2025 International RoboSub Competition

HammerHead AUV, Technical Design Report

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Abstract

The HammerHead Autonomous Underwater Vehicle (AUV), developed by Embry-Riddle's Team Unsinkable, focuses on efficiency within the constraints of limited resources. Now in the second year of a four-year design cycle, HammerHead prioritizes mechanical robustness, comprehensive six-degree-of-freedom control, and a reliable ROS2-based software architecture. Mechanical enhancements include a dual-tube hull configuration, providing increased internal volume for improved thermal management, and a modular connector box that simplifies assembly and servicing. Electrical improvements focus on reliability, notably through an upgraded emergency stop system. Precise navigation and control are achieved through sensor fusion using a Doppler Velocity Logger, Inertial Measurement Unit, scanning sonar, and stereo vision. Iterative testing via simulation, benchtop prototypes, and underwater validation ensures subsystem performance, positioning HammerHead competitively for selected RoboSub tasks.

Keywords: RoboSub; AUV; ROS2; Stereo Vision; Systems Engineer; Sensor Fusion

Nomenclature

AMRA	Autonomous Maritime Robotics Association at Embry-Riddle Aeronautical University
AUV	Autonomous Underwater Vehicle
CV	Computer Vision
DVL	Doppler Velocity Logger
ERAU	Embry-Riddle Aeronautical University
IMU	Inertial Measurement Unit
ROS2	The Robotics Operating System v2

1. Competition Strategy

Our competition strategy is to maximize our point total while minimizing the effort required. This approach is a consequence of our most limited resource: experienced team members. The 2025 Competition marks the fourth competition since the re-establishment of the Embry-Riddle RoboSub Team after the COVID-19 Pandemic. The team's knowledge base is still recovering from the loss of senior team members' experiences due to the 3-year gap in recruitment and retention. While we have team members who are "Senior" in terms of experience, such members are still limited in number and split their attention between developing new systems and mentoring less-experienced team members. Therefore, we limit our scope each year to a small number of tasks that are scored based on the potential points earned and the estimated effort to develop the AUV to realistically accomplish those tasks.

2. Task Priority and Selection

There were two data points used to score the tasks relative to their potential points and expected effort. The potential earned points were estimated using the 2024 RoboSub Team Handbook [1]. The possible points for each task recorded in the handbook were then assessed to determine what the "goal" number of points would be. This was based on a reasonable threshold of success determined by the Project Lead. These points are recorded under the goal column in Table 1.

The estimated effort required was calculated using a survey of experienced team members. The survey asked team members to estimate the effort needed to develop our system to a point that it could accomplish the task listed. It was a logarithmic, relative rating scale where one unit increase in the rating corresponded to roughly a ten-fold increase in effort. The effort does not correspond only to the time it would take, but also encompasses the general complexity, required skills, and financial burden. The result was the tasks being sorted into tiers, which can be seen in Table 1.

The combination of the goal points and the task tier was used to create a function that output a weighted score that could be used to help determine what tasks should be prioritized.

$$\Psi = \frac{\kappa}{10^{\xi}} \tag{1}$$

In Equation (1), κ is the "goal" score, ξ is the task tier, and Ψ is the weighted priority score. A higher score denoted a task to be prioritized in our competition strategy.

Table 1. Task Weighted Priority

Task Name	Possible Points	Goal	Percent Maximum	Task Tier	Weighted Priority
Weight Measurement	199.5	4	2%	0	0.4
Heading Out (Coin Flip)	300	300	100%	2	10.0
Task 1 - Collecting Data (Gate)	1850	1050	57%	1	52.5
Task 2 - Navigate the Channel (Slalom)	800	600	75%	2	20.0
Task 3 - Drop a BRUVS (Bins)	1600	0	0%	3	0.0
Task 4 - Tagging (Torpedoes)	2000	0	0%	4	0.0
Task 5 - Ocean Cleanup (Octagon)	5000	800	16%	5	13.3
Task 6 - Return Home	500	500	100%	2	16.7
Pinger Task	2000	0	0%	5	0.0
Inter-vehicle Communication	1000	0	0%	6	0.0

3. Design Strategy

HammerHead AUV is in its second year of development with an expected four-year design cycle. The goals for the end of this development year are a mature design for the core elements of the mechanical system, a control system for all 6-DOF for the AUV, and basic navigation and mapping. These design goals were chosen based on the assessed requirements for the task we selected.

3.1. Mechanical Systems

The mechanical systems of HammerHead AUV are foundational to the development of further systems. We are constantly balancing cost, weight, density, volume, strength, and complexity. The primary sub-systems that were developed under the mechanical development group were: the hull, the frame, the thrusters, the internal mounting hardware, the external mounting hardware, and heat management. All these hardware systems impact each other and aspects of the electrical and software subsystems.

3.1.1. Hull Design

The second generation of the AUV underwent many revisions to the resulting hull shape. There was a clear goal established to increase the internal volume due to issues with system reliability and heat from overcrowding. During the preliminary design stage, there was difficulty in deciding to what extent we would increase the volume. The deciding factor was the regulation-imposed weight limit and the correlated volume limitation due to buoyancy. The goal was to maximize the internal volume, allowing for more systems, better cable management, and improved cooling while being within the legal weight limit, and the safe limit for buoyancy[1].

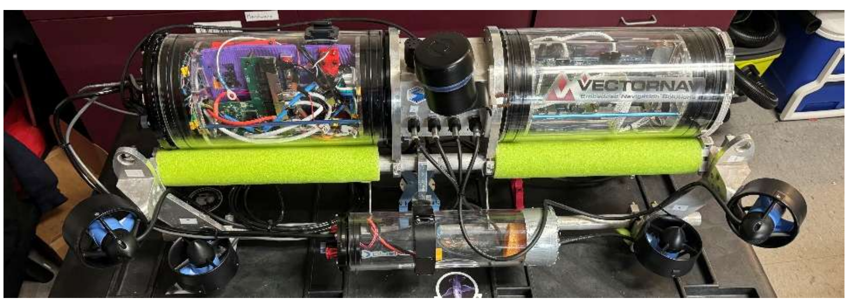

Figure 1. AMRA AUV Version 1.0, Nautilus, 2020 to 2023

To determine the proper direction for the hull design, a trade-off study was performed that calculated an estimated weight, net buoyancy force, and cost of each theoretical configuration. The totality of these trade studies can be seen in Appendix A for reference. The result of the trade study was to pursue a hull consisting of two tubes with a connector box. This follows the design philosophy that was developed for the prior version of the AMRA AUV, while increasing the internal volume by 108%, simplifying cable routing, and allowing for future work to improve the cooling system. Table A1 shows the trade-off study that led to the pursued design, and an excerpt of Table A1 can be seen in Table 2.

[1] A large net buoyancy force would result in unsafe conditions for divers during an emergency stop and put unnecessary strain on the thrusters.

Table 2. Except of Table A1, Final Design Trade Study

	Total Weight [lbs.]	Total Buoyancy [lbs.]	Net Buoyancy [lbs.]	Total Cost [USD]
Total	81.99	85.34	3.35	$4,710.00
Goal	82.00	80.00	2.00	$4,500.00
Percent Difference	0%	7%	67%	5%

The trade study yielded a preliminary design that would hit the goal weight of 82 lbs. with a net buoyancy of positive 2 lbs. This net buoyancy was low enough to be safe and not strain the thrusters more than necessary.

Figure 2. AMRA AUV Version 2.0, Hammerhead, Hull Manufactured 2024

3.1.2. Connector Box Design

The backbone of the AUV is a part dubbed "the connector box". This part is where all connections that pass from the interior to the exterior of the hull are routed. This provides a large flat surface that penetrators from Blue Robotics [2] and Blue Trail Engineering [3] can seal against using their O-ring-based seals. Without this connector box, the only flat surface that would be able to support these connectors is the back face plate of the AUV, which can be seen partially in the version 1.0 AUV seen in Figure 1. The connector box was designed with a large wall thickness of 0.5" to allow for blind tapping threads for attachment points for other components of the sub, like the acrylic tubes and the AUV frame.

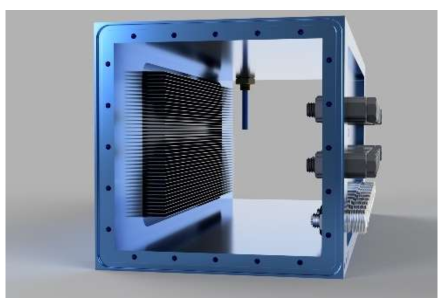

Figure 3. Connector Box Cooling Design

The connector box includes a large internal volume and an access hatch allowing ease of assembly and servicing. The large volume allows for airflow between the acrylic tubes and the connector box, providing convective cooling to cycle air from the hot electrical components to the connector box that is cooled by the water outside the sub, acting as a heatsink. Previously, airflow was impeded as the connector box was saturated with wires and connectors. This connector box includes fins to increase the surface area for heat conduction on one surface and uses flat plates on other surfaces with forced convection for cooling.

3.1.3. AUV Frame Design

The AUV Frame was redesigned to use T-slot aluminum extrusion instead of round aluminum or carbon fiber tubing. The previous rail designs required custom mounts to interface with the rails, leading to increased weight and bulk. The switch to T-slot extrusion has allowed the use of T-nuts to attach systems to the rails with ease and allow the frame to be assembled with cross supports that are screwed together with tapped holes and clearance holes.

3.2. Electrical Systems

The electrical system improvements have been minimal, currently using the same power delivery system that provides direct battery power to our thrusters and using 12V DC-DC converters to provide stable power to our electronics. The only system that was improved was the emergency stop. The contactor relay was replaced with a higher quality unit. The Panasonic AVEA1251 is rated to 250A, instead of 100A for the automotive relay, and has reduced the temperature in the rear compartment because it does not heat up as much under 100A of continuous current.

3.3. Software Systems

The software design strategy was to maximize reliability by using a reliable middleware that allowed for easy integration and expansion of new systems into the software framework. To accomplish this, ROS2, an industry standard for robotics middleware, was used to provide a single framework for sending information between all the software components that comprise the AUV.

The perception tasks were the most challenging to attempt. We decided to take a multifaceted approach to sensing, utilizing IMU, Sonar, DVL, and Computer Vision. These provide robust sensing data that can be combined to form an accurate picture for our mission planner. This year, the data that our strategy is most reliant on is from the DVL, the IMU, and Computer Vision. Since the tasks we are targeting are based on precise movement, the DVL and IMU allow us to provide real time and accurate feedback to our control systems to keep us stable and on path. Computer Vision will help to augment the path with real time data provided by the stereo vision camera. Together the system will use the data to accomplish gate, shalom, and return home as our primary strategy.

4. Testing Strategy

Team Unsinkable has been extremely fortunate to have continued access to ERAU’s Electrical Engineering and Computer Science Department Capstone Lab for building and benchtop testing both our software and robotic equipment. Furthermore, the Embry-Riddle Fitness Center has worked with Team Unsinkable to facilitate weekly tests in its pool, which greatly helps with underwater testing the more complex and extensive systems on the AUV. While the team strongly values these full-scale opportunities that mimic the competition environment, they require significant planning time and resources. To compensate for smaller scale testing that does not require the pool setting, Team Unsinkable has developed an iterative engineering model that allows for different stages of testing to occur with no interference in progress. Within this model, a simulation is to occur first, followed by prototyping both on the benchtop and during pool tests, and then a final installation of the subsystem on the AUV.

4.1. Software Spotlights: Computer Vision & Sonar Development

The computer vision pipeline was initially developed through simulation and offline testing of multiple detection and tracking models, including YOLO-based object detection, homography estimation, optical flow, key point detection, reidentification, and color isolation. Following successful validation in simulation, a prototype stereo vision setup was assembled and tested on a benchtop rig (Figure 4) to evaluate depth estimation accuracy and calibration repeatability.

Integrated pool trials combined stereo vision system with the Ping 360 sonar and a simple deep-water camera to collect underwater visual and positional data. These trials enabled refinement of detection algorithms and informed parameter tuning for real-time performance. Final integration with the main AUV is ongoing, with the full vision system demonstrating stable performance across multiple hardware configurations at frame rates acceptable for real-time deployment.

Figure 4. Stereo Vision Benchtop Testing Rig

The sonar development was a system created to compliment the computer vision pipeline by providing robust underwater target detection at an accessible cost. The team selected the Ping360 Scanning Imaging Sonar [4] for its low cost and high efficiency, making it suitable for rapid prototyping of acoustic analyzing models and field deployment. Initial development focused on implementing robust noise filtering and clustering algorithms to detect and track objects in real-time.

Benchtop and pool tests demonstrated that the Ping360 provides sufficient range and resolution for short to mid-range detection tasks relevant to the AUV's mission. Early trials confirmed the effectiveness of the clustering approach and noise suppression under typical underwater conditions. Full integration of sonar and computer vision data will be validated during the next phase of field testing to ensure accuracy and precision.

4.1.1. Mechanical Spotlight: Frame Rails

The frame rails are a key structural element for the current AUV design and are increasingly critical considering future possibilities in tasks such as torpedoes and bins. A preliminary design for the torpedo launchers was developed through Fusion360 so they can be mounted on the AUV's frame rails. This design was then 3D-printed and installed on the original carbon fiber square frame railing. In early stages of benchtop testing, the carbon fiber rails proved challenging to modify, as drilling for external attachments was impractical and most components had to rely solely on friction fits. This design was further scrutinized due to strain failure, which showed up after a few months of the rails being installed.

To address this, a redesign of the frame using aluminum with T-Slot extrusions was modeled and simulated. Matching mounting brackets were developed for each planned attachment point on the AUV. A prototype of this configuration was then 3D printed, attached to the hull with all the prototype attachments, and stress tested to determine its strength and versatility needed for the ever-expanding mechanical design of the team's AUV (Appendix B). Finally, a black-anodized, 6063 aluminum rail system was installed on the AUV and demonstrated no signs of degradation or failure during underwater testing, while also allowing straightforward installation of all attachments in the field.

5. Acknowledgements

Firstly, Team Unsinkable would like to highlight our faculty advisors at ERAU's College of Engineering, like Dr. Brian Butka, Professor Daniel Penny, and Professor Leo Ghelarducci, as the work of our team would not be possible without their support. We also thank the College of Engineering, William "Bill" Russo, and Kim May for access to the machine shop and guidance in designing. Furthermore, we thank Wanda Rodriguez from the Department of Electrical Engineering and Computer Science for her tremendous help with finances, funding, outreach, and her amazing attitude that makes the whole team smile. Additionally, we thank the Department of Electrical Engineering and Computer Science and the ERAU Fitness Center for granting us use of the Capstone Lab and the Fitness Center pool for both benchtop and underwater testing. Lastly, we are thankful for our generous sponsors: Infinity Center of Education, VectorNav, and Primor Group. Without their support, our team would not be in such a fortunate position. Team Unsinkable is excited to work with each one of our supporters to create an amazing working environment for future engineers to thrive in.

6. References

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Appendix A. AUV Configuration Trade Studies

A.1. 2-Tube, 8-inch, 8 Vectored Thrusters Configuration

Table A1. Trade Study on AUV Configuration

Item	Weight [lbs.]	Buoyancy [lbs.]	Quantity	Cost	Total Weight	Total Buoyancy	Net Buoyancy	Total Cost
Connector Box	10.39	19.49	1	$ 400.00	10.39	19.49	9.11	$ 400.00
6 in Flange Plate	0.41	0.30	0	$ 63.00	0.00	0.00	0.00	$ -
8 in Flange Plate	0.73	0.51	2	$ 72.00	1.47	1.02	-0.44	$ 144.00
Connector Box Plate	1.73	0.65	1	$ 70.00	1.73	0.65	-1.08	$ 70.00
8" Enclosure	3.29	24.07	2	$ 330.00	6.58	48.14	41.56	$ 660.00
8" Flange	1.52	0.51	4	$ 120.00	6.08	2.05	-4.03	$ 480.00
8" Aluminum Blank	3.21	0.51	1	$ 48.00	3.21	0.51	-2.70	$ 48.00
8" Acrylic Blank	1.24	1.02	1	$ 60.00	1.24	1.02	-0.22	$ 60.00
6" Enclosure	2.49	14.08	0	$ 200.00	0.00	0.00	0.00	$ -
6" Flange	1.11	0.30	0	$ 84.00	0.00	0.00	0.00	$ -
6" Aluminum Blank	0.79	0.30	0	$ 42.00	0.00	0.00	0.00	$ -
6" Acrylic Blank	0.73	0.60	0	$ 50.00	0.00	0.00	0.00	$ -
48" Aluminum Extrusion	2.10	0.76	8	$ 36.00	16.80	6.05	-10.75	$ 288.00
45" Carbon Fiber Tubing	0.52	0.33	0	$ 90.90	0.00	0.00	0.00	$ -
Lithium-ion Battery	2.56	0.00	2	$ 400.00	5.12	0.00	-5.12	$ 800.00
T200 Thrusters	0.94	0.41	8	$ 220.00	7.53	3.28	-4.25	$ 1,760.00
Internals	15.00	0	1	NA	15.00	0.00	-15.00	NA
Ballast Weight	0.42	0.06	2	NA	0.84	0.11	-0.73	NA
Miscellaneous Adjustment	1.00	0.50	6	NA	6.00	3.00	-3.00	NA
Total					81.99	85.34	3.35	$ 4,710.00
Goal					82.00	80.00	2.00	$ 4,500.00
Percent Difference					0%	7%	67%	5%

A.2. 4-Tube, 8-inch, 8 Vectored Thrusters Configuration

Table A2. Trade Study on AUV Configuration

Item	Weight [lbs.]	Buoyancy [lbs.]	Quantity	Cost	Total Weight	Total Buoyancy	Net Buoyancy	Total Cost
Connector Box	22.18	44.19	1	$ 1,200.00	22.18	44.19	22.00	$ 1,200.00
6 in Flange Plate	0.41	0.30	0	$ 63.00	0.00	0.00	0.00	$ -
8 in Flange Plate	0.73	0.51	4	$ 72.00	2.93	2.05	-0.89	$ 288.00
Connector Box Plate	1.73	0.65	2	$ 70.00	3.47	1.30	-2.17	$ 140.00
8" Enclosure	3.29	24.07	4	$ 330.00	13.16	96.28	83.12	$ 1,320.00
8" Flange	1.52	0.51	8	$ 120.00	12.16	4.10	-8.06	$ 960.00
8" Aluminum Blank	3.21	0.51	2	$ 48.00	6.43	1.02	-5.40	$ 96.00
8" Acrylic Blank	1.24	1.02	2	$ 60.00	2.48	2.05	-0.43	$ 120.00
6" Enclosure	2.49	14.08	0	$ 200.00	0.00	0.00	0.00	$ -
6" Flange	1.11	0.30	0	$ 84.00	0.00	0.00	0.00	$ -
6" Aluminum Blank	0.79	0.30	0	$ 42.00	0.00	0.00	0.00	$ -
6" Acrylic Blank	0.73	0.60	0	$ 50.00	0.00	0.00	0.00	$ -
48" Aluminum Extrusion	2.10	0.76	0	$ 36.00	0.00	0.00	0.00	$ -
45" Carbon Fiber Tubing	0.52	0.33	8	$ 90.90	4.17	2.64	-1.53	$ 727.20
Lithium-ion Battery	2.56	0.00	2	$ 400.00	5.12	0.00	-5.12	$ 800.00
T200 Thrusters	0.94	0.41	8	$ 220.00	7.53	3.28	-4.25	$ 1,760.00
Internals	15.00	0	1	NA	15.00	0.00	-15.00	NA
Ballast Weight	0.42	0.06	0	NA	0.00	0.00	0.00	NA
Miscellaneous Adjustment	1.00	0.50	6	NA	6.00	3.00	-3.00	NA
Total					100.63	159.90	59.28	$ 7,411.20
Goal					82.00	80.00	2.00	$ 4,500.00
Percent Difference					23%	100%	2864%	65%

A.3. 2-Tube, 6-inch, 8 Vectored Thrusters Configuration

Table A3. Trade Study on AUV Configuration

Item	Weight [lbs.]	Buoyancy [lbs.]	Quantity	Cost	Total Weight	Total Buoyancy	Net Buoyancy	Total Cost
Connector Box	3.00	3.47	1	$ 400.00	3.00	3.47	0.47	$ 200.00
6 in Flange Plate	0.41	0.30	2	$ 63.00	0.81	0.60	-0.21	$ 126.00
8 in Flange Plate	0.73	0.51	0	$ 72.00	0.00	0.00	0.00	$ -
Connector Box Plate	1.73	0.65	0	$ 70.00	0.00	0.00	0.00	$ -
8" Enclosure	3.29	24.07	0	$ 330.00	0.00	0.00	0.00	$ -
8" Flange	1.52	0.51	0	$ 120.00	0.00	0.00	0.00	$ -
8" Aluminum Blank	3.21	0.51	0	$ 48.00	0.00	0.00	0.00	$ -
8" Acrylic Blank	1.24	1.02	0	$ 60.00	0.00	0.00	0.00	$ -
6" Enclosure	2.49	14.08	2	$ 200.00	4.98	28.15	23.17	$ 400.00
6" Flange	1.11	0.30	4	$ 84.00	4.44	1.20	-3.24	$ 336.00
6" Aluminum Blank	0.79	0.30	1	$ 42.00	0.79	0.30	-0.49	$ 42.00
6" Acrylic Blank	0.73	0.60	1	$ 50.00	0.73	0.60	-0.13	$ 50.00
48" Aluminum Extrusion	2.10	0.76	8	$ 36.00	16.80	6.05	-10.75	$ 288.00
45" Carbon Fiber Tubing	0.52	0.33	0	$ 90.90	0.00	0.00	0.00	$ -
Lithium-ion Battery	2.56	0.00	2	$ 400.00	5.12	0.00	-5.12	$ 800.00
T200 Thrusters	0.94	0.41	8	$ 220.00	7.53	3.28	-4.25	$ 1,760.00
Internals	15.00	0	1	NA	15.00	0.00	-15.00	NA
Ballast Weight	0.42	0.06	0	NA	0.00	0.00	0.00	NA
Miscellaneous Adjustment	1.00	0.50	6	NA	6.00	3.00	-3.00	NA
Total					65.20	46.64	-18.56	$ 4,002.00
Goal					82.00	80.00	2.00	$ 4,500.00
Percent Difference					20%	42%	1028%	11%

A.4. 4-Tube, Combo, 8 Vectored Thrusters Configuration

Table. Trade Study on AUV Configuration

Item	Weight [lbs.]	Buoyancy [lbs.]	Quantity	Cost	Total Weight	Total Buoyancy	Net Buoyancy	Total Cost
Connector Box	22.18	44.19	1	$ 400.00	22.18	44.19	22.00	$ 200.00
6 in Flange Plate	0.41	0.30	2	$ 63.00	0.81	0.60	-0.21	$ 126.00
8 in Flange Plate	0.73	0.51	2	$ 72.00	1.47	1.02	-0.44	$ 144.00
Connector Box Plate	1.73	0.65	2	$ 70.00	3.47	1.30	-2.17	$ 140.00
8" Enclosure	3.29	24.07	2	$ 330.00	6.58	48.14	41.56	$ 660.00
8" Flange	1.52	0.51	4	$ 120.00	6.08	2.05	-4.03	$ 480.00
8" Aluminum Blank	3.21	0.51	1	$ 48.00	3.21	0.51	-2.70	$ 48.00
8" Acrylic Blank	1.24	1.02	1	$ 60.00	1.24	1.02	-0.22	$ 60.00
6" Enclosure	2.49	14.08	2	$ 200.00	4.98	28.15	23.17	$ 400.00
6" Flange	1.11	0.30	4	$ 84.00	4.44	1.20	-3.24	$ 336.00
6" Aluminum Blank	0.79	0.30	1	$ 42.00	0.79	0.30	-0.49	$ 42.00
6" Acrylic Blank	0.73	0.60	1	$ 50.00	0.73	0.60	-0.13	$ 50.00
48" Aluminum Extrusion	2.10	0.76	0	$ 36.00	0.00	0.00	0.00	$ -
45" Carbon Fiber Tubing	0.52	0.33	8	$ 90.90	4.17	2.64	-1.53	$ 727.20
Lithium-ion Battery	2.56	0.00	2	$ 400.00	5.12	0.00	-5.12	$ 800.00
T200 Thrusters	0.94	0.41	8	$ 220.00	7.53	3.28	-4.25	$ 1,760.00
Internals	15.00	0	1	NA	15.00	0.00	-15.00	NA
Ballast Weight	0.42	0.06	0	NA	0.00	0.00	0.00	NA
Miscellaneous Adjustment	1.00	0.50	6	NA	6.00	3.00	-3.00	NA
Total					93.80	138.00	44.20	$ 5,973.20
Goal					82.00	80.00	2.00	$ 4,500.00
Percent Difference					14%	73%	2110%	33%

Appendix B. AUV Mechanical Modeling Work

B.1. Motor Mounting Brackets and Aluminum Rails

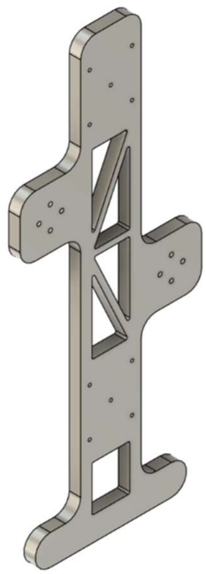

Figure 5: Redesigned Motor Mount

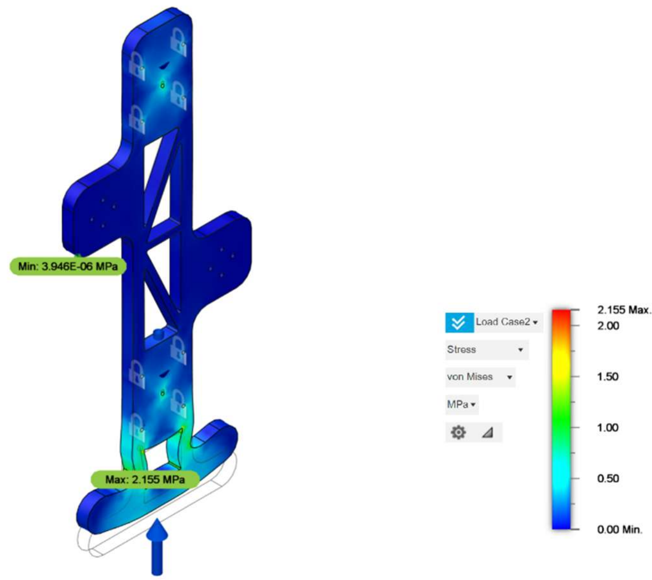

Figure 6: Simulation of a "Hard" Impact (140 N)

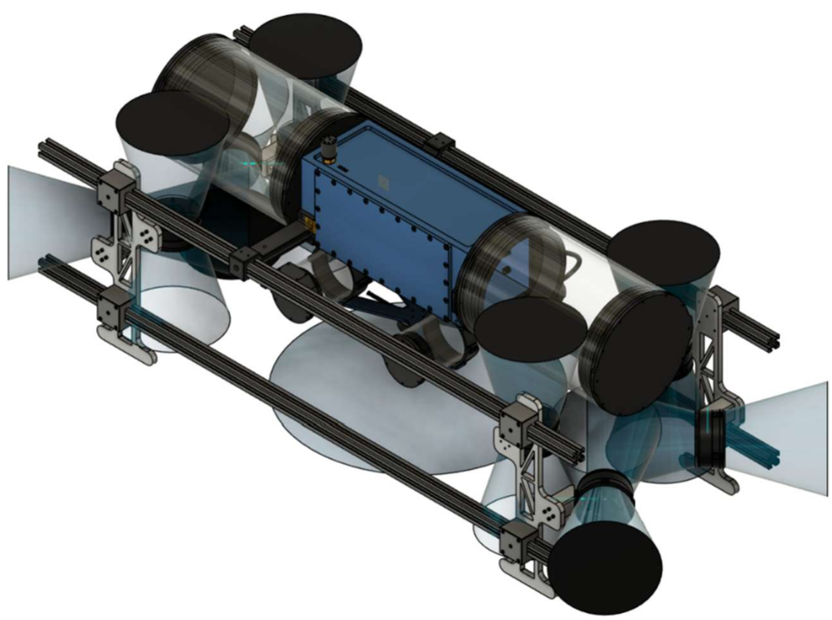

Figure 7: Updated Frame Assembly (Cones Represent 15° Thruster Wake)

B.2. Torpedoes and Launch Rails

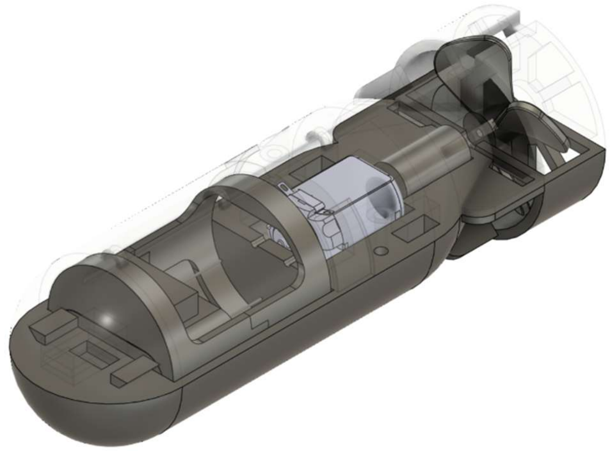

Figure 8: Capacitor-Discharge Torpedo Prototype

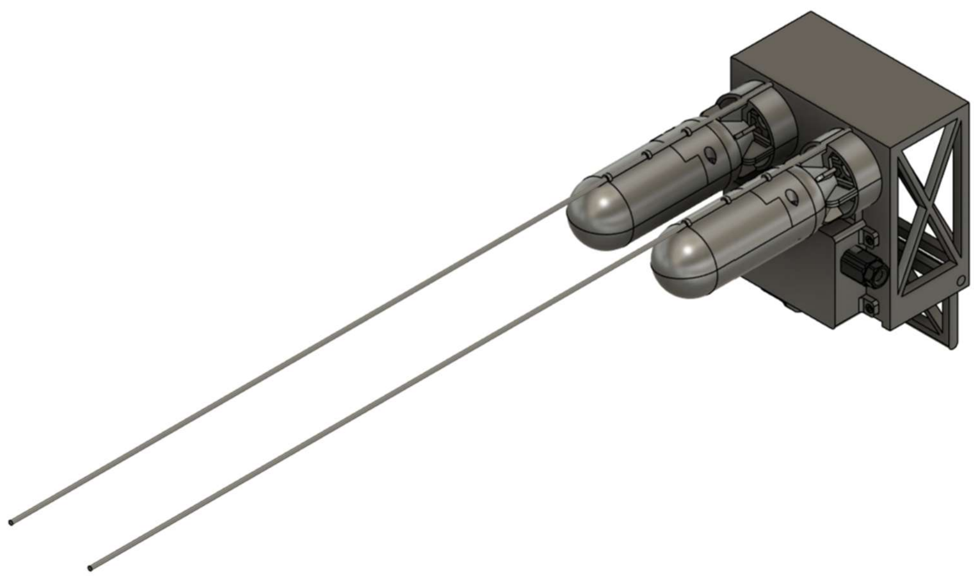

Figure 9: Two Torpedoes and Launch Rail System