Embry-Riddle Aeronautical University: Team Unsinkable

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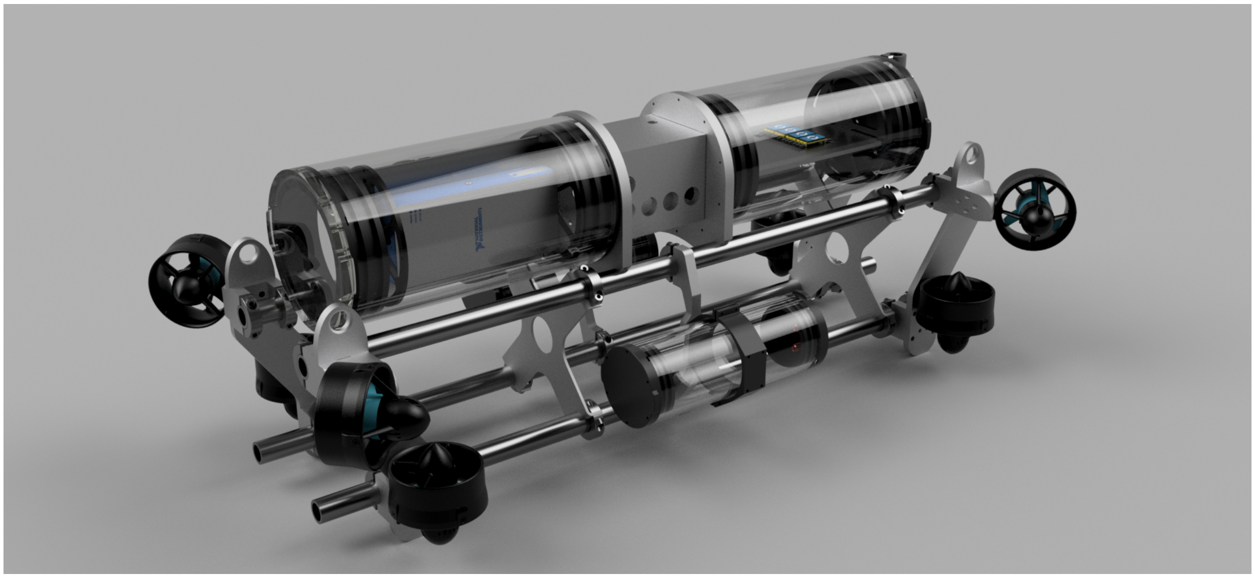

Abstract
Team Unsinkable from Embry-Riddle Aeronautical University (ERAU) is using a custom-designed platform currently in the final stages of development. The platform, Nautilus, was originally designed for the 2020 Association for Unmanned Vehicle Systems International (AUVSI) Foundation RoboSub Competition. Nautilus was developed with universal compatibility and adaptability in mind. The platform is intended as the primary Autonomous Underwater Vehicle (AUV) for the team.

I. Competition Strategy
The strategy employed this season was to attempt simple and low difficulty tasks. It was expected that there would be many challenges and obstacles to overcome while designing a new Autonomous Underwater Vehicle (AUV). Having a larger emphasis on the development of the AUV such as configuring controls, vision, and various physical elements, and attempting low level tasks such as the gate and buoy would ensure success in future competitions. The goal was to achieve complete reliability in the gate and buoy tasks. Doing so would create a foundation that could easily be built upon in the future for more complex tasks. The primary method used for autonomy was computer vision. Computer vision is something that the team has prior experience with and would yield the best results. While vision was a large focus, the team had discussed using more complex systems such as sonar and Doppler Velocity Loggers (DVLs) in the future. These systems were planned to be onboard the AUV even while not operative in order to allow a smooth transition to their proper use in future years. It was planned to have the systems collecting data that could be used to

develop them into the platform when the time comes. With a new and complex custom design, there was an issue raised regarding the reliability of the platform. Many precautions had to be taken and critical systems had to be planned meticulously in order to avoid failure. The team utilized faculty and graduate advisors to assist in all stages of development. Their advice guided the team during the design process and helped avoid possible issues in the design of the new platform. Many backup plans were created if one or more of the systems on board had failed. This included but is not limited to considerations of failure in power distribution, leaks, sensor failure, and software

II. **Design Creativity**

Software

Software is a crucial component of an AUV. The team's goal was to perfect a basic system of vision detection before integrating more complex sensors and the accompanying software. The main tool for vision detection used was a neural network trained in TensorFlow. The team developed a Google Colab notebook as it has many advantages. Google Colab is a cloud-based Python development environment that allows users to train on Google's cloud-based GPU's [1]. This allowed the team to train more efficiently. The completely cloud-based system guarantees that the team can train the network anywhere in the world where an internet connection is available. Other advantages that Colab provides is the general ease of use. Previously, the team had to run multiple scripts in order to train a network. With Colab, all the scripts can be placed into one notebook, allowing anyone to train a network with the click of a button after the dataset has been labelled. During initial experimentation with Colab, the team found that training was done 4-5 times faster than the training being done on the machine available to them.

Electrical

With a custom AUV design, it was determined that a custom power distribution board was also necessary. Its purpose is to handle the miscellaneous tasks on board the AUV, such as emergency shutoff, leak detection, voltage regulation, and power management. Initially, it was going to use an Atmel Atmega as its main processor, but because ethernet connectivity is a major factor in its design, we eventually switched to an Mbed NXP LPC1768 as the main processor due to its native ethernet capabilities and ease of use.

The reason for the ethernet connectivity so that the subs main computer can gather data such as battery voltage, to calculate its remaining runtime; or immediate battery current, so the computer can calculate the most effective thrust values to output to the thrusters, so the electrical system is not overloaded from the thrusters current. Another reason the power distribution board supports ethernet is to allow the sub to be gracefully shut down. When the power switch is turned off, the sub will not immediately power down. Instead, the power distribution board will first tell the computers that they need to shut down and wait until they have successfully shut down before finally cutting power to the sub. We made this decision after observing how typically, flipping the power switch causes the power to the computers to be cut while they are running, and saying "There has to be a better solution." By allowing the computers to gracefully shut down, we mitigate any potential damage to the OS's caused by improper shutdown. Finally, the last use of the ethernet capabilities is to let the power distribution board receive statuses from the main computer and report them visually by numerous RGB leds around the enclosures. This lets us determine what the sub is doing by a quick glance.

Another key aspect of the power distribution board is to manage the thruster's emergency stop and the water intrusion detection. The emergency stop is set up in such a way that both the user and the software have the ability to activate it, however, they are set up in series so that one cannot override the other under any circumstance. This allows both the divers around it and the crew managing the base station to safely immobilize the sub in the event of an emergency while knowing that the sub cannot accidentally be rearmed by the other party or by the autonomous code. The power distribution board also monitors various leak sensors positioned around the sub that when triggered, activates a single use kill switch that cuts power to the entire sub. This switch cannot be reset unless the batteries are removed which makes sure that the sub cannot accidentally regain power while flooded.

The last interesting design decision is the heat dissipation of the power regulators. Initially, we had onboard a network switch that included POE for use with our cameras. This switch required 48V which meant that the power distribution board had to contain multiple large, inefficient power supplies. We noted that these supplies got extremely hot and that to be cooled, we would have to mount the power distribution board to the aluminum connector box to dissipate the heat generated by these power supplies into the surrounding water. This severely limited the physical size our power distribution board could be because of the little space available in the connector box, and as a result, the capabilities we could add. To solve this, we changed our cameras to smaller units that were not powered over ethernet. This allowed us to change the network switch to a much lower power device that does not require the power-inefficient power supplies. This change let us move the power distribution board out of the confined connector box and into a more spacious tube and to be able to cool the remaining voltage regulators using the internal air circulation fans.

As of right now, the thrusters are controlled using an Arduino Mega because of its large number of PWM pins. Eventually, we plan to make an expansion module off the power distribution board that acts as a motor controller board. We also have a DVL installed for the purposes of data collection. While the data from the DVL will not be used for autonomous decisions this year, we plan on using the data we acquired to aid the DVL's software integration in the future. For the main computers, we have decided on an Intel NUC to control the sub and the various other tasks, and an NVIDIA Jetson TX2 for vision processing. As stated before, the cameras used previously were POE IP cameras, but this was eventually swapped out to higher resolution cameras from Leopard Imaging that talked over a MIPI interface directly to the Jetson.

Mechanical

The chassis of the AUV is built around a modular frame consisting of four rails arranged in a rectangle. This design allows the team to add, move, remove, or replace components as needed in order to achieve versatility in sensor configuration and to be able to assemble or disassemble the AUV efficiently. This modularity allows the team to swap sensor configurations in a short period of time. In a competition setting, this can be used to change which tasks will be attempted by the AUV. In the future, if a second identical platform was to be built, the sensors and equipment can be interchangeable. Allowing for many different competition strategies, as well as an additional backup in the case of equipment failure. In order to achieve this configurability, the frame of the AUV is designed with a large hollow area under the main electronics enclosure to allow ample space for both current and future systems. Such

as but not limited to sonar, DVL, dropper, downward facing camera, etc.
To facilitate the modular design, it was decided to use detachable waterproof connectors in order to attach all peripheral components to the primary electronics enclosure of the sub. This provides many advantages such as the ability to ship the chassis separately, swap out electronics enclosures, and work with the enclosure separately from the chassis for repairs and maintenance. The primary vendor for connectors that will be used on the sub is Blue Trail Engineering, a small startup company based in Colorado. This vendor was chosen due to their product being highly cost effective compared to the other options considered, and providing connectors that exactly suit the team's needs. In addition to the Blue Trail connectors, the team made use of a SUBCONN connector for its wet mate ability to use on the tether. Without these connectors, the modular design of the AUV would not be possible.

III. Experimental Results

Even with COVID-19 restrictions still in place in 2021, we were able to test at one of our member's pools with the approval of our university. We submitted an off campus form agreeing to follow all COVID-19 safety guidelines at the pool: wearing masks and maintaining at least six feet of distance from each other. With this we were able to test multiple aspects of our submarines.
We were able to do our first leak test and test drive test just a few months ago. Our first test leak was a success, we pressurized the interior of the submarine and monitored it for about ten minutes to see if there were any variations of pressure due to a leak. After that out of water leak test was a success, we placed it underwater and flipped it multiple times without the electronics inside. Once we were able to determine no leaks, we inserted all the electronics to do a drive test. On our second time doing a drive test we found that our submarine was beginning to leak even after all our extensive precautions the first time we did a leak test. After pulling the Submarine out of the water and checking all the connections we found that one of the connectors was missing its O-ring and the cable the connector was attached to is mostly hollow, making it act as a hose for water to rush through. Thankfully, none of our electronics got damaged as we were able to act quickly. We noted in our logs to always check all O-rings are in place before placing it in the water.
We utilized our second submarine, which we competed with in the 2019 RoboSub competition, to test the Ping 360 from Blue Robotics. We got beautiful results from the sonar in the pool we were testing in as seen below.

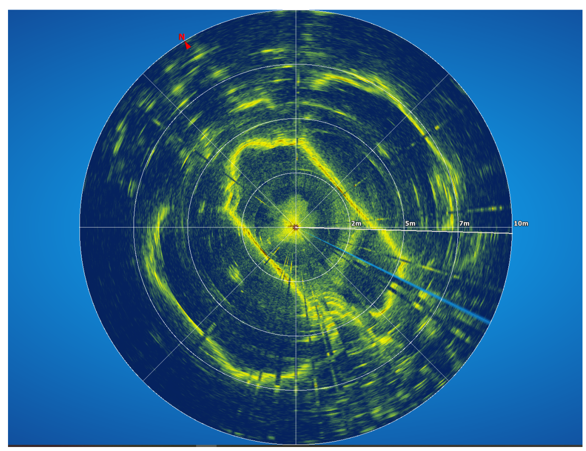

Figure 1: Sonar image captured with Ping 360 of a backyard pool.

With the results gained from the testing of the sonar, we are thinking of ways to get our two submarines to communicate with each other, so that we can have the second submarine utilize sonar as well as communication capabilities.

IV. Acknowledgements

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V. References

[1] Google Colab. (2020). Google. [Online]. Available: https://colab.research.google.com/

Appendix A: Component Specifications

Component	Vendor	Model/Type	Cost (if new)
Buoyancy Control	Blue Robotics	Subsea Buoyancy Foam	N/A
Frame	Custom Design		
Waterproof Housing	Blue Robotics	6" Series Watertight Enclosure	$560.00
Waterproof Connectors	Blue Trail Engineering	Cobalt Series	TBD
Thrusters	Blue Robotics	T200	$206.00 Each
Motor Control	Blue Robotics	Basic ESC	$27.00 Each
High Level Control	Arduino	Mega	$38.95
Battery	TBD		
Converter	VICOR	Micro Family	$177.55
Regulator	muRata	UWE Series	$73.00
CPU	Intel	NUC NUC717DNBE	~$700
Internal Comm Network	NETGEAR	8-Port PoE Switch	$69.99
Programming Language 1	Python 3		
Programming Language 2	C++		
Compass	VectorNav	VN100	$800.00
Inertial Measurement Unit (IMU)	VectorNav	VN100	$800.00
Sonar	Blueview	M900	~45-50k
Doppler Velocity Log (DVL)	Nortek	DVL 1000	~$18k
Camera(s)	Leopard Imaging	LI-IMX477-MIPI-M12	$279.00
Algorithms: Vision	TensorFlow		
Algorithms: Autonomy	Custom scripts using ROS integration		
Open Source Software	TensorFlow, ROS		
Team Size	Roughly 10 Members		
HW/SW expertise ratio	Roughly 2:1		
Testing Time: In-Water	~10 Hours		

Appendix B: Outreach Activities

On April 21st, the sub was brought to the Marine Discovery Center in New Smyrna Beach, to help show elementary school age children and their parents functional submarines, including piloting demonstrations in a small pool, and explain how they work. The team also answered questions various guests asked.