**ME 2110 – Section A10**

**Final Project Report**


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**Abstract**

This report details the design, fabrication, and testing processes that were involved in building a robot to maximize points in the ME 2110 competition and design challenge. Team Cloudjumper approached the design and fabrication process by aiming to package mechanisms for all possible competition tasks within size constraints, with materials that fit within budget restrictions. Testing consisted of the evaluation of completion accuracy and consistency of the robot's mechanisms. The entire building process involved many alternative designs and constant iterative testing, leaving the team with a robot that prioritized consistency over complexity. Cloudjumper ultimately achieved 13$^{th}$ place out of 70 teams in the final competition, with the 3rd highest average score of 156 points per run.

**Introduction**

The team was tasked with building a robot for PatternFox Design, a company looking to get a start in educational robotics competitions starting with the ME 2110 competition. With the goal of maximizing points in the competition while staying within restrictions and guidelines, the team had to manage different design tradeoffs. For example, the team aimed to package together 5 subassemblies to complete each possible competition task, with guidelines restricting the robot's size within a 12" x 24" x 18" box. Within those 5 subassemblies, the limited number of actuators and motors needed to be carefully allocated. In order for the robot's mechanisms to be consistent and durable, choices were made regarding the cost of materials, needing to stay within the $120 budget. This report will discuss the considerations and choices made in the process of designing and building a robot for this unique design challenge with complex tradeoffs.

**Problem Understanding**

The team used the House of Quality (HOQ) to define the customer needs which are separated into four main categories, performance, task completion, disqualifications, and other needs (Fig. 1). All of the needs related to avoiding disqualification are weighted at 10's. Each of the other tasks have different weights depending on the points expected to be gained from them, for example the water bucket task is weighted at a 9 while lighting the bonfire is a 6. The team chose to not leave the starting area for sprint 1, which introduced difficulties with platform height variability. Therefore, the emphasis on leaving the starting area increased from seven to nine. Following sprint 2 the team placed a larger emphasis on aesthetics and designed mechanisms with that in mind. However, after sprint 3, the team pivoted away from aesthetics to maximizing competition points by completing the fish/eel task.

The customer needs directly relate to the specific engineering requirements created for the robot to satisfy the customer (Fig. 2). Some of the most important engineering requirements include repeatability, measured by the robot being functional for 300+ runs, durability of materials, looking for 0% plastic deformation, and size, being within 12x24x18 inches. These requirements had the most correlation with the customer needs making them a larger priority. The team's specification sheet highlights how the target metric for the engineering requirements will be evaluated (Table 1). For example, the robot's repeatability is measured through repeated testing trials while the size constraint is evaluated through the boxing test.

The requirements presented multiple tradeoffs for the team to consider, such as number of given actuators versus number of tasks to complete. The team had to carefully allocate actuators for each task by looking at the prioritization of each task and assigning more reliable actuators to tasks with more weight, such as using a motor for the water bucket task and solenoids for the fish/eels. Additionally, the team tried to maximize durability of materials while minimizing cost to stay within budget. This meant using more expensive materials only for key connections or mechanisms. One of the synergies that existed between engineering requirements is minimizing repair time by maximizing the durability of materials.

**Conceptual Design**

In order to maximize the points gained during the competition, an ideal robot addresses all point tasks presented in the competition rules. Some of the main functions are highlighted in the function tree and are split into two separate sections, one to avoid disqualification and the other to earn points. Avoiding disqualification is done by passing the boxing test which is accomplished through several functions (Fig. 3). Tasks that involve earning points include: activating the robot, moving the entirety of the robot out of the Dragon Stables (starting area), move the torch pucks into the bonfire zone (Fig. 4), extend to hit the water bucket lever, gathering fish/eel, storing the fish/eel, storing fish/eel, hold sheep, and deposit sheep from the robot to the Great Hall container (Fig. 5). By looking at possible methods of accomplishing each function the team gained insight into which actuators could be used for various tasks.

All of these functions, along with possible ways to tackle each of them, are presented in the morphological matrix (Table 2) which outlines possible methods to accomplish point earning tasks. Examples of possible devices include motorized wheels to move the robot off the starting area, an extending motor-powered rail to flip the bucket, and a four bar linkage to move the torches. The sheep process consists of functions to both hold and distribute the sheep, where one possible method is a mechanically activated system that releases a sheep as the Great Hall rotates. The fish and eel subsystem consists of multiple functions, each of which requires a specialized piece of equipment. A hook attached to the end of a swing arm is responsible for collecting fish and eels from the rotating center stand. Sorting and putting the fish and eels in their respective areas involves a size-restrictive ramp that leads to ramps capable of guiding the fish and eels to their respective locations.

The final decisions as highlighted in the matrix include extension arms to collect the torches, wheel to move the robot, a telescoping arm to extend to the water bucket, a sweep bar to collect fish/eels, a sizing ramp to separate, and pivoting swipers to distribute, a vertical container to hold the sheep and a piston to distribute them.

**Design Overview**

The overall dimensions for the robot are 10” x 23.5” x 18”, built with an MDF base and four wooden 2” x 1”posts on the corners to provide mounting points (Fig. 6). The drivetrain has four wheels located inside the frame of the robot, raising the base of the robot two inches above the ground to allow clearance for the torches (Fig. 7). The robot is rear wheel drive with a 3:1 gear ratio to increase the robot speed and leave the starting area faster (Fig. 8). A flanged coupling connector is used to avoid slippage between the gear and motor.

The sheep mechanism involves a vertically-oriented PLA container which holds all 4 sheep (Fig. 9). The container has an opening where one sheep can make contact with a mounted piston that shoots sheep into the sheep pen once a limit switch hits the rotating wall of a pen. The following sheep fall into place due to gravity. The piston and the container are mounted on an MDF plate, which rests on 3D-printed sleeves that wrap around the corner pillars of the robot. There are multiple sleeves per pillar, allowing for height adjustment of the entire mechanism according to nominal differences in tracks.

The waterbucket design (Fig. 10) is inspired from a traditional crane telescopic boom. The main boom is made from PVC and wood cylinders interconnected by string. 3D printed caps maintain interlayer space for the string to rest to reduce friction and increase the outer radius the string flips over. The activation lever is -50deg angle with respect to the ground, so the goal of the boom is not to push through the lever but to elevate a mousetrap up to activation range (Fig. 11). The mousetrap is restricted by a milled slot of delrin and when the boom reaches max height another string goes through releasing the mousetrap arm. Delrin was chosen for this purpose because it’s durable and will have less deformation over time. This has a substantial amount of force in addition to a parallel angle to the lever, which has made our success rate above 95%.

For the fish/eel subsystem (Fig. 12), track height variation was a big design constraint and to combat this the team used a solenoid to release a sweeper arm that falls from above onto the track. This ensures that the arm will land above the track and not get stuck below. After the fish and eels are collected they get sorted through a sizing ramp into two boxes in the robot.

Swing arms attached to the buckets are tensioned with rubber bands and mounted at an angle at the pivot allowing them to naturally swing out of the robot and align with the respective troughs (Fig. 13). A second solenoid is utilized to hold the tensioned system in place until the last 7 seconds of competition, when the arms are released and the fish/eels that were collected get distributed into their sections. 3 seconds later both solenoids release and drop so that there's no movement after the 40 seconds, to avoid disqualification.

The torch subsystem went through multiple iterations before finally consolidating on the final design, which consists of a piston-driven scissor arm with plates on the end responsible for dragging the torches back in upon piston retraction (Fig. 14). A slot was cut into the center of the robot, serving as a guide for the piston-to-scissor arm connector. Upon activation, the piston pushed along the guide insert, ensuring that the scissor arms open perpendicular to the robot consistently (without rotation). In order to maximize the scissor arms durability, lasercut aluminum scissor beams were utilized near the center of the scissor arms, seeing as aluminum is better equipped than other materials to handle the stresses and sudden acceleration of piston actuation. The ends of the scissor arms were printed out of PLA to minimize the amount of weight pulling down on the scissor arms at full extension.

The algorithm that the code follows to ensure each system activates and complies with the 40 second time period is found in the flow chart (Fig. 15). Upon activation, the robot moves forward and the torch arms extend, until a limit switch on the front of the robot is triggered by hitting the Great Hall. Once the robot stops moving, the torch scissor lifts contracts to bring in the torches, the solenoid triggers to release the fish/eel collection hook, and the telescoping arm extends for 12 seconds. Simultaneously, when the limit switch for the sheep mechanism triggers, the piston fires to launch a sheep into the pen. After 33 seconds the second solenoid fires to release the fish/eel distribution buckets.

Each component on the robot can be found in the first half (Table 3) and second half (Table 4) of the Bill of Materials (BOM), which includes the material, supplier, cost, and sizing. The total cost of the components is $100.29, which complies with the $120 budget.

**Alternative Designs**

All developed robot designs were compared via the evaluation matrix. Areas of weighted comparisons included all of the competition point tasks, along with customer needs (Fig. 16). The first alternative design considered using drawer slides to reach the Great Hall rather than moving the whole robot, consistent with the design utilized for Sprint 1 (Fig. 17). Alternative designs for the subsystems included: a sheep dispensing mechanism laid horizontally, a scissor lift for hitting the water bucket (Fig. 18), two deployable pivoting rails under the robot for bonfire lighting, and foldable walls that fall once activated in order to funnel fish and eels (Fig. 19). The areas that set the final competition robot design (Alternative Design 3) apart, according to the Evaluation matrix, were the torch mechanism, which consisted of the scissor arm system and was capable of accumulating more points, and the fish and eel separation device, which, despite depending on robot movement speed, was still effective. All areas were scored subjectively, with the team relying on sprint experiences and testing for point decisions.

**Performance Results**

Overall there was huge improvement in the robot's performance from sprint 1 to competition which can be seen in figure 20. The robot's average increased by 153 points, and went from a low score of -2 points in sprint 1 to the highest scoring robot in competition with 219 points. Through this process the team conducted many tests to benchmark the robot's performance. The three main aspects the team was testing was accuracy, consistency, and ideal alignment, for each subsystem and for full robot tests on various tracks (Table 5). The testing results for the most tested subsystem, the water bucket mechanism, show the consistency, achieving 50 points every time, and the ability to reset in under 1 minute (Fig. 21). In competition, the water bucket mechanism continued to be the most reliable subsystem which means the team met that customer need which was weighted at a 9.

**Conclusion**

In the ME 2110 design challenge, the team was able to build a robot that completed all five possible competition tasks while staying within all restrictions and guidelines. Out of all design alternatives, the final robot implemented a telescoping boom for hitting the water bucket, a rear-wheel drivetrain, a vertically-oriented sheep-piston system, a piston-driven scissor arm for bringing in torches, and a size-sorter swing-arm mechanism for collecting fish and eel. This design managed the packaging of all potential mechanisms while achieving consistent functionality and maintaining simplicity. In the final competition, the robot was able to achieve the 3$^{rd}$ highest average score of 156 points per run, a massive increase from an average of less than 3 points in Sprint 1. Through this design challenge, the group successfully learned how to manage tradeoffs to maximize performance despite limitations.

## Appendix

| | | |
|---|---|---|
| Performance | 9 | Consistent Robot Performance |
| | 8 | Durability |
| | 10 | Move autonomously |
| | 8 | Balanced movement |
| Task Completion | 9 | Leave starting area |
| | 6 | Separate and deposit fish & eel |
| | 6 | Light bonfire |
| | 8 | Deposit sheep |
| | 9 | Extinguish fire |
| Disqualifications | 10 | Complete within time restriction |
| | 10 | Built within budget |
| | 10 | Fits size restrictions |
| | 10 | Stop when power is cut |
| | 10 | Fits component restrictions |
| Other | 4 | Aesthetic |
| | 8 | Safety |

*Figure 1: Customer needs*

| Engineering Requirements | Target |
|---|---|
| Repeatability | Functional for 300+ runs |
| Points acquired per run | >150 points |
| Location Consistency | 10% margin of error |
| Repair Time | < 10min |
| Reset Time | < 1 min |
| Percentage of robot in starting position | 0% of robot in starting area |
| Accuracy of fish/eel separation | > 90% accurate |
| Durability of Materials | 0 plastic deformations |
| Projectile Launch Angle | < 0 degrees |
| Projectile Velocity | < 100in/sec |
| Arm accuracy for water bucket | 95% of attempts knock over water bucket |
| Completion Time | 40 seconds limit |
| Cost | < $120 |
| Size | 12in x 24in x 18in |
| Number of energy storing devices | 2 mousetraps, 5 rubber bands, 4 actuators, 2 motors |
| Safety | 0 external damages caused |

*Figure 2: Engineering specifications & quantitative targets*

*Table 1: Specification Sheet*

| D/W | Requirements | Responsibility | Source/Rationale | How Validated |
|---|---|---|---|---|
| Safety | | | | |
| D | 0 external damages caused | Testing Team | Competition safety requirements | Repeated Testing Trials |
| Geometry | | | | |
| D | 12in x 24in x 18in | Design Team | Competition requirements/box dimensions | "Boxing" |
| Material | | | | |
| D | 2 mousetraps, 5 rubber bands, 2 actuators | Design Team | Materials provided by competition organizers | Bill of Materials |
| W | 0 Plastic deformation of materials | Manufacturing & Design Team | Provide more durability, longevity, and consistency is systems | Repeated Testing Trials |
| Maintenance | | | | |
| W | Functional for 300+ runs | Testing Team | Maximize durability to increase performance consistency | Repeated Testing Trials |
| W | < 10 min repair time | Testing Team | Minimize time lost in case of any malfunctions to run through competition smoothly | Repeated Testing Trials |
| D | 0 electrical failures | Mechatronics Team | Ensure all connections are soldered to minimize system failures | Repeated Testing Trials |
| W | < 1 minute reset time after competition | Competition Team | Make sure going on and off the track is done quickly | Repeated Testing Trials |
| Operation | | | | |
| D | 0 Premature activations | Testing Team | No movement, activation during boxing period | Repeated Testing Trials |
| D | 40 second run time | Mechatronics Team | Perform tasks only during length of competition | Timer |
| W | 5% margin of error for location of robot | Mechatronics Team | Maintain consistent location to improve repeatability of tasks | Repeated Testing Trials |
| D | Run on 120V | Mechatronics Team | Power supplied by track | Electrical components' specification sheets |
| W | Acquire 150+ points | All Teams | Acquire enough points during competition to ensure a satisfactory performance | Repeated Testing Trials |
| W | 0% of robot left in starting position during competition run | Testing Team | Maximize point gain during competition | Measurement Tools |
| W | 90% accurate fish/eel separation during competition run | Testing Team | Maximize point gain and minimize point loss during competition | Repeated Testing Trials |
| Costs | | | | |
| D | < $120 | Manufacturing Team | Competition budget requirements | Bill of Materials/Budget spreadsheet |
| Kinematics | | | | |
| W | Projectile velocity < 100in/sec | Design Team | Putting sheep into quadrants without the bouncing out | Kinematic Software |
| W | Projectile launch angle =< 0° | Design Team | Competition requirements | Kinematic Software |
| W | The arm extension knocks over the water bucket when the water falls out => 95% | Design Team | Minimize distance between extended arm and water bucket to maximize point gain | Measurement Tools |

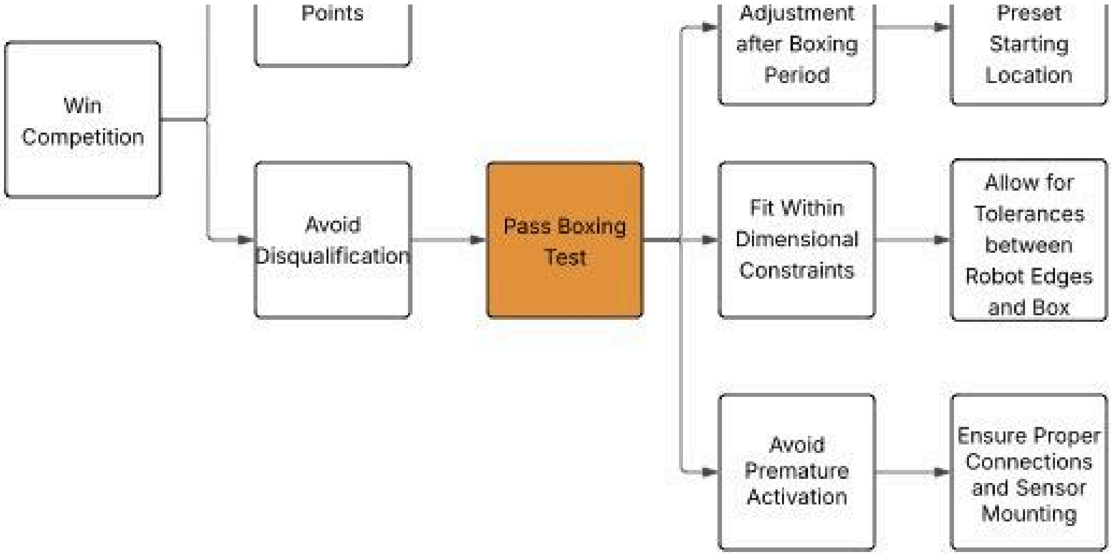



*Figure 3: Function Tree part 1*

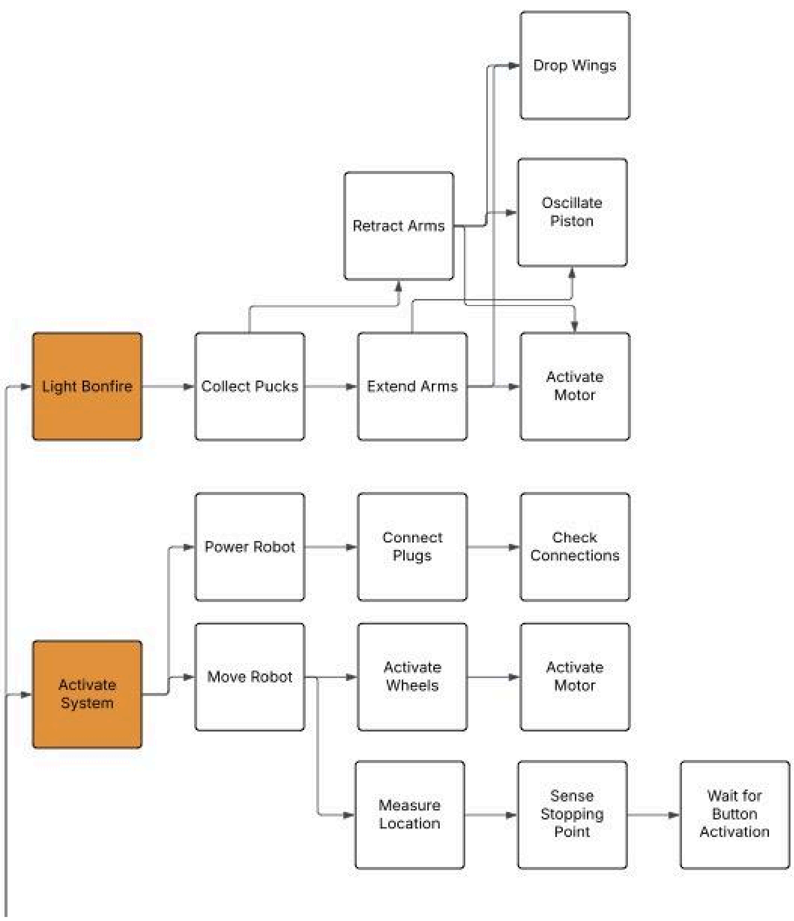



*Figure 4: Function Tree part 2*

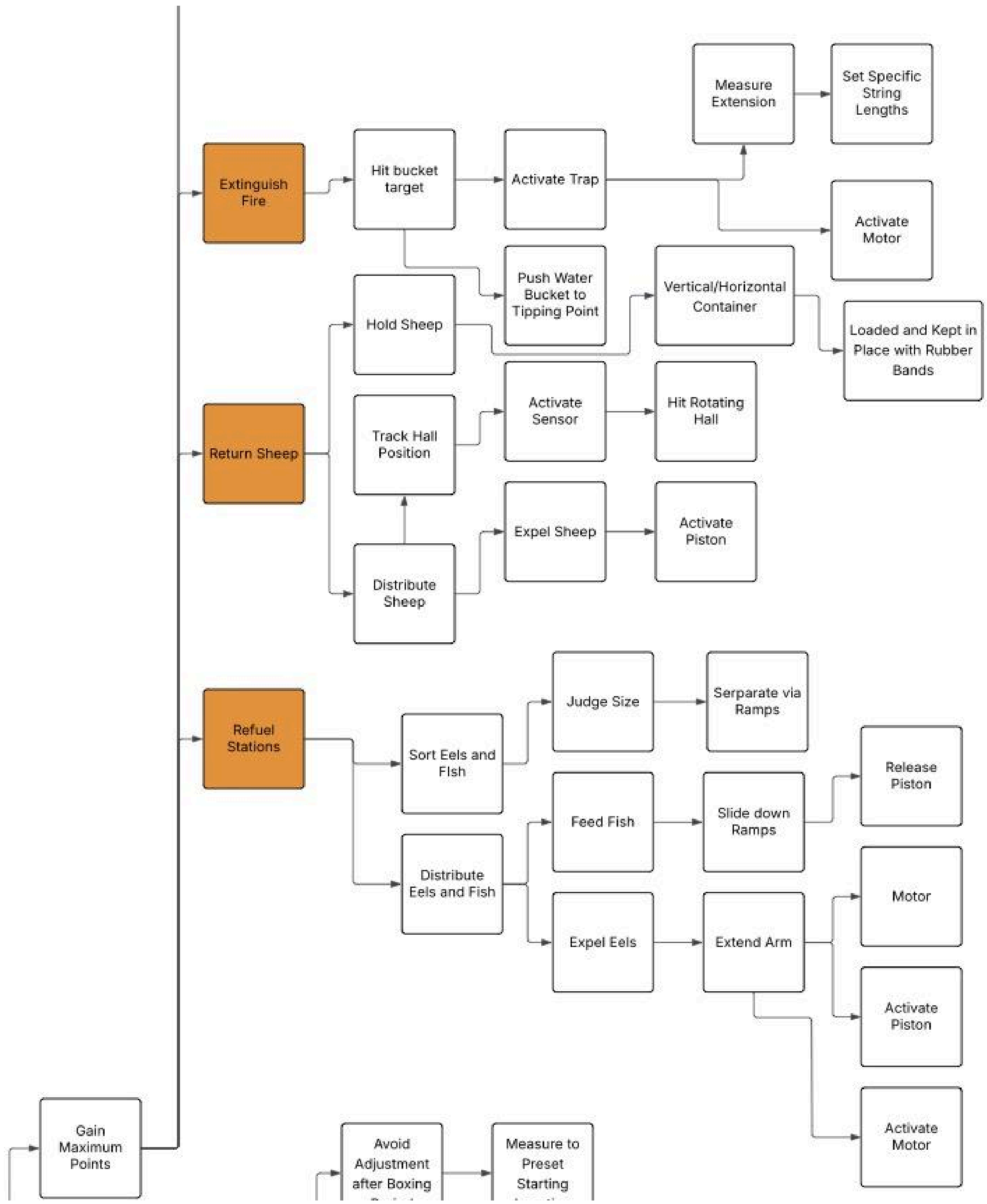
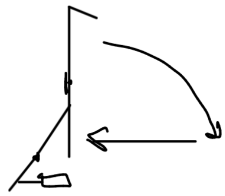
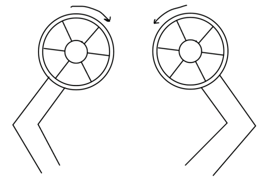
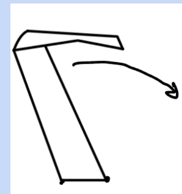
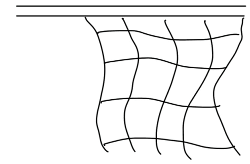
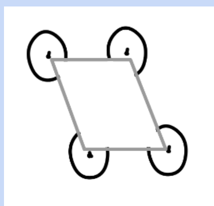
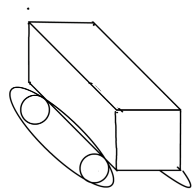
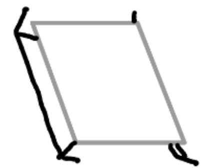
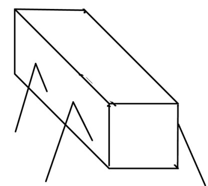
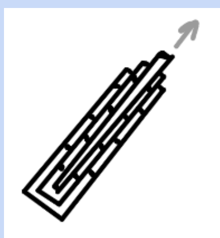
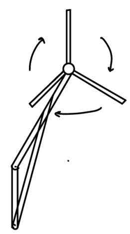
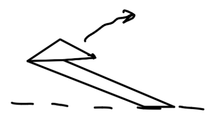
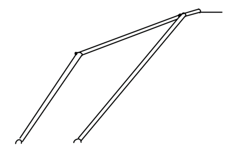
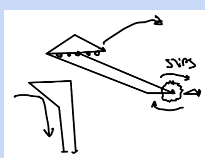
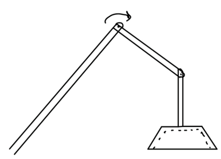
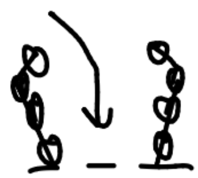
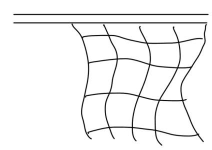
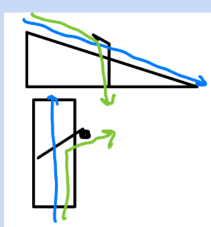
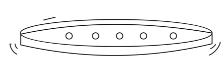
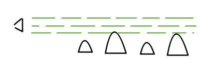
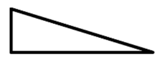
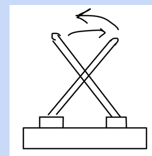
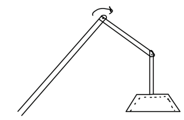
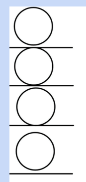
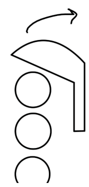
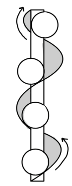
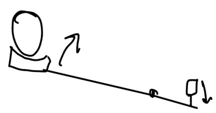
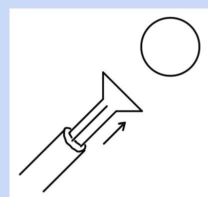
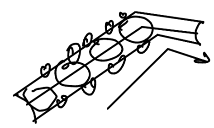
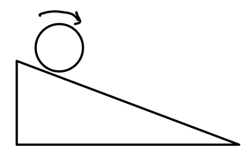



*Figure 5: Function Tree part 3*

*Table 2: Morphological Matrix*

| **Functions** | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| **Collect Torches** |  4-Linkage Rotating Bar |  Wheel Intake |  Swing Arm |  Net |
| **Move Robot** |  Wheels |  Treads |  Sliding Rails |  Legs |
| **Hit Water Bucket** |  Telescoping Arm |  Spinner |  Extending Arm |  3-Linkage Bar |
| **Collect Eels/Fish** |  Sweep Bar |  Bucket |  Wheel Intake |  Net |
| **Separate Eels/Fish** |  Sizing Ramp |  Sorting Plate |  Funnel |  Size Sensor |

| | | | | |
|---|---|---|---|---|
| **Distribute Eels/Fish** |  Ramp |  Wipers |  Cylinder |  Bucket |
| **Hold Sheep** |  Container |  Vertical Container |  Gate |  Screw Ramp |
| **Distribute Sheep** |  Catapult |  Piston |  Wheel track |  Ramp |

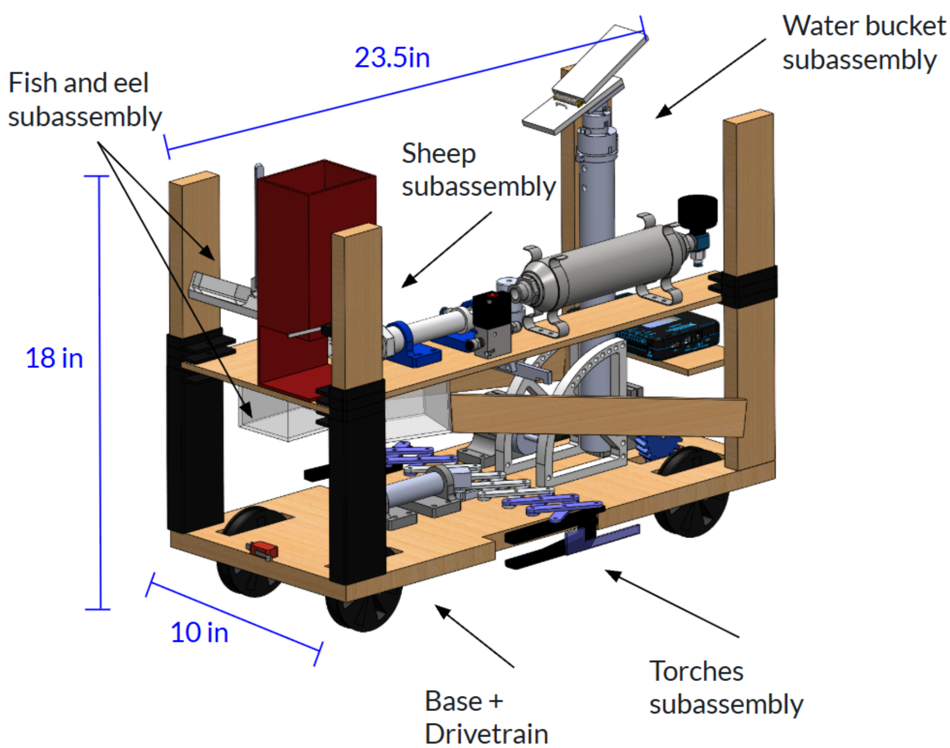



*Figure 6: Full robot CAD with Dimensions*

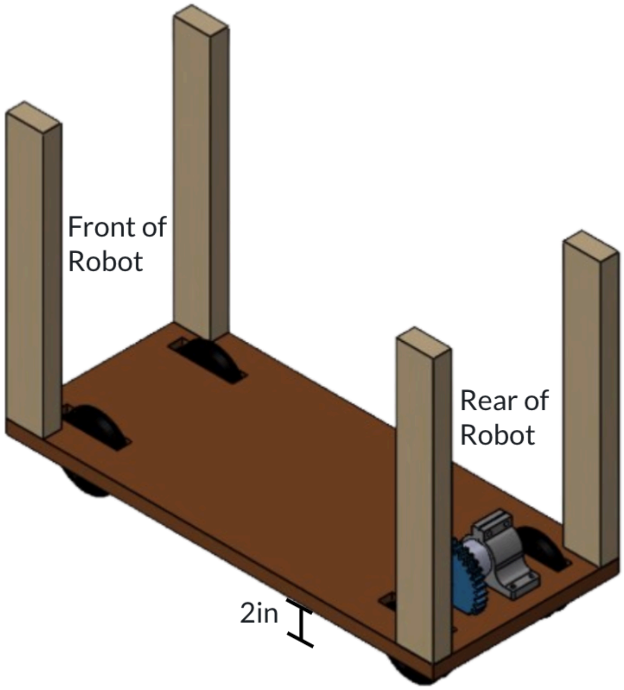



*Figure 7: Base and frame subassembly*

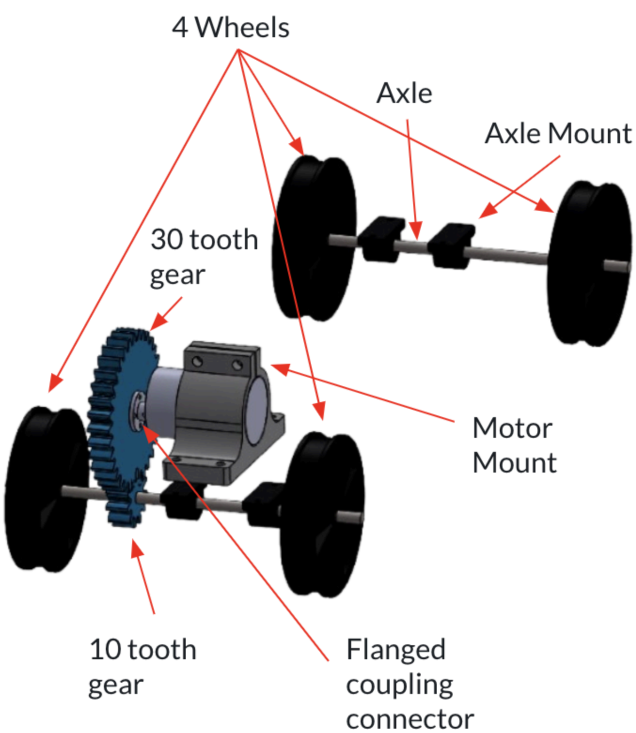



*Figure 8: Drivetrain*

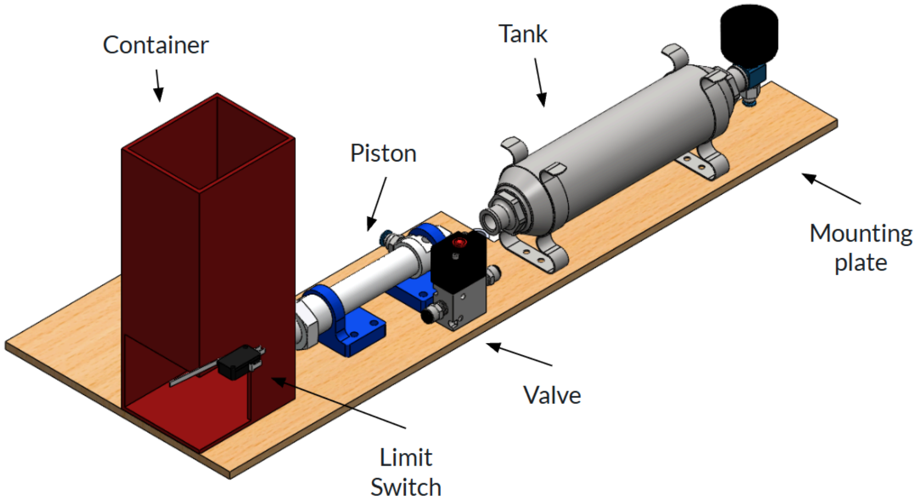



*Figure 9: Sheep Subsystem and Mounting Plate*

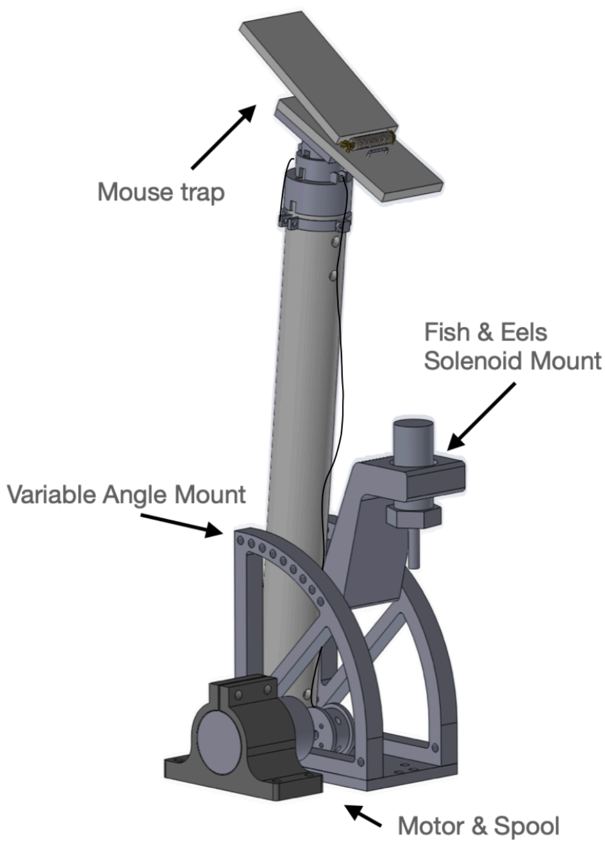



*Figure 10: Collapsed water bucket subsystem*

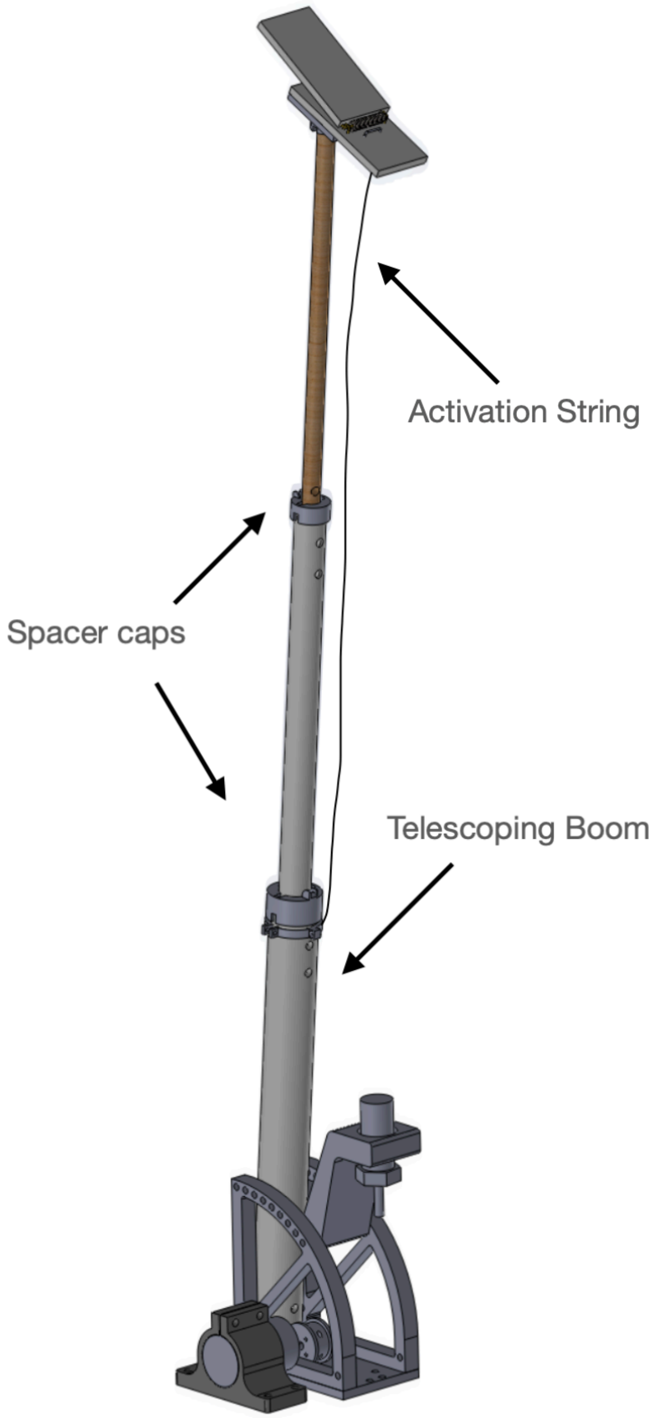



*Figure 11: Extended water bucket assembly*

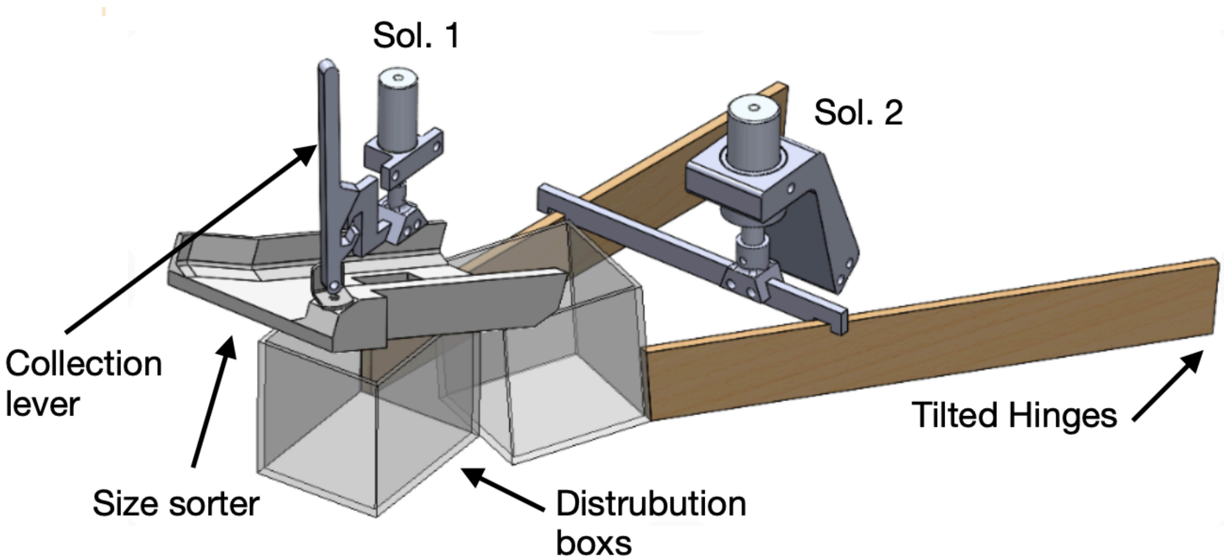



*Figure 12: Fish and Eel Subsystem*

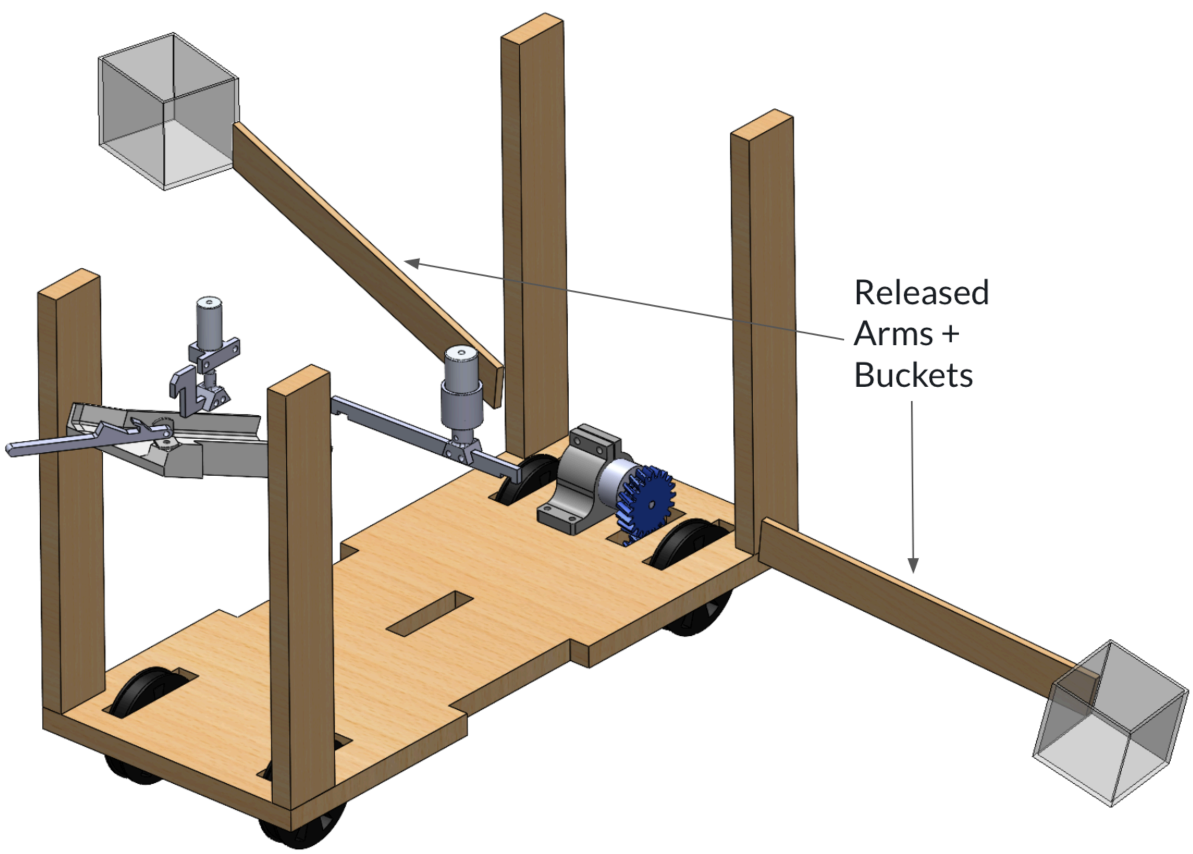


*Figure 13: Released fish/eel system*

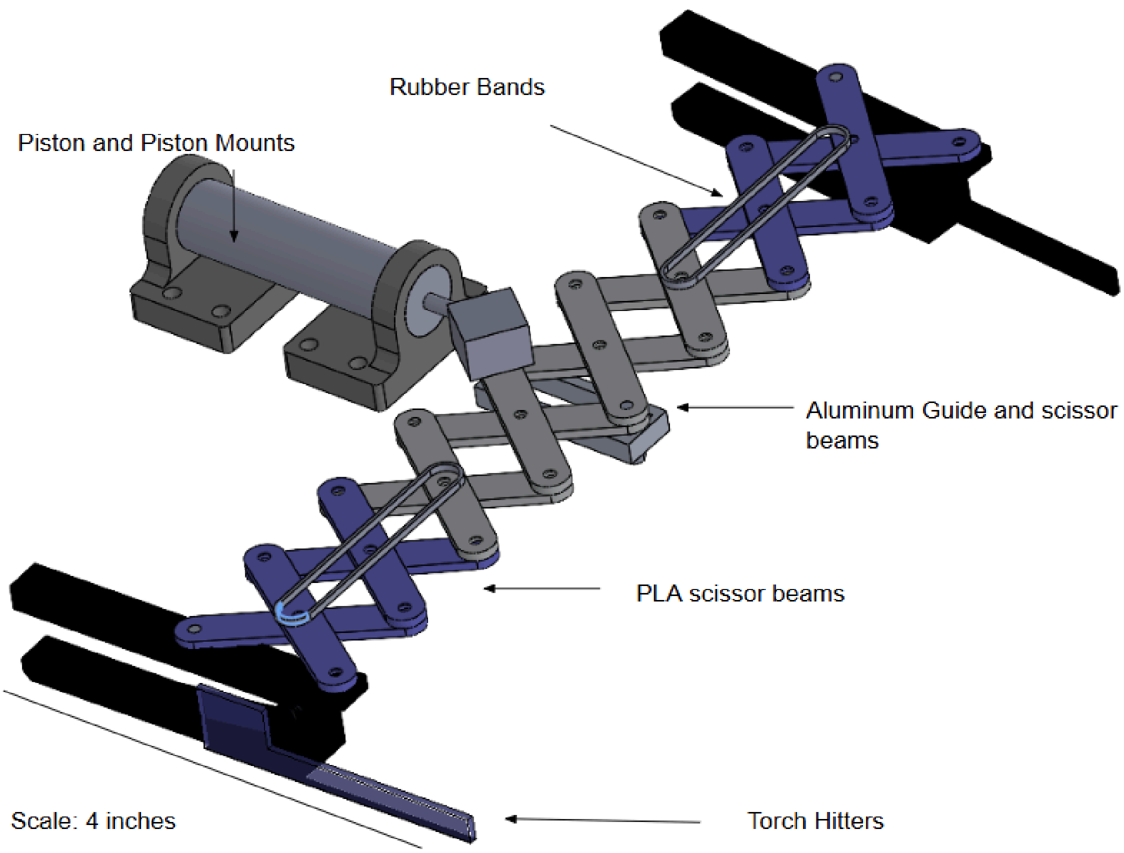



*Figure 14: Torches CAD*

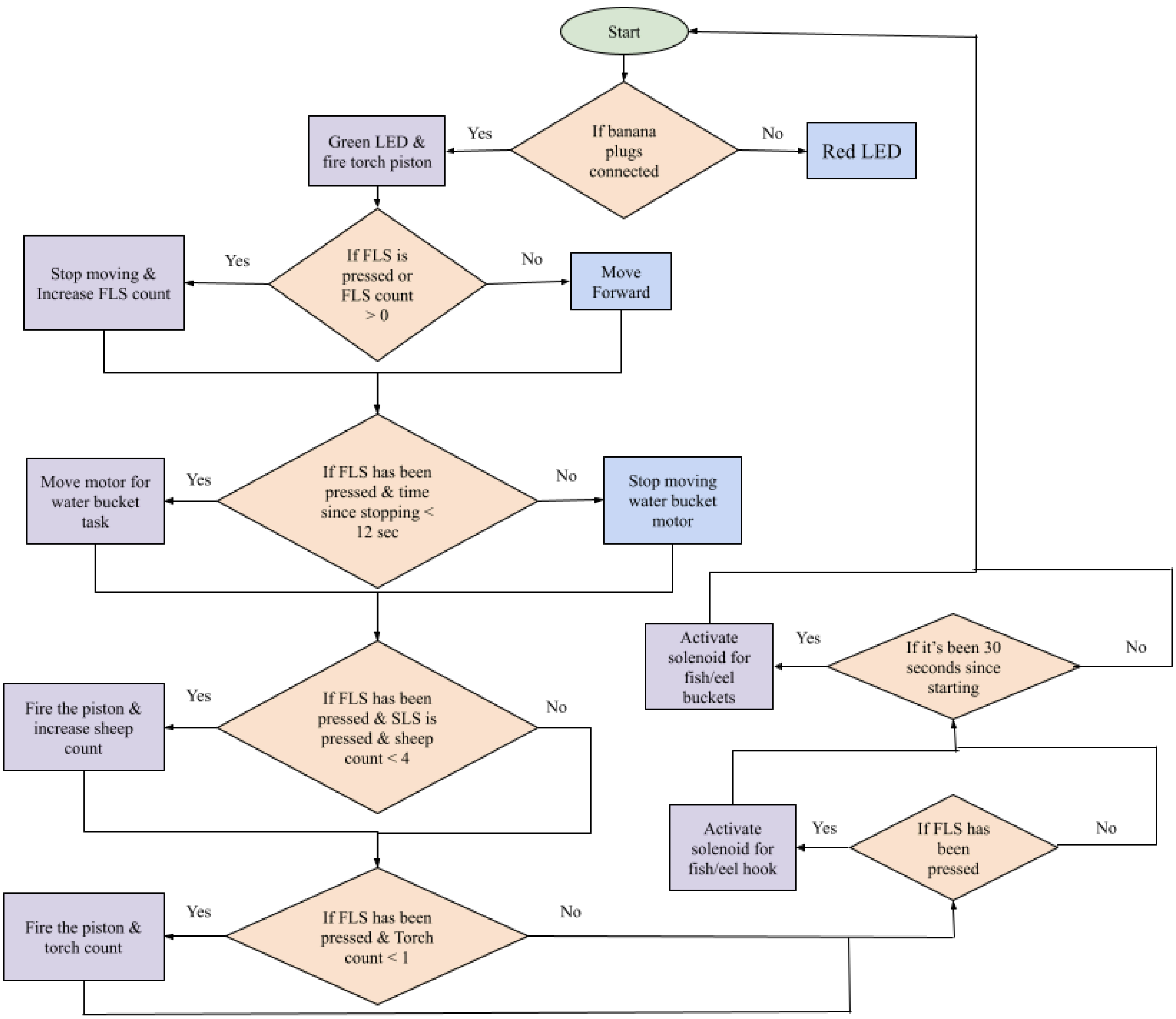



*Figure 15: Flow chart for algorithm*

*Table 3: First half of Bill of Materials*

| Bill of Materials: Project/Product Development | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Project:** | ***ME 2110 Final Competition*** | | | | | | |
| **Engineering Team:** | Vaughn Berhoff | | | | | | |
| | Youseung Kim | | | | | | |
| | Reena Shah | | | | | | |
| | David Trujillo | | | | | | |
| **Date:** | 11/14/2025 | | | | | | |
| | | | | | **Mfg. + Other Analysis** | | |
| **Module/ Part #** | **Description/Name** | **Qty** | **Unit Cost ($)** | **Total Cost ($)** | **Purchase Link/Supplier** | **Mass (g)** | **Material** |
| A-1: Water bucket Telescoping Boom | | | | | | | |
| A-1-1 | Outer PVC | 1 | $0.76 | $0.76 | Home Depot | 186.27 | PVC |
| A-1-2 | Middle PVC | 1 | $0.68 | $0.68 | Home Depot | 58.97 | PVC |
| A-1-3 | Inner Wood | 1 | $0.60 | $0.60 | Home Depot | 18.14369 | Wood |
| A-1-4 | String | 1 | $0.08 | $0.08 | Home Depot | N/A | String |
| A-1-5 | Outer Cap | 1 | $0.16 | $0.16 | N/A | 8 | PLA |
| A-1-6 | Middle Cap | 1 | $0.08 | $0.08 | N/A | 3.92 | PLA |
| A-1-7 | Middle Bace Cap | 1 | $0.03 | $0.03 | N/A | 1.62 | PLA |
| A-1-8 | Inner Bace Cap | 1 | $0.03 | $0.03 | N/A | 1.36 | PLA |
| A-1-9 | String Clip | 1 | $0.06 | $0.06 | N/A | 3.1 | PLA |
| A-2: End affecter | | | | | | | |
| A-2-1 | Mouse trap | 1 | $0.00 | $0.00 | Given | Given | Given |
| A-2-2 | MDF Hand | 1 | $0.11 | $0.11 | Home Depot | 19 | MDF |
| A-2-3 | Hand Adapter | 1 | $0.19 | $0.19 | N/A | 9.74 | PLA |
| A-2-4 | Delrin Axctivater | 1 | $0.98 | $0.98 | McMaster, 8662K21 | 1.41 | Delrin |
| A-2-5 | String | 1 | $0.08 | $0.08 | Home Depot | N/A | String |
| A-2-6 | Screws | 8 | $0.16 | $1.28 | McMaster | N/A | Screws |
| A-2-7 | Washers | 4 | $0.60 | $2.40 | McMaster | N/A | Washers |
| A-2-8 | Nuts | 8 | $0.02 | $0.16 | McMaster | N/A | Nuts |
| A-3: Base | | | | | | | |
| A-3-1 | 3D Printed supports | 2 | $1.32 | $2.64 | N/A | 52.7 | PLA |
| A-3-2 | Screws | 10 | $0.16 | $1.60 | McMaster | N/A | Alloy Steel |
| A-3-3 | Long Screws | 3 | $1.32 | $3.96 | McMaster | N/A | Alloy Steel |
| A-3-4 | Nuts | 10 | $0.02 | $0.20 | McMaster | N/A | Nuts |
| A-3-5 | L-Bracket | 4 | $1.27 | $5.08 | McMaster | N/A | Aluminum |
| A-3-6 | Motor Mount | 1 | $1.61 | $1.61 | N/A | 32.12 | PLA |
| A-3-7 | Motor | 1 | $0.00 | $0.00 | Given | Given | Given |
| A-3-8 | Flange Coupling Connector | 1 | $0.88 | $0.88 | Amazon | 22.963 | #45 Steel |
| A-3-9 | Flange Bolts - 4x40 | 4 | $0.12 | $0.47 | McMaster | N/A | Black-Oxide Alloy Steel |
| A-3-10 | Flange Nuts | 4 | $0.04 | $0.15 | McMaster | N/A | Zinc-Plated Steel |
| A-3-11 | Motor Mount Bolts | 4 | $0.24 | $0.94 | McMaster | N/A | Black-Oxide Alloy Steel |
| A-3-12 | Motor Mount Nuts | 6 | $0.02 | $0.12 | McMaster | N/A | Zinc-Plated Steel |
| A-3-13 | Spool | 1 | $0.30 | $0.30 | N/A | 5.9 | PLA |
| B-1: Robot Frame | | | | | | | |
| B-1-1 | MDF Base | 1 | $3.00 | $3.00 | Home Depot | 6371.29 | MDF |
| B-1-2 | Corner Post | 4 | $0.25 | $1.00 | Home Depot | 201.849 | Wood |
| B-1-3 | Wood Screws | 8 | $0.12 | $1.00 | McMaster | N/A | Zinc Plated Steel |
| B-1-4 | Bumper | 1 | $0.14 | $0.14 | Home Depot | 245.8 | MDF |

*Table 4: Second half of Bill of Materials with final cost*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| B-2: Drivetrain | | | | | | | |
| B-2-1 | Wheels | 4 | $2.02 | $8.06 | N/A | 40.32 | PLA |
| B-2-2 | Lower Gear | 1 | $0.23 | $0.23 | N/A | 4.54 | PLA |
| B-2-3 | Upper Gear | 1 | $1.42 | $1.42 | N/A | 28.42 | PLA |
| B-2-4 | Motor Mount | 1 | $1.61 | $1.61 | N/A | 32.12 | PLA |
| B-2-5 | Motor | 1 | $0.00 | $0.00 | Given | Given | Given |
| B-2-6 | Axle Mounts | 4 | $0.18 | $0.70 | N/A | 3.5 | PLA |
| B-2-7 | Axles - 0.25in diameter | 2 | $1.09 | $2.18 | Home Depot | 201.638 | #45 Steel |
| B-2-8 | Flange Coupling Connector | 1 | $0.88 | $0.88 | Amazon | 22.963 | #45 Steel |
| B-2-9 | Flange Bolts - 4x40 | 4 | $0.12 | $0.47 | McMaster | N/A | Black-Oxide Alloy Steel |
| B-2-10 | Flange Nuts | 4 | $0.04 | $0.15 | McMaster | N/A | Zinc-Plated Steel |
| B-2-11 | Axle Mount Bolts | 16 | $0.13 | $2.10 | McMaster | N/A | Black-Oxide Alloy Steel |
| B-2-12 | Axle Mount Nuts | 16 | $0.02 | $0.25 | McMaster | N/A | Zinc-Plated Steel |
| B-2-13 | Motor Mount Bolts | 6 | $0.24 | $1.42 | McMaster | N/A | Black-Oxide Alloy Steel |
| B-2-14 | Motor Mount Nuts | 6 | $0.02 | $0.12 | McMaster | N/A | Zinc-Plated Steel |
| C-1: Sheep Mechanism | | | | | | | |
| C-1-1 | Sheep Container | 1 | $8.37 | $8.37 | N/A | 167.41 | PLA |
| C-1-2 | Elevated Plate | 1 | $2.43 | $2.43 | Home Depot | 189.37 | MDF |
| C-1-3 | Short Pillar Sleeve | 1 | $0.48 | $0.48 | N/A | 19.05 | PLA |
| C-1-4 | Long Pillar Sleeve | 1 | $1.14 | $1.14 | N/A | 45.74 | PLA |
| C-1-5 | Pillar Sleeve Segment | 9 | $0.19 | $1.71 | N/A | 7.63 | PLA |
| C-1-6 | Piston Mount | 2 | $0.31 | $0.62 | N/A | 12.44 | PLA |
| E-1-10 | Piston | 1 | $0.00 | $0.00 | Given | Given | Given |
| C-1-7 | Bolts | 10 | $0.52 | $5.22 | McMaster | N/A | Black-Oxide Alloy Steel |
| C-1-8 | Nuts | 10 | $0.02 | $0.20 | McMaster | N/A | Zinc-Plated Steel |
| D-1: Fish & Eel Collection | | | | | | | |
| D-1-1 | Hook | 1 | $0.26 | $0.26 | N/A | 5.22 | PLA |
| D-1-2 | Ramp | 1 | $4.54 | $4.54 | N/A | 90.75 | PLA |
| D-1-3 | Bolts | 6 | $0.16 | $0.94 | McMaster | N/A | Zinc-Plated Steel |
| D-1-4 | Nuts | 6 | $0.02 | $0.12 | McMaster | N/A | |
| D-1-5 | Solenoid Mount | 1 | $0.20 | $0.20 | N/A | 3.95 | PLA |
| D-1-6 | Solenoid | 1 | $0.00 | $0.00 | Given | Given | Given |
| D-1-7 | Actuation Piece | 1 | $0.04 | $0.04 | Home Depot | 7.3 | MDF |
| D-1-8 | Small Solenoid Adapter | 1 | $0.17 | $0.17 | N/A | 3.35 | PLA |
| D-2: Fish & Eel Distribution | | | | | | | |
| D-2-1 | MDF Box Sides | 6 | $0.13 | $0.75 | Home Depot | 11.06 | MDF |
| D-2-1 | Clear Box Sides | 4 | $0.50 | $2.00 | Amazon | 21.75 | Acrylic |
| D-2-2 | MDF Wings | 2 | $2.78 | $5.56 | Home Depot | 49.16 | MDF |
| D-2-3 | Hinges | 2 | $1.64 | $3.28 | Home Depot | N/A | Zinc-Plated Steel |
| D-2-4 | Eel Box Stopper | 2 | $0.01 | $0.02 | Home Depot | 33.4 | Plywood |
| D-2-5 | Large Solenoid Adapter | 1 | $0.24 | $0.24 | N/A | 4.77 | PLA |
| D-2-6 | Wing Holder | 1 | $0.02 | $0.02 | Home Depot | 19.5 | Plywood |
| D-2-7 | Bolts | 4 | $0.18 | $0.72 | McMaster | N/A | Zinc-Plated Steel |
| D-2-8 | Nuts | 4 | $0.02 | $0.08 | McMaster | N/A | Zinc-Plated Steel |
| D-2-9 | Rubber bands | 2 | $0.00 | $0.00 | Given | | Given |
| D-2-10 | Solenoid Mount | 1 | $1.72 | $1.72 | N/A | 34.48 | PLA |
| D-2-11 | Solenoid | 1 | $0.00 | $0.00 | Given | | Given |
| E-1: Torch Mechanism | | | | | | | |
| E-1-1 | Scissor Lift Segments | 8 | $0.01 | $0.08 | Home Depot | 2.57 | Aluminum |
| E-1-2 | Scissor Lift Segments | 12 | $0.14 | $1.69 | N/A | 2.82 | PLA |
| E-1-3 | Torch Capturer | 2 | $0.89 | $1.79 | N/A | 17.85 | PLA |
| E-1-4 | Connector | 1 | $0.44 | $0.44 | N/A | 8.84 | PLA |
| E-1-5 | Extendor | 2 | $0.88 | $1.75 | Amazon | 3.63 | Acrylic |
| E-1-6 | Scissor Lift Flat Head Screws | 22 | $0.07 | $1.54 | McMaster | N/A | Stainless Steel |
| E-1-7 | Scissor Lift Flat Head Nuts | 22 | $0.03 | $0.62 | McMaster | N/A | Zinc-Plated Steel |
| E-1-8 | Capturer Bolts | 4 | $0.13 | $0.52 | McMaster | N/A | Black-Oxide Alloy Steel |
| E-1-9 | Capturer Nuts | 4 | $0.02 | $0.06 | McMaster | N/A | Zinc-Plated Steel |
| E-1-10 | Piston mount | 1 | $0.63 | $0.63 | N/A | 12.67 | PLA |
| E-1-11 | Piston | 1 | $0.00 | $0.00 | Given | Given | Given |
| | | | | | | | |
| | | | Final Cost: | $100.29 | | | |

| **Customer Need** | Consistent Performance | Durability | Move Autonomously | Balanced Movement | Leave Starting Area | Separate and Deposit fish/eel | Light Bonfire | Deposit Sheep |
|---|---|---|---|---|---|---|---|---|
| **Weight** | 9 | 8 | 10 | 8 | 9 | 6 | 6 | 8 |

| **Customer Need** | Extinguish Fire | Complete within time restriction | Build within Budget | Fits size restriction | Stop when power is cut | Fits components restrictions | Aesthetic | Safety |
|---|---|---|---|---|---|---|---|---|
| **Weight** | 9 | 10 | 10 | 10 | 10 | 9 | 4 | 8 |

| **Task Criteria** | **Importance** | **Design 1 (score\| weighted score)** | **Design 2 (score\| weighted score)** | **Design 3 (score\| weighted score)** | **Design 4 (score\| weighted score)** |
|---|---|---|---|---|---|
| Extinguish Fire | 9 | 0\|0 | 5\|45 | 5\|45 | 4\|36 |
| Deposit Sheep | 8 | 0\|0 | 3\|24 | 3\|24 | 3\|24 |
| Light Bonfire | 6 | 0\|0 | 2\|12 | 4\|24 | 4\|24 |
| Separate and Deposit fish/eel | 6 | 4\|16 | 0\|0 | 1\|4 | 0\|0 |
| Leave Starting Area | 9 | 0\|0 | 5\|45 | 5\|45 | 5\|45 |
| Overall TOTAL (all criteria): | | 59.9 | 80.7 | 85.4 | 79.1 |

*Figure 16 : Evaluation Matrix Customer Needs (Top) and Task Needs (Bottom)*

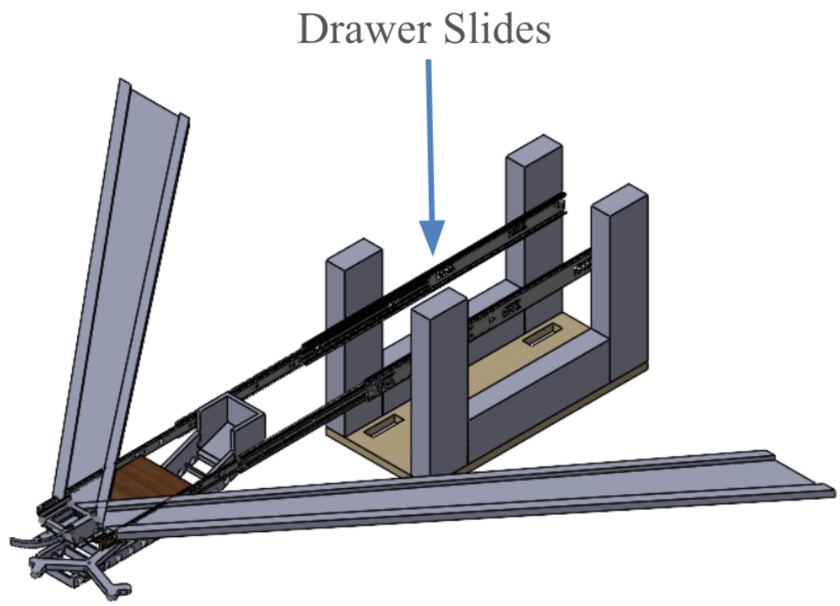



*Figure 17: Alternative Design 1*

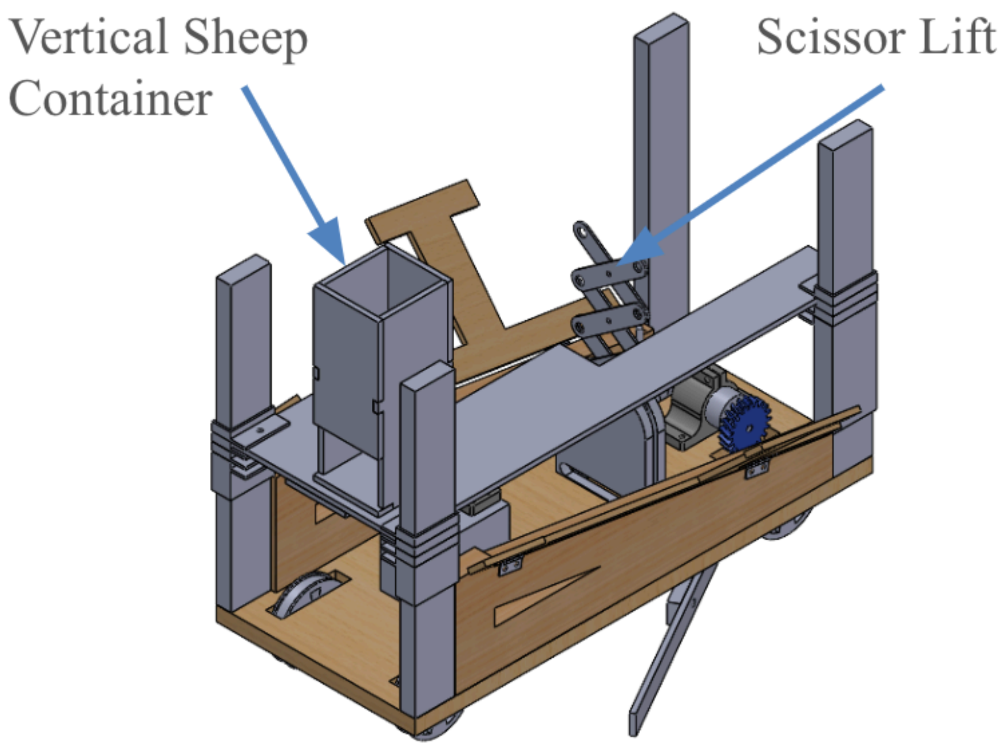



*Figure 18: Alternative Design 2*

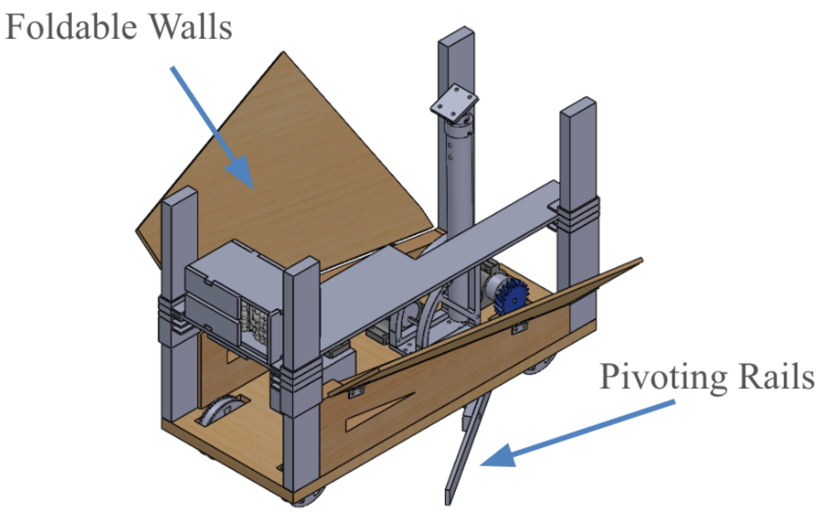



*Figure 19: Alternative Design 3*

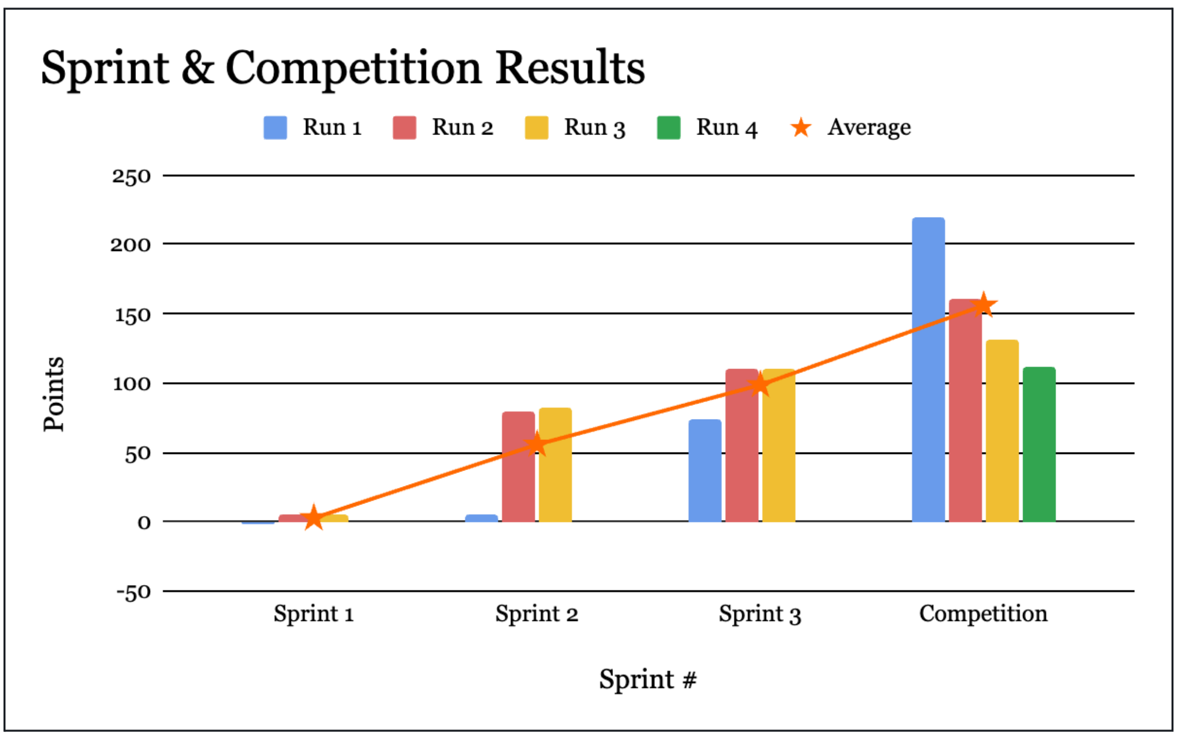



*Figure 20: Sprint and competition results graph*

*Table 5: Testing objectives*

| | | **Test Type** | | |
|---|---|---|---|---|
| | | **Accuracy** | **Consistency** | **Alignment** |
| **Subsystem metric** | **Drivetrain** | Stopping with correct alignment for torches and sheep | 9/10 trails: stopping in same place at the same time | Measurement from front and side of starting area for each track |
| | **Water Bucket** | Hits the center of the water bucket | 9/10 trials: knocks water out of the bucket | Measure and set angle for each track |
| | **Sheep** | Same timing between limit switch triggering and launch of sheep | 9/10 trials: 3 sheep located in the pens | Measure stopping distance for accurate performance from limit switch & height measurement on each track |
| | **Torches** | Arms capable of bringing torches into center of target | 9/10 trials: second or their ring of target | Measurement to keep robot centered between torches on each track |
| | **Fish/Eel** | 95% of fish/eel in their respective trough & 0% eel in fish trough | 9/10 trials: gain at least 25 points from fish/eel | Height measurement on each track to align collector arm |
| | **Overall** | Robot capable of earning 130 points | 9/10 trails: earn 130 points | Under 2:30 minute boxing and set-up |

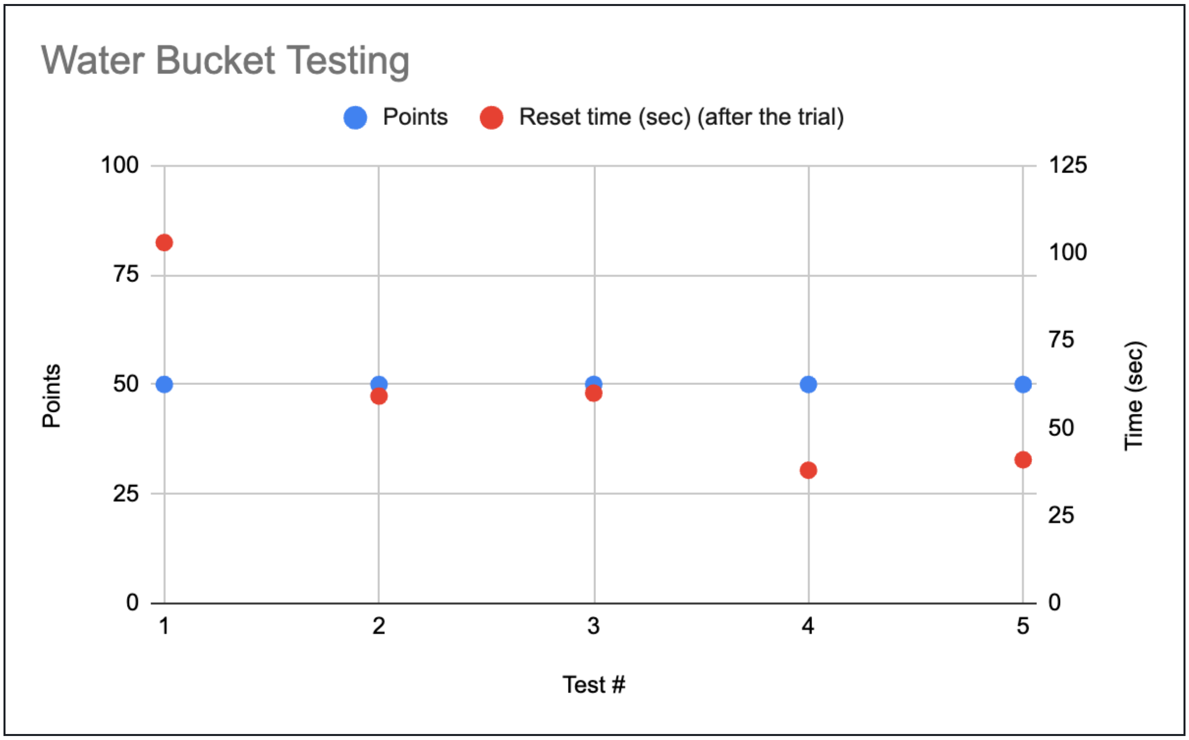



*Figure 21: Water bucket mechanism testing graph*

**Contribution Statement**

1. Vaughn Berhoff – Contributed to the conceptual design, design overview, and related figures
2. Youseung Kim – Contributed to the abstract, introduction, design overview, conclusion, and related figures
3. Reena Shah – Contributed to problem understanding, performance results, design overview, and related figures
4. David Trujillo – Contributed to alternative designs, design overview, torch sub-assembly, and related figures