systems to complete competition tasks. The robotic arm proved the most complex to design and operate. The team has several Robotics and Mechatronics Engineering students who helped with this project and are experienced with operating robotics equipment such as Festo and Fanuc automation systems. A two-axis arm was decided upon with a Blue Robotics end effector due to its simplicity and time restrictions for the project. The arm is primarily servo-actuated on the bending axis while the end effector is actuated with a DC motor and a stop switch. This system is controlled and linked to the software and is visible from the front-facing camera.

Figure 2. Robotic Arm End Effector Testing

Multiple torpedo launcher and propulsion designs were considered and tested thoroughly, leveraging the SolidWorks computational fluid dynamics (CFD) simulation package. Each torpedo design was run through a series of simulations in an attempt to evaluate the performance of the torpedo before production. Several variations of the torpedo launching mechanism went through multiple rounds of revisions to select the final design. The final launcher utilizes an elastic band to propel the torpedo out of the launcher. This design was chosen for its simple and robust design.

The torpedo is a simple, solid torpedo design. The body is made from a steel bar to give the torpedo the needed mass to maintain enough speed. The rear fins are 3d printed to allow for ease of manufacturing. The tip is made of a pointed rubber to prevent injury to divers while helping to maintain a hydrodynamic design.

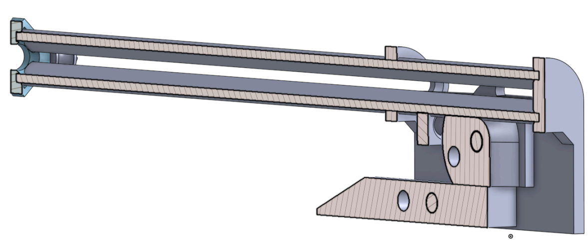

Figure 3. Torpedo Launching Mechanism

B. Electrical Design

1) Custom Designed Electronics: The electronics system is completely redesigned from the ground up. This allows for complete customization over the system's functions to meet our needs. All designs were created in Altium software. The electrical team worked with the mechanical team on the creation of 3D-printed mounts to provide stability for electrical components. This also allowed for better wire management to allow for easy debugging.

2) Card-Based Modules: The most major change for this year is the use of standardized cards which all electrical functions are based on. Each card slots into a motherboard, consisting of a number of PCIe connectors that handle all power and signalling requirements.

3) External Electronics: The connections between sub-electronics are shown in Fig. 4. Hope utilizes eight BlueRobotics thrusters for maneuverability. Two electronic speed controllers (ESCs) regulate the speed of the thrusters. The ESCs receive instructions by pulse width modulation from the ESC Controller and give the ability to control the level of thrust.

4) Power Distribution: Three lithium polymer batteries power the sub's motors, onboard computer, and sensors. Power distribution is managed through the Power Safety Module, designed for controlling and monitoring power sent to the rest of the electrical system.

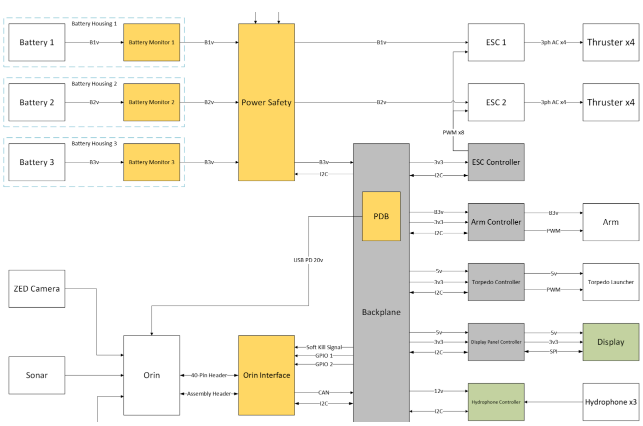

Figure 4. Electrical System Overview

5) Kill Switch: The kill switch, part of the Power Safety Module, controls the flow of power from the batteries to the rest of the components. The killswitch will immediately kill all power when water is detected inside the housing, it detects abnormal voltage or current, or if it is told to by the Orin.

6) Hydrophones: The RESON TC4013 are the hydrophones that were chosen for detecting the varying frequencies of the Robosub set. A pinger with a set frequency would act as the target for our sub to detect and perform the appropriate task accordingly. The hydrophone was tested by attaching it to an oscilloscope and placing it in the testing pool with the pinger oscillating at a specific frequency. The test was designed to test the hydrophone's capabilities for a set range. Frequencies between 20kHz and 40kHz were produced by the pinger and were tested at a variety of distances. The hydrophones picked up the frequencies produced from the pinger, and its output was recorded by the oscilloscope.

7) Pinger: The JW Fishers MFP-1 Pinger was the device used to test out the functionality of the hydrophones. The pinger is a manual switch-based frequency changer that can produce different frequencies, but only allows for a singular frequency to be produced at a time. This allows for multiple tests of different frequencies.

8) Filter: IC filters were chosen to detect certain frequencies and ignore irrelevant ones. Specifically, our team used band-pass filters because of their unique property to filter a specified frequency range (25kHz - 35kHz) and ignore all frequencies that are present. The LTC1068 chip was chosen due to its clock-tunable bandpass filter. This would allow the use of a microcontroller to send PWM signals and vary the frequency to change the center frequency of the bandpass filter. This would enable the ability to switch what frequency is let through the filter on the fly.

9) Amplifier Circuit: The amplifier circuit was designed to allow for the sub to amplify the frequencies trying to be detected through the IC filters. The filters are connected to a series of capacitors to help amplify the signals passing through the IC filters. In addition, this helps with the processing software by providing clearer signals to prevent the sub from getting confused about where or what signals it is receiving.

C. Computer and Software Design

1) Hardware: Similar to last year, we utilized the Nvidia AGX Orin 32 GB Developer Model as the core processing unit. This model boasts much greater performance over the Nvidia TX2 that was used in previous years, allowing our software to avoid the inefficiencies and stuttering seen in previous years.

We are also utilizing the ZED 2i stereographic camera and the Anker Power Conf C200 2k camera for our Camera package. These cameras allow us to get both front-facing and bottom-facing views, and in the case of the ZED camera, allow for us to perform depth sensing.

2) Software Architecture: The software architecture of Type X is built upon the Python Programming language (version 3.10.2), similar to last year. Our decision last year to remove the Robot Operating System (ROS) code developed by our alumni members has allowed for quicker development time and an easier time onboarding new developers. The architecture consists of one main process with five sub-processes linked together with multiple relational databases. The five sub-processes are as follows:

- Hardware Interface
- Movement Package
- Camera Package
- AI Package
- Sonar Package

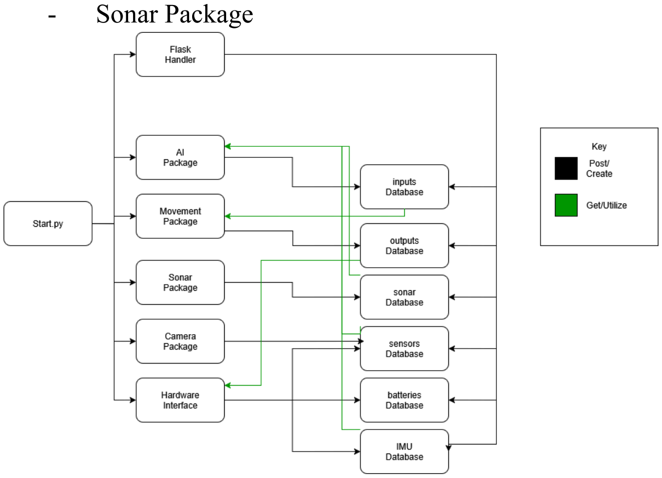

Figure 5. Software Architecture

3) High-level Control: Type X is controlled by the AI package, which was developed through imitation learning and reinforcement learning. The AI acts as the brain of the sub, responding to external stimuli such as props, pings, and obstacles to make decisions.

4) Cameras: Type X utilizes one ZED 2i depth sensing camera and one Anker Power Conference C200 camera. The ZED camera is used to provide a front-facing view and allows for distance measurements to detect objects in front of the sub.

5) Hardware Interface: The hardware interface sub-process handles all communication between the electrical system and the Orin. Written in Python, the subprocess communicates with the electrical system over I2C communication lines, ensuring accurate and fast communications between them. All sensor data is stored within the relational database, and all of the movement data is queried from the same database and sent to the necessary electrical hardware.

6) Simulation: Using the Unity game engine allowed our team to expand on our previously created simulated environment from last year. The updated simulation allows for practicing competition runs without the need to build mission props and having to train the AI in the real-world. The simulation is still built with two levels; the first level includes the pre-qualification run, and the second level includes the main qualification run. Due to how we structured our AI model this year, we can simply train our model within the simulation, only having to change out the object-detection model we use to have the sub-function in a real-world environment.

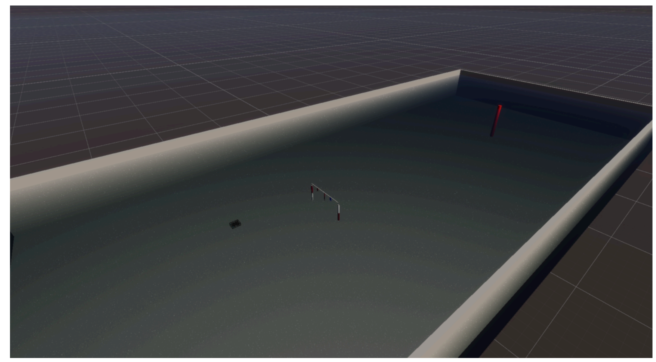

Figure 6. Prequalification Simulation

III. Experimental Results

A. In-Pool Testing

Our pool testing focused on verifying that the elements of the sub worked correctly, specifically the updated frame, wiring, and neural network architecture. While limited testing was conducted in both the fall and early spring semesters, our primary testing period was cut short due to delays in material shipping. In response to this challenge, the software team focused on using the previously developed simulation to virtually test novel project aspects and to train the AI model as discussed in Section II.C.6.

B. Design of the Internals

The design of the interior was a complicated problem. It had been “solved” several times, but while each design looked great in CAD, the solutions proved too complicated or cluttered in real life.

To better understand how components would fit in person, the mechanical team decided to subvert the traditional use of computer-aided design and instead, implemented “cardboard-aided design” to create mock-ups of the sheet metal front tube racks. This was done by cutting sheets of cardboard and laying out scale models of the computer components. The team produced four competing ideas to find traits that would benefit the sub: an improved, removable version of the current rack, a trifold design, a “T” shaped design, and an “I” shaped design. The cardboard mockups were given to the electrical team to get feedback on what traits work and what traits hinder.

IV. Acknowledgments

The team would like to thank Dr. Muhammad Tanveer for acting as our faculty advisor, all our engineering and technology professors for their instruction, the KSU Student Activities Board Advisory Committee, the KSU Alumni Association, and all of our generous sponsors who helped make the Hope platform a reality.

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Appendix A: Component Specifications

Component	Vendor	Model/Type	Specs	Cost (if new)
Buoyancy Control	N/A			
Frame	KSU AUV	Custom	2 x 1 meter in Length, 30cm in Height	58.84
Waterproof Housing	KSU AUV	Custom	25.4cm x 25.4cm x 18 cm	$130.00
Waterproof Penetrators	Blue Robotics	Red/Black Wetlink Penetrators	N/A	$150
Waterproof Connectors	Blue Trail Engineering	Cobalt Series 8 - Pin Connector	600m depth	$234.00
Thrusters	Blue Robotics	T200	17 A @ 12 v	$ 1600
Motor Control	JLCPCB	Custom ESC Controller PCB	45A	$120.00
High-Level Control	Nvidia	Jetson AGX Orin	Quad-core ARM Cortex-A57 MPCore processor (1.43 GHz)	$1,248.75
Propellers	Blue Robotics	T200	N/A	$8
Battery	Zeee	High performance Lithium Polymer Battery 120C 14.8V 148Wh 4S 10000mAh	10000mAh, 4S	$97.20
Embedded System	Nvidia	Jetson AGX Orin	Quad-core ARM Cortex-A57 MPCore processor (1.43 GHz)	$99
Internal Comm Network	N/A	N/A	I2C	$10
External Comm Interface	Blue Trail Engineering	Cobalt Series 8 - Pin Connector	600m depth	$234.00
Programming Language 1	Python			
Programming Language 2	C++			
Inertial Measurement Unit (IMU)	N/A	Custom	BNO086 with Custom Circuitry	15.00
Camera(s)	ZED Amazon	ZED 2I C200	Dual 1080p @ 60fps Single 2k @ 60fps	$519 $59.99
Hydrophones	Teledyne Marine	RESON TC4013	N/A	$1500
Manipulator	Blue Robotics	Newton Subsea Gripper	14.8V DC Motor Based manipulator waterproof up to 300m	$680
Algorithms: vision	Tensorflow	Custom	N/A	$0
Algorithms: autonomy	KSU AUV	Custom	N/A	$0
Open source software	Python, Flask, Flask SQLAlchemy, Python State Machine, Tensorflow			
Team size (number of people)	15			
HW/SW expertise ratio	2 HW: 1 SW			
Testing time: simulation	100+ hrs.			
Testing time: in-water	30+ hrs.			