2022

# GR2 Assignment

MECHENG 2C04 | December 4, 2022

LAB L01

GROUP 1

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## Introduction
The goal of this project is to design, prototype, and test a creative and lightweight robot with the capability of navigating an L-shaped course in as little time as possible. The robot should use a transmission to transmit power from the standard motors to at least two wheels each. It must be able to turn left or right autonomously, based on the placement of a block on the course.

As a strategy, our group decided to optimize the speed with which our robot can complete the course, while scoring points in other “bonus” categories like number of contact points and creativity where possible. Consequently, we put a lot of focus on the leg design, transmission, and ability to turn. This approach was taken based on the given evaluation criteria, which is more heavily weighted towards speed. Having an efficient transmission allows us to meet the criteria for multiple ground contact point per motor and to convert unnecessary torque to faster rotation. Additionally, our selected wheel-like leg design maximises the distance covered per rotation, ultimately maximising the robot’s speed.

## Design Refinements
There were two principal aspects of the robot that were significantly improved over the development of the robot, being the chassis and the folding wheel.

The chassis went through three design iterations, each time incorporating new aspects. The first design iteration was a good stepping stone toward our end goal, but it did not have enough space to house all the robot components (no space for the Arduino, Servo, or limit switches). The robot had some sag due to the under-constrained shafts, and we had space to hold idler gears which were deemed unnecessary in later iterations. The trusses were intentionally designed to be symmetrical to balance weight.

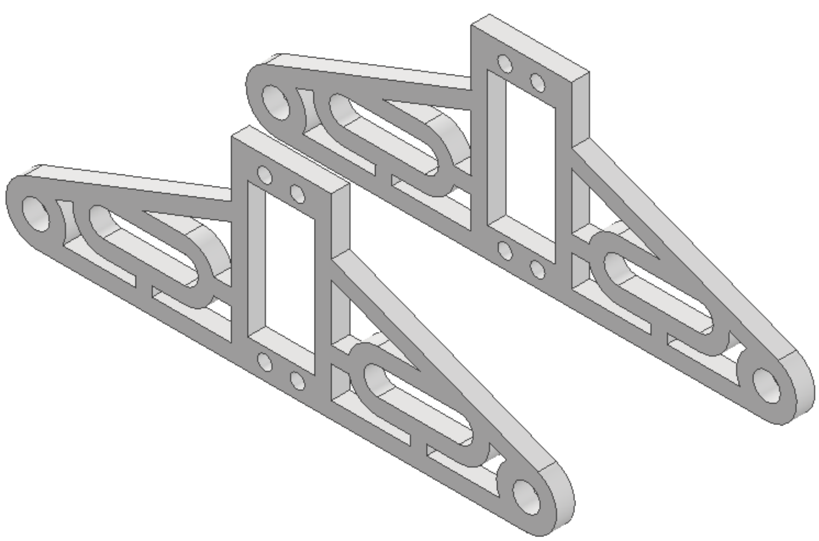


*Figure 1: First Chassis Design Iteration*

The second chassis design iteration consisted of weight savings, more housing space (front ledges for the Arduino), and no more idler gears (we went directly from the motor gear to the drive gear). There was still some slight sagging that we had not addressed, and we were still lacking housing space for the Servo and both limit switches. At this point in time, the left and right trusses were identical.

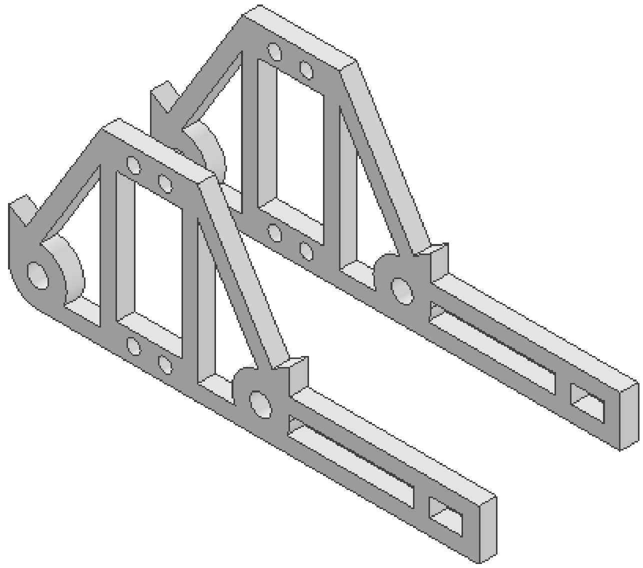


*Figure 2: Second Chassis Design Iteration*

The final chassis design iteration consisted of two asymmetrical trusses and a central shaft connection component. The central component used the shafts on both sides of the robot to constrain each other, such that the bot no longer sagged. Holes with counterbores were also added in this iteration so that a limit switch housing unit could be connected to each truss, and holes corresponding to the Arduino and Servo were included for vertical mounting of each component, which gave rise to better cable management.

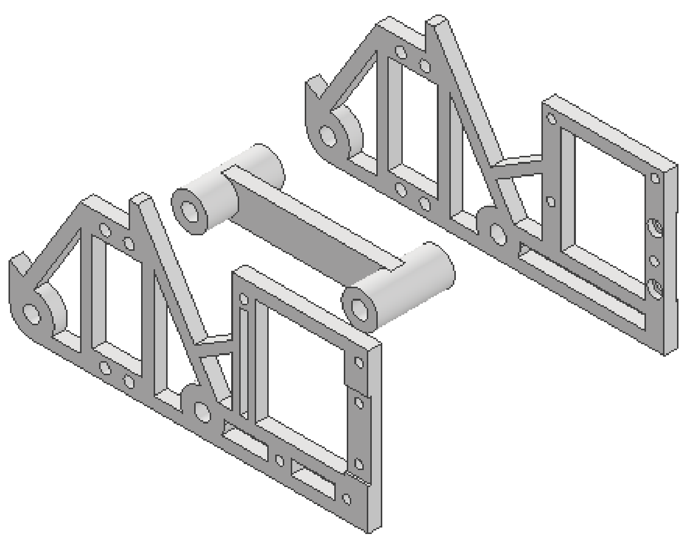


*Figure 3: Final Chassis Design and Shaft Connecting Component*

The folding wheel went through four iterations, each adding one significant change alongside multiple smaller changes. The first draft of the wheel executed the basic function of rolling up but was designed for a D-shaped shaft and lacked features to add magnets.

*Figure 4: First Wheel Design Iteration*

This was fixed in the second iteration, which also included slots for magnets, a smaller hub with set screw press-fits, and a chamfer on the first segment to locate the final segment of the wheel when folded.

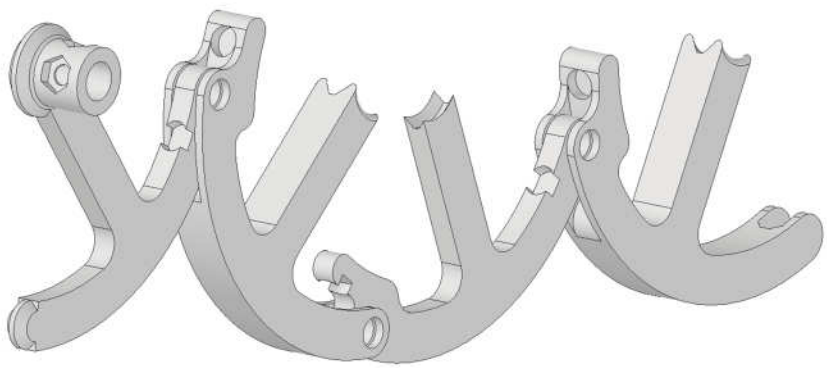


*Figure 5: Second Wheel Design Iteration*

The third iteration made several aesthetic changes, notably putting a uniform radius on similar parts, and making the spokes a uniform thickness. It also removed the chamfer on the first segment, favouring another tab for the seventh and eighth magnet slots and to improve the mechanical strength of the last connection. It also added a chamfer to each magnet slot, making assembly easier as the magnets became somewhat self-locating.

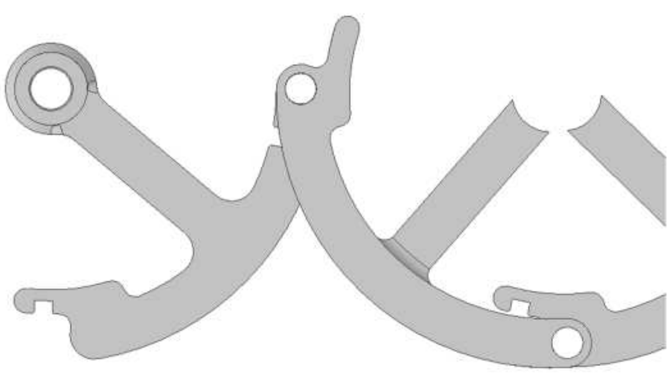


*Figure 6: Third Wheel Design Iteration*

On the final iteration the hub was made significantly larger and consequently, the spokes made shorter, to account for a redesigned set screw slot which proved much more effective for locking onto the shaft and transmitting torque. Minor clearance changes were also made on the critical surfaces of the part.

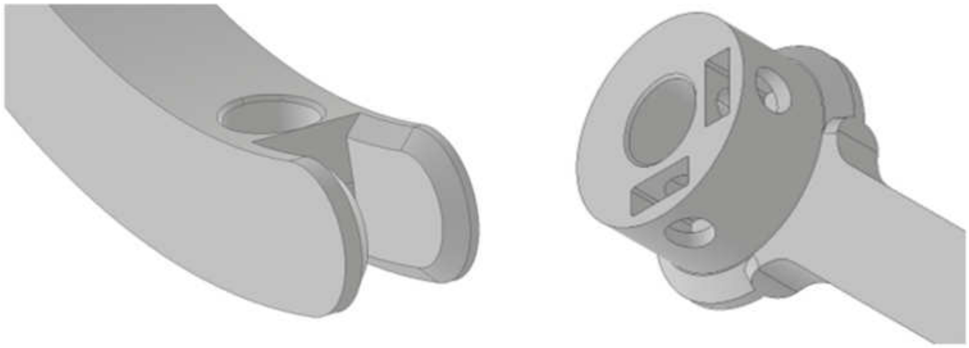


*Figure 7: Final Wheel Design Iteration*

## Final Design

For the reader's understanding, a physical assembly as well as an isometric image of our robot has been provided below.

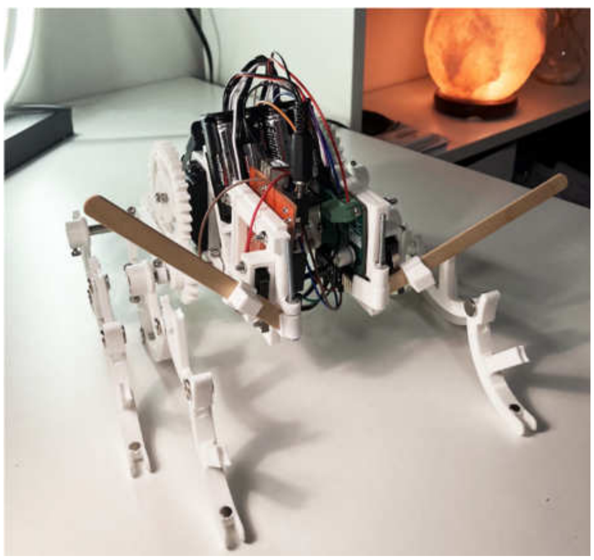


*Figure 8: Unrolled Physical Assembly*

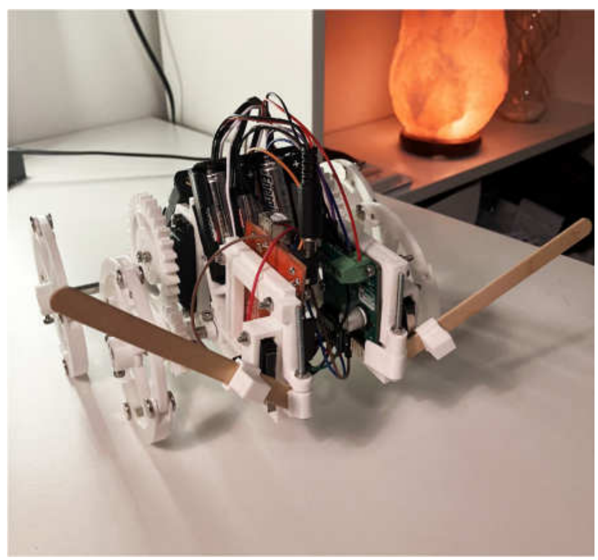


*Figure 9: Rolled Up Physical Assembly*

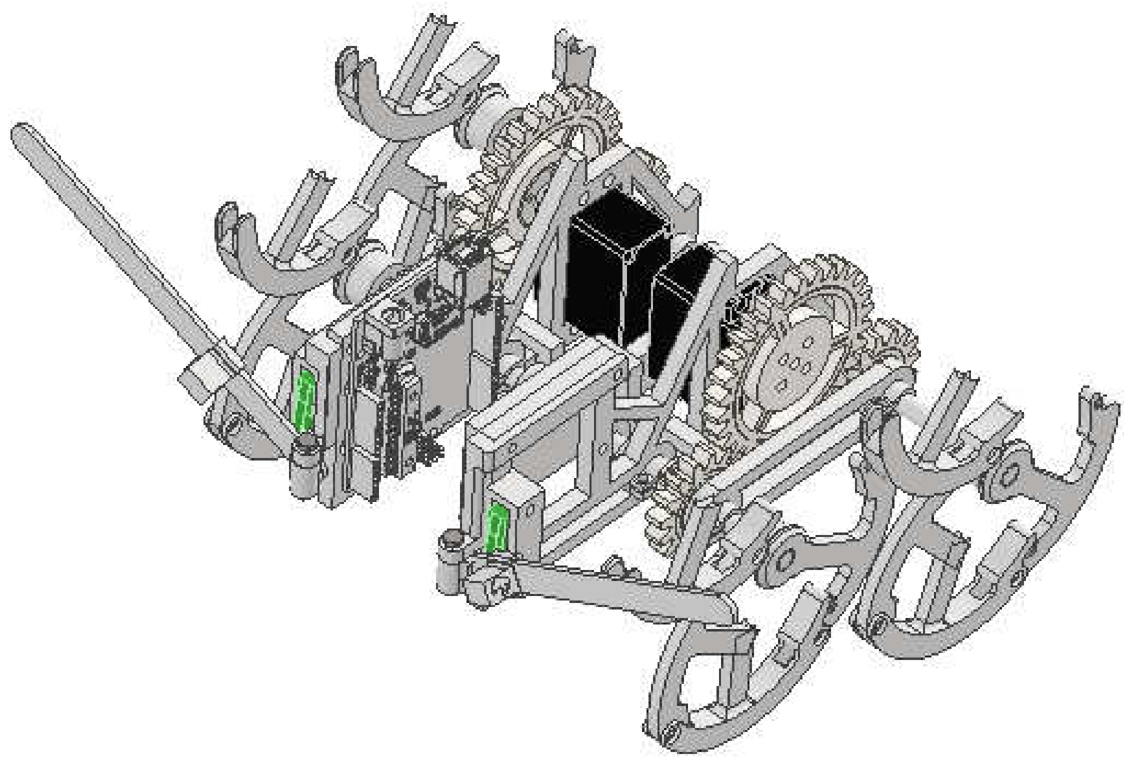


*Figure 10: Full Robot Design*

As a strategy, our group decided to optimize the speed with which our robot could complete the track while scoring points in other “bonus” categories such as the number of contact points, creativity and build quality. Our method in this endeavour was to use roll-up wheels, such the radius of the wheels was as large as possible while remaining in a 30x30x30 cm footprint. We deemed this technique challenging enough that it would offer a learning experience for each member of our group, as well as enough risk that, if executed properly, would score highly in terms of creativity, and build quality. A maximized radius with continuous ground contact was our strategy to cover the track in a minimized time.

For our transmission, we decided to use a gear train with a gear ratio of approximately 1.9. This strategy was based on the small axle-to-axle distance, low cost, and general ease of implementation (no belt tensioning). It proved to be a reliable way to transmit power to the wheels.

In terms of turning, we simply reversed one of the motors for a fraction of the turning time, such that the robot completed a 90-degree turn in the desired direction. The fold up wheels were able to stay together during this reversal due to the magnets placed at the joint connections. We used limit switches to sense an object that was placed on the track, which were activated when a ‘whisker’ on the front of the bot was pressed. This design was chosen to avoid hitting the wheels when they are in the unrolled position, and to use leverage to limit the input force required to begin the turn sequence. Further unwanted collision with the object was avoided by briefly reversing the robot before it turned. To stop at the end of the course, both whiskers could be pressed simultaneously, or one if the robot had already turned.

We tried to optimize mass the best we could, as evident in the compact chassis, as well as truss and wheel iterations presented in this report. We figured in addition to the grade calculated based on our weight, a reduced mass would also assist in the initial rolling of our wheels. Although we did have a relatively lightweight robot in contrast to the class average, we recognize there are revisions we could make to optimize our robot more. A few of these proposed design improvements can be seen in a subsequent section of the report.

## Final Budget

**Notes:**

• Assuming a labour rate of: $110.00 CAD/hour

• For 3D printed parts, assuming a material cost of: $15.00 CAD/cubic inch

and a **manufacturing** labour cost of: 15.00 minutes/build plate

**Overall budget per device**

| | |
|---|---|
| Purchased Parts | $62.10 |
| Material | $191.64 |
| Labour | $225.65 |
| *Total* | **$479.39** |

**Assembly Index** * calculated per lecture slides

* also called design efficiency

**9.2%**

Assembly Index = (Total Theoretical Part Count)*3/(Total Assm Time)

| | |
|---|---|
| Total Theoretical Part Count | 61 |
| Total Assm Time | 1,985 |

**Purchased Parts**

| *Part Name* | *Part Cost (CAD/per)* | *Number* | *Total Part Cost* | *Theoretical Part Count* | *Assembly Time per part (s)* | *Total Assembly Time (s)* | *Assembly Labour Cost* |
|---|---|---|---|---|---|---|---|
| M3 x 16 Bolt | $0.42 | 8 | $3.36 | 0 | 10 | 80 | $2.44 |
| M3 x 8 Bolt | $0.42 | 34 | $14.28 | 0 | 10 | 340 | $10.39 |
| M3 x 20 Bolt | $0.42 | 6 | $2.52 | 0 | 10 | 60 | $1.83 |
| M4 x 12 Bolt | $0.92 | 8 | $7.36 | 0 | 10 | 80 | $2.44 |
| M5 x 8 Chicago Screw | $0.40 | 12 | $4.80 | 12 | 15 | 180 | $5.50 |
| M3 Nuts | $0.55 | 8 | $4.40 | 0 | 7 | 56 | $1.71 |
| M4 Nuts | $0.20 | 45 | $9.00 | 0 | 7 | 315 | $9.63 |
| Magnets | $0.11 | 32 | $3.52 | 32 | 10 | 320 | $9.78 |
| Motor Spline | $4.38 | 2 | $8.76 | 0 | 7 | 14 | $0.43 |
| Rear Shaft | $1.00 | 2 | $2.00 | 0 | 15 | 30 | $0.92 |
| Front Shaft | $1.00 | 2 | $2.00 | 0 | 15 | 30 | $0.92 |
| Popsicle Sticks | 0.05 | 2 | $0.10 | 0 | 5 | 10 | $0.31 |
| **Subtotal** | | | $62.10 | 44 | 121 | 1,515 | $46.29 |

**Manufactured Parts**

| Part Name | Material Cost (CAD/per) | Number | Total part material cost | Manufacturing Time (s) | Theoretical Part Count | Assembly Time per part (s) | Total Assembly Time (s) | Total Labour Cost |
|---|---|---|---|---|---|---|---|---|
| Motor Servo Truss Mount | $18.89 | 1 | $18.89 | 900 | 1 | 10 | 10 | $27.81 |
| Motor Arduino Truss Mount | $19.50 | 1 | $19.50 | 0 | 0 | 10 | 10 | $0.31 |
| Lateral Connection Lock | $3.35 | 2 | $6.69 | 0 | 0 | 15 | 30 | $0.92 |
| Central Level Lock | $13.17 | 1 | $13.17 | 0 | 0 | 10 | 10 | $0.31 |
| Limit Switch Housing | $2.36 | 2 | $4.71 | 900 | 0 | 20 | 40 | $28.72 |
| Axial Collar | $0.21 | 12 | $2.52 | 900 | 0 | 5 | 60 | $29.33 |
| Motor Gear | $10.16 | 2 | $20.31 | 900 | 2 | 20 | 40 | $28.72 |
| Reduced Shaft Gear | $4.32 | 4 | $17.28 | 0 | 4 | 15 | 60 | $1.83 |
| Outer Truss | $5.39 | 2 | $10.77 | 0 | 2 | 10 | 20 | $0.61 |
| Fold Up Leg Right | $17.19 | 2 | $34.38 | 900 | 2 | 30 | 60 | $29.33 |
| Fold Up Leg Left | $17.19 | 2 | $34.38 | 900 | 2 | 30 | 60 | $29.33 |
| Arduino Whisker Mount | $2.60 | 1 | $2.60 | 0 | 1 | 20 | 20 | $0.61 |
| Servo Whisker Mount | $2.43 | 1 | $2.43 | 0 | 1 | 20 | 20 | $0.61 |
| Limit Switch Press | $1.08 | 2 | $2.16 | 0 | 0 | 5 | 10 | $0.31 |
| Arduino Hinge | $0.93 | 1 | $0.93 | 0 | 1 | 10 | 10 | $0.31 |
| Servo Hinge | $0.93 | 1 | $0.93 | 0 | 1 | 10 | 10 | $0.31 |
| **Subtotal** | | | $191.64 | 5,400 | 17 | 240 | 470 | $179.36 |

**Calculations**

| Part | Part Volume (mm^3) | Part Volume (cubic inches) | Material Cost |
|---|---|---|---|
| Motor Servo Truss Mount | 20627.92 | 1.259 | $18.89 |
| Motor Arduino Truss Mount | 21305.97 | 1.3 | $19.50 |
| Lateral Connection Lock | 3648.32 | 0.223 | $3.35 |
| Central Level Lock | 14389.34 | 0.878 | $13.17 |
| Limit Switch Housing | 2571.64 | 0.157 | $2.36 |
| Axial Collar | 222.77 | 0.014 | $0.21 |
| Motor Gear | 11093.17 | 0.677 | $10.16 |
| Reduced Shaft Gear | 4718.64 | 0.288 | $4.32 |
| Outer Truss | 5881.57 | 0.359 | $5.39 |
| Fold Up Leg Right | 18786.91 | 1.146 | $17.19 |
| Fold Up Leg Left | 18786.91 | 1.146 | $17.19 |
| Arduino Whisker Mount | 2835.98 | 0.173 | $2.60 |
| Servo Whisker Mount | 2660.71 | 0.162 | $2.43 |
| Limit Switch Press | 1180.94 | 0.072 | $1.08 |
| Arduino Hinge | 1014.81 | 0.062 | $0.93 |
| Servo Hinge | 1014.81 | 0.062 | $0.93 |

## Test Results

*Testing observations*

In general, testing went well and our robot behaved as expected. The robot successfully completed the course in 8.87 seconds after making the correct turn in response to the physical obstacle. In addition, the motors had no issues rolling up the wheels and slipping was minimal. A few trials were needed before the course was completed, due to veering in the robot's trajectory and limit switch sensitivity. During testing we noticed that the robot tended to veer very slightly to the left, meaning that we had to readjust the obstacle a few times for the limit switches to be hit accurately. In addition, the use of limit switches simplified the coding process for the Arduino, but their sensitivity revealed an oversight in the code. Based on the parameters of the course, the code was implemented in such a way that if a switch was activated a second time, the robot would stop. On some trials the sensitivity of the switch meant that it would register the first obstacle twice and therefore stop midway through the course. This problem was overcome by altering the code and doing several trials.

*Comparison with theoretical calculations*

Appendix A shows the calculations from our Group 1 project. In them, our previous speed calculations can be found to support the following observations and analysis. Our theoretical calculations estimated an average speed of 0.881m/s. When taking the distance of the robot track into account, it takes a calculated time of 2.27s from start to finish to complete the course. This value deviates 74% from our actual test result and can be attributed to both theoretical simplifications and unaccounted factors observed during the assembly and testing processes. To begin with, the theoretical calculations did not consider the then unknown mass, geometry, and drivetrain of the robot, all of which have compounding effects on the output torque and RPM. In addition, the final wheel design had a radius of 45mm, which is 55mm smaller than those used in the calculations. Due to the direct relationship between the leg's length and velocity, the output time would be increased. Considering the gear ratio in the drivetrain as well results in a new estimated output time. Furthermore, the estimated time assumes a constant velocity, which cannot be replicated in testing perfectly.

*Comparison with other groups*

When comparing results with other groups, using data from robot designs with differing legs, chassis and transmissions has allowed us to effectively compare the trends of weight and speed.

| Group Number | Speed (seconds) | Weight (kg) | Locomotive system |
|---|---|---|---|
| 1 (reference) | 8.87 | 0.739 | Fold-Up wheel |
| 12 | 6.95 | 0.820 | Fold-Up wheel |
| 37 | 9.71 | 0.929 | Leg with passive wheels |
| 21 | 25.3 | 1.150 | Toothed leg with passive wheels |
| 20 | 4.48 | 1.101 | Pie shaped leg with passive wheels |

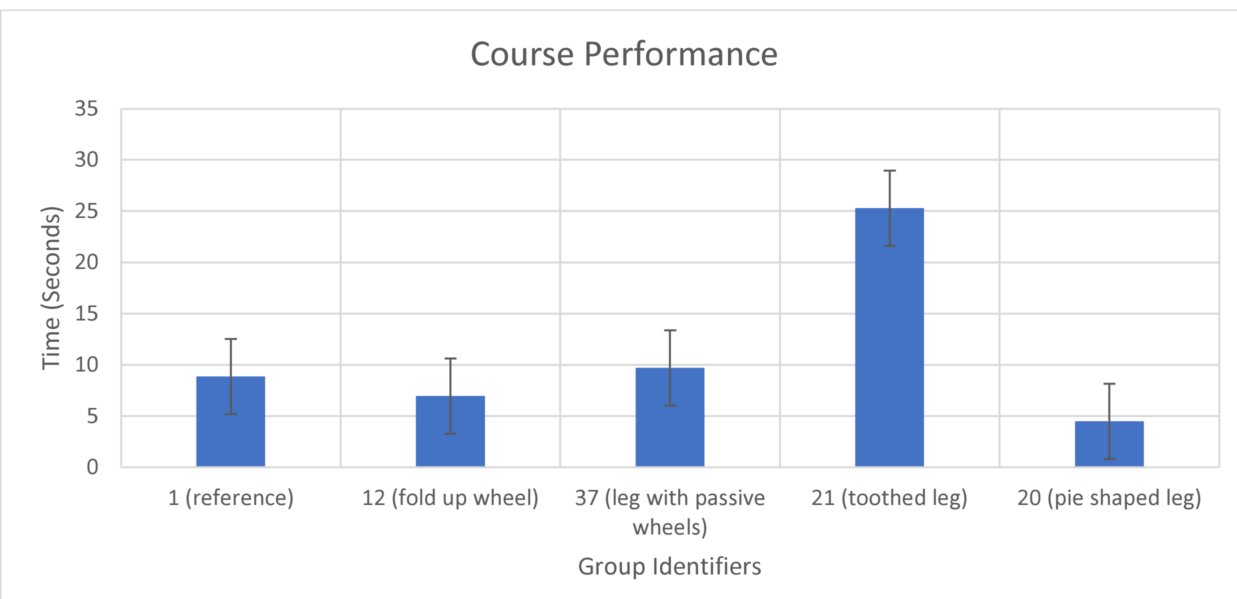



*Figure 11: Course Performance Comparison*

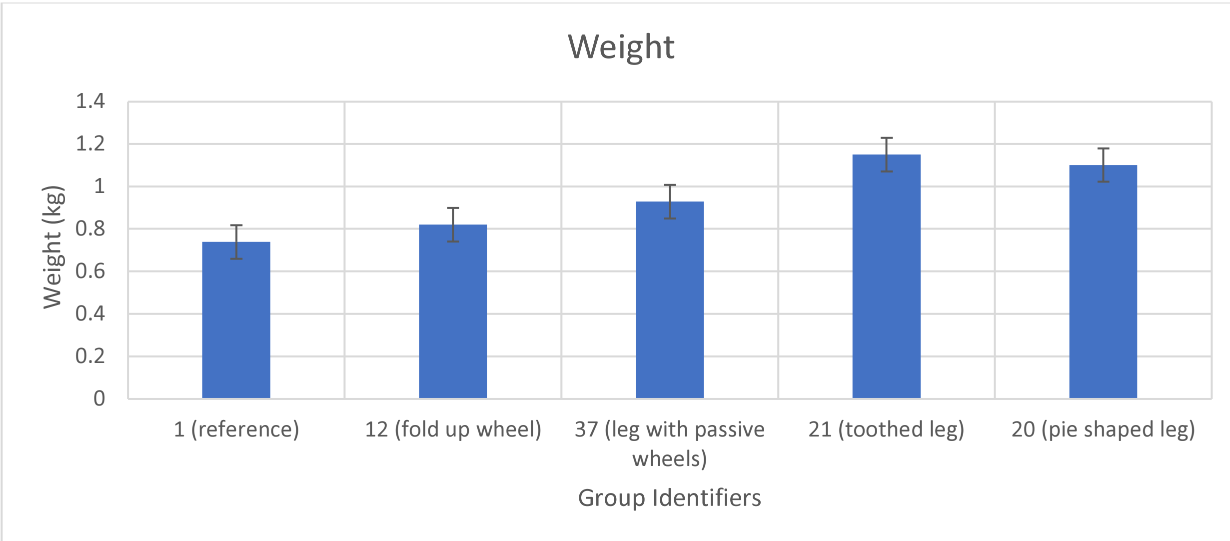



*Figure 12: Weight Comparison*

Our group performed relatively well when compared to groups 12, 37, 21 and 20, having the third fastest time and lowest weight of the sample. Although minute, there appears to be a slight positive correlation between the weight of the robot and time taken to complete the course, with the exception of group 20 which displayed the fastest time despite having the second heaviest design. This trend remains true upon further analysis into the rest of the class with weight and time having a slight positive correlation of 0.023. This shows that although its not necessary to have a lighter robot, it is certainly beneficial when it comes to speed. Furthermore, by looking at the respective designs, the "fold up wheel" systems—seen in group's 1 and 12—tend to be lighter. This can be due to the necessity of passive wheels in more typical leg designs which add extra weight to the system.

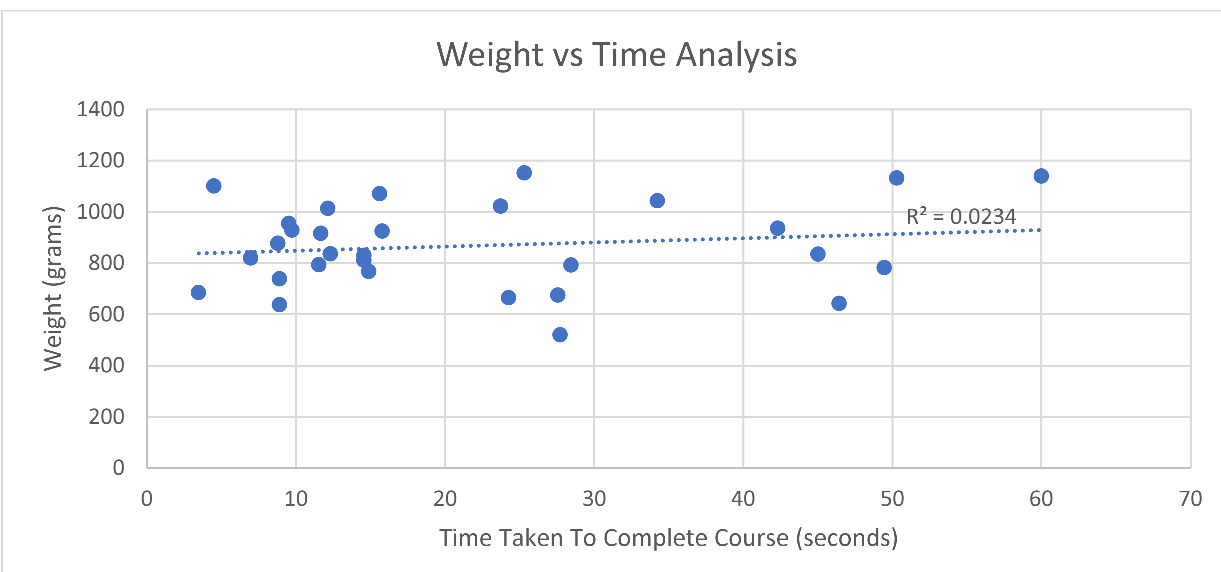



*Figure 13: Full Class Weight vs Time Analysis*

## Proposed Design Improvements

Based on our testing results, our group feels comfortable with the leg design. However, there is more room for improvement in terms of the robot mass. One of the easiest design changes we would make as a group is to change out the 360mm of steel shaft for aluminum tubing. It's affordable and significantly lighter. According to volume/density calculations, using a density of steel of 7.9g/cm$^3$ and aluminum of 2.7g/cm$^3$, the robot's mass would drop by 70 grams, and the change would require almost no design changes on any other part.

$$V_{shaft} = \pi r^2 h = \pi \cdot (3.175)^2 \ mm^2 \cdot 360mm = 11401 \, mm^3$$

$$V_{tube} = \pi(3.175^2 - 1.93^2) \, mm^2 * 360mm = 7186 \, mm^3$$

$$m_{shaft} = 11.401 * 7.9 = 90.1g \qquad m_{tube} = 7.186 * 2.7 = 19.4 \, g$$

Tubes would be ideal due to their significant weight savings for little to no torsional rigidity losses, but even solid aluminum bar stock would have notable benefits. It would cost as little as $15 and barely any machining time. Given that our robot was 250% faster, but only 15% lighter than the class average, this design change would be simultaneously the easiest and most important.

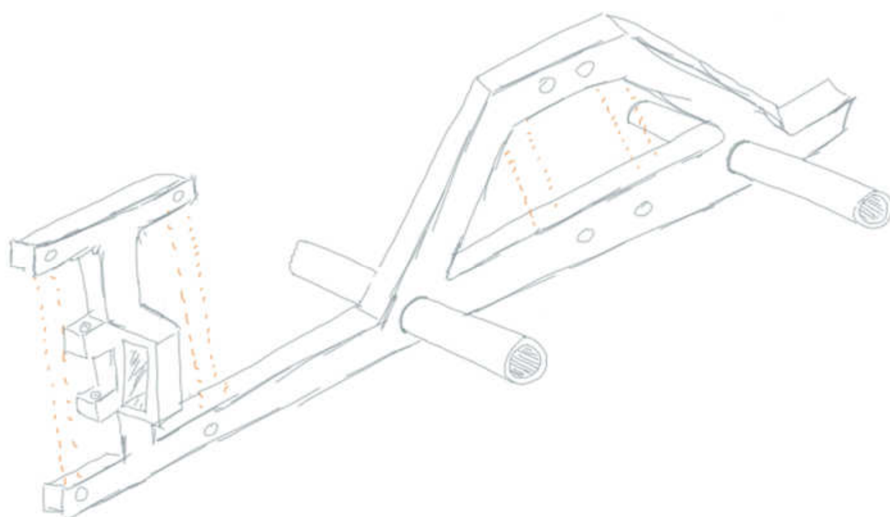


*Figure 14: Sample weight-saving truss design, featuring an incorporated limit switch housing, whisker mechanism pivot, and thin-walled aluminum tube shafts. Some of the removed truss elements are highlighted in orange.*

Using an optimized gear ratio would directly improve our time. During testing, we noticed that our robot had enough torque to flip itself over when we had accidentally programmed the servos to move in reverse. It's certainly more than necessary to roll up the wheels and travel on a smooth, flat surface. It's a simple trade-off which would further improve our results. Currently, our gear ratio is 30/16, or 1.875. As seen in the sensitivity analysis and calculations below, the higher the gear ratio, the less time the robot takes to complete the course. We could easily incorporate a gear ratio of 3 to improve our speed by 160%:

$$v_2 = \frac{3}{1.875} v_1 \quad Given \; t = \frac{d}{v_1} = 8.87s, \;\; t_2 = \frac{d}{v_2} = \frac{1.875}{3} \, t_1 = 5.54s$$

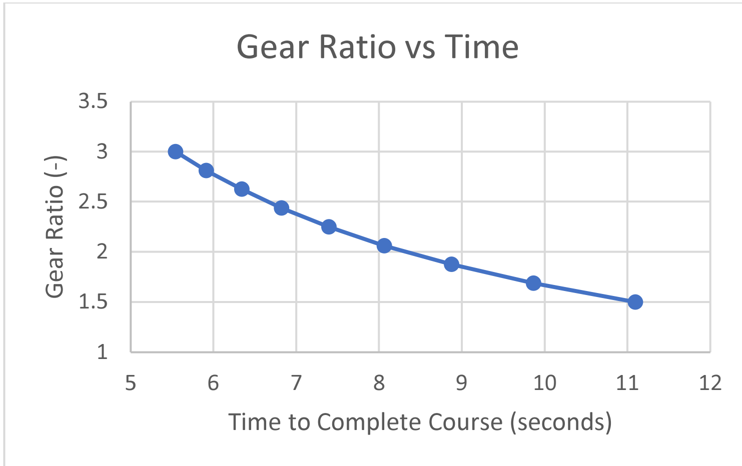
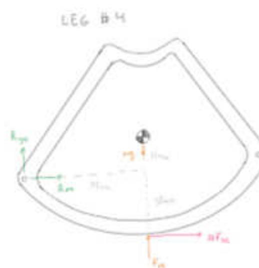



*Figure 15: Gear Ratio Sensitivity Analysis*

There are also several smaller, ‘quality of life’ design changes that could be made. Currently, the head of the Chicago bolts extend past the bottom surface of the wheels, making their contact with the ground uneven. Adding high-friction material or changing the geometry of the wheels would alleviate this issue and reduce torque loads on the motors, allowing us to further optimize their speed. Better wire management could be used on the Arduino and Servo Six. Due to their vertical orientation on the chassis, the limit switch wires frequently became disconnected, causing the turning strategy to fail. This problem often took a while to identify during testing and could be improved by mounting the Servo in a different position. Other small changes like incorporating the limit switch ‘whiskers’ into the chassis as one part, optimizing the insertion of magnets, and other general weight savings practices like thinning the chassis and wheels won’t individually make a significant change, but together could improve our results and assembly time.

## Appendix A: Supporting Calculations

$R_x = A \quad R_y = B \quad F_N = C \quad D = ?$




$\Sigma F_x = R_x + \mu F_{N1} = 0$

$\Sigma F_y = F_{N1} - mg + R_y = 0$

$m = \sim 0.015\,kg$

$\mu = 0.36 \cdot 1.25 = 0.45$

$\Sigma M_{com} = \mu F_{N1} \cdot 50mm + R_x \cdot 15mm - R_y \cdot 75mm = 0$

by matrix operations:

$R_x = -0.055N \quad R_y = 0.0255N \quad F_N = 0.122N \quad \mu F_N = F = 0.055N$

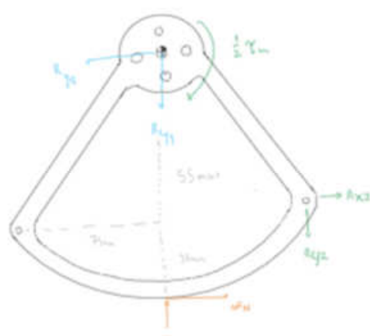
similarly, for leg 3 and 2,

$R_{x3} = 0.1286N$

$R_{y3} = 0.00847N$

$R_{x2} = 0.19N$ (forward)

$R_{y2} = 0.02N$ (up)



$\Sigma F_x = \mu F_N - R_{x1} + 0.19N = m a_x$ (= 0)

$\Sigma F_y = F_N - R_{y1} - 0.02N = 0$

$\Sigma \tau = 0.1m \cdot 0.45 F_N - \frac{1}{2}\tau_m - 0.02 \cdot 0.075m + 0.055m \cdot 0.19N$

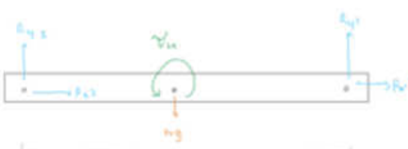
$R_{x1} = \mu F_N + 0.19N$

$F_N = \frac{R_{x1} - 0.19N}{\mu}$

$R_{y1} = F_N - 0.02N$

$\frac{1}{2}\tau_m = 0.045 F_N - 0.00895N$

$F_N = \frac{\tau_m}{0.09} + \frac{0.00895N}{0.045}$



$\Sigma F_x = R_{x1} + R_{x2} = m_B a_x$

$\Sigma F_y = 0 = R_{y1} + R_{y2} - mg$

$\Sigma \tau = 0 = \tau_m + R_{y1} \cdot 0.2m - mg \cdot 0.1m$

$\tau_m = 0.1mg - 0.2R_{y1}$

$\tau_m = 0.1mg - 0.2(F_N - 0.02N)$

$= 0.1mg - 0.2\left(\frac{\tau_m}{0.09} + 0.1989N - 0.02N\right)$

$= 0.1mg - \frac{0.2}{0.09}\tau_m + 0.03579N$

$\tau_m = \frac{0.1mg + 0.03579N}{\left(1 + \frac{2}{0.9}\right)}$

$= 0.102342463\,Nm$

$= 0.102\,N \cdot m$

Using linear interpolation:

$$m = \frac{T_2 - T_1}{\omega_2 - \omega_1} = \frac{0 - 1.35\ N\cdot m}{1.52 - 0\ rad/sec} = -0.89\ \frac{N\cdot m}{rad/s}$$

$$T = -0.89\ \frac{N\cdot m}{rad/sec} \cdot \omega + 1.35$$

[illegible]

Leg length = $2\pi r$

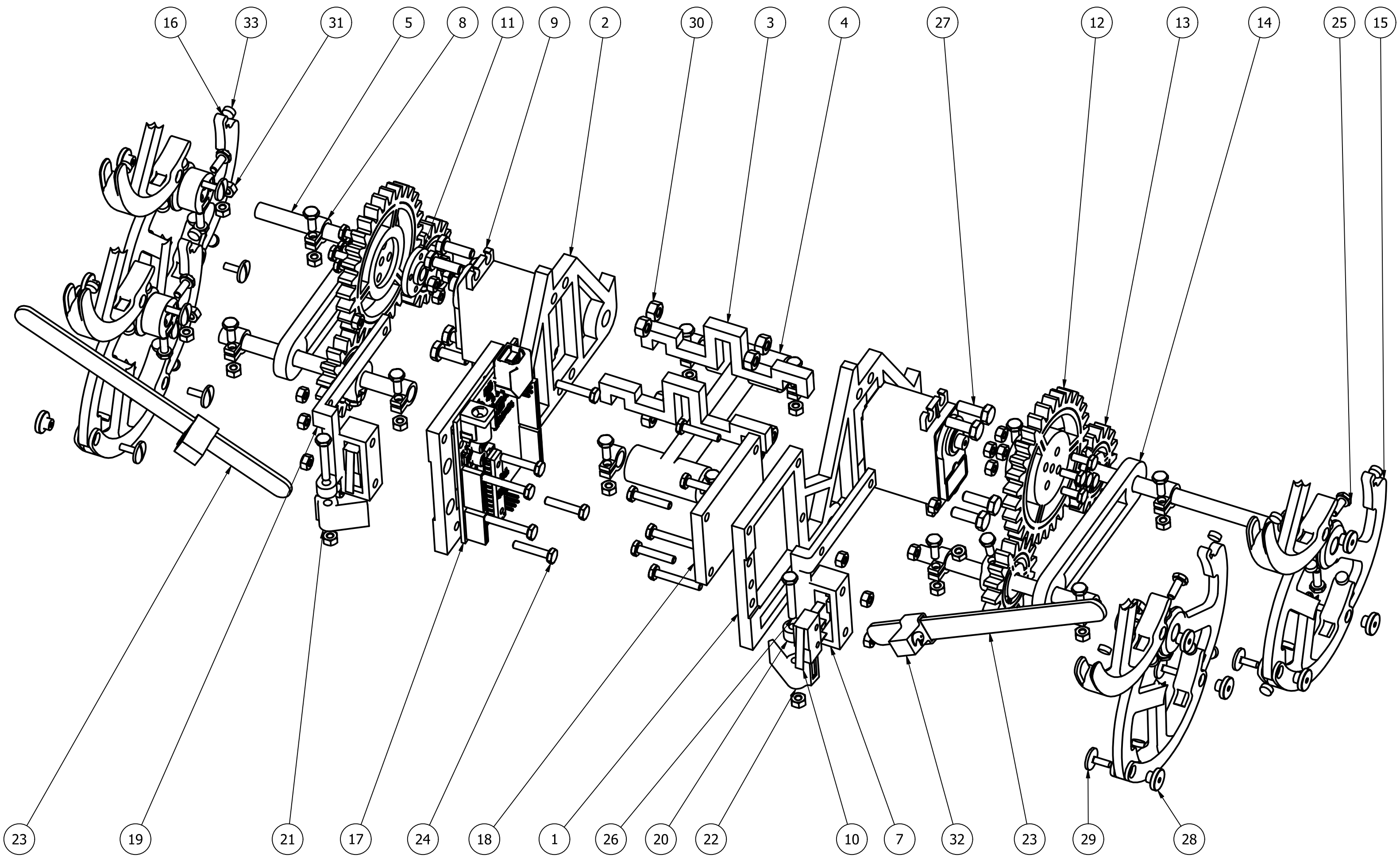
$= 2\pi(0.1m)$ /rotation

$= 0.6283$ m/rotation

[illegible]

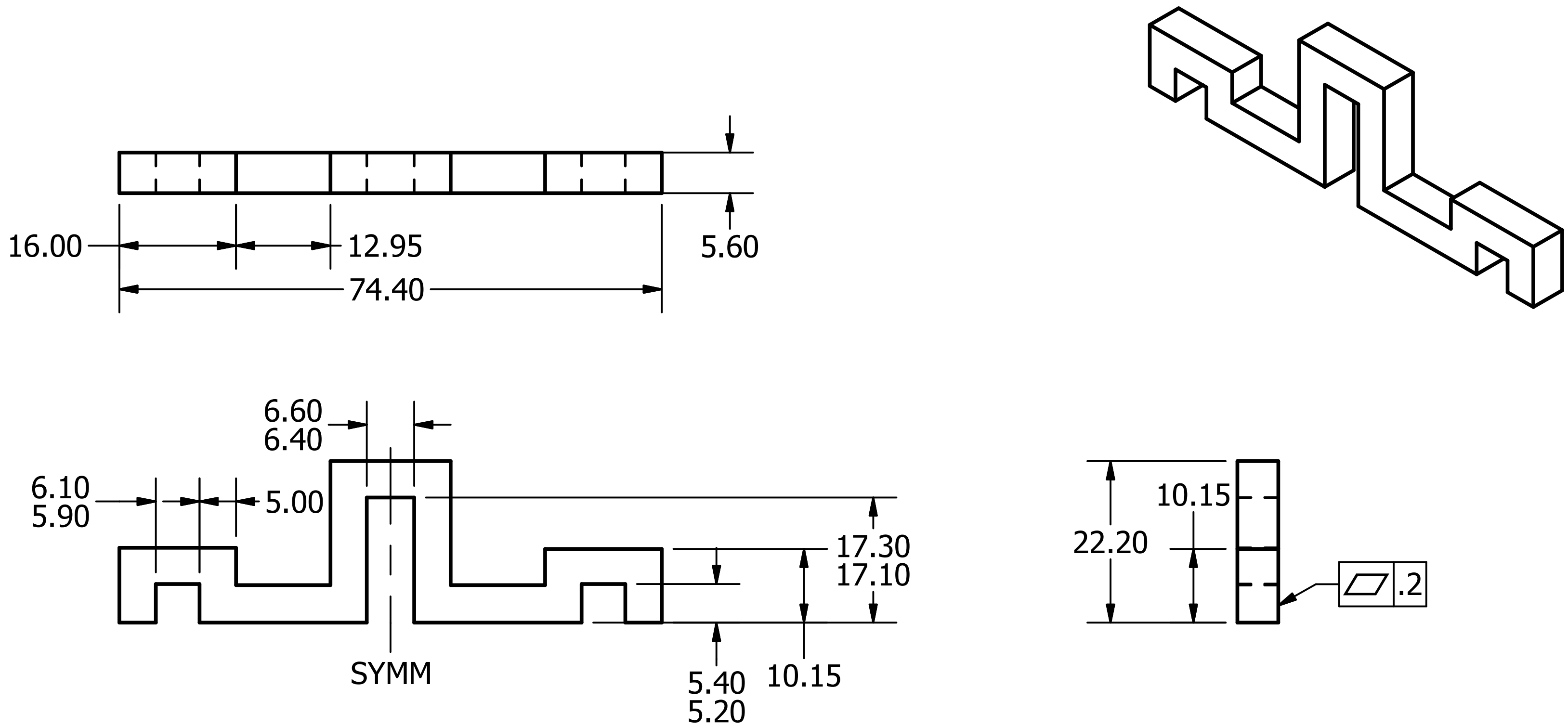
## Appendix B: Drawing Package

The drawings of our exploded assembly and 4 of our manufactured parts are attached below.



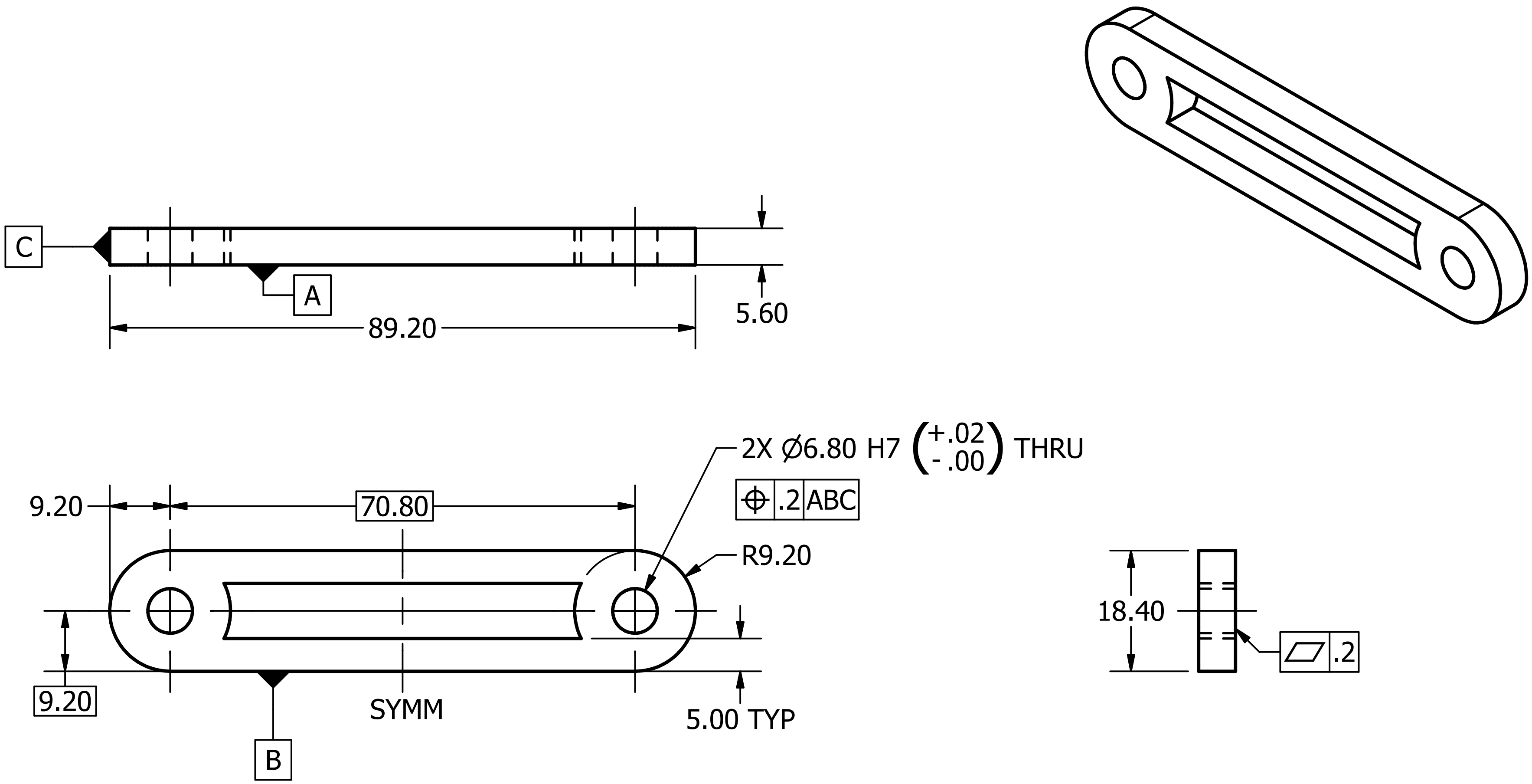

| PARTS LIST | | |
|---|---|---|
| ITEM | QTY | PART NUMBER |
| 1 | 1 | MotorServoTrussMount |
| 2 | 1 | MotorArduinoTrussMount |
| 3 | 2 | LateralConnectionLock |
| 4 | 1 | CentralLevelLock |
| 5 | 2 | RearShaft |
| 6 | 2 | FrontShaft |
| 7 | 2 | LimitHousing |
| 8 | 12 | AxialCollar |
| 9 | 2 | ServoMotor |
| 10 | 2 | Limit Switch |
| 11 | 2 | MotorSplineConnection |
| 12 | 2 | MotorGear |
| 13 | 4 | ReducedShaftGear |
| 14 | 2 | OuterTrussV2 |
| 15 | 2 | FoldUpLegRightSide |
| 16 | 2 | FoldUpLegLeftSide |
| 17 | 1 | Arduino uno |
| 18 | 1 | ServoPlaceHolder |
| 19 | 1 | ArduinoWhiskerMount |
| 20 | 1 | ServoWhiskerMount |
| 21 | 1 | ArduinoHinge |
| 22 | 1 | ServoHinge |
| 23 | 2 | PopsicleStickPlaceHolder |
| 24 | 8 | AS 1110 - M3 x 16 |
| 25 | 34 | AS 1110 - M3 x 8 |
| 26 | 6 | AS 1110 - M3 x 20 |
| 27 | 8 | AS 1110 - M4 x 12 |
| 28 | 12 | CSN 021461 - M2 |
| 29 | 12 | Screw GB 947 M2.5 x 8 |
| 30 | 8 | ANSI B18.2.4.2M - M4x0.7 |
| 31 | 45 | ANSI B18.2.4.2M - M3x0.5 |
| 32 | 2 | LimitSwitchPress |
| 33 | 32 | Magnets |

| | | |
|---|---|---|
| DRAWN Group 1 | 2022-12-04 | |
| CHECKED JD, MS, AD, ST | | TITLE |
| QA | | Group1EngineeringDrawingPackage |
| MFG | | |
| APPROVED | | |
| | | SIZE C · DWG NO BlownUpAssemblyDwg · REV |
| | | SCALE 3:4 · SHEET 1 OF 5 |



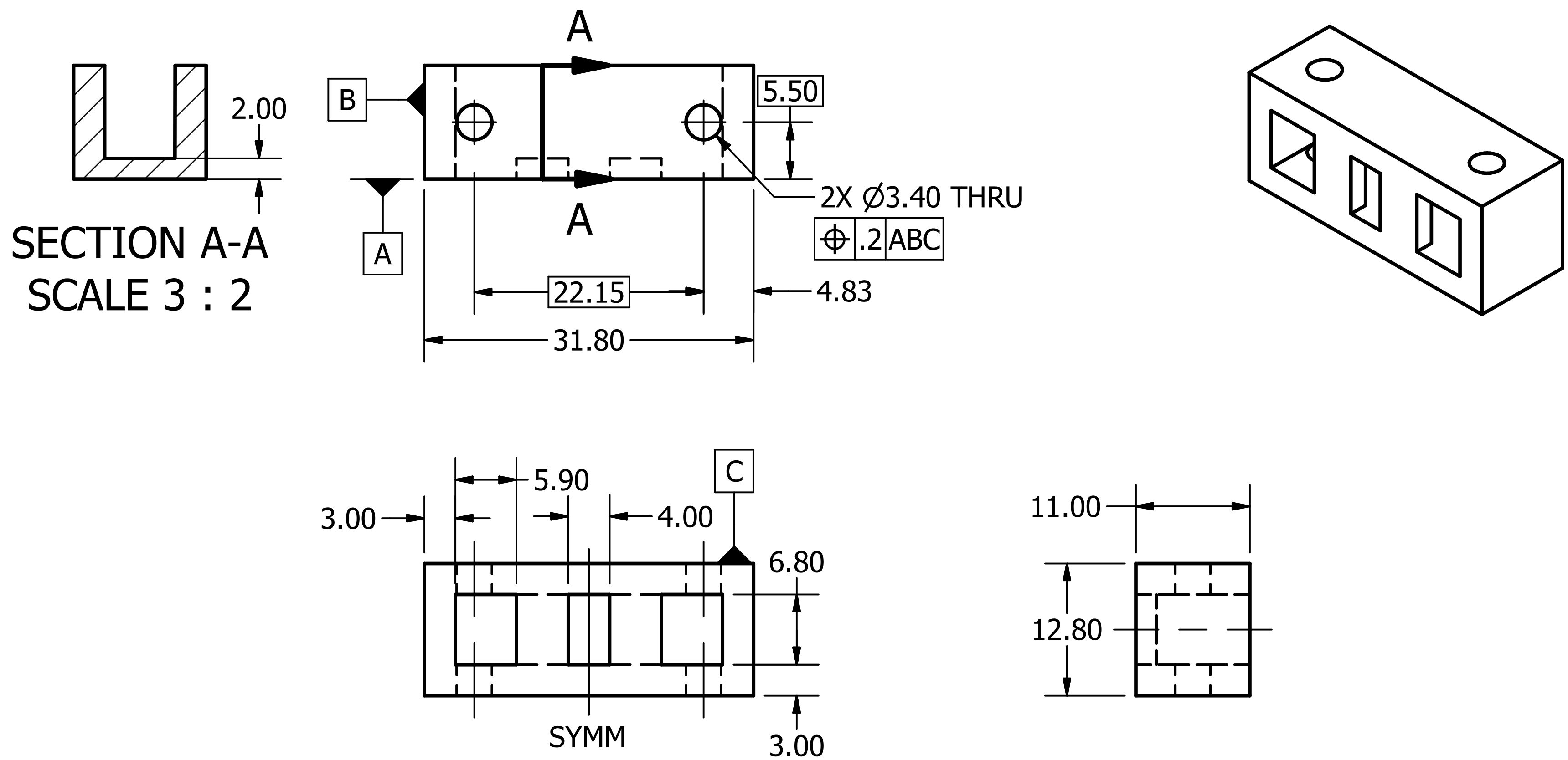

| | | |
|---|---|---|
| DRAWN Group 1 | 03/12/2022 | |
| CHECKED JD, MS, AD, ST | | TITLE |
| QA | | Group1EngineeringDrawingPackage |
| MFG | | |
| APPROVED | | |
| | | SIZE A | DWG NO GR2 Drawing Package | REV |
| | | SCALE 1 : 1 | SHEET 2 OF 5 |

NOTE:
ALL DIMENSIONS IN MM
ALL TOLERANCES HELD TO
PLUS OR MINUS 0.5MM
UNLESS OTHERWISE NOTED




| | | | | | |
|---|---|---|---|---|---|
| DRAWN Group 1 | 03/12/2022 | | | | |
| CHECKED JD, MS, AD, ST | | TITLE Group1EngineeringDrawingPackage | | | |
| QA | | | | | |
| MFG | | | | | |
| APPROVED | | SIZE A | | DWG NO GR2 Drawing Package | REV |
| | | SCALE 1 : 1 | | SHEET 3 OF 5 | |

NOTE:
ALL DIMENSIONS IN MM
ALL TOLERANCES HELD TO
PLUS OR MINUS 0.5MM
UNLESS OTHERWISE NOTED




NOTE:
ALL DIMENSIONS IN MM
ALL TOLERANCES HELD TO
PLUS OR MINUS 0.5MM
UNLESS OTHERWISE
NOTED

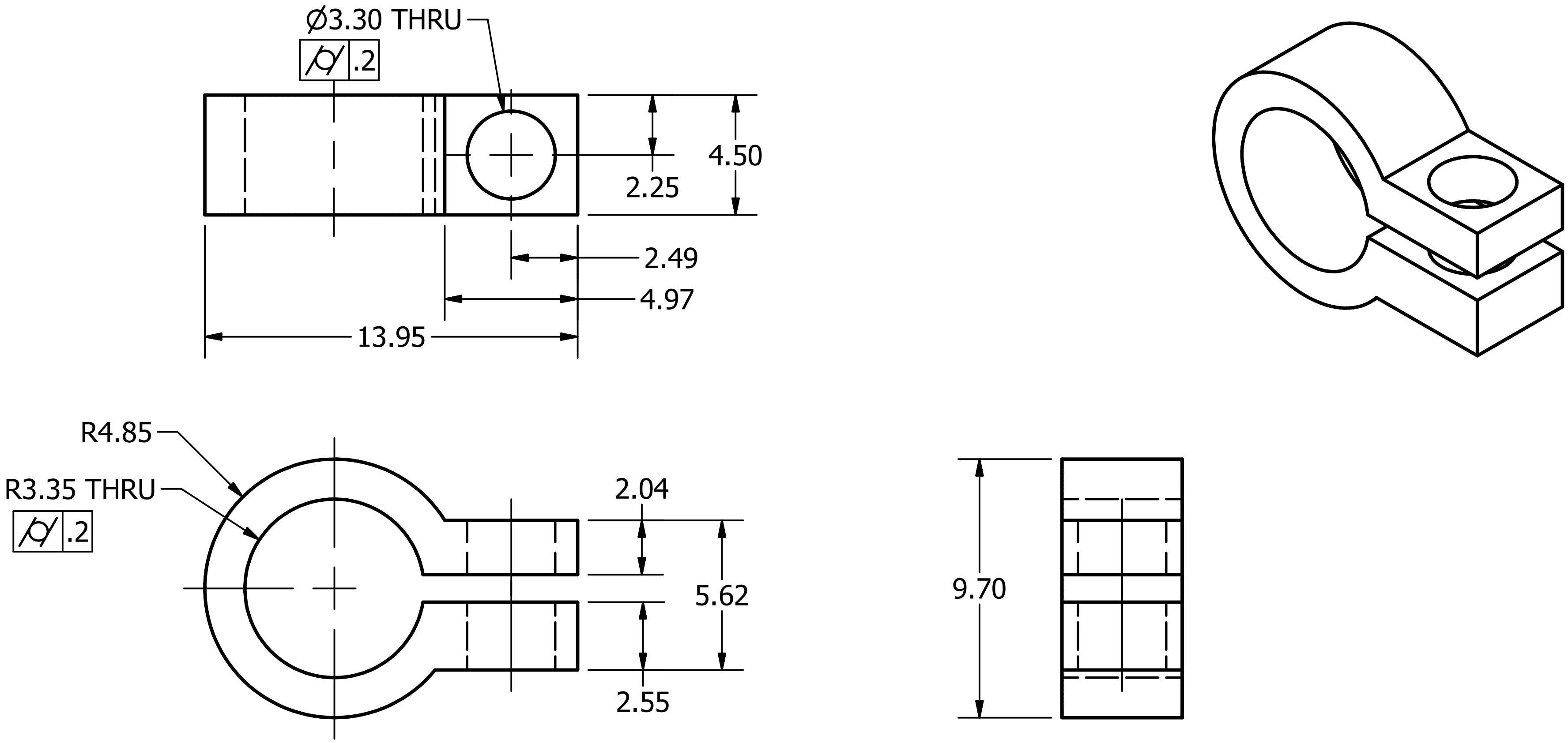
| | |
|---|---|
| DRAWN Group 1 | 03/12/2022 |
| CHECKED JD, MS, AD, ST | |
| QA | |
| MFG | |
| APPROVED | |

TITLE

Group1EngineeringDrawingPackage

| SIZE | DWG NO | REV |
|---|---|---|
| A | GR2 Drawing Package | |

SCALE 3 : 2 | SHEET 4 OF 5




NOTE:
ALL DIMENSIONS IN MM
ALL TOLERANCES HELD TO
PLUS OR MINUS 0.5MM
UNLESS OTHERWISE NOTED

| | |
|---|---|
| DRAWN<br>Group 1 | 03/12/2022 |
| CHECKED<br>JD, MS, AD, ST | |
| QA | |
| MFG | |
| APPROVED | |
| | |

TITLE

Group1EngineeringDrawingPackage

| SIZE | | DWG NO | REV |
|---|---|---|---|
| A | | GR2 Drawing Package | |
| SCALE 4 : 1 | | SHEET 5 OF 5 | |