George Mason University PLUNGE - AUV Debut for ROBOSUB 2025

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ABSTRACT - This paper focuses on George Mason University's PLUNGE team's (Patriots Leading Underwater Navigation, and General Engineering) design of an autonomous underwater vehicle (AUV) nicknamed *DORITO* (for its triangular shape, to be seen) to complete the varied challenges presented by RoboSub, with concentration on visual/navigation tasks, torpedoes, and markers. This focus is an interdisciplinary effort, split between Fabrication, Software, and Electrical teams as the main designers supported by financial and graphic design subteams. As a completely new AUV and new club at George Mason, the students have worked hard through both the creation of the university's organization and the brainstorming and full development of the system. With the diverse backgrounds of the team and the support from professors and sponsors, PLUNGE Robotics is confident in the abilities of the submersible.

I. COMPETITION STRATEGY

As a first-year RoboSub team, PLUNGE was operating with limited resources and a tight budget. On account of this, the team's primary goals for this competition are centered around learning and collaboration. Rather than attempting to cover every challenge in the competition, the team made a strategic decision to focus on a select few tasks in order to focus their time and efforts to maximize performance. These tasks include Heading Out (Coin Flip), Collecting Data (Gate), Navigate the Channel (Slalom), Tagging (Torpedos), and Return Home. In line with this approach, the AUV was designed to prioritize simplicity and cost-effectiveness. Unlike conventional AUV designs which often use a square frame with 10 thrusters, the AUV features a triangular frame with 6 thrusters. The design is much more manageable with the team's current resources and skill level and still provides sufficient maneuverability for the focused tasks.

PLUNGE's overall goal for this competition is to gain hands-on experience with AUV design, construction, testing, along with learning how to operate within a team; their ultimate goal is to use this experience to lay the foundation for future competition seasons by creating a modular, expandable platform.

II. DESIGN STRATEGY

In order for George Mason University to prepare for ROBOSUB 2025 as a new entrant, a complete mechanical, electrical, and software system needs to be brainstormed, designed, and interconnected to both establish a system capable of undertaking multiple tasks to new points for the competition, but to remain modular enough for future Mason teams to modify what was designed previously. This document defines each sub team's efforts to realize these engineering goals.

A. Fabrication Strategy

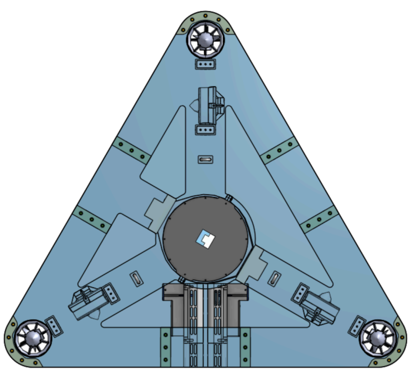
To prepare for the first competition entered by George Mason University and lay the groundwork for future iterations of the vehicle, the fabrication team focused on the development of the submarine's chassis and torpedo system.

Both components are integral to the competition and complex enough to enable incremental improvements each year, and this section elaborates on the steps taken to design these systems.

a) Body

The body's design had to incorporate enough flat surfaces to enable placement of the projectile, visual, and propulsion subsystems while maintaining a degree of streamlining to not accumulate additional resistance during *DORITO*'s trial runs. Additional challenges to consider include weight, size, and financial limitations. Fabrication took to analyzing research proposals on sub-surface motion to maintain six degrees of freedom with the fewest number of thrusters possible, and determined a triangular frame where six thrusters were capable of the motion as opposed to seven.

Figure 1: Top-Down View of Triangular System



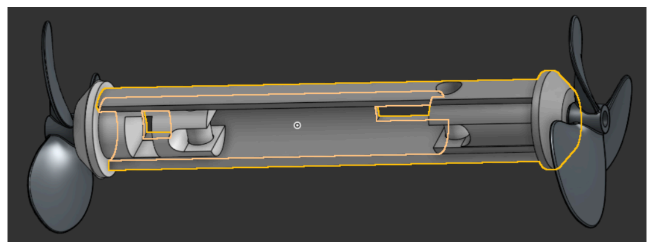
Thrusters have equilateral placement to match the desired angles of motion, while a central, round enclosure is present for the electrical box. The torpedo system is shown on one side while the other extraneous components (such as visual sensors) were left off for ease of sight and future diagrams.

b) Torpedo

The main goal for the torpedo design was to have greater range and efficiency than it would have if it were simply launched by a spring. Based on prior year's contestants, many used a spring-propelled torpedo, which has a limited range before it begins to sink. This places the strength and efficiency of the torpedo on the spring used. The envisioned concept should move away from these shortcomings by being a low-tech, self-propelled design.

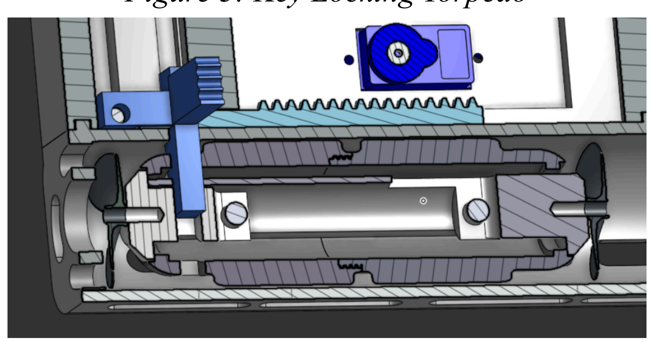
A solution that meets these requirements is a toy torpedo design on Maker World that uses only propellers and a rubber band. Its accompanying video shows promising performance, showing it traveling straight with good speed. Thus, the design was largely based on the mechanism for the torpedo.

Figure 2: Contra-Propeller Set Up



The mechanism consists of a propeller on each end of the torpedo, and a body. Each propeller is then connected to each other by a rubber band. The propellers rest on spindles that extend over each other to allow for a key to insert into aligned holes, locking the torpedo. When the key is released, the spindles turn, which moves the propellers and creates motion. Since the propellers are on each end, this creates a contra-propelling design, which also reduces risk of rollover torque.

Figure 3: Key Locking Torpedo



B. Electrical Strategy

With George Mason University's ROBOSUB team going through their first year of competition and implementing a new design from scratch, the Electrical Subteam was focused on constructing a system highlighting simplicity, integrity, and function over optimization. This necessitated the electronic system to be subdivided further into the sensing, power distribution, and waterproofing subgroups.

1. Sensing

PLUNGE took inspiration from past winning teams as well as previous GMU clubs that participated in ROBOTX competitions as well as trade studies (visible in Appendix I & II) when selecting components. As a new team with a tight budget, specialized sensors, such as sonar, were not feasible. Instead, the focus was on finding reliable and relatively inexpensive cameras, as visual sensing would be necessary for any task we wished to complete. It was decided that having a primary camera combined along with a secondary camera would be ideal. The primary camera would be used for maneuvering and navigation and would be mounted on top of the AUV within a clear dome allowing for a good field of view. The secondary camera is to be mounted alongside the torpedo tubes so that it can be used for aiming during the torpedo task. The ZED 2i camera was chosen as the main camera with a Saylas 2K/30fps camera chosen as the secondary.

2. Power Distribution

The cameras, 9g servos, T200 thrusters, and the Jetson Orin Nano all require battery power. By far, the main power draw is from the six T200 thrusters. The battery was selected through a similar process to the cameras with primary focuses on cost, size, capacity, and output. Although an older model, the Blue Robotics Lithium-ion 14.8V 18Ah batteries were selected for their cost and capacity (Appendix 3). Electronic speed controllers were purchased with the T200s to reduce the danger of voltage jumps from the batteries, and the overall design was split into a two-battery system with one battery dedicated to supplying the thruster motors. The second battery provides power to the Jetson who directly supplies the other components with its ports and GPIO. This battery also goes through a voltage converter to reduce voltage fluctuations to the Jetson. The kill switch for the AUV is planned to be situated at the batteries and directly disconnect them, thereby guaranteeing an immediate shutdown of all systems.

3. Waterproofing

It is a well known fact that water and electronics do not mix, or rather that they shouldn't mix. This poses something of a challenge when creating an underwater vehicle. Waterproof versions of certain components do exist, but they are generally much more expensive. Other components have no such version. The processor, batteries, and primary camera will all be stored within a waterproof enclosure at the center of the AUV. The enclosure is custom built and made from a clear acrylic cylinder. Each end is to be capped off with rubber rings used to keep the enclosure watertight. Wetlink penetrators sold by Blue Robotics will be used to connect components within the enclosure to those outside it. The main components in need of waterproofing are the servos used for launching the torpedoes, as they cannot easily be placed within an enclosure while still being used for their intended purpose. A conformal coating will be applied to the electronics within each servo, and they will connect to the processor via the aforementioned wetlink penetrators.

C. Software Strategy

The PLUNGE robotics Software team's job was to bring the AUV to life, combining the efforts done by the Electrical and Fabrication team. The idea behind our software's architecture was to keep everything modular and hidden from the other components of the system. Each subsystem our AUV needs, such as the camera system, propulsion system, navigation system, etc. , is its own module. A module is a closed system where the only way to communicate with other modules is by sending messages to a core module which handles that communication of all the subsystems. If the navigation module needs to fetch data from the camera module, it must first go through the core to request whatever data it needs from the camera.

This approach might seem unnecessarily complicated, “why can’t the modules just communicate with each other directly” you may ask. By keeping everything contained in its own module, the code becomes more stable. The stability comes from the impossibility of one module depending on any other module for its own logic or functionality.

Back to the navigation and camera module interaction, if the navigation module had direct access to the camera module’s data, we would need to worry about updating how that data is interacted within *two* places. And if someone forgets about that fact, we would run into issues our compilers would not help us solve. By keeping everything modular, decoupled, and hidden behind more abstract application programming interface (API) calls, we can better ensure things break less often. If the navigation module instead sends a message to the core requesting data from the camera, that message can be more generalized across each of the systems and how they interact with the core. Once the core gets the message from the navigation module, it has complete control over the message; the navigation module has nothing more to do but wait for a response. The core can then dispatch the message to the appropriate subsystem, and await its response, to be relayed back to the original subsystem. A design like this, relying on messages through a core system only cares about the data itself, not how it is implemented or handled by the data’s parent module. This also has the advantage of making the internals of any module completely irrelevant to the rest of the system from an implementation perspective. So long as the module adheres to the API requirements mandated by the core system for any particular API call, the module is functional. Now, this does not guarantee that the output to any API call will be correct, but all that matters is that an API can be called and data is returned in a way that the original messenger expects. A system designed like this is analogous to the way the modern internet is designed. Each computer is not talking to each other directly, but through a more centralized server architecture. That is the idea we are trying to recreate here, but with subsystems of an AUV instead of a network of computers.

I. TESTING STRATEGY

Before it is sent to competition, the AUV and its constituent components will be thoroughly tested. This includes, but is not limited to, ensuring the enclosure is watertight, confirming the functionality of subsystems such as the torpedoes and their launchers, and trial runs of the AUV’s autonomous functions.

1. Waterproofing

The waterproofing of the main enclosure is vital to the success of the AUV, as it will contain a number of extremely important components which cannot survive in the water. Therefore, it is of the utmost importance to test it in a safe and controlled manner. The test will be performed using a vacuum plug. The enclosure will be pressurized, and then the pressure will be monitored for about 15 minutes. If the pressure has decreased significantly, then that means there is a leak. If this first test is successful, then the enclosure is safe to be placed in the water.

The PLUNGE team plans to partner with the Freedom Fitness and Aquatic Center on the SciTech campus of George Mason University.

Previous RobotX teams with the university have received permission to run pool and waterproofing tests in their water and the submarine created by the group will require multiple rounds of environmental examination before the submarine is competition ready.

2. *Torpedos*

Torpedo testing consists of basic functionality and performance. Functionality is graded on movement. Since the torpedo is self-propelled, it can fall victim to torque-rollover, affecting its path. Whether it is functionable as a design is if the tested design is able to reduce the torque-rollover enough to travel straight, or with very little deviation from its travel path. Performance is judged by speed and range, which can help achieve extra points from range.

Another aspect of torpedo testing will be the AUV's ability to aim the torpedo during firing. The current design incorporates two payloads side by side. Being able to fire the torpedo would entail being able to aim in a way that adjusts for the offset of the torpedo payload.

3. *Trial Runs*

Trial runs will consist of small-scale versions of the different tasks that the competition will present. These are Coin Flip, Gate, Slalom, Tagging, and Return Home. Each task will gauge the AUV's ability to perform each task, such as (1) navigating the coin flip, (2) pass gates, (3) performs slalom, (4) shoots torpedoes through designated holes, (5) navigates home.

The effectiveness of performing each task is further assessed by (1) ability to head out in both heads and tails. (2) pass games with "style." (3) stays on the same side of the red pipe during slalom. (4) shoots the torpedo from greater range. This can provide performance data of the AUV, and the utmost ceiling for performance that the AUV can reach.

II. ACKNOWLEDGEMENTS

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APPENDIX

APPENDIX I: PRIMARY CAMERA TRADE STUDY

Camera Name (Main)	Cost	Port Popularity	Size	Quality	Power	Total
ZED 2i Stereo Camera (USB)	5 (free through RobotX)	2 (USB)	1	2.5	3	13.5
Saylas 2K/30fps 1080p/60fps Webcam	4	2 (USB for Side Cams)	2	2	4	14
BlueView M900 Mk2	X (unknown)	Ethernet	0	3.5	1	4.5 + X
Low-Light HD USB	3	2 (USB)	2.5	2.5	3	13

APPENDIX 2: SECONDARY CAMERA TRADE STUDY

Camera Name (Secondary)	Cost	Port	Size	Quality	Power	Total
Saylas 2K/30fps 1080p/60fps Webcam	4	3 (USB)	2	2	4	15
Arducam 5 Megapixels	4 (free, unknown provenance)	1 (MIPI)	3	1	4	13
Low-Light HD USB	3	3 (USB)	2.5	2.5	3	14

APPENDIX 3: BATTERY TRADE STUDY

Name	Cost	Size	Capacity	Output	Port Accessibility	Special Consideration	Total
2x Ovonic 14.8V 7.2Ah Lipo	3	3	2.5	3	1	-1	11.5
Lithium-ion 14.8V 18Ah (**BluRob**)	1	3.5	4	3	1	1	13.5
Bioenno 12V, 12Ah LiFePO4	2	3	3	3	1	0	12
Turmera 12v 17ah Lithium Rechargeable Battery	3	3	3	4	1	-1	13

APPENDIX 4: POWER & SIGNAL SYSTEM DIAGRAM