

Troy High SPEAR Technical Design Report

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Abstract — Troy SPEAR’s 2026 AUV, ORCA, underwent significant upgrades for the RoboSub 2026 competition, incorporating redesigned mechanical subsystems, an improved electrical architecture, and a refined software pipeline. Mechanically, the claw, dropper, and torpedo systems were redesigned to improve reliability, modularity, and overall performance. Electrically, the power distribution and kill switch systems were enhanced to improve safety, scalability, and debugging efficiency. On the software side, the team refined its ROS2-based architecture and vision pipeline, integrating ZED 2i stereo cameras and YOLOv26 object detection to support robust localization and autonomous task execution. These improvements were made with an emphasis on establishing a reliable and modular foundation for future development while maximizing consistency and performance in competition environments.

I. COMPETITION STRATEGY

A. Task Prioritization

In order to maximize the retention of points during our competition runs and the use of our limited time, we decided to approach the tasks with a designated priority. This ranking factors each task’s difficulty, time constraints, and available resources.

1. Task 1 – Begin Assessment
2. Task 3 – Recon
3. Task 5 – Resupply
4. Task 2 – Avoid Debris
5. Task 4 – Torpedoes
6. Task 6 – Return Home

Task 1 lacks intensive use of logic and movements, resulting in its highest placement in our priorities, as it results in a more reliable retention of points. Tasks 3 and 5 are our main focus for our claw subsystem, and are in our second set of priorities due to their increased complexity with their simultaneous use of both the mechatronics and software subsystems. Lastly, Tasks 2, 4, and 6 are in our final set of priorities due to their heavy reliance on our localization and mechatronics system which are not as reliable in the dynamic competition environment.

B. Subsystem Rationale and Specifications

(i) Claw

The series gear system at a 1:1 ratio of our 2025 claw system did not reliably transfer enough torque in order to grip onto objects. In order to account for this, an arc-shaped space was created in the middle of the claw, with interlocking teeth on the bottom. However, this didn’t directly solve our problem and only decreased surface contact. Looking into past team designs and considering these issues, it became clear that a compliant claw mechanism was necessary. Hence, we devised a hybrid compliant claw system with PLA and TPU parts, aiming to use the adaptability of TPU and the structure and rigidity of PLA for the current season.

(ii) Dropper

The 2025 Dropper and Torpedo system was driven by a single servo motor, incorporating a rotating barrel and spring-loaded torpedo

launch. Although the system conserved the use of an additional servo and kept the two systems organized, combining them proved to present individual inefficiencies for the sake of a two in one product. Therefore, the systems are to be kept separate for 2026, improving upon issues such as backlash and marker path optimization. Design specifications for the markers and dropper subsystem include the use of weights, strategic fin placement, and overall tuning of the marker path to be as uniform and straight as possible, increasing marker accuracy during actuation. By reducing the complexity of this subsystem, we aim to increase our consistency, enhancing our ability to score points during the competition.

(iii) Torpedo

We have transitioned from a more traditional spring loaded launcher to a self propelled electric torpedo. This switch was made due to the improved launch consistency of a self-propelled system, combined with previous difficulties in the reliability of a spring based launcher. The torpedo uses a small DC motor to drive a propeller for propulsion and a microcontroller and photoresistor to interpret binary encoded signals transmitted by the onboard computer via an external LED.

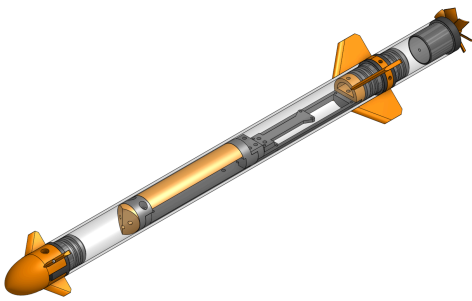


Figure 1. Initial proof-of-concept prototype for an electric torpedo.

(iv) Vision

The AUV's primary sensor architecture features a dual-camera payload. We use two

ZED 2i stereoscopic cameras, one forward-facing and one downward-facing. This configuration combines high-fidelity depth maps, 6-DoF positional tracking, and bottom-camera tracking of fixed floor markers to achieve robust localization grounding. This eliminates visual drift without a complex DVL system from our previous years, minimizing the complexity of our software stack through enabling both the visual capabilities and the localization of the AUV in one unit.

This reduction in complexity is complemented with a minute decrease in accuracy, as our previous use of a DVL resulted in refined localization data. However, our ZED 2i camera's built-in operations with its localization data enables our team to rapidly debug and incorporate high-tier localization along with our other software subsystems, justifying this tradeoff.

II. DESIGN STRATEGY

A. Mechatronics

The primary objective for ORCA was to develop a reliable and modular AUV, allowing efficiency upon future modifications. Our designs also considered the manufacturing tools we had access to. Most custom components, such as the claw and dropper, were 3D printed using PLA and TPU, while the frame and main compartments were machined from 6061 aluminum. Our design decisions were also heavily influenced by anticipated implementation challenges from the electrical and software subteams, with an emphasis on balancing functionality and feasibility.

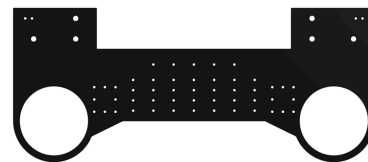


Figure 2. AUV mounting plate

One particularly notable feature is the customizability of the bottom panels, shown in

Fig. 2, which incorporates an array of holes to allow for modular mounting of components like the torpedo launcher or claw. This flexible layout also makes the frame more reusable for future iterations.

(ii) Main Compartment

The electrical bay houses all the AUV's primary electrical and hardware components in a clear acrylic enclosure. It features one window and twenty ports to allow for camera visibility and scalability. We switched back to off-the-shelf acrylic parts due to quality control issues regarding waterproofing with our custom enclosure in 2025. The components inside are mounted by a custom 3D-printed electronics tray, designed for modularity and customized for the integrated components.

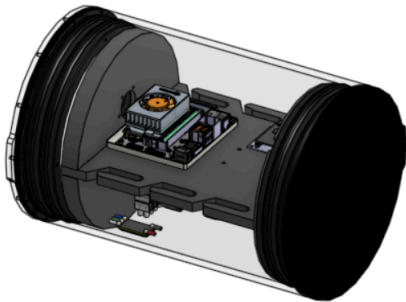


Figure 3. Main Compartment

(iii) Cameras

The AUV is equipped with two ZED 2i cameras from Stereolabs, which feature a built-in accelerometer, inertial sensors, and an SDK that allows integration of YOLO models for object detection on the course. Due to its IMU capabilities, the cameras allowed us to phase out the DVL system used in the previous season, which proved too complex for our team to utilize effectively. The stereo setup enables accurate triangulation and distance estimation through dual-lens depth sensing, while also supporting the precise generation of mesh maps for more efficient localization.

(iv) Dropper System (UPD)

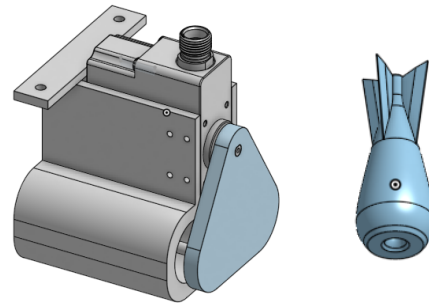


Figure 4. V1 Dropper

We revamped the revolver-barrel system and went for a simple two-barrel design with cover plates restricting the markers from falling, inspired by Delhi Technological University's Lapra's 2.0 [1]. This allowed for a simple, yet effective design, where the markers fell aligned to the projected strategy, rather than perpendicular.

This year, we used a SER-2010 servo to actuate markers to fall swiftly, influenced by internal weight, in order to complete the Recon (Bins) task (Task #3). The first iteration the dropper design (fig. 4) utilized a 6mm rod as a guide and fins on the marker to ensure the straightest path possible.

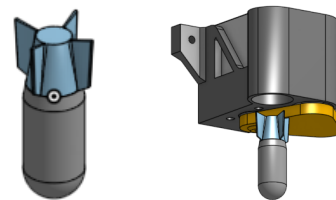


Figure 5. V2 Dropper

In the current iteration, we used a two-part design with a compartment for steel weights for quick and efficient actuation. The first iteration of the markers themselves utilized a set of helical fins in order to add rotational inertia with the hopes of stabilizing the path of the dropper. This proved to be false, and simple fins were used in a torpedo-like profile.

(v) Torpedoes

A crude proof-of-concept system was made initially to demonstrate its feasibility. The initial design was made only with readily available materials, resulting in faster development time but a larger overall product at 18 inches in length. Subsequent designs focused on reducing the size down to regulation while also experimenting with various hull and material configuration.

A notable challenge while developing the torpedo was waterproofing. For example, because of the small scale of the device, commercially available brushless watertight motors were not available, so a custom watertight hull had to be developed to fit an existing DC brushed motor.

(vi) Claw

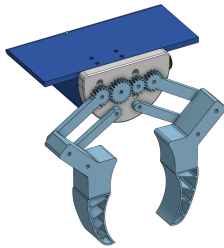


Figure 6. Claw Assembly

We originally aimed to create TPU “bristles” to add more grip through friction, taking advantage of its inherent flexibility and rubber-like texture to provide more grip. However, further research concluded that printing small bristles would be difficult to print successfully and would create heavy TPU waste through support material, leading us to reconsider.

While the bristles have a higher performance standard as they can completely conform around the object, we decided to go with a compliant claw attachment due to the fact that it is easier to make and test, allowing for rapid prototyping and easy assembly (Fig. 7). Additionally, we maintained a four-bar attachment system or a “Double-Joint” (Fig. 6b).

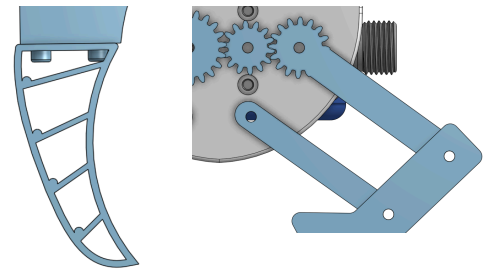


Figure 7. Closeup of the Compliant Claw (left), Closeup view of Double-Joint mechanism (right)

For the gearing, we first considered using a worm gear in order to transfer torque to the claw. However, this was not possible due to the rotational limits of the servo. Moving forward, we settled with a series gear train, utilizing four gears including an idler gear to ensure the proper rotation of the claw arms in opposite directions (Fig 8).

The gearing is based on a plate that is fastened to the face of the motor. A circular profile is cut out of the surface behind the gear plate in order to keep the front face of the servo completely flush to the plate. Holes are countersunk to ensure that fastening nuts are flush, such that mounting is not interfered with (Fig 8).

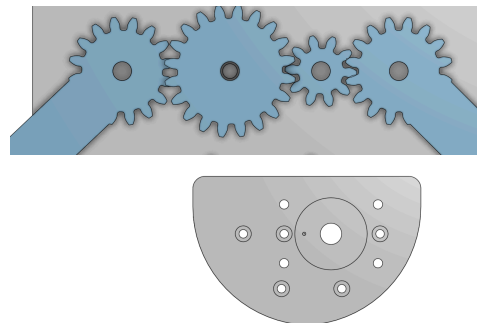


Figure 8. Gearing Closeup (top), Back view of the gear plate (bottom)

B. Software

(i) Object Detection

In order to facilitate rapid detection to minimize the time our AUV requires to complete tasks, we utilize our own YOLOv26

[2] detection pipeline. Once a target class is recognized, the AUV executes a two-stage intercept:

1. Repositioning - Upon detecting a target, the AUV reorients itself to center the object within the frame of the front camera and aligns itself at the same depth level.

2. Distance Estimation - The ZED 2i stereo camera provides 3D depth data, which is leveraged to estimate the relative positions. This spatial information is then fed into the behavior tree and returns a resulting action.

By publishing 3D bounding boxes and grounded coordinates directly to the movement stack, our AUV dynamically closes the loop between visual perception and thruster control to navigate the pool, allowing us to handle more tasks and gain more points as a result.

(ii) Architecture and Navigation

To enable efficient operation underwater, our system relies on a coordinated system of specialized processes. Communication between these processes is handled using the publisher and subscriber model provided by ROS2 [3], ensuring modularity. For interfacing with our low-level hardware, we used MAVROS to bridge ROS with MAVLink, allowing communication with the Pixhawk PX4 flight controller, as demonstrated in Figure 9. This architecture allows data exchange across all components from high-level mission planning to low-level motor control.

For navigation and localization, we used the IMU integrated within the ZED 2i cameras and its odometry from its processed localization data, to estimate the AUV's position within the environment. Leveraging data from the IMU, the PID control loop dynamically adjusts the pulse-width modulation (PWM) signals sent to the thrusters, enabling more accurate and reliable movement in parallel with the camera's built-in localization data, improving overall stability and precision. In turn, this results in a more robust, yet, steadfast AUV.

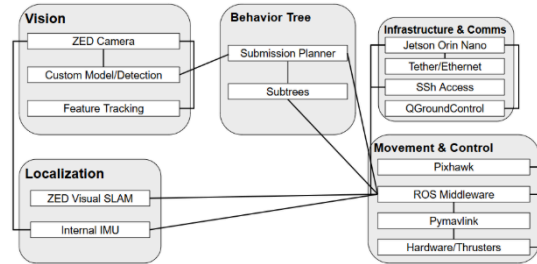


Figure 9. Software stack in relation to entire system

(iii) ROS Nodes

ROS (Robot Operating System) is a modular framework, integrating different subsystems within the AUV. Our 4 main ROS nodes are as follows:

1. Detection: Generates 3D bounding boxes and publishes object locations.
2. Localization: Determines the AUV's relative position from the origin and supports loading or generating maps of the pool environment, with the help of NAV2.
3. Behavior Tree: Handles high-level decision-making based on mission objectives and sensor inputs.
4. Control: Converts decisions from behavior tree callouts into motion commands and transmits them via MAVLink to the Pixhawk.

C. Electrical

(i) Kill Switch

The high power board serves as the central distribution hub for the AUV's moving parts. It efficiently regulates and routes power from the main 14.8V LiPo batteries to the downstream modules. It features two buck converters configured to provide two independent 7.125V rails, accommodating the lower power requirement of the servos, and uses a separate buck regulator to supply a stable 12V rail for the thrusters. An earlier iteration of this board had problems with inrush current; to mitigate such electrical surges, the board incorporates a 555 timer-driven precharge circuit that actuates

a high-current relay via a MOSFET. A diode array provides overvoltage protection with screw terminals for ease of repair. The kill switch directly cuts off power to this board, disabling propulsion, preventing the AUV from moving without forcing a full system reboot. With each subsystem forced to undergo a clean initialization after a hard kill, this makes it easier to isolate any faulty mechanisms while testing. Such faulty mechanisms may include sensor desynchronization or software deadlocks. Since the hard kill immediately cuts power to all thrusters and actuators, this allows for safer handling of the AUV during any potential debugging process. Finally, the binary option utilized by a kill switch removed the need for any complicated logic associated with soft kills.

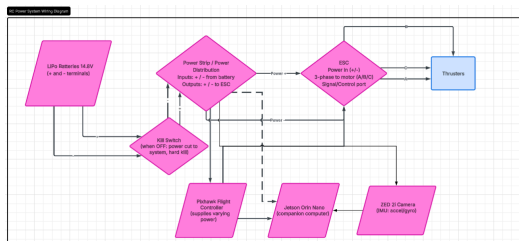


Figure 10. Schematic of the electrical system

III. TESTING STRATEGY

(i) Markers

Given the simplicity of the Recon (Bins) task in competition, consistency is a major determining factor for the acquisition of its associated points. Therefore, testing is critical; each iteration of the marker was dropped into a pool about 6ft deep and its trajectory was observed with a metal rod. The first iteration completely failed to fall due to its lack of density caused by the fully 3d-printed nature. Therefore, in the second iteration, a 14mm 316L steel bearing was added to increase the overall density. However, due to the lack of fins, it did not fall straight. Thus, in the third iteration, helical fins were added. However, it was changed in the fourth iteration to straight fins to reduce complexity. An extra bearing was

added for higher consistency, which proved to be effective in testing.

IV. ACKNOWLEDGEMENTS

Our team's success would not have been possible without our mentors, Cdr. William Lauper and Lt. Roger Fronek, and support from our generous sponsors. We would like to thank the following organizations for sponsoring our team: Troy High School NJROTC, Blue Robotics, Blue Trail Engineering, Onshape, Water, SimScale, Navy League of the United States Inland Empire Council, and the Navy League of the United States STEM Institute.

V. REFERENCES

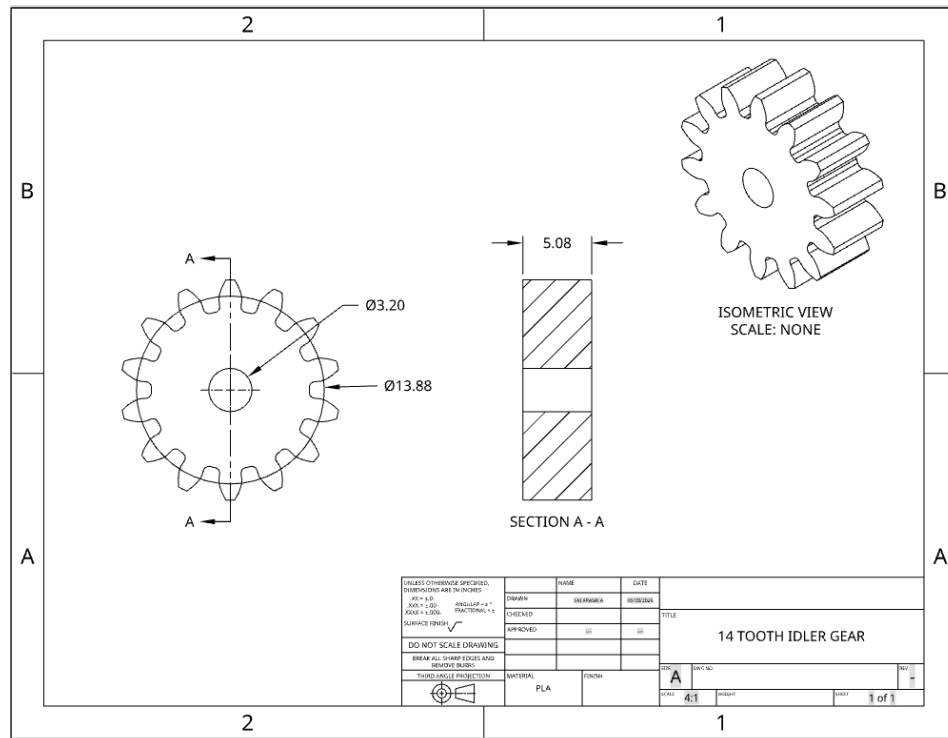
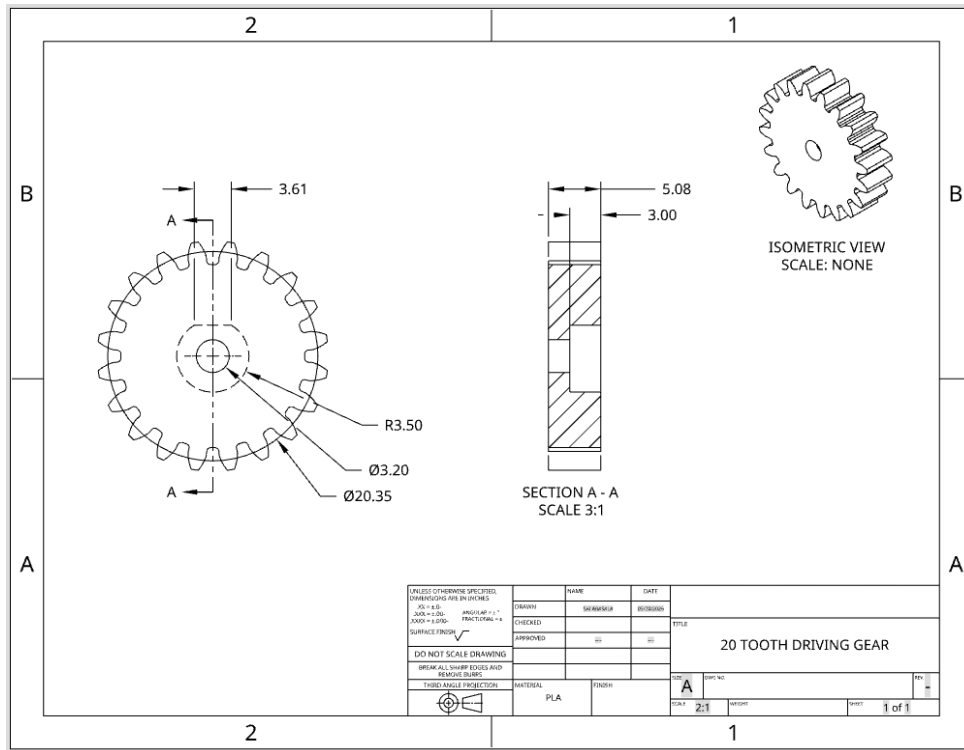
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- [3] "BlueROV2 ROS Simulation," UUVControl GitHub Repository, Jun. 16, 2023. [Online]. Available: <https://github.com/UUVControl/bluerov2>. [Accessed: May 27, 2026].
- [4] "ZED SDK," Stereolabs GitHub Repository, May 24, 2025. [Online]. Available: <https://github.com/stereolabs/zed-sdk>. [Accessed: May 27, 2026].
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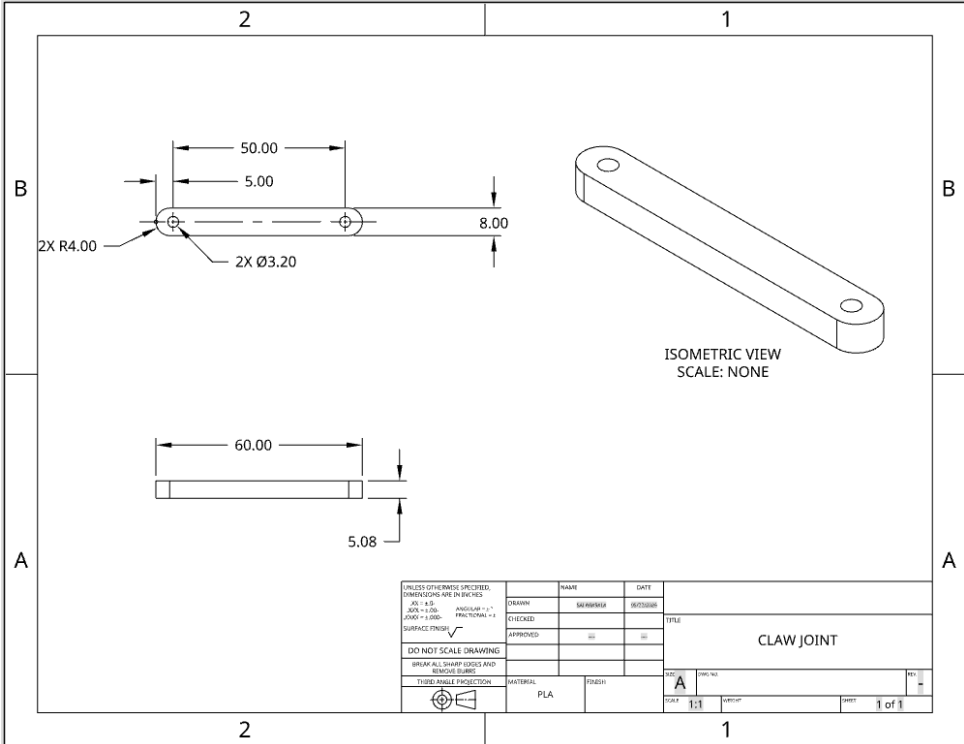
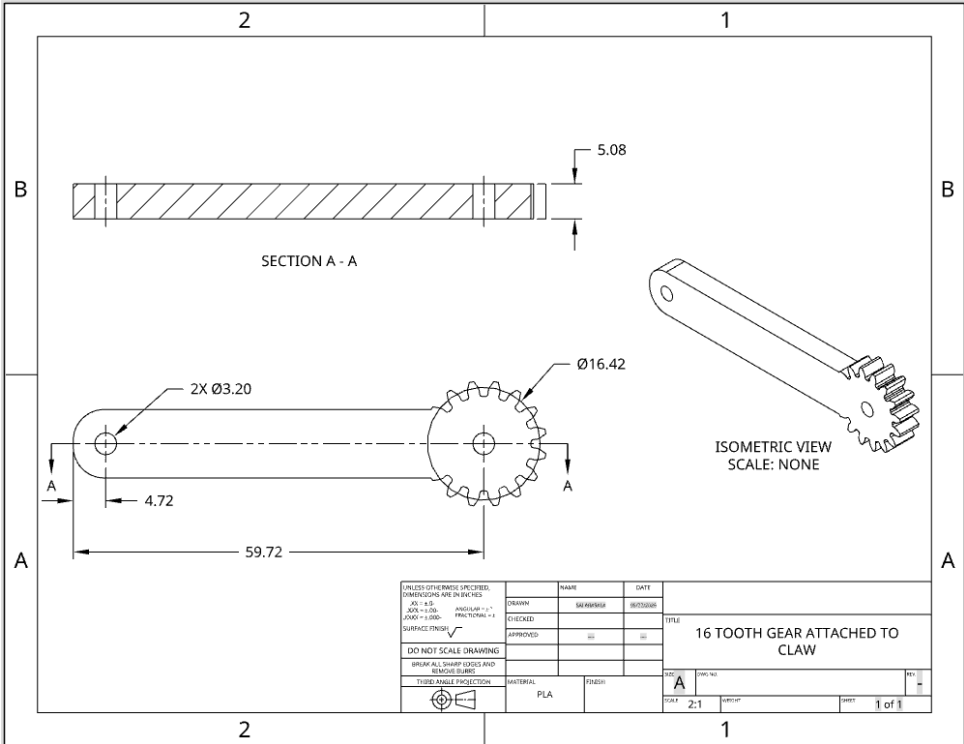
APPENDIX A: COMPONENT SPECIFICATIONS

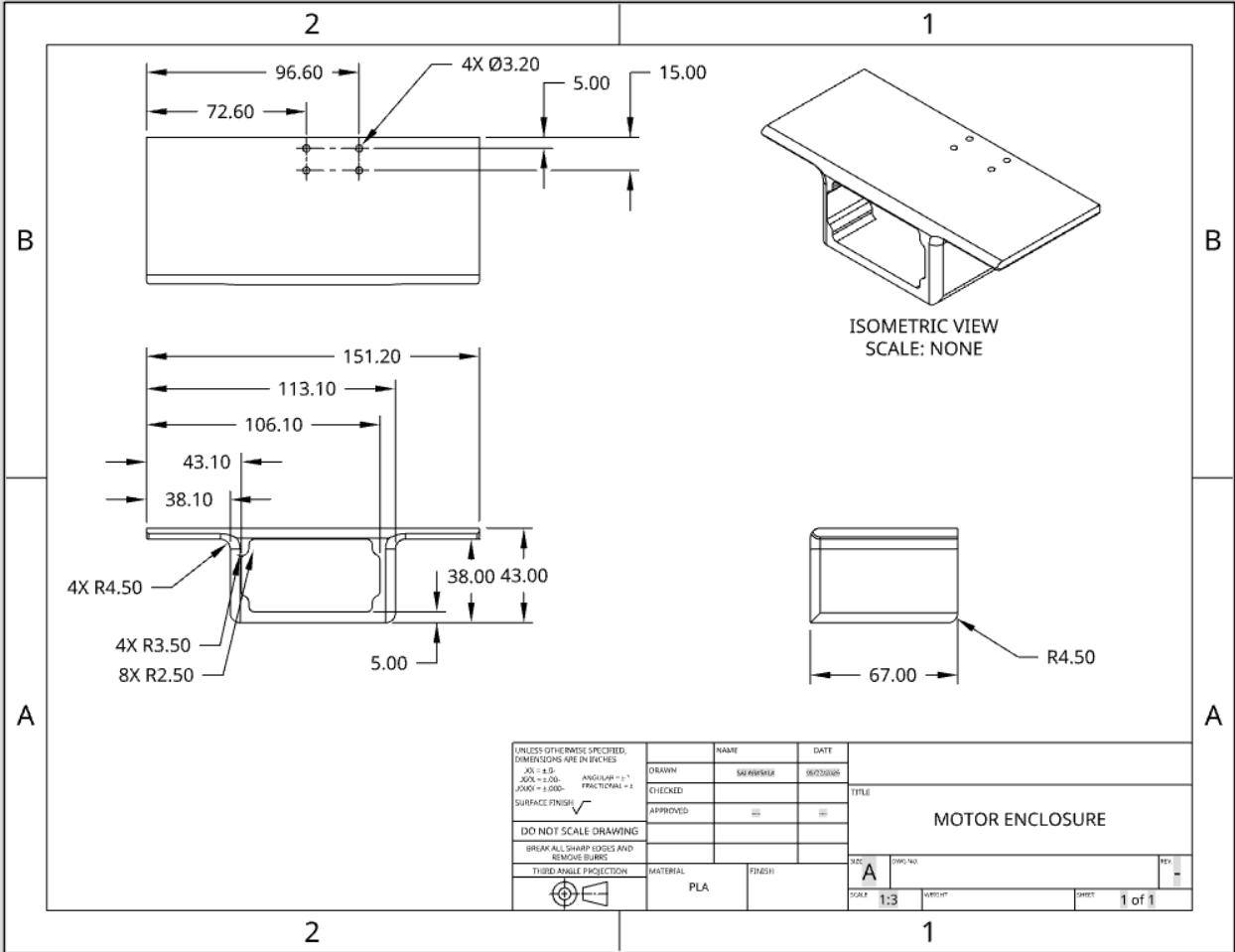
Component	Vendor	Model/Type	Specs	Qty	Total Cost
Battery	Turnigy	Turnigy Graphene Panther 5000mAh 4S 75C	-	4	\$206.08
Battery	Blue Robotics	Lithium Polymer Battery (14.8V, 10Ah)	-	2	\$480.00
CPU	Nvidia	Jetson Orin Nano Developer Kit	GPU and 4 GB of RAM	1	\$429.97
Camera	StereoLabs	ZED 2i Camera	120mm Stereo Baseline, Built-in IMU, barometer, & magnetometer 1080p @ 30fps	2	\$998.00
3D Printer Filament	Elegoo	ELEGOO PLA Filament Black & White	1.75mm 2kg	1	\$28.69
Battery Bags	Amazon	Tenergy 2 Pack, Fire Retardant Lipo Bags	-	1	\$11.99
Kill Switch	Amazon	Hmknana IP67 Waterproof Inline Cord Switch	IP67 12V-24V 20A	1	\$14.99
Tether Spool	Amazon	Fathom Spool	-	1	\$784.00
Algorithms: vision	-	-	YOLOv26 Object Detection, ZED SDK	-	-
Algorithms: localization and mapping	-	-	ZED SDK, Nav2	-	-
Open source software	-	-	ROS Humble, OpenCV, Yolov26, PyTorch, Pymavlink, ZED SDK	-	-

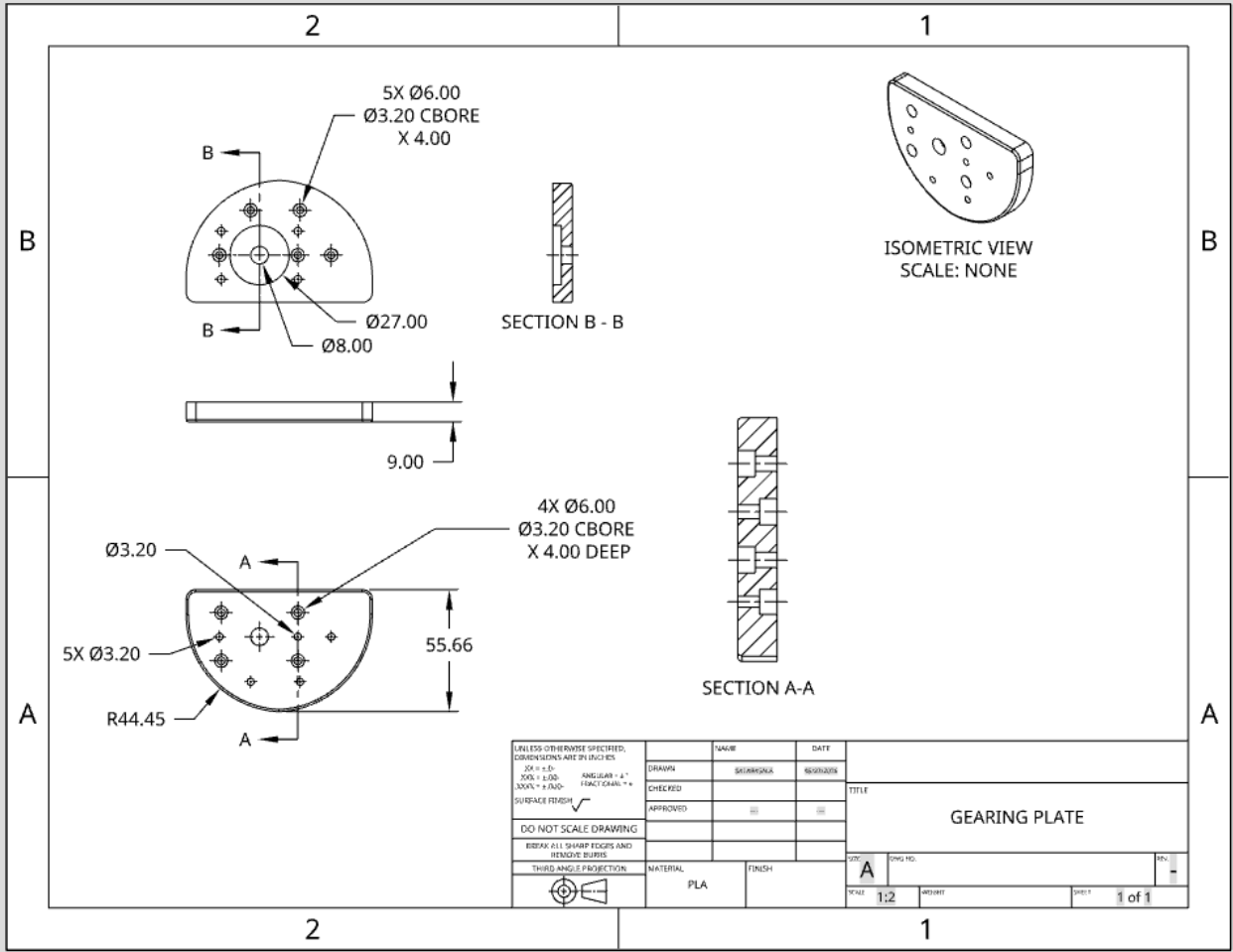
Team size (number of people)	-	-	17 persons	-	-
Expertise ratio (software vs. electrical vs. mechanical)	-	-	6 Software 3 Electrical 8 Mechanical	-	-

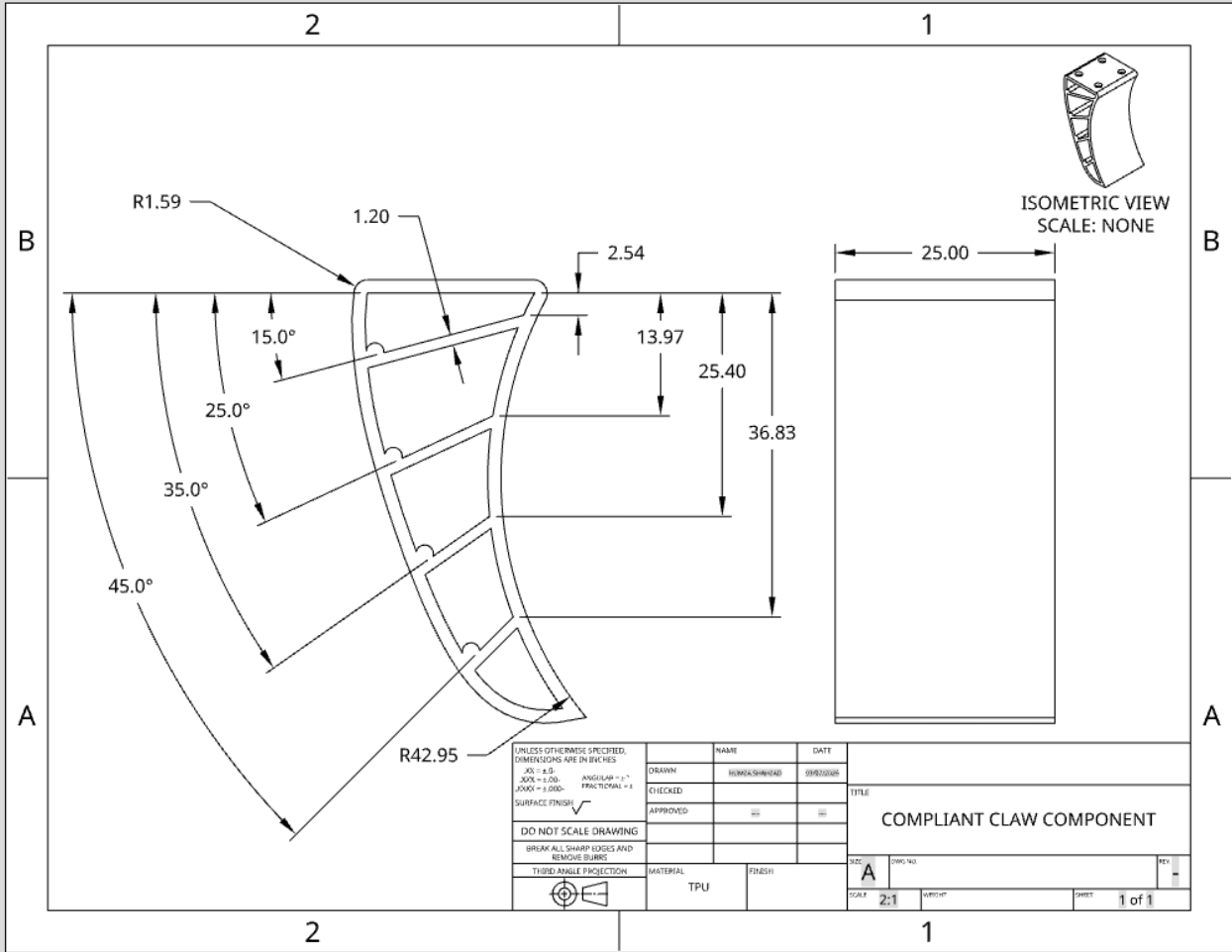
APPENDIX B: CAD DRAWINGS FOR CLAW COMPONENTS



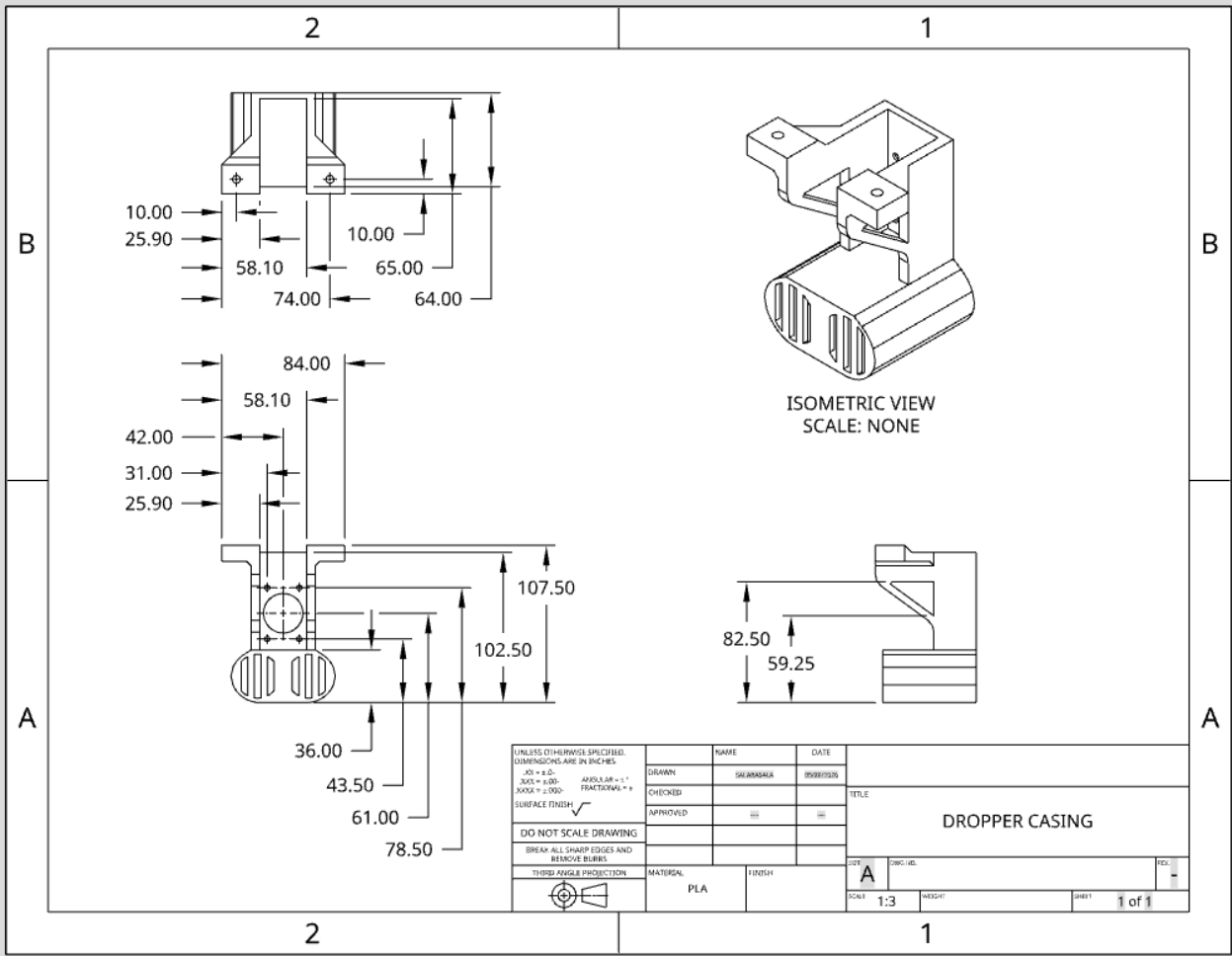


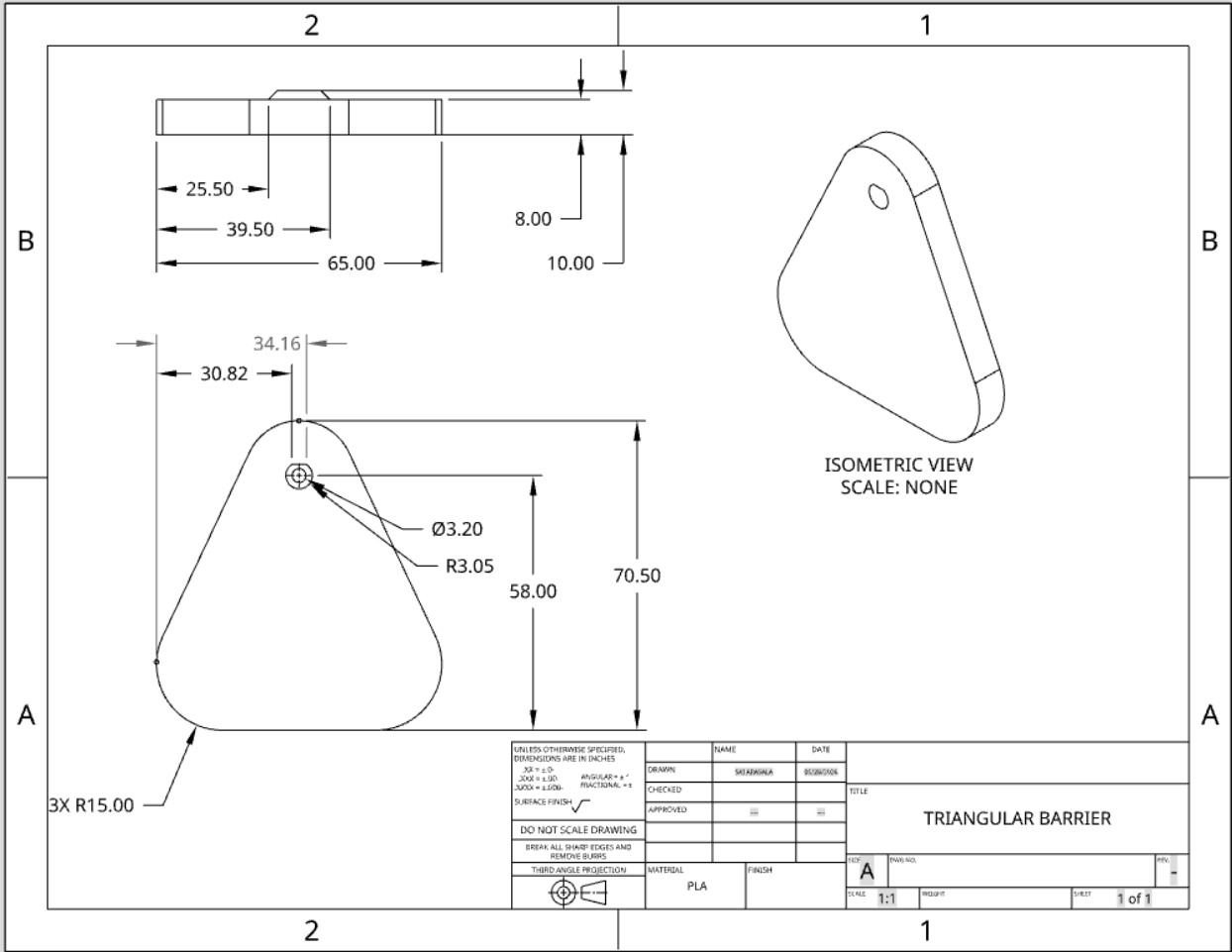






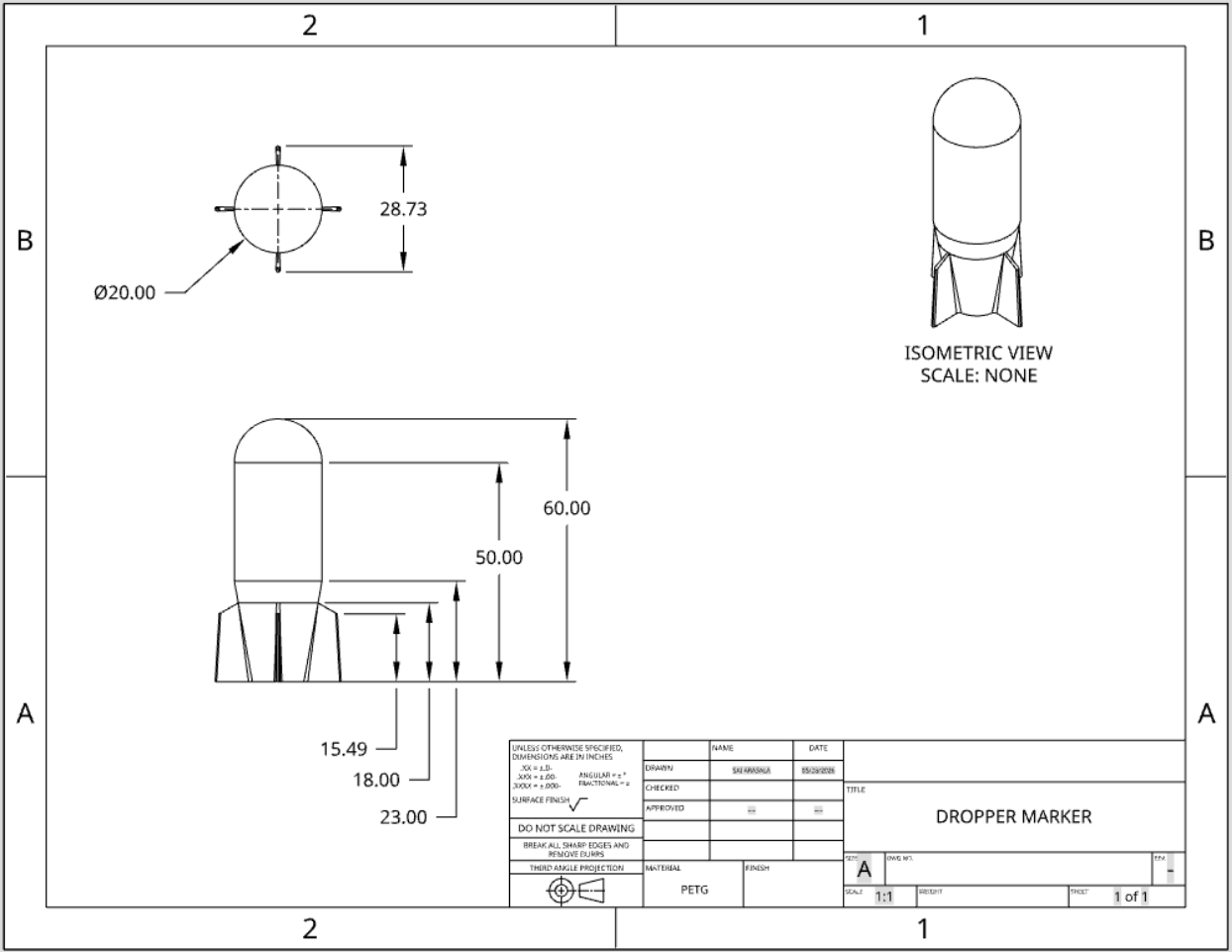
APPENDIX C: CAD DRAWINGS FOR DROPPER COMPONENTS





3X R15.00

<small>UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES</small> <small>3X ± 0.000 ANGULAR ± 0.1°</small> <small>±0.005 ± 0.001 FRACTIONAL ± 0.005</small> <small>SURFACE FINISH ✓</small> <small>DO NOT SCALE DRAWING</small> <small>BREAK ALL SHARP EDGES AND REMOVE BURRS</small> <small>THIRD ANGLE PROJECTION</small>	NAME	DATE	TITLE TRIANGULAR BARRIER	
	DRAWN	SEARHREA		8/26/2008
	CHECKED			
	APPROVED			
	MATERIAL	FINISH	REV. A	
	PLA		SCALE 1:1 SHEET 1 of 1	



APPENDIX D: TESTING STRATEGY FOR MECHANICAL SYSTEMS

Claw tests:

<p>- Strength</p>	<ol style="list-style-type: none"> 1. Have claw pick up an object of 1 lb 2. Move claw around and see if object falls out 3. Increase the weight by 1 lb until the claw cannot hold the weight anymore 4. Repeat this process underwater
<p>- Shape</p>	<ol style="list-style-type: none"> 1. Have claw pick up a circle shaped object 2. Repeat the process for a square shape, a hoop, a handle, and hexagonal shape 3. Record data in the data table

Dropper Tests:

- Accuracy	<ol style="list-style-type: none">1. Place dropper above circular object2. Release dropper3. Record how far dropper falls from intended target4. Repeat for 10 times and record data in data table
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Torpedo Tests:

- Accuracy	<ol style="list-style-type: none">1. Aim torpedo at target2. Release torpedo3. Record how far off it is from the actual target4. Repeat for 10 times and record all data in data table
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