# <u>ESquad</u>

Team Members:
Marwah Sabrah
Daniel Getega

Class:
ES51

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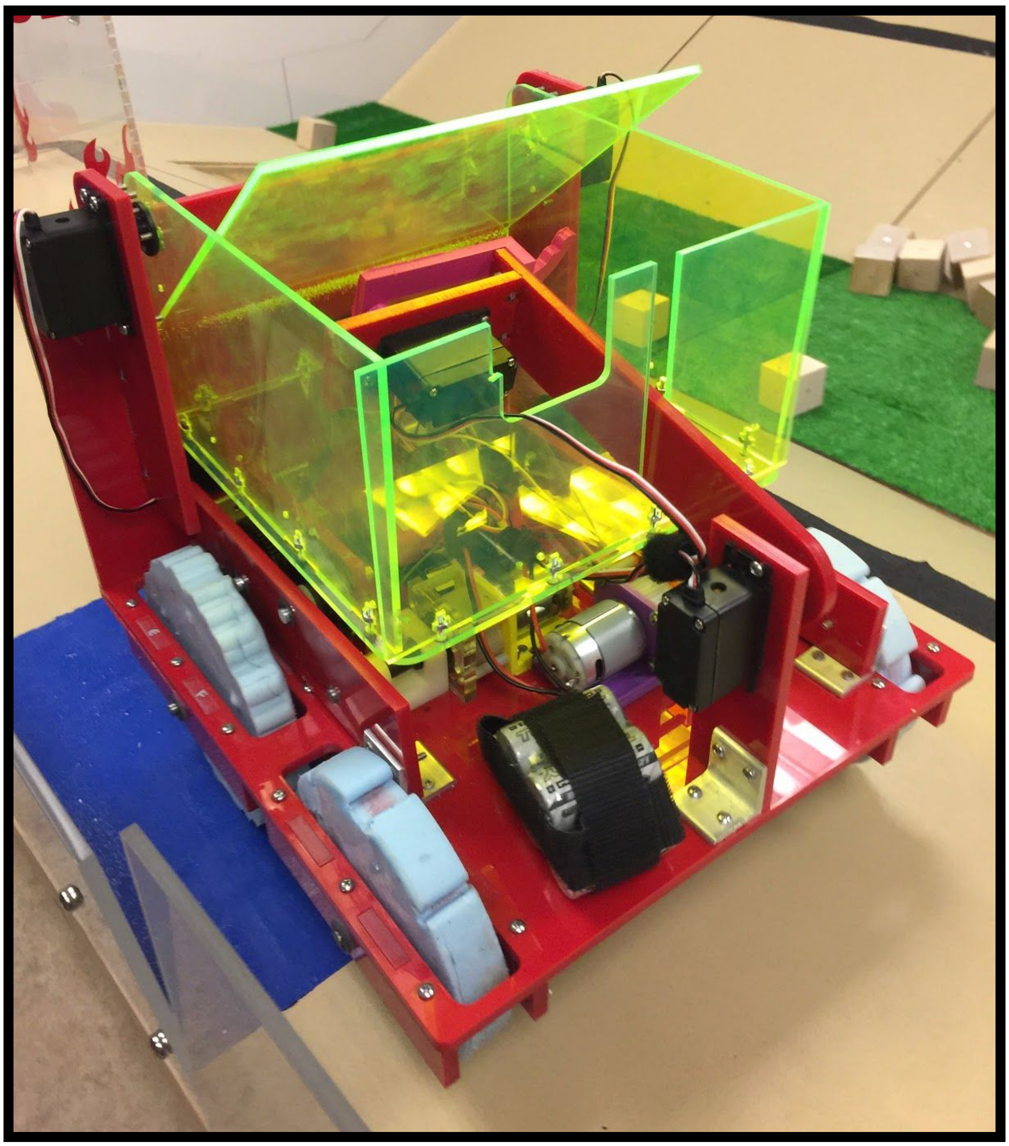


ABSTRACT

The project assignment for ES51 is to design a robot that can score more points than other teams while successfully overcoming the obstacles within a three minute window. Obstacles in this case would be "Power Cubes" in the arena (see figure 1 below), maneuvering about opponents, and going up a ramp. Points are scored by moving the "Power Cubes" from the pit floor to the scoring staircase. Each level of the staircase represents a different point value (5, 3 and 1 for high, medium and low levels respectively). The main obstacle is the ramp that separates the pit from the scoring staircase. Teams must decide whether to drive over the 30 degree ramp or the 15 degrees ramp.

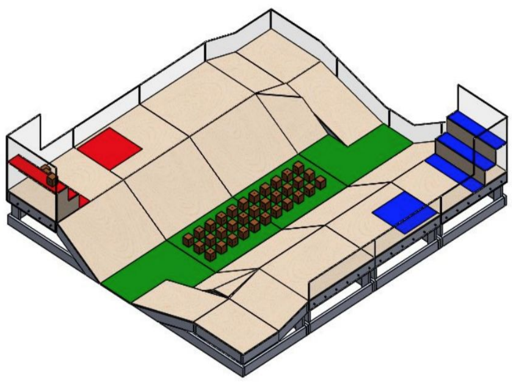


Figure 1: The arena showing the Power Cubes in the pit and the ramps. Scoring zones are highlighted in red & blue.

Our team's approach was to design a mechanism that could pick up the Power Cubes without needing high remote control precision, to ensure that blocks would not fall during transport, and to dump them out all at once. Our design (The Dumper, aka The Beast) utilises a claw that easily picks up Power Cubes and drops them into a bucket. Once collected, the robot transports the Power Cubes to the scoring area. The bucket then rotates over to dump all the blocks in the 3 point and 5 point scoring zones. Our strategy was to limit the amount of trips necessary so as to collect many power cubes in one trip and score them all at once. We initially designed the robot to have a capacity for 12 power cubes that could be scored in the 5 point and 3 point zone. Our final design was capable of scoring up to 21 points by dumping 7 blocks in the 3 point zone.

Concept Development

Before beginning the brainstorming process for our robot, we needed to take into consideration all possible design constraints. We identified and quantified limitations we expected to encounter:

1. 3 sheets of 12" x 24" x ~1/4" acrylic and 1 sheet of 12" x 24" x 1/8" acrylic. This is critical for the robot design because most of the robot is constructed out of acrylic.
2. Remote controllers had a maximum of 6 channels, meaning all design ideas were limited to a combined maximum of 6 servos and motors.
3. Most motors had a no load speed between 7 to 8 rad/s at 1.6V. This affects the max torque and speed we could get from each motor.
4. Robots are limited to a size of 12" x 12" x 12"

Our design needed to be able to overcome the following challenges:

1. Pick up blocks from the pit
2. Drive on both sand paper and turf
3. Drive on an inclined plane of at least 15 degrees
4. Drop/deposit power cubes within the scoring zone
5. Complete the above within 3 minutes

To achieve these challenges while staying in the scope of our limitations, we designed three robots: Model K: The Dumper, Model G: The Magnetizer, and Model M: The Claw (see Figure 2 below).

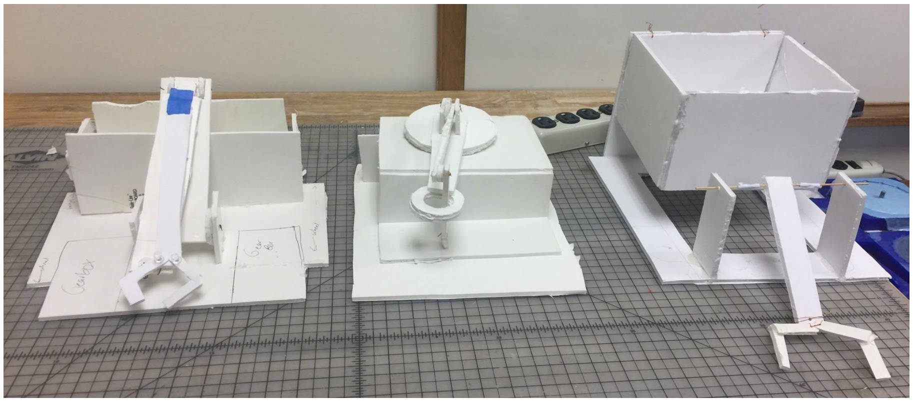


Figure 2: The foam core prototypes of our initial designs. From left to right: The Arm, The Magnetizer, and The Dumper. These prototypes do not include wheels because we decided on the same wheel configurations for all designs.

**The Claw**

The Claw was designed with an arm that could extend up to 8 inches and retract into 4 inches. The claw would open and close to grab Power Cubes. It incorporated a rear container with a capacity to carry 8 Power Cubes from the pit to the scoring zone (see Figure 3 below). The key advantage of this design was the flexible long-reach capabilities of the arm, which gave it the potential to score points from the pit without going all the way up the ramp. It was also advantageous because the simple arm design would allow our robot to be relatively lightweight. Unfortunately, the disadvantages of this design limited its functionality extensively. First, the robot would have to be maneuvered and positioned very precisely into order to pick up blocks, which is both difficult and time consuming. Second, the claw could not pick blocks back up from its rear container because it can only move along two axes, which means it can't score. Finally, the system would be too slow since we would have to pick up and score each block one by one.

**The Magnetizer**

The Magnetizer takes advantage of the screws in the Power Cubes by lifting them with a magnet. Similar to The Claw, this design carries up to 4 blocks at the rear of the robot and then unpacks them at the scoring zone. This system was advantageous because it required a minimal amount of control from the driver's end, since it only rotates left and right. Additionally, the magnet only needed to be within half an inch of a block to pick it up. However, the drawbacks of this design made it too inconvenient. The system was only capable of scoring at the 3 point zone, which accumulated to a lot of points when considering an additional 2 points are gained for each block in the 5 point zone (see Figure 4 below). Similar to the Claw, this design was also too slow because each block had to be scored one by one.

**The Dumper**

The Dumper had us mesmerized from the start. With a capacity of 12 Power Cubes, the Dumper used a claw that only needed to be in the general proximity of a block to pick it up (see Figure 5 below). The arm fit perfectly into the rear container, allowing it to accurately package blocks. The high container walls ensured blocks would not fall during transportation. The rotating mechanism of the rear container allowed us to dump multiple blocks into the scoring zone all at once. Nonetheless, there were still some disadvantages. First, the arm had limited movement, meaning robot positioning was critical for success, which is challenging. Second, the large container made the robot fairly heavy, causing the drivetrain to require more torque.

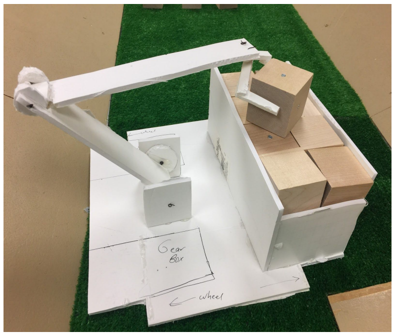


Figure 3: The Claw design packs blocks in a rear container using a long flexible arm.

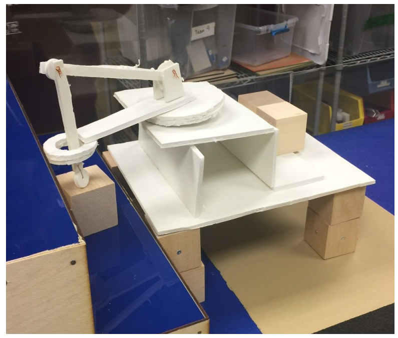


Figure 4: The Magnetizer demonstrates it scoring abilities. Blocks beneath the prototype accommodate height of wheels.

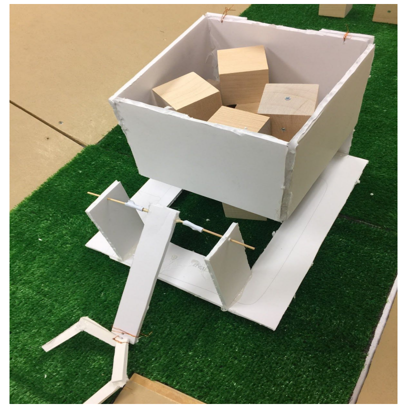


Figure 5: Showing damper with it's capacity to carry many power cubes.

To determine the best design option for our robot, we developed a pugh matrix to assess which model would best meet a set of criteria (see Table 1). Ultimately, we chose The Dumper for its stunningly high pugh matrix score.

Table 1: Pugh matrix compares three models based on select criteria. Scores range from -3 to 3.

| **Criteria** | **Mass** | **Dumper** | Reasoning | **Magnet** | Reasoning | **Claw** | Reasoning |
|---|---|---|---|---|---|---|---|
| Ease of Use (controlling) | 2 | 2.33 | 3 simple moving parts | 0 | Requires precision | 0 | Lots of arm pieces |
| Design & Build Simplicity | 2 | 1.33 | Container torque is high | 0 | Requires precise arm | 0 | 2 floating servos |
| Blocks per Trip | 3 | 3 | up to 15 | 0.66 | 3-4 | 1.33 | 8ish |
| Time to Score (total trip time/blocks per trip) | 2 | 3 | [(5sec/block)(15blocks)+(10 seconds)+(30seconds)]/15 = **7.66 seconds to score one block** | 2 | [(5sec/block)(4blocks)]+(5secs/block)(4)+30)]/4 = **17.5 seconds to score one block** | 1 | [(10sec/block)(8blocks)+(10sec/block)(8blocks)+30]/8 = **23.75 seconds per block** |
| Adaptability (if parts fail) | 2 | -1 | High reliance on container | -1.33 | Relies on one arm gear | 1.66 | Scores from pit, has 2 arm gears |
| Pick up Reliability | 3 | 2 | Precision not needed | 0.66 | High precision needed | 0 | A lot of moving parts for the arms |
| Drop off Reliability | 3 | 2.33 | Wall prevents falling | 0.66 | Same mechanism as pick up | 0 | Can't reach its own container |
| Scoring Zone | 2 | 1.66 | mostly 3's, some 5's | 0 | exclusively 3's | 3 | up to 5's |
| **TOTAL:** | | 36.65 | | 9.34 | | 15.33 | |

Analysis

While the best design solution was The Dumper as it were initially modeled, we decided to incorporate advantageous design concepts from The Claw and The Magnetizer. In particular, we wanted to reduce the control precision that the claw demanded. Thus, we replaced the claw with a magnet so that we could pick blocks from approximately half an inch away from the center of the block. We tested this magnet concept by 3D printing a model and attempting to carry blocks with it (see Figure 6 below). We noticed that any rapid movements caused the block to fall, making it unreliable. Furthermore, we realized that by modifying the claw to be longer and curved, it would require less precision. Thus, we ultimately switched back to a claw design for our final model (see Figure 7 below).

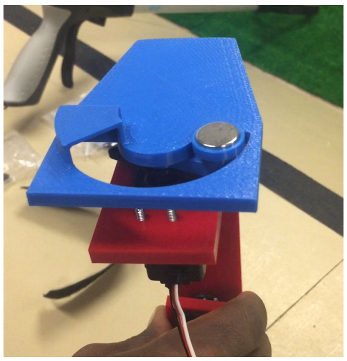


Figure 6: The magnet design. When exposed, the magnet picks up blocks. When rotated under the overhang, the magnet drops blocks.

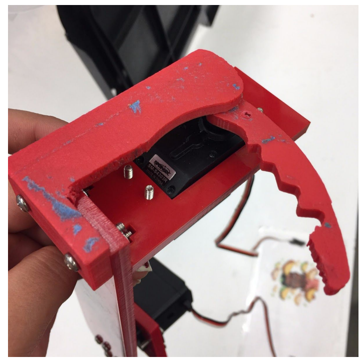


Figure 7: The claw design. The grooved texture of the claw allows it to easily and securely grasp blocks by locking into their edges.

The wheels of the robot also required a lot of design revision. Based on our initial calculations, we saw that both Ecoflex 50 and Smooth Silicon would provide the necessary friction for our robot, estimated at 4kg, to go up either incline. We created a set of four Ecoflex 50 wheels to ensure we had enough friction. As we started building the drivetrain, the wheels seemed to work seamlessly. However, once we assembled the container at the rear, the robot faced two issues. One, the center of gravity was shifted to the top back of the robot, causing it to flip when driving up the 30 degree incline (driving down was fine). This was manageable because we still had the option of the 15 degree incline. Two, the increased weight caused the silicon portion of the wheel to bend on the turf, making it incredibly difficult to drive. We resolved this by creating a new set of Smooth Silicon wheels, which were more rigid. While this helped with the bending issue, a new issue arose: the drive wheels would sometimes rotate without moving the robot. To redirect more weight onto the back drive wheels, we replaced the non-drive wheels with two new smaller wheels, leading us to our final design.

Final Solution

Functionality - The final solution has an arm that picks up Power Cubes using a claw (see figure 7 above). The claw is attached to one end of the arm and is controlled using a servo. The arm is attached to the front of the base of the robot using an L support. We used a continuous servo to rotate the arm because we needed it to rotate approximately 260 degrees from the pick up position to the container-deposit position. Once the blocks are placed in the container, the robot approaches the scoring zone using the 15 degree ramp; the additional weight of the blocks further shifts the center of gravity, so this requires careful driving to prevent flipping. To score points, the bucket is lifted using the two servos. The back wall of the bucket is bent so blocks can slide into the scoring zone. By positioning the robot right against the staircase, we ensure that all blocks fall in either the 5 point or 3 point zones.

Competition - The robot did well in the competition and we were ranked 3rd. During the competition, our highest score was 15 points with 5 blocks on the 3 point zone in two trips. Our robot performed just how we expected it to.
Driving - Our robot was designed to move at 0.15m/s at using 1.6V supply. The batteries we have produce a voltage of 5.8V and we can control the speed of the robot using the controllers which incorporate pulse width modulation (PWM) to control speed. Our robot only went up the 15 degree ramp to avoid the risk of flipping over.

The Bucket - Our design was eventually able to dump a max of seven power cubes as they were considerably heavy.
The Arm - We were satisfied with our decision to choose the claw over the magnet. The claw had a firm grip on every block we picked, and we were able to minimize the precision necessary by extending one side of the claw.

Advantages - Dumping blocks was a very quick process. Our robot was very strong and heavy, so it was able to withstand collisions with other robots. The powerful drivetrain allowed it to move at very high speeds. Our final wheel design gave it good traction, making driving and rotating much easier.
Disadvantages - It's heavy, so it loses to other opponents during ties. The center of gravity is concentrated at the back, so it cannot go up the steeper incline. It could only dump 7 blocks even though it was designed for 12.
Improvements - Given more time, we would increase the torque of the claw to pick up two blocks at once by increasing the gear ratio. We would also very slightly adjust the bend angle of the container's back wall to ensure blocks slide out more smoothly.

Final Design Specifications

| | |
|---|---|
| Mass | 4.23kg |
| Dimensions | 11" x 11.5" x 12" |
| Undercarriage Clearance | 2.5" |
| Turning radius | Turns in place, so 6" |
| Drivetrain Gear Ratio | Approx. 3:1 |
| Speed | Approx. 1 m/s |

Bill of Materials

Standard Parts

| Part | Quantity | | Part | Quantity |
|---|---|---|---|---|
| 12" x 24" x ~1/4" acrylic | 3 | | Steel Hex Rod 1/4" | 12 inches total |
| 12" x 24" x 1/8" acrylic | 1 | | Al Flat Rod 1/4" thick | 10 inches total |
| Al Angle Iron 1/8" thick | 15 inches total | | Gears: 64T, 24T, 16T | 6, 1, 2 respectively |
| Continuous Servo | 4 | | Screws | Around 100 |
| Motors | 2 | | Bolts | Around 50 |
| Smooth Silicon | 600 grams total | | E-clips | Around 50 |

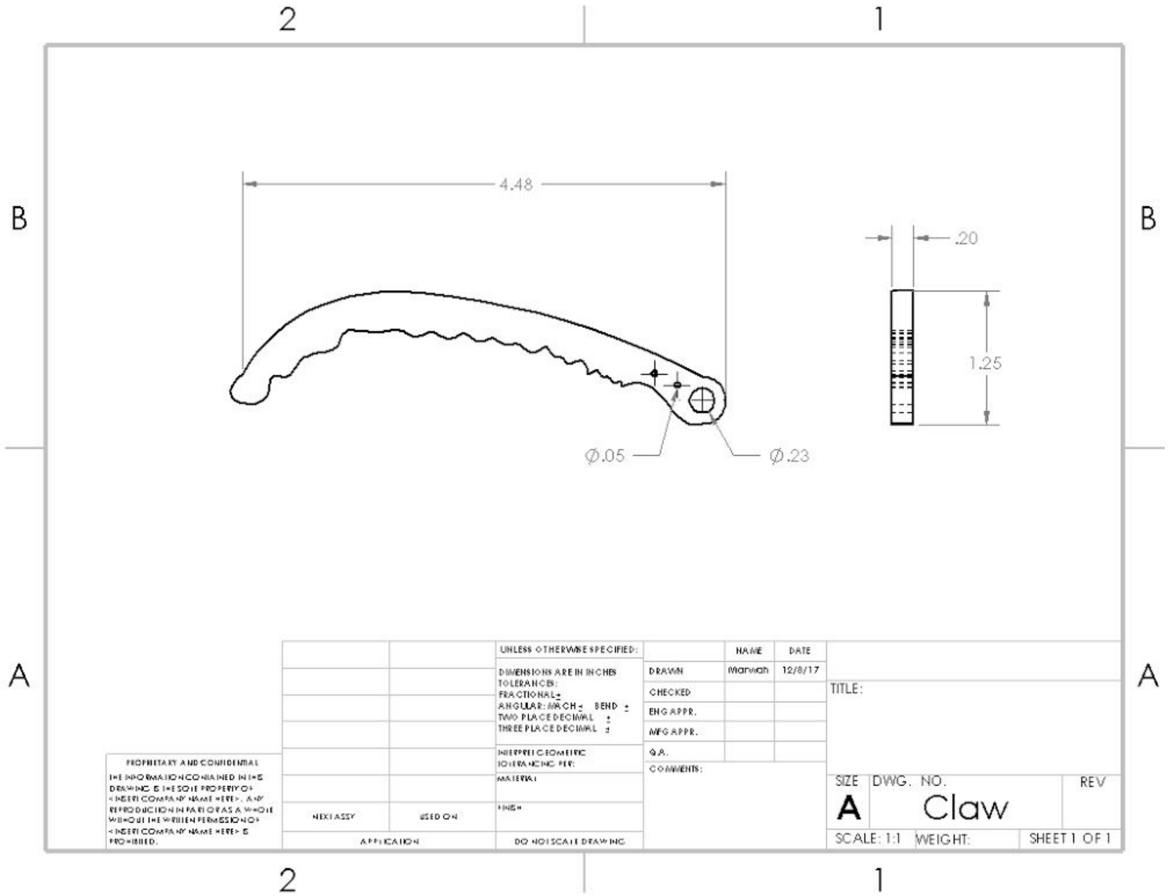
Non-standard Parts

| Part | Manufacturing Technique |
|---|---|

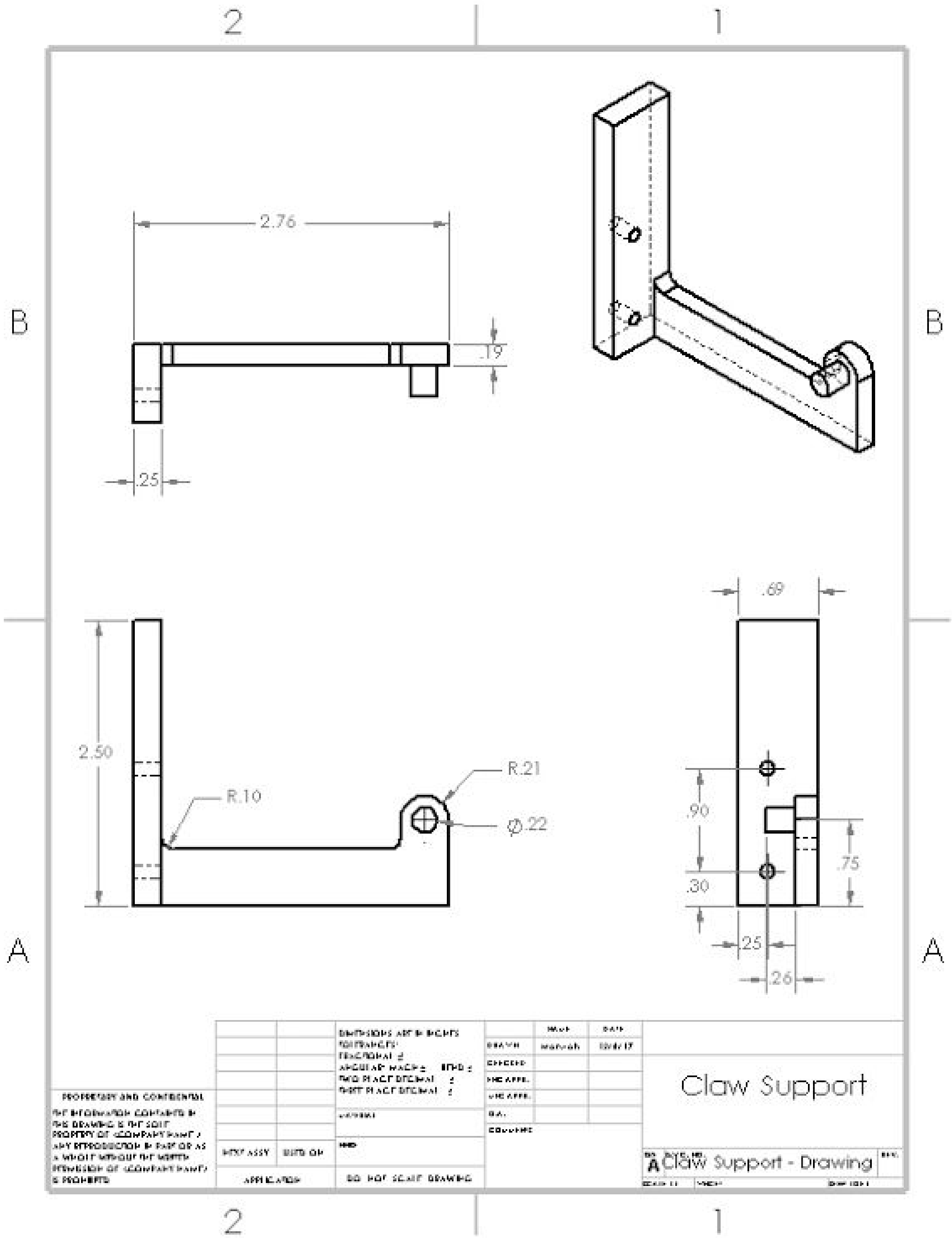
| | |
|---|---|
| Acrylic pieces | Laser cut |
| L-Supports (Aluminium) | Vertical Bandsaw and Drill |
| L-Supports (Derlin) | Mill |
| Wheels | Mold (milled) |
| Shafts | Lathe |
| Claw and Claw Support | 3D Printed |

Appendix

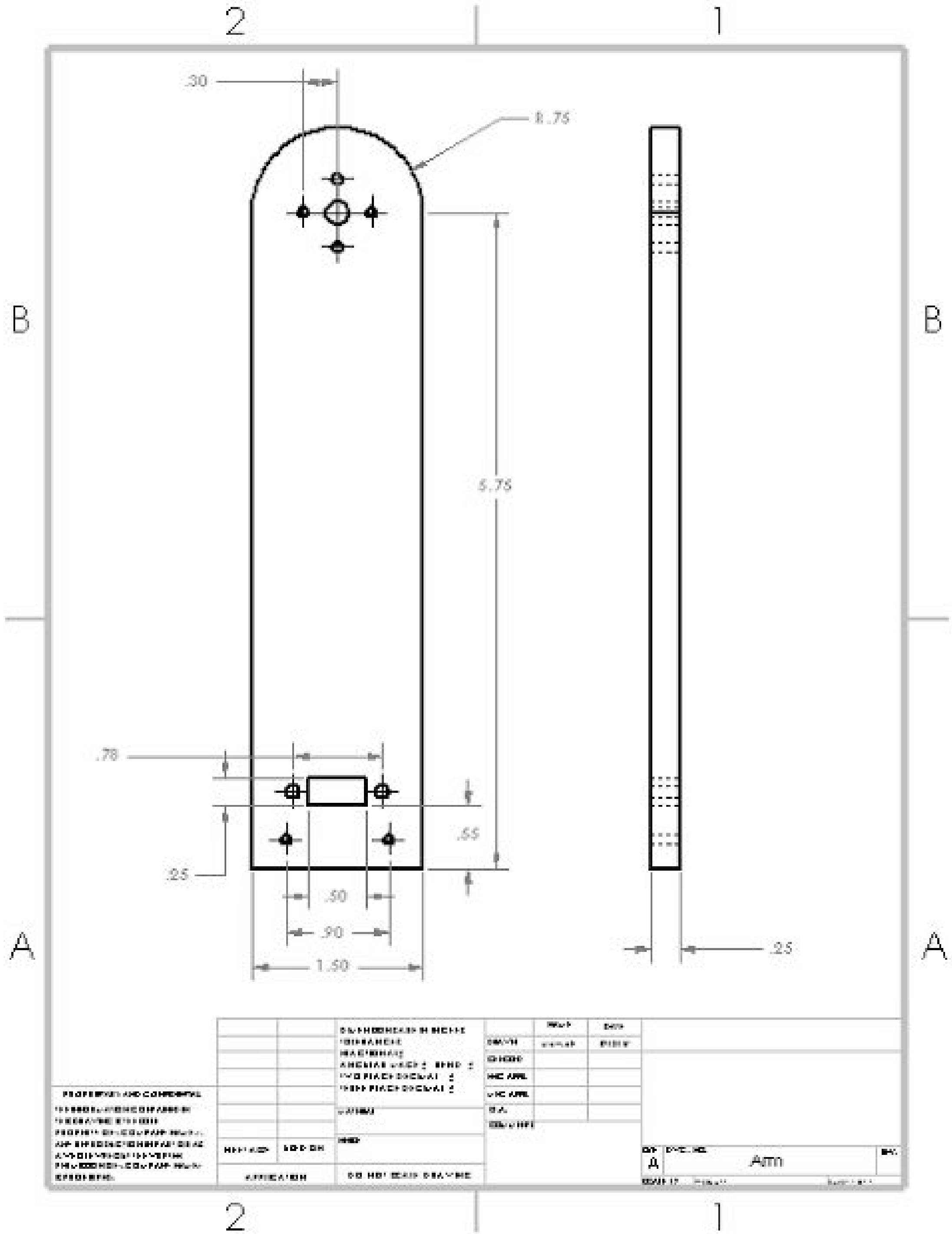
**Claw**



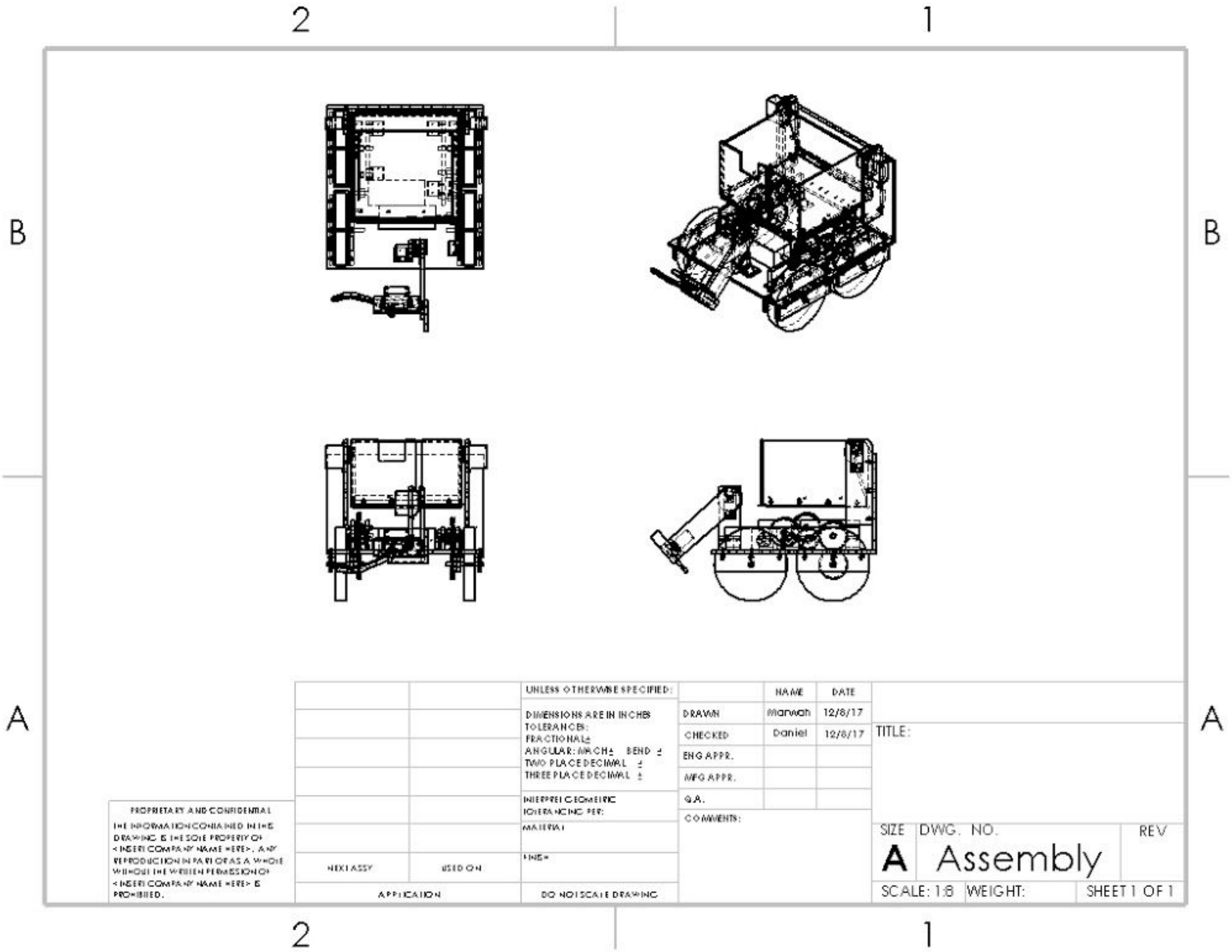
**Claw Support**

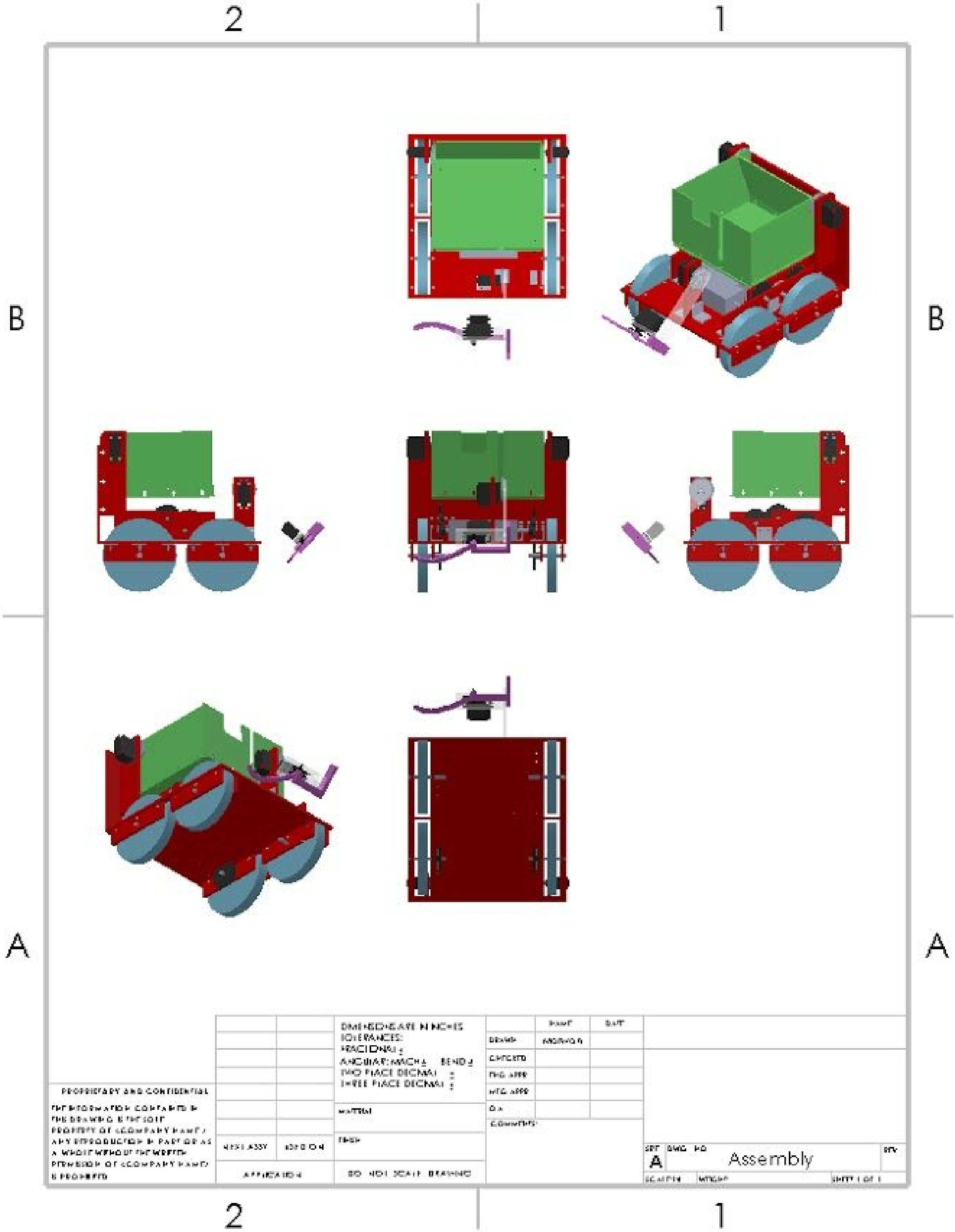


**Arm**



**Assembly Views**

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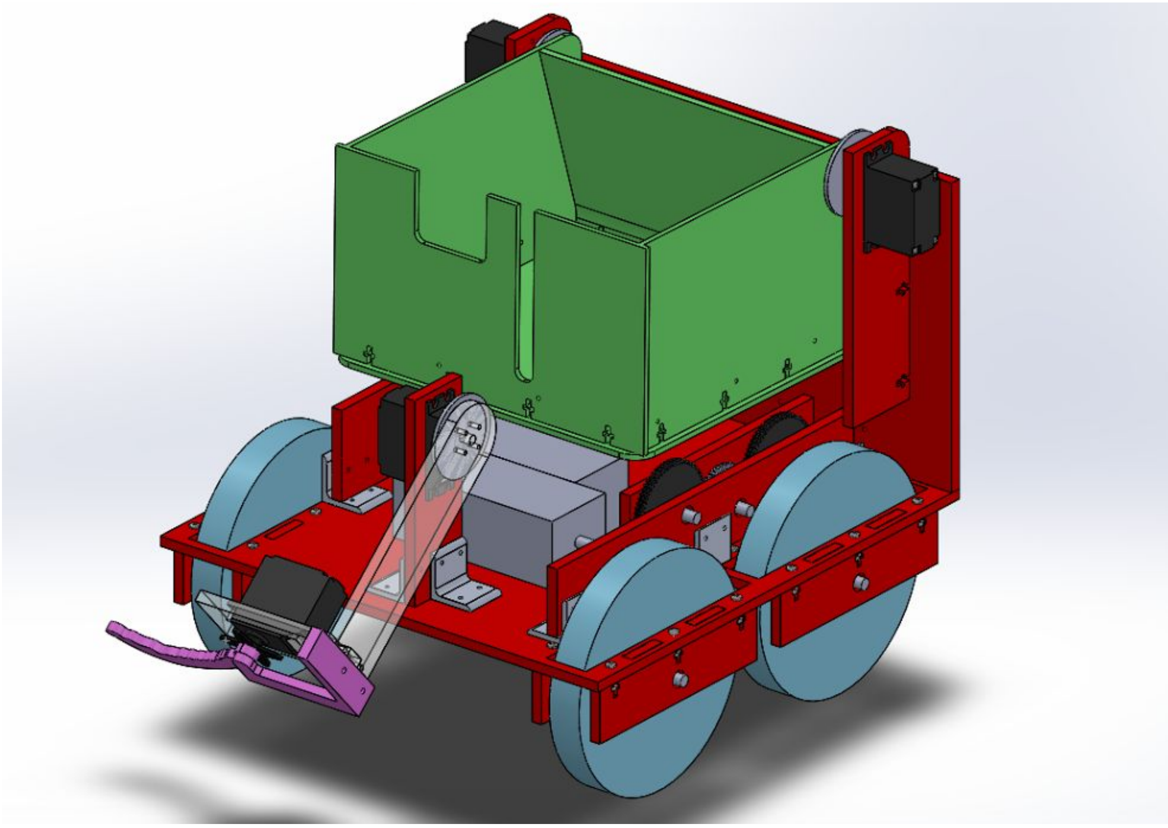
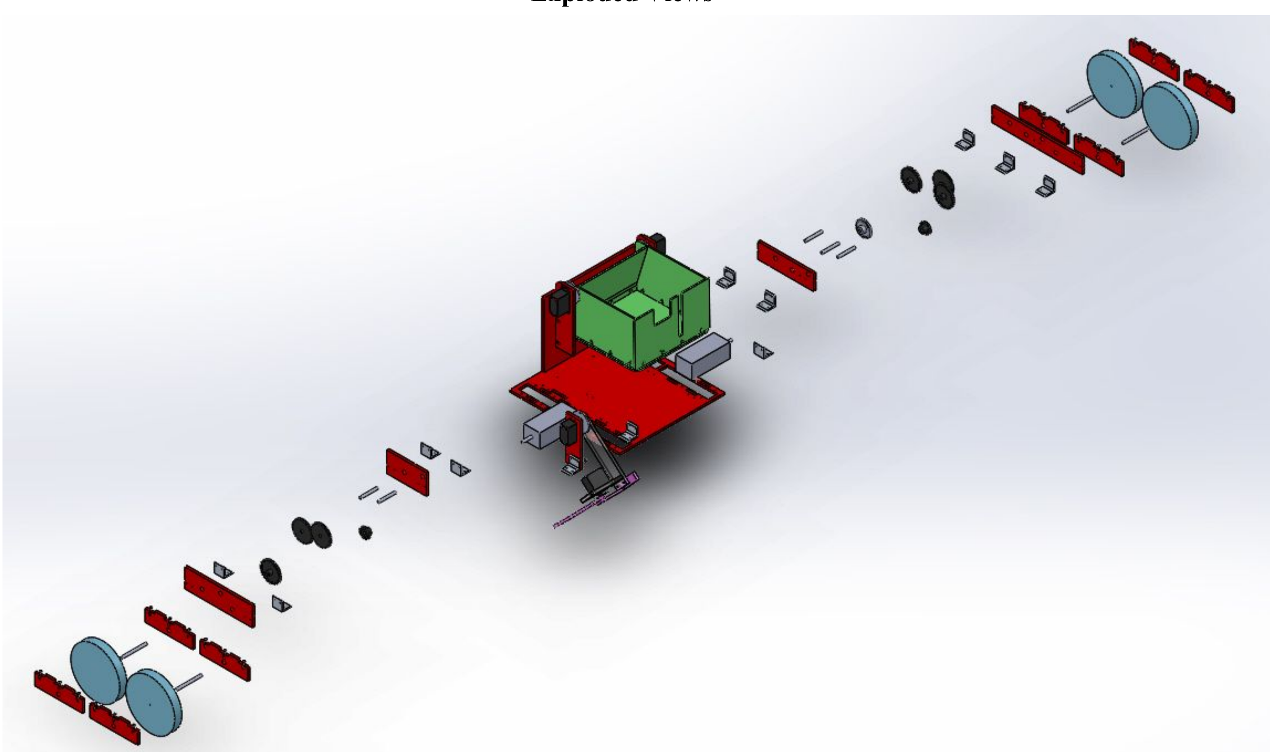
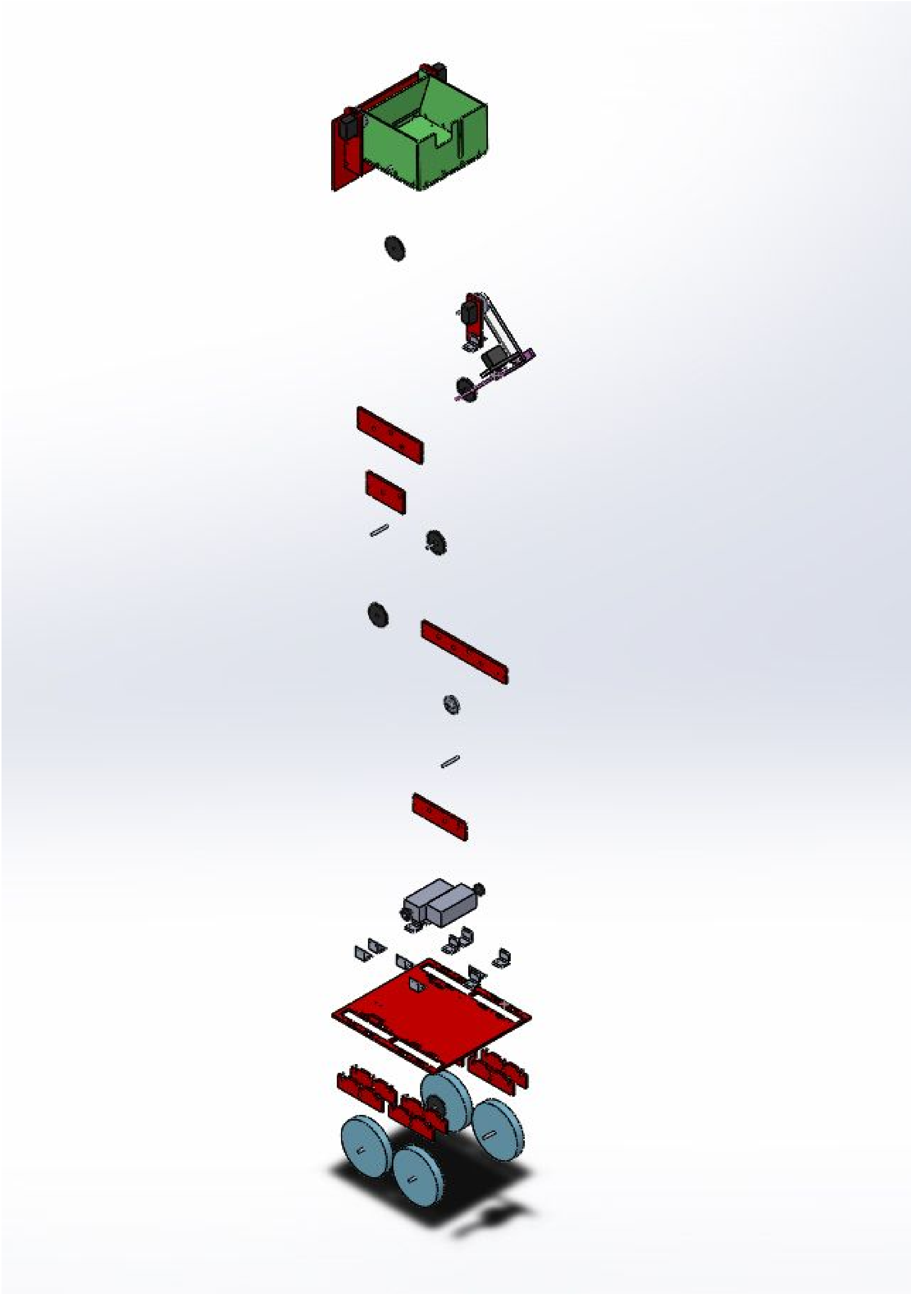
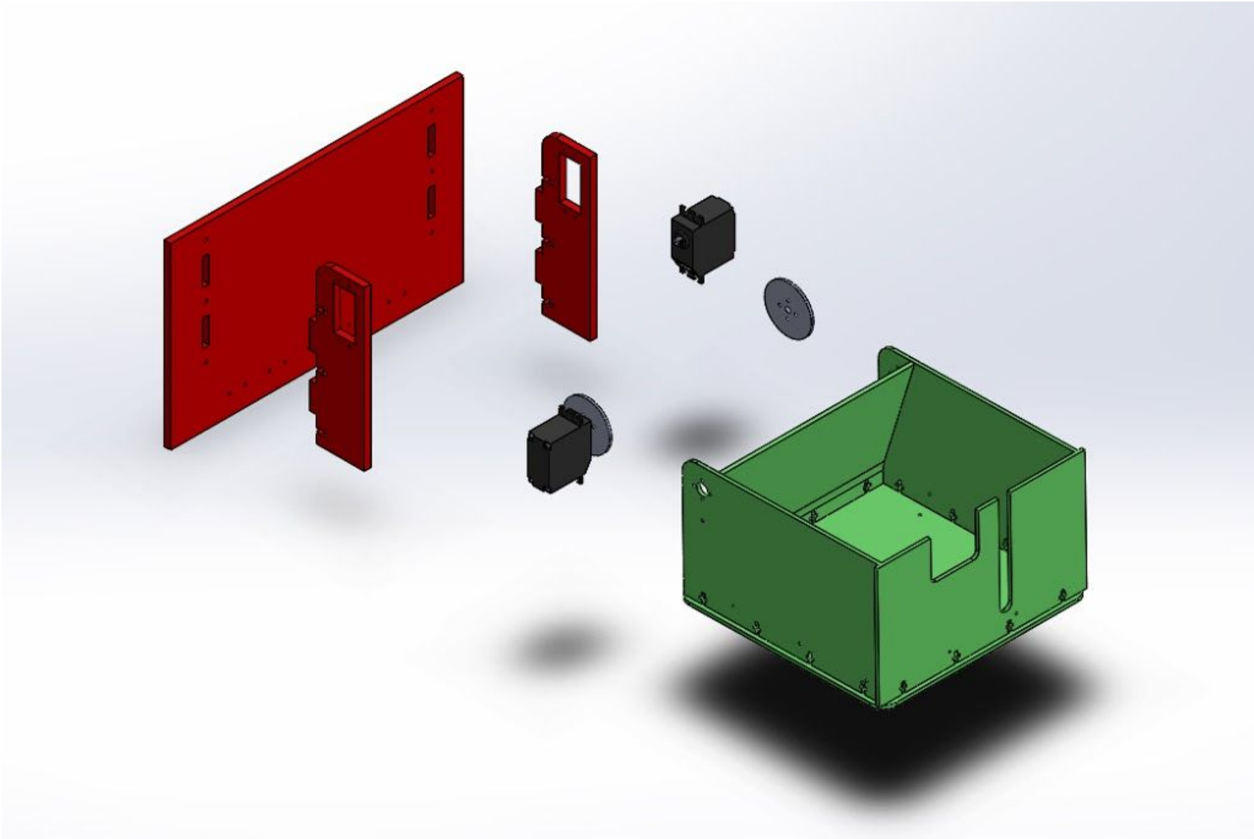
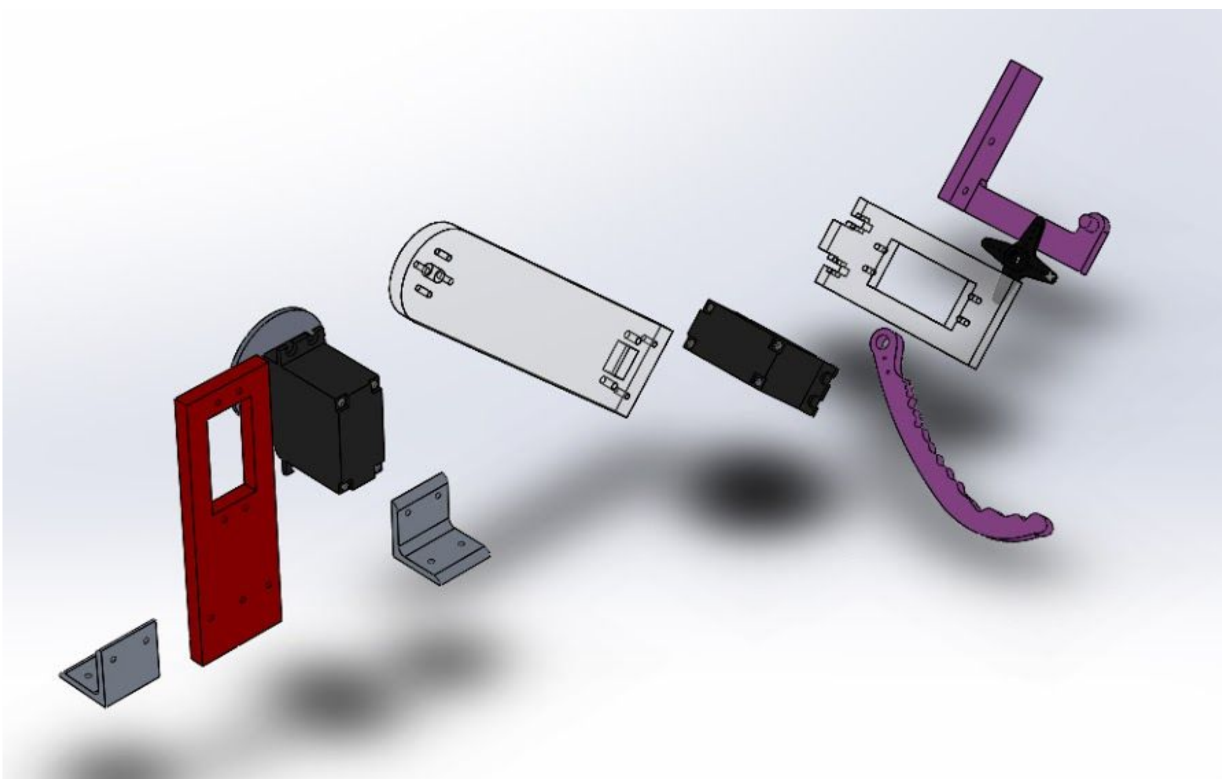


**Exploded Views**









**Pictures**