FINAL DESIGN REPORT

Org^{2}

Dynamic Stiffness Test Organizer (DSTO)

6th of June 2023

Department of Materials
Royal School of Mines

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Introduction

We addressed the company's task by recognizing the potential for innovation and design among many young engineers. To capture this and cultivate it in a way where everyone's ideas had been heard, we decided to split the group up into 3 brainstorming subgroups. The idea of this was to allow people to speak within an environment that avoids the possible intimidation that would come if we did this all together.

We split the overall project into three sub-sections: the feeder component, the testing component, and the sorting component. Each group was tasked with creating a viable solution for each of these components, then asked to present these designs as a quick sketch which included the number of electrical components for the design. One person from each group was then assigned the role of explaining their subgroup's ideas.

Once each subgroup was ready, we came back together and held a meeting. All three subgroups were heard and criticized constructively. This allowed for productive conversations to take place and for us to reach a unanimous decision on our final project. There were a lot of clear overlaps between the designs of each subgroup, so we utilized this advantage by taking ideas from the separate designs and combining them to produce something we were all happy with.

The subgroups were then allocated with a good spread of abilities in each, progress has been fast, and our subgroups have been working very effectively. The three subgroups have been finalizing their respective designs whilst utilizing the available 3D-printed rapid prototyping. Fortunately, many problems have arisen through doing this which has allowed us to mitigate potential issues with our overall design.

Communication between the subgroups since last term has been much better, which has allowed us to integrate designs more efficiently, such as our new diagonally facing testing design. To briefly highlight some problems, we found that balls were getting stuck in our original feeder design so rotating wheels were implemented and a new component was created. Also, we reduced the possibility of balls falling out of the sorting component by adding ramps around the rotating sorter lid to reduce the possibility of this. Box joints were added throughout the design where the laser-cut MDF was used to increase structural stability and reduce manufacturing costs of screws.

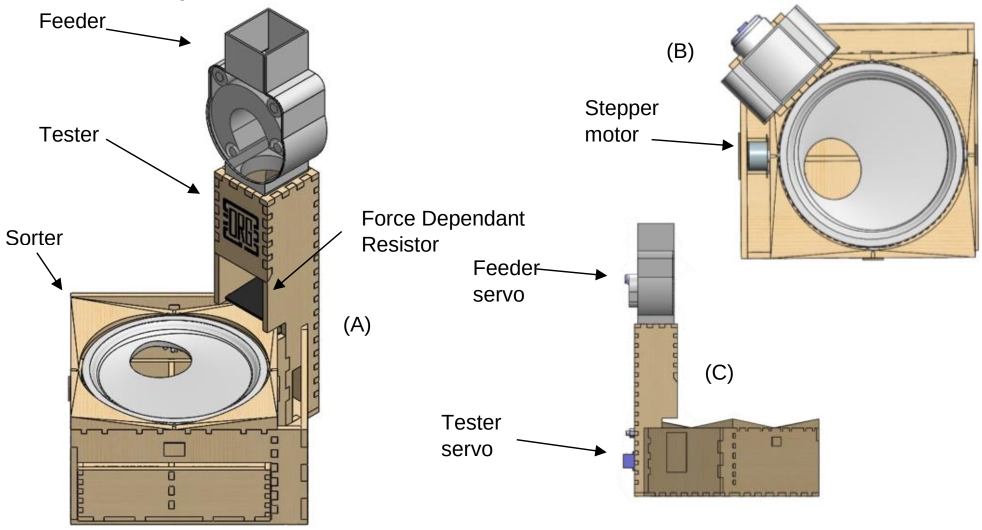


FIGURE 1: FULL FINAL RENDERING OF PROTOTYPE (A) SIDE VIEW (B) TOP VIEW (C) ISOMETRIC SIDE VIEW

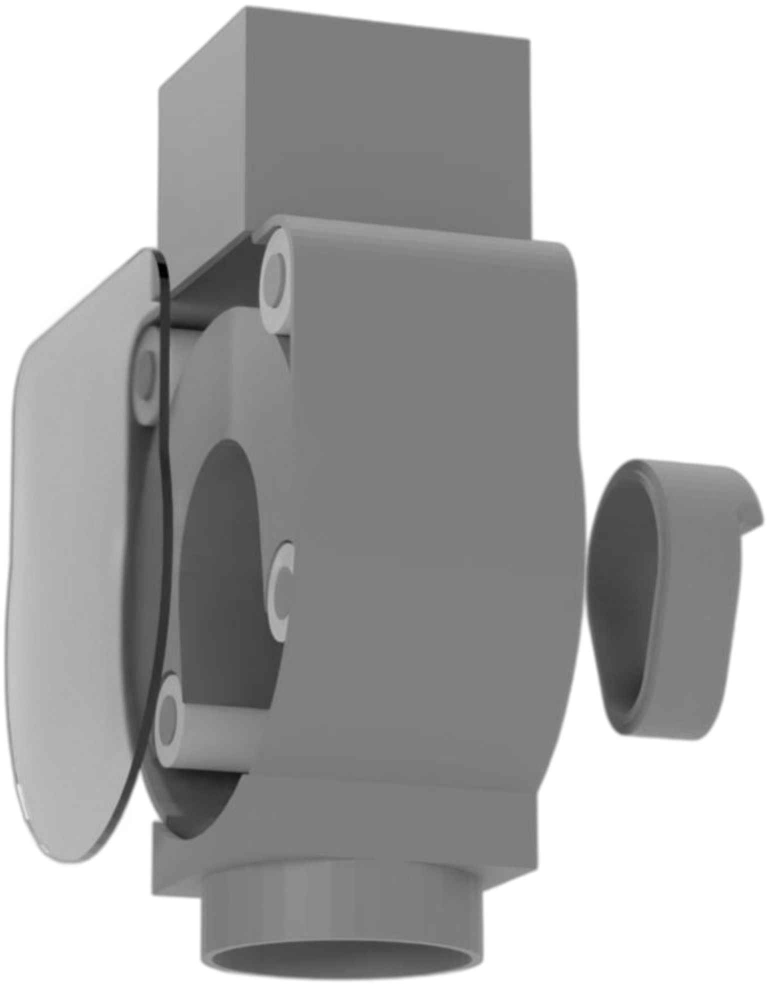
FEEDING ELEMENT

Bubi Zhou

Charles Li

Yifan Shen

Yifan Zhou



PROLOGUE

The feeder subgroup was responsible for creating a mechanism which introduces the ball to the testing mechanism one by one. This includes mostly CAD design and collaboration with the coding group to ensure that the final design is functional.

Director, Bubi Zhou was responsible for concept ideation, CAD modelling, overall communication, and management of the company. He proposed ideas for various parts of the machine, such as using a dynamic stiffness test for the sensor element and a rotating lid sorting mechanism during the brainstorming phase. Within the subgroup, he modelled the final feeder shell and the motor mount. He worked closely with Chief Engineer Mervyn Ochoa-Dugoy to encourage inter-subgroup communication, ensuring that the groups are working in unison and communicating proactively. With Deputy Director Felix Watson he organized the operations within the company and provided support to those who need it

Chief sustainability officer, Charles Li worked under the Feeder Subgroup in addition to the duties of his job title. His work includes CAD modelling in all phases of the design process, Brainstorming and managing the sustainability aspect of the company. In the prototype phase, Charles worked with Yifan Shen to create and modify the rotating separator and enclosure design. He was also responsible for the creation of the final rotating separator and kept track of the company's environmental impact and wrote sustainability reports.

3D printing engineer, Yifan Shen was involved in all phases of the feeder design process. She worked alongside Charles Li to create the CAD models for the first two prototypes. Yifan contributed to the organization of company files and improved coordination between design and manufacturing. She also produced technical drawings and renders for the feeder subgroup in the concept design report and the final design report.

Laser cutting engineer, Yifan Zhou was responsible for laser cutting prototype and final parts. Her contribution includes transforming 3D files into 2D templates suitable for laser cutting. As a dedicated Laser cutting engineer, she works to ensure that the laser cut parts achieve optimal quality. She also participated in the brainstorming process in the initial concept phase and the feeder redesign after the second prototype, where she contributed interesting ideas.

Director	Bubi Zhou	[illegible]
Chief of Sustainability	Charles Li	李晨阳
Laser Cutting Engineer	Yifan Zhou	[illegible]
3D Printing Engineer	Yifan Shen	[illegible]

INTRODUCTION

Unsorted balls will be dispensed into the feeder through the square tube on the top. The series of balls stack naturally above the opening with one ball inside the rotating separator. The U-shaped separator then turns 180 degrees, separating the ball inside from the stack above, and allowing it to fall into the Sensor Chamber through an opening on the bottom of the enclosure. Two undriven rollers are installed on each side of the separator's opening to allow the balls to roll and eliminate friction while separating them. Another two rollers are placed above the separator, connected to the enclosure to allow the balls above to spin freely while the separator moves.

FIGURE 2: A TOP-DOWN VIEW OF THE FEEDER ASSEMBLY.

This part of the machine has gone through 2 major iterations before its current design:

The first prototype featured a separator with 3 cavities for the balls and a simple socket for a stepper motor on the back. The major drawback with this design was that the soft and heavy ball made of an elastomer tends to create a lot of friction between itself and the enclosure causing the mechanism to get stuck whenever the rubber ball was entering the feeding mechanism and when it was inside.

For the second iteration, lubrication and low-friction materials were proposed as potential fixes but were not realized. Instead, testing showed that when the ball was pushed below its horizontal axis, less friction was produced. Thus, the shape of the rotating part was revised to have a stepped protrusion at the bottom of the walls of the cavities, lowing the contact point. The top of the rotating part was also filleted to address the issue of the rubber ball getting when it was the next ball to be fed into the mechanism. However, the result of these measures was not satisfactory and thus the team decided to pursue a different concept which became the final design.

The new design has a few advantages:

1. Accommodates the higher-torque micro servo motor through a specially designed mounting bracket on the back of the enclosure.
2. The amount of torque required was minimized as it contained only one ball at a time instead of 2 and the ball was placed in the center of rotation.
3. The size and thus the weight of the part was drastically reduced, facilitating more mounting options and an overall less top-heavy machine compared to the first prototype.

CONTENT

The Rotating Separator

The rotating separator has a circular base, U-shaped side walls and two undriven rollers at each side of the opening where the ball moves in and out.

The base plate is 2mm thick with a cylindrical mounting bracket on the back. The mounting bracket was designed to fit a disk servo arm compatible with the Arduino micro servo. It has 4 screw holes 90 degrees away from each other for torque transfer and another in the middle for another M2 screw to be directly screwed onto the servo motor from the ball chamber. Thus, a 2mm deep circular cut was made to keep the bottom of the ball chamber flush.

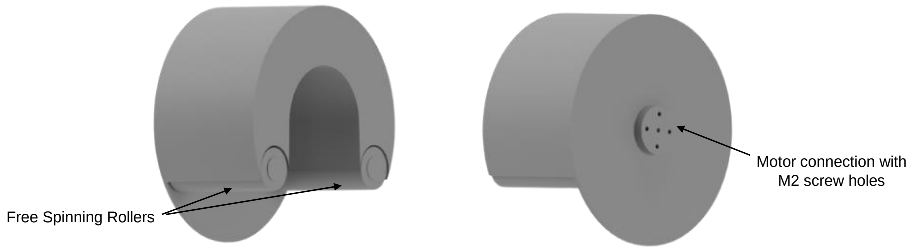


Figure 3: Detailed renders of the Rotating separator displaying key features.

The side walls of the rotating body have a similar footprint to the letter U. The outer perimeter is circular to comply with the overall cylindrical shape. The inner perimeter is a semicircle connected to two straight lines at the opening. The diameter of the inner semicircle is slightly bigger than the biggest ball to keep the ball inside stable and make sure the balls are released when the rotating body is turned over. The opening flares slightly outward to increase fault-tolerance.

At each side of the opening, there is a free spinning roller. These rollers aim to minimize friction between the balls and the rotating body. When one ball is fully seated in the ball chamber, the next ball in the stack will also be partly in the rotating body. As the body rotates, the rollers help to push the unwanted ball back up without creating friction.

The Shell

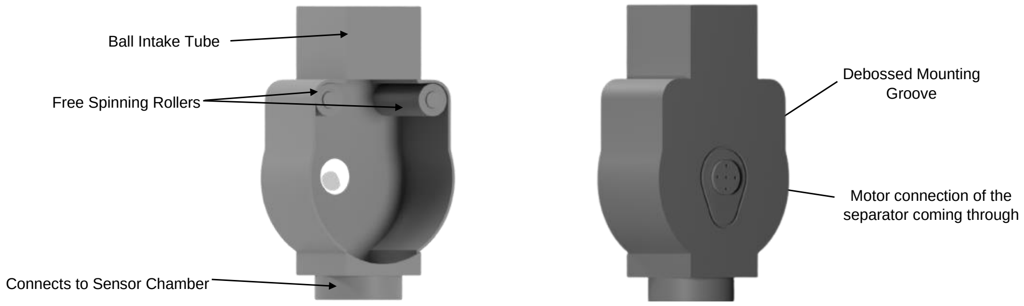


Figure 4: Rendering showing the feeder shell from a front and back diagonal view

The shell has a square ball intake tube at the top, two undriven rollers on each side at the end of the intake tube, the main closure in the middle and a tube below the main enclosure where the feeder is connected to the testing chamber.

It is possible to add attachments onto the square ball intake tube to hold more balls and reduce the number of times required to load the balls.

The two rollers on each side of the bottom of the intake tube reduce friction while the feeding mechanism operates. It does so by allowing the second ball in line to roll while the rotating separator is moving instead of getting stuck to one side of the wall. They also reduce the risk of two balls getting stuck and double feeding.

On the back of the shell there is a hole designed for the mounting bracket on the back separator to come out and connect to the micro servo motor.

There is also a 1mm deep debossed groove on the back of the feeder shell. This was designed to accommodate the motor mount. The debossed groove allows the motor mount, which has a raised layer of the same shape to be seated at exactly the desired location. The motor mount is glued onto the shell thus the grooves increase contact area and improve stability.

THE MOTOR MOUNT

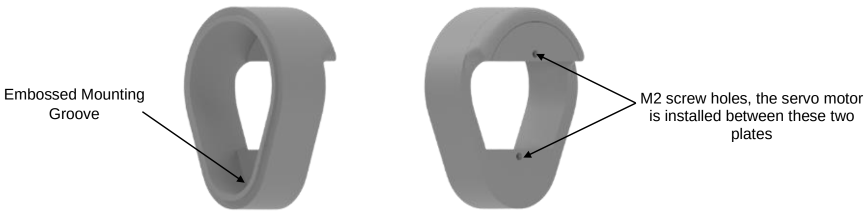


FIGURE 5: RENDERING SHOWING THE MOTOR MOUNT FROM A BACK AND FRONT DIAGONAL VIEW

The motor mount is a single 3d printed piece designed to be attached to the back of the feeder enclosure and accommodate a micro servo motor.

There are two screw holes which line up with the mounting holes on the micro servo. Two M2 screws are used to attach the motor to the mount. The mount is anchored onto the shell by an adhesive. The raised layer around the side in contact with the shell fits the debossed groove which increases the contact area.

THE WINDOW

An acrylic window is installed on top of the feeding element to display the inner workings and allow the user to monitor the progress of the machine.

SENSOR CHAMBER

Mervyn Ochoa-Dugoy

Geronimo Lauzan

PROLOGUE

The Sensor chamber subgroup consists of two members; Chief Engineer, Mervyn Ochoa-Dugoy, and Chief of Production, Geronimo Lauzan. For the initial stages of the ideation process, they collaborated with Director, Felix Watson. Once the sketching was done, Ochoa-Dugoy worked on most of the CAD design, with Lauzan doing what was left. They both assembled the two prototype test chambers. Both members were also constantly communicating with the coding, feeder, and sorter subgroups to fulfill the design requirements of each group.

Chief Engineer, Mervyn Ochoa-Dugoy, sketched all the sensor group schematics in the report. As part of his role, he took charge of gathering all subgroup parts, using the part list document made by Adele Morgan Delarboulas, and making the final assembly. Ochoa-Dugoy ensured all designs were in line with each other, informing subgroups of any issues that arose. Furthermore, he was responsible for managing the technical drawings, ensuring a high standard.

Chief of Production, Geronimo Lauzan, chose appropriate materials suitable for the chamber and made the technical drawings for all the parts and full assembly of the sensor chamber. He was also involved with laser cutting prototypes for subgroups, as well as an Excel sheet for the costs of materials and how much to order, and another for keeping track of the production of parts.

Chief Engineer	Mervyn Ochoa-Dugoy	
Chief of Production	Geronimo Lauzan	geronimo

INTRODUCTION

The sensor subgroup was responsible for designing the chamber where the ball's weight and stiffness would be tested (including the code used for this) while connecting the feeder and sorter parts. The chronological layout of the part is as follows: the ball will be received from the feeder, at which point it will drop 156 mm, falling onto a force sensor connected to a test plate. That information is sent to Arduino, where a program categorizes the ball based on stiffness and mass. Once the sorter part has finished moving, a mechanism consisting of a pear-shaped cam and T-shaped follower will lift the test plate up so the ball rolls onto the sorter section.

CONTENT

Though the main concept remained the same, after testing a lot of problems with the original design were brought to light. These problems were categorized into three groups: Main structure, movement of balls between sub-parts, and testing.

The main structure of the testing chamber was very stable, with finger joints and glue connecting the pieces securely. However, it was slightly too large (95 mm x 90 mm x 391.67 mm), which made it difficult to maneuver with the rest of the prototype, despite being mostly made of lightweight materials like cardboard. We resolved this issue by overlapping the sorter and the chamber, which helped make the overall design significantly smaller. To make the design more compact, two decisions were taken. One was re-dimensioning the chamber to 72mm x 72mm x 282mm, as thickness of MDF used also had to be changed from 5mm to 6mm MDF because of stock availability. The second was the feeder now positioned vertically above the testing chamber to not occupy as much horizontal space. These changes significantly reduced the amount of material used, reducing both cost and environmental impact by a considerable margin.

The transport of balls between the feeder and testing chamber, and subsequently testing chamber to sorter proved surprisingly more challenging than anticipated. As a result, the trapdoor concept was discontinued from the prototype due to structural instability with 1 servo motor suspended at the back piece, and dropped balls would tilt to one side inside the chamber – causing unrepresentable results. Adding a second motor was proposed but was deemed too energetically draining to justify for Arduino. As for the testing chamber's connection to the sorter, the main issue was stopping the ball from bouncing to the sorter once it hit the test plate. Prototypes included a "speedbump" and curtains with frills similar to those in car washes. Ultimately, these ideas did not guarantee stopping the ball from falling into the next part, so were discarded. The solution was to tilt the test plate downwards by 5° towards the back piece, as the ball would bounce and roll towards the back wall instead of bouncing randomly, and the 5° tilt did not affect the results. The plate was also made thicker to improve endurance upon impact. Both changes increase the amount of work the pear cam mechanism does to push the plate upwards.

Minor adjustments were made to the mechanism responsible for moving the ball to the sorter correctly. The cam mechanism worked satisfactorily: the snail cam rotated, pushing the follower upwards and secured by support blocks using MDF. We changed all parts of the mechanism to PLA as it is tougher, more impact resistant, and easier to manufacture due to the complex shape of the re-designed support block. The cam shape was changed from snail to pear, and the follower was filleted at the point of contact with the cam for smoother motion.

MAIN BODY OF CHAMBER

Composed of the top, left, right, back, and front pieces, this forms the main body and structure of the sensor. As mentioned earlier, the main body is defined to 72 mm x 72 mm x 282mm. Series of finger joints on each piece ensures the chamber is rigid when glued together, with holes on relative side pieces (as seen in Figure 6) to account for bolts and Arduino components. For aesthetic purposes, the Org^2 logo has been placed at the front piece to authenticate our prototype. All these pieces are laser cut with 6 mm MDF so that intricate, precise cuts are made for the joints and holes.

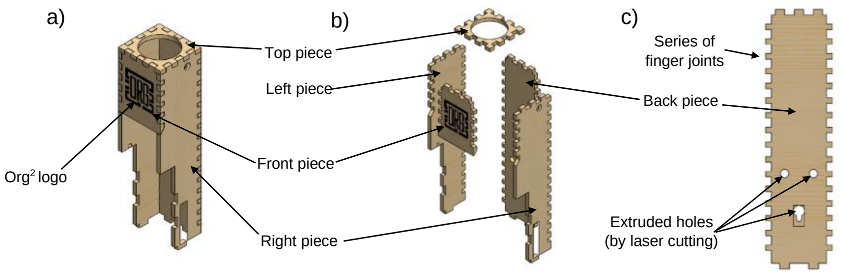


FIGURE 6: MAIN BODY OF THE SENSOR CHAMBER WITH NO INTERNAL COMPONENT. A) THE CHAMBER WHEN COMBINED USING FINGER JOINTS WITH B) AN EXPLODED VIEW TO FURTHER ILLUSTRATE. C) BACK PIECE SHOWING EXTRUDED HOLES FOR BOLTS AND SERVO MOTOR OPERATING THE MECHANISM.

TOP PIECE

The top piece, 72 mm by 72 mm, serves 2 primary features. First, it has a 54 mm hole through its centre (see appendix) which the 3D printed feeder is inserted into, up to its rounded neck. As shown in figure 7, a small section of the feeders' output is inside the chamber to ensure the ball is centred at the initial stages of the drop. Secondly, it serves as a detachable part for the user to access the wiring on the right piece in case any issue arises with connection to the feeder. The top piece has a series of finger joints that align perfectly with the main faces of the chamber, which require laser cutting on MDF.

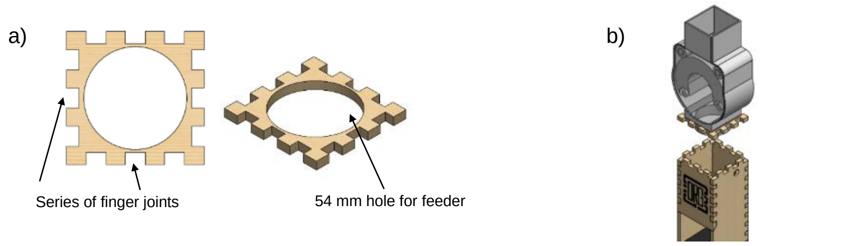


FIGURE 7: PROFILE VIEWS OF THE TOP PIECE. A) TOP AND ISOMETRIC VIEWS OF THE COMPONENT ALONE. B) INTEGRATION OF THE FEEDER DESIGN WITH THE TOP PIECE USING AN EXPLODED VIEW SHOWING THE COMPONENT BEING DETACHABLE.

RIGHT PIECE

The right piece is a mirror image to the left piece, but with modifications to accompany all subgroups. To facilitate the feeder's Arduino requirements, a 3 mm deep groove is made along the inside piece for wiring to fit inside (by gluing agents), leaving exposure to a minimum when the product is at work. This is followed with a small 5 mm hole near the top of the piece for the wires to exit. Furthermore, a 45^o angular cut is made just below this groove to insert part of the breadboard and other Arduino components inside (if necessary), while aligning to the design of the sorter. Like the left piece, there is a support rod hole for the 3D printed Arduino piece to pivot the testing plate for rotary motion.

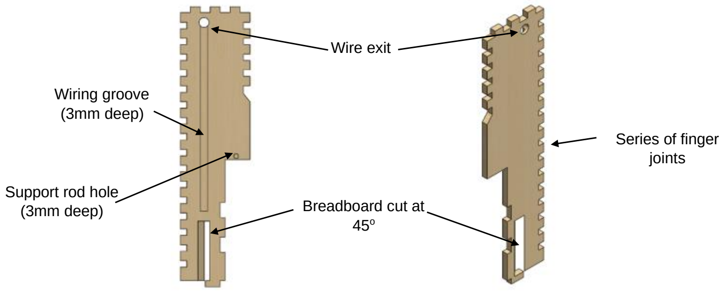


FIGURE 8: FRONT AND ISOMETRIC VIEW OF THE RIGHT PIECE. THE PART INCLUDES THE LOCATIONS OF THE GROOVE AND HOLES FOR FEEDER WIRING AND THE BREADBOARD.

TESTING PLATE

A 3D printed test plate is suspended prior to the ball drop at 5^o towards the back piece to reduce the chances of the balls bouncing or falling towards the sorter without completed data analysis from Arduino. The thickness is set to 7mm with 100% filling for impact resistance and durability against the weight of the falling balls, especially the cue ball. The dimensions are 58mm by 58mm to allow a 1 mm tolerance on all sides to prevent friction on the main body pieces, followed by an extruded circular cut at one side of its thickness to the part can be freely rotated (under the support rod) as seen in figure 9. The force sensor, 40 mm x 40 mm, will be attached at the centre of the surface of the plate facing towards the ball drop, with wiring coming off to the side in alignment to the right piece wiring for the feeder.

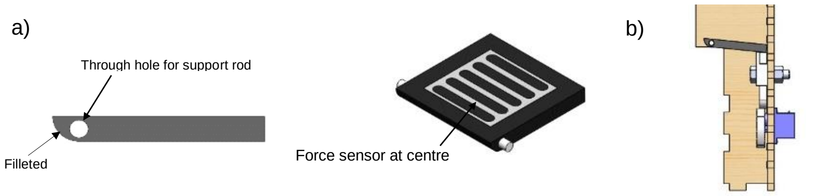


FIGURE 9: A) TEST PLATE DESIGN, INCLUDING THE PLACEMENT OF THE FORCE SENSOR. B) SIDE VIEW OF THE THE TEST PLATE AT REST, WITH THE NON-FILLETED END SITTING ON THE FOLLOWER OF THE MECHANISM.

Mechanism

Composed of the pear cam, support block and T-shaped follower, they are all 3D printed parts that are facilitated by the servo motor, which is screwed at the lower centre of the back piece. The teeth of the servo motor drive the pear cam in rotary motion, oscillating the follower up and down, restricted by the support blocks. 9 mm extruded holes on the support block allow M8 bolts to be inserted through, locking the block and the follower in place with accompanying nuts. The slight offset of 2 mm of the cam with the other components, due to the dimensions of the servo motor, has no effect on force felt by the follower, as all parts are 7 mm thick (with ± 0.5 mm tolerances in place across all dimensions).

The motions are controlled by the Arduino program and activated once the data has been processed for the sorter to respond. By then, the follower will undergo max extension when the servo motor rotates the pear cam 180° to its tip (Figure 5), in which the tested ball will start to roll into the sorter. It then returns to its base position by rotating 180° anti-clockwise for the next ball to drop.

The total distance travelled by the follower is equal to the height of the pear cam, from tip to tip. To fulfil this in practice with no errors, the T-shaped follower was filleted at the end to ensure smoother contact with the cam, as previously mentioned. The location of the mechanism is 159 mm from the very top of the chamber, calculated by adding the drop height (from the top of the chamber) with the vertical distance of the testing plate when suspended 5° at rest, using trigonometry.

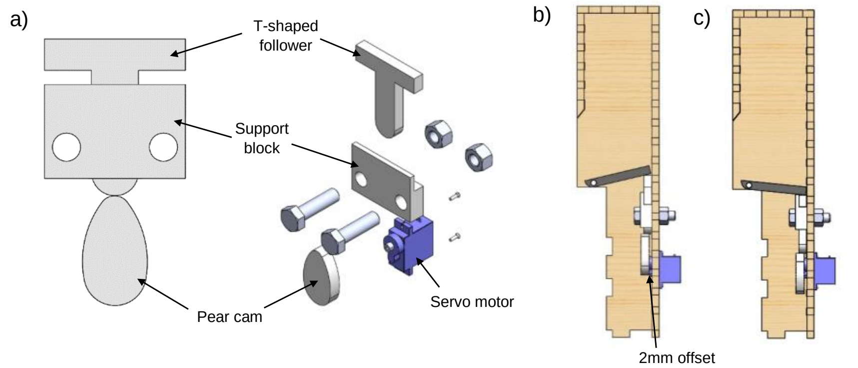


Figure 10: A) FRONT AND EXPLODED VIEWS OF MECHANISM COMPONENTS. SIDE VIEWS OF THE MECHANISM, OPERATED BY THE SERVO MOTOR (ARDUINO), AFFECTING THE TEST PLATE WHEN B) FULLY EXTENDED, C) AT BASE POSITION AFTER EACH BALL DROP.

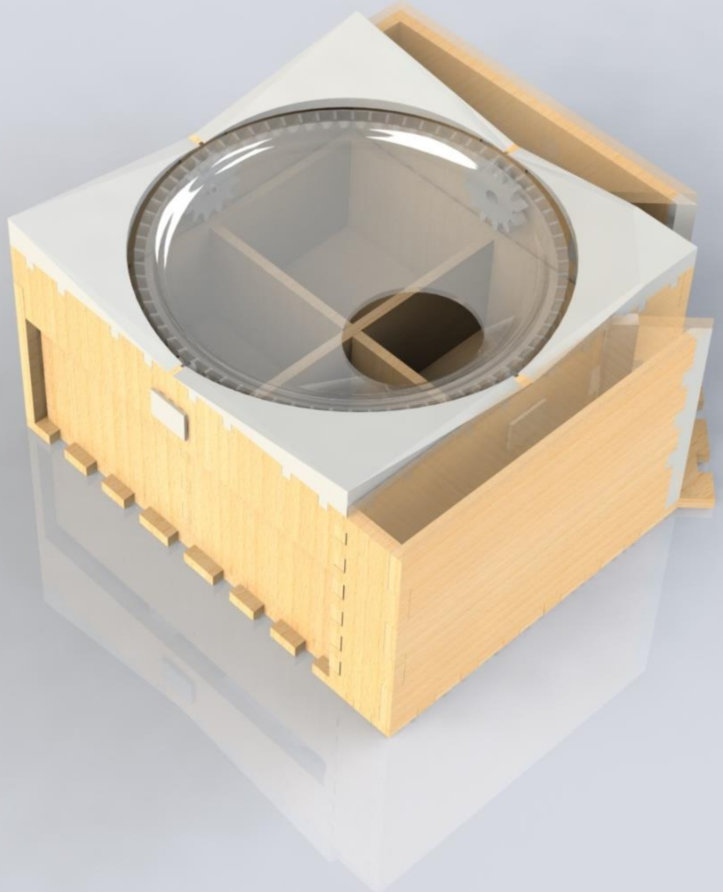
SORTER ELEMENT

Adele Morgan Delarboulas

Donya Sharifi

Rishi Karthikeyan

Yancheng Meng



PROLOGUE

Deputy Chief Engineer, Adele Morgan Delarboulas, enacted a subgroup leader during the design and production of the sorting element: organizing, scheduling, and leading the team through design and problem mitigation, from the concept design to the final production of the element. Morgan Delarboulas designed the main aspects of the sorter, designing the gears and rotating plate in SolidWorks during the prototyping stages and then designing the bulk of the compacted exterior in the final production stages. She continually liaised with Chief Engineer, Mervyn Ochoa-Dugoy, and Chief of Production, Geronimo Lauzan, to ensure continuity through production and ensure the sensor element as well as the wiring components would efficiently integrate within the whole design.

Equality, Diversity and Inclusion Officer, Donya Sharifi, was responsible for aspects of the CAD work throughout both the prototyping and final production stages. Sharifi performed the task of meticulously adding finger joints to the bulk of the design in preparation to be laser cut. Further assisting Deputy Chief Engineer, Adele Morgan Delarboulas in designing the pinion and bevel gears in the prototyping stage, and consequently making the final design of external gears and clips in the final stages of design. Sharifi also hosted frequent meetings with the entire company to ensure company morale, efficiency and communication were performed throughout the project's progression.

Chief Financial Officer, Rishi Karthikeyan, contributed a sizable proportion of the technical drawings produced in both the prototyping stages and final production stages of the element. Karthikeyan assisted Deputy Chief Engineer, Adele Morgan Delarboulas, with aspects of the exterior CAD design during both production stages of the elements and provided financial input as to the appropriate materials to be used within production. He provided further financial guidance and documentation of spending for the entirety of the company, liaising with Chief Engineer Mervyn Ochoa-Dugoy, Deputy Director Felix Watson and Production Engineer Geronimo Lauzan throughout the project.

3D Printing Engineer, Yancheng Meng, first assisted with the CAD design of the element's holding box during the prototyping stages of the sorting elements. Once production began, Yancheng became responsible for the bulk of the 3D printing and production of all three elements of the machine. Yancheng continually liaised with Chief of Production Geronimo Lauzan, Chief Engineer Mervyn Ochoa-Dugoy, Deputy Chief Engineer Adele Morgan Delarboulas and Director Bubi Zhou to ensure production of printed elements were efficient and scheduled to meet the demands of the company.

Adele Morgan Delarboulas

Donya Sharifi

Rishi Karthikeyan

Yancheng Meng

CONTENT

The sorting element acts as the final component of the machine, amalgamating the data output from the sensor area into mechanical rotations of a sorting plate. This would allow the ball to be assigned and delivered to its appropriate holding chamber based on the categories mass and hardness.

Our team chose to approach this via 3 major elements to the design: a 4-pinion-bevel gear system, a rotating plate, and a drawer-like holding chamber. These elements are then expected to perform a cascade of functions. Once the output data is received from the sensor area the rotating plate is programmed to turn via a stepper motor n turns from the origin position based on the ball category assigned. Once the motor has finished rotation, this would signal the sensor area to release the ball into the sorting chamber where then it would roll down the plate like a funnel into its assigned holding chamber of the drawer. An appropriate amount of time after the ball is released, the plate will then be turned back to its original position, signaling the next ball to be tested and the process to repeat.

During the prototyping stages we produced an array of designs for the rotating plate, one of which was designed based on a shape similar to a donut shape which would be rotated directly via a stepper motor from its center. Another design was a plate which derived its outer circumference on a bevel gear, this would then be supported and rotated by a 4-pinion-gear stepper system. The plate design was decided on due to the lower power output of the stepper motor and allowed a distribution of the balls mass onto the gears rather than a more intensified stress on the motor attachment when at its center. Gear attachment pieces, gears of different teeth and segment of the plate were then produced and tested via 3D printing. Gears of 12 teeth and a bevel plate of 72 teeth were proven to be successful balance of the gear module and sizing and were of adequate amount to facilitate efficient plate rotations (3 rotations per 180° turn of plate). The plate design was produced and deemed successful and has remained unchanged since the prototyping stage.

A rectangular drawer with a cross-section divider and an external network to support the gear and motor were designed and produced via laser cutting of cardboard to minimize PLA use. Teeth joints were introduced to increase mechanical rigidity of the design and decrease PVA glue use.

At the end of the prototyping phase, although the design was successful and allowed for the plate to be supported and rotated, key aspects of the design were required to change to allow for efficient use of space and material.

KEY AIMS AFTER PROTOTYPING

-Make supporting and holding chamber more compact whilst still protecting plate from tipping, prior excess of 25mm of space on each side

-Minimize length of gear shaft and introduce additional support to mitigate turning/bending of shaft

-Integrate motor into wall rather than being exposed in chamber

-Find alternative for attachment of gear to motor due to motor overheating and melting PLA when directly attached

-Find more appropriate way to integrate sorting piece with entirety of machine, in particular connection to the sensor area and adequate spacing for circuit-ware and wiring

Rotating Plate

To reiterate what has been stated before, the rotating plate has made no design changes since the prototyping stage.

The plate (figure 11) is developed from a 72-teethed bevel gear which has been integrated into a off center funnel, with a 20mm drop in height. An ellipse of max length 60mm has been added, a sufficient tolerance to allow the largest ball through. This element will be supported at 4 positions on its circumference, 90° apart, via a set of pinion gears. This acts as a feeder to the holding chamber. See appendix A for the technical drawing.

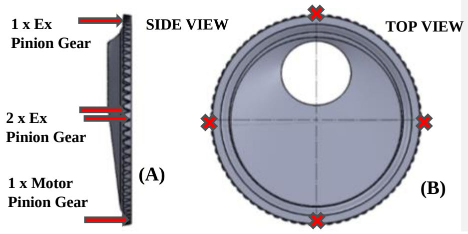


FIGURE 11: SCHEMATIC OF R PLATE FILE (A) SIDE VIEW OF PLATE, RED ARROWS INDICATING PINION GEAR SUPPORTS (B) TOP VIEW OF PLATE, RED CROSSES INDICATING WHERE GEARS SUPPORT.

4-Pinion-Gear System

In order to minimize the space of the holding chamber, the shaft length of both the exterior gears and motor gear were reduced in length to approximately 3mm exposure in the main chamber (figure 12a, 12b and 12d). However, this increased the potential for the gear to fall from its holders, so gear clips were developed and printed as an alternative to bearings, to fix the external gears into place.

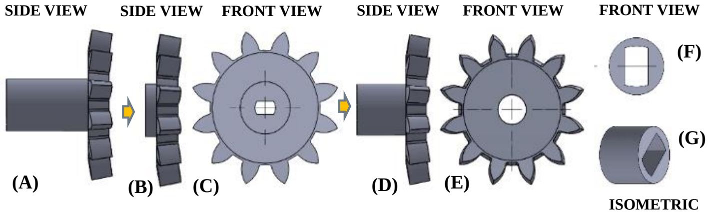


FIGURE 12: SCHEMATICS OF (A) SIDE VIEW OF PROTOTYPE EXTERNAL GEAR WITH ORANGE ARROW INDICATING CHANGE TO (B) SIDE VIEW OF FINAL EXTERNAL GEAR. (C) FRONT VIEW OF PROTOTYPE MOTOR GEAR WITH ARROW INDICATING CHANGE TO (D) SIDE AND (E) FRONT VIEW OF FINAL MOTOR GEAR.

As a replacement for the gear attachment to be external to the gear than integrated, a gear attachment piece (figure 12f and 12g), laser cut from MDF, was developed and placed in the internal cylinder of the motor gear (figure 12e). This acts as an effective insulator preventing burning/melting of the PLA gear when the stepper motor overheats.

The 4-pinion gear system is comprised of 4 pinion gears, 3 of which are external gears and 1 a motor gear. All gears have 12 teeth with a module of 2.5. These act as 4 supports for the rotating plate and allow for rotation of the stepper motor to turn the plat by degree rotations. They are fixed onto the external support system via protrusions on the wall (gear holder). Refer to appendix B and C for gear technical drawings.

HOLDING CHAMBER

The holding chamber has made minimal changes since the prototyping stage. The width of the box has reduced approximately 25 mm to 186mm to minimize the size of the chamber, making for a more compact design. Furthermore, now produced from MDF rather than wood, which minimized the cost of the chamber.

The holding chamber (figure 13) is designed after a drawer, with a cross section division in order to hold the ball in their individual categories. The entire piece is laser cut out of wood and adhered together via PVA of the finger joins for structural integrity. Refer to appendix D for technical drawings.

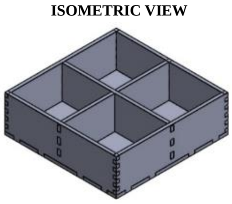


FIGURE 13: SCHEMATIC OF ISOMETRIC VIEW OF SORTING BOX USED FOR HOLDING CHAMBER.

External Support System

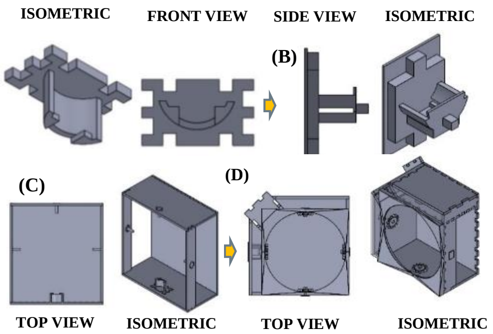


Figure 14: Schematics showing (a) prototype gear holder and orange arrow indicating (b) new finalized motor holder. Schematic of (c) prototype external support system with orange arrow indicating (d) new external support system

The main challenge for developing the external system from the prototyping stage was making the entire system more compact and isolating the motor and circuit ware to a separate chamber.

The main chamber was made more compact by reducing the gear shaft and main holding chamber by approximately 25mm. The motor holder was moved to a separate chamber of approximately 28mm wide and motor flipped altering the design (figure 14a to 14b) to reduce the height of the overall chamber by lowering the placement of the motor gear. The chamber in which the senor chamber attached moved to diagonal (figure 14d) instead of parallel to side of the chamber (figure 14c) to allow a more compact integration of the separate parts and allow for circuit ware to be entirely stored in the sorter part. This room being found in the isolated chamber of the motor and chamber normal to it (figure 14d).

Elevated borders were developed to fit around the rotating plate, preventing the ball from escaping the plate or chamber and ensuring the plate wont slip of tip from it allocated position due to the ball, these will be 3D printed.

The external support system is hybrid MDF, PLA system which is used to integrate all separate parts of the sorting element into one product, supporting the motor, gears and storing the main chamber.

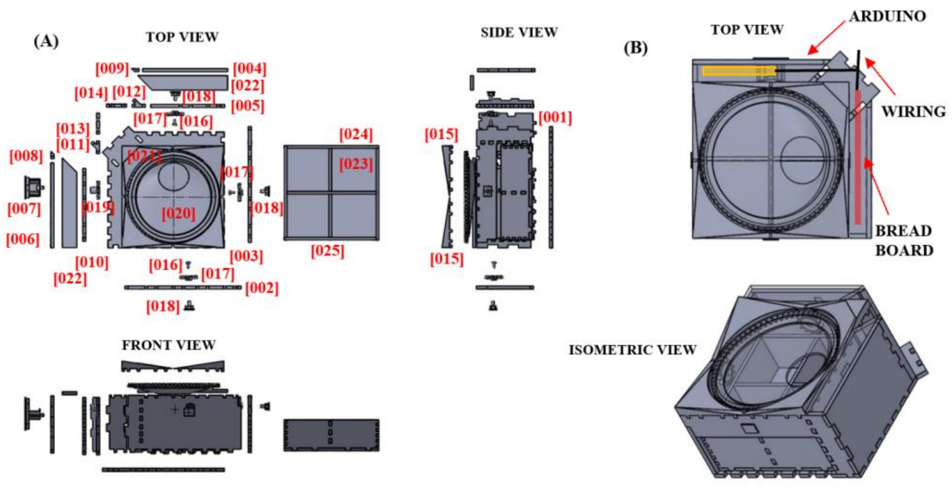
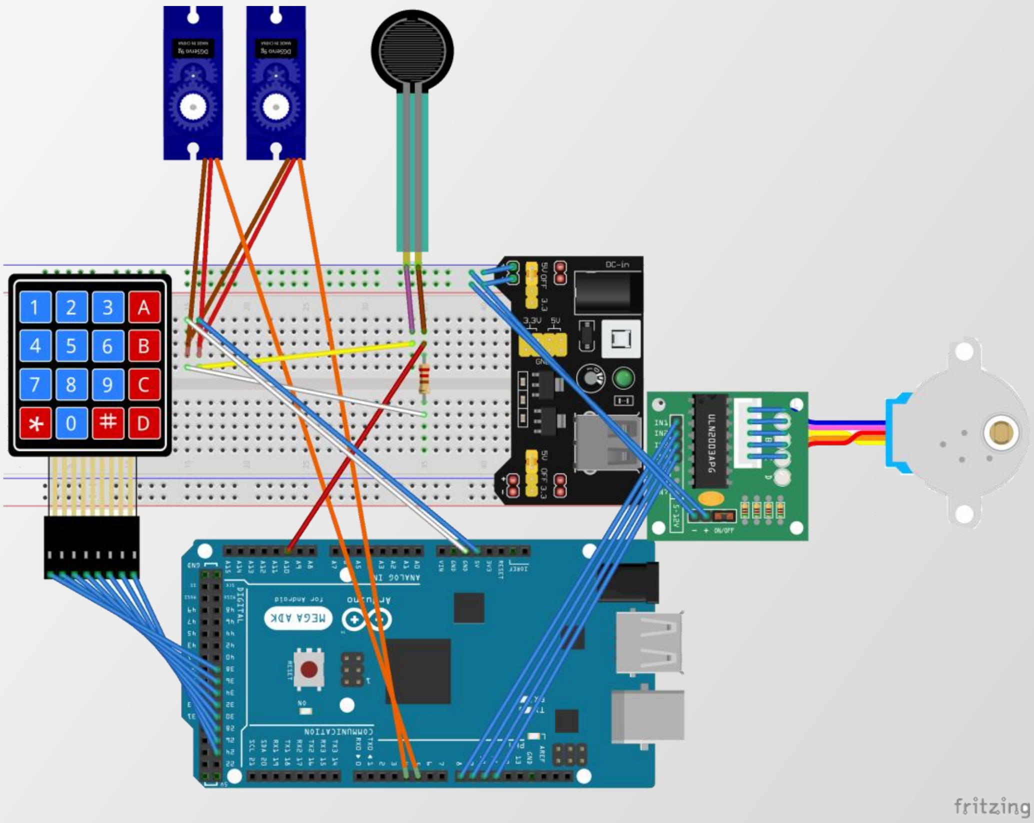


Figure 15: (a) Exploded schematic of final external support system, shwoing top view (top left), side view (middle), front view 9(left bottom) Red numbers indicating to parts list in appendix (b) schematic of external support system showing circuitware and wiring


1 2 3 A
4 5 6 B
7 8 9 C
* 0 # D
ULN2003APG
MEGA ADK
fritzing

PROLOGUE

Chief of automation and control, Matt Price, enacted as subgroup leader and oversaw the coding from the prototype stage up until the final product was produced. Initially, he liaised with Chief Engineer Mervyn Ochoa-Dugoy, Deputy Director, Felix Watson and Production Engineer, Geronimo Lauzan to refine the theory behind the dynamic stiffness testing. Then went onto making it a reality, trying a load cell, but further settling to use a force sensitive resistor (FSR). Price worked on translating the change in voltage from the FSR into a measurable force and went onto refining the reliability of the testing by reducing background noise.

Deputy Director, Felix Watson, previously had never coded with C before. He therefore learnt C in his own time to help with the coding workload for the project. Watson liaised with each subgroup to code all the motors for the project as well as the touchpad. Watson also assisted in many of the group's design and integrated the motors into their parts to ensure the electrical components had the correct fittings and attachments. Also, he worked outside of his subgroup, aiding other members to refine designs and organize overall operations within the company. He was also in constant communication with the Director, Bubi Zhou, and the Equality, Diversity and Inclusion Officer, Donya Sharifi, to ensure targets were being met and to highlight any issues within the team.

Both Price and Watson wrote the code for their respective components separately so that it could be worked on efficiently. Once both were happy with the individual performance, the circuits and code were integrated into one by Price and the final code was perfected. They have also liaised with Deputy Chief Engineer, Adele Morgan Delarboulas and Ochoa-Dugoy to ensure the wiring and bread board was correctly stored within the product.

Chief of automation and control	Matt Price (He/Him)	
Deputy Director	Felix Watson (He/Him)	

INTRODUCTION

The primary function of the coding for this project is to move the balls around the product using the motors as well as test the weight and hardness of the individual balls. A dynamic stiffness test was adopted to test the hardness, in brief, this measures the force against time of an impact from the ball with an FSR electrical component. The force-time graph is used to calculate the stiffness and mass of the balls using the following equations: $k = \frac{F_{Max}^2}{I\sqrt{2gh}}$(Where k is the stiffness, F_{Max} is the maximum force, I is the integral of the force-time graph, also known as the impulse, g is the gravitational acceleration, and h is the fall distance). And $m = \frac{I}{\sqrt{2gh}}$ (Where m is mass).

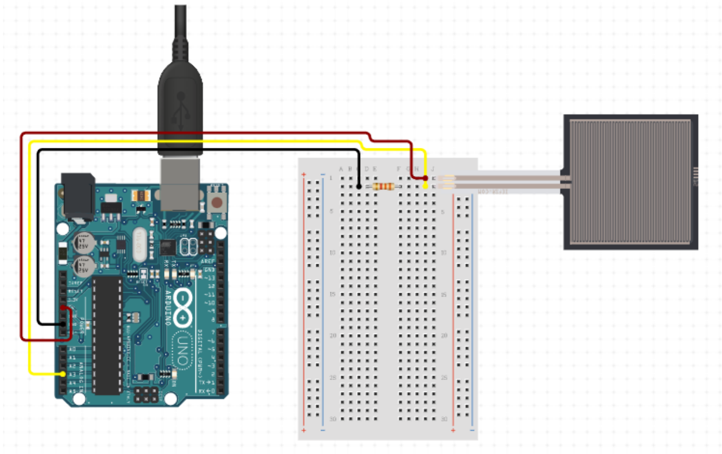


FIGURE 16 ARDUINO FORCE SENSOR CIRCUITRY

The force sensor works by lowering its resistance the more force that is applied to it, this means that by combining it with a resistor (Figure 16) which acts as a voltage divider[1], you can create a voltage input into the analog to digital converter which varies according to the resistance on the sensor. With no force applied to the sensor it has an almost infinite resistance giving a reading of 0v into the analog input, with all the voltage directed into the ground wire, this voltage rises with a decrease in resistance in the sensor due to an increase of force onto it. The analog-to-digital conversion pin works by converting the voltage it obtains into a value between 0 and 1023 which is relative to the reference voltage which is usually the voltage output of the circuit.

```
float FSR::getResistance()
{
  float senVoltage = read() * Vcc / 1023;
  return res * (Vcc / senVoltage - 1);
}
```

FIGURE 17*:* FUNCTION FOR OBTAINING RESISTANCE FROM ANALOG VOLTAGE READING.

This meant that the voltage of the sensor could be returned by a function (Figure 17) by reading the input to the analog pin and multiplying it by the reference voltage and dividing by 1023. The resistance could then be found by multiplying the resistance of the resistor acting as a voltage divider by the ratio of output voltage to voltage received at analog pin. Once the function to obtain the resistance was created this now needed to be converted to a force reading as resistance is not directly proportional to force.

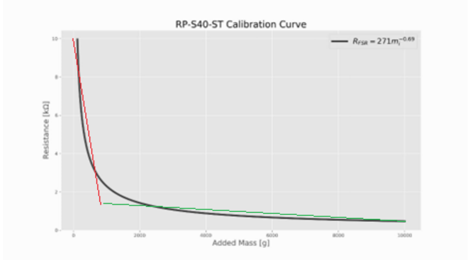


FIGURE 18 CALIBRATION CURVE FOR RP-S40-ST FORCE SENSOR SPLIT INTO TWO COMPONENTS.

The calibration curve (Figure 18) was obtained online, relating the added mass (directly correlated to the force) to the sensor's resistance output. This curve could be approximated by splitting it into two separate linear curves (in red and green).

```
float FSR::getForce()
{
  float resistance = getResistance();
  //calculate force using curve broken into two parts of different slope
  if (resistance <= 600)
    return (1.0 / resistance - 0.00075) / 0.00000032639;
  else
    return (1.0 / resistance)  / 0.000000642857;
}
```

FIGURE 19 FUNCTION FOR OBTAINING A FORCE MEASUREMENT FROM RESISTANCE MEASUREMENT

Then we could simply create a function in the FSR library's source file, assigning the resistance to a variable from the getResistance() function, and then determining which curve to calculate the force from. Once a function returning the force applied to the sensor had been created, in the main loop we assigned a float, force, to the getForce() function and then printed it into the serial monitor. This created a live force-time graph in the serial plotter, allowing the force and time of impact of the balls to be observed. As predicted, the heavy balls produced a much higher peak on the force-time graph compared to the light and the soft balls produced a higher time of impact than the hard balls. This meant all that was needed was to find the time of impact and its maximal force to determine if it was heavy, light, soft or hard. Next in the main loop, a program was coded (Figure 20) to print out the max force and time of impact for the duration of the force reading exceeding a threshold value.

```
if (fsrSquareForce > threshold){
      if (aboveT == false){
        aboveT = true;
        startT = int(millis());
        Serial.println("Above threshold");
      }
      if (fsrSquareForce > maxForce){
        maxForce = fsrSquareForce;

      }
    }

else{
    if (aboveT == true){;
      finishT = int(millis());
      totalT = finishT - startT;
      aboveT = false;
      Serial.println("Below Threshold");
      Serial.print("Max Force:");
      Serial.println(maxForce);
      Serial.print("Time: ");
      Serial.println(totalT);
      printResult();
      maxForce = 0;
      taken = true;
      delay(1000);
    }
  }
```

FIGURE 20 CODE FOR RECORDING THE TIME AND FORCE OF IMPACTS OF BALLS HITTING THE SENSOR

This code recorded the time since the program started once the threshold value is exceeded, and the time once the force had gone back below the threshold to then calculate the overall time of impact. As well as this, in each loop of this program it checks for if the current force is higher than the maxForce variable, and if this is true, it assigns the maxForce float the value of the current force. A delay was added at the end of this code to ensure the forces from the ball bouncing were ignored, as these would give much lower maximum force values, ruining the assumption of them all being dropped from the same height so they would be able to gain the same velocity if air resistance is negated.

The first major issue encountered was that the light-soft ball, the ball giving out the lowest maximum force, would often give out a maximum force lower than the background noise of the readings when no force was being applied to the sensor. It was discovered that the reason for this background noise was due to the variance in the operating voltage of the board, as the analog pins reading the voltage use the assumption of there being a constant voltage across the circuit. To combat this, the analog reference pin was used to compare the voltage from the analog reader directly to the input received at the reference pin. This meant that the background noise was mitigated.

The next issue was that due to the time and area being so short, the difference in the max force between the two hard balls was not large enough to accurately determine between the two. After some testing, it was discovered that placing a rubber cover over the force sensor meant the time of impact was lengthened so that there was a higher chance the maximum force could be picked up by the sensor and distributed over the entire sensor rather than just where the ball landed.

```
void ReadForce::printResult()
{

  if (maxForce < 500){
    Serial.println("Soft Light");
    isHard = false;
    isHeavy = false;
  }else if(maxForce < 2000){
    Serial.println("Hard Light");
    isHard = true;
    isHeavy = false;
  } else{
    if(totalT > 7){
      Serial.println("Soft Heavy");
      isHard = false;
      isHeavy = true;
    }else{
      Serial.println("Hard Heavy");
      isHard = true;
      isHeavy = true;
    }
  }
}
```

FIGURE 21 FUNCTION FOR DETERMINING THE TYPE OF BALL IN THE CATEGORIES: LIGHT SOFT, HEAVY SOFT, LIGHT HARD AND HEAVY HARD

The next step was creating the function to give the result of the test (Figure 21) by assigning them to two boolean variables. This was so that when integrated with the motors these variables can be used to determine the amount the stepper controlling the sorting unit will rotate. Printing to the serial monitor was for testing purposes to allow the boundaries to be altered until results are consistently accurate. This function was then called at the end of the readForce function (Figure 20), freeing our main loop (Figure 21) from clutter for the force sensor.

```
void loop() {
  readForce.takeForce();
}
```

FIGURE 22 MAIN LOOP FOR FORCE SENSOR TESTING BEFORE ITS INTEGRATION WITH MOTORS

Once inserted into the finished product these conditions for maximum force and time of impact these boundary values for the different types of balls will likely have to be recalibrated due to a number of factors such as:

- The angle at which the ball is dropped
- The friction of the ball against the tube surface
- The air resistance from air trapped in the tube
- The soft balls bouncing between the walls of the tube affecting the velocity
- Bending of the wire from the force sensor affecting the resistance of the circuit

These factors are unable to be tested until the final product is developed therefore there will likely need to be small alterations in the code at the end of development.

To code the UI and make the device accesble for the user we used a keypad so that when the '#' button is pressed, the code will run to measure the impact of the ball. This was then adjusted to make it take only one force before another input was needed, so one ball at a time could be measured, allowing time for the balls to be sorted. This is later going to be adjusted to take an input at the beginning for the number of balls wanting to be measured allowing for a more user friendly interface and allowing for no power wastage once all items have been sorted so buttons do not have to constantly be pressed while the program will stop when needed.

Citation:

1. learn.sparkfun.com. (n.d.). Force Sensitive Resistor Hookup Guide - learn.sparkfun.com. [online] Available at: https://learn.sparkfun.com/tutorials/force-sensitive-resistor-hookup-guide/all.

GANTT CHART

		Ta...	Task Name	Durat...	Start	End	Completion
1			**Org² DESIGN PROJECT**	**117 d...**	**09-01-...**	**20-06-...**	**92%**
2			**CONCEPT PHASE**	**30 days**	**09-01-...**	**20-02-...**	**100%**
3			Brief Breakdown	7 days	09-01-...	17-01-...	100%
4			Logo Design	1 day	14-01-...	16-01-...	100%
5			**Concept Decision**	**16 days**	**09-01-...**	**30-01-...**	**100%**
6			Concept Brainstorming	11 days	09-01-...	23-01-...	100%
7			Sub Group Proposals and Feed...	1 day	23-01-...	23-01-...	100%
8			Final Concept Schematics	6 days	23-01-...	30-01-...	100%
9			**Concept Design Report**	**17 days**	**23-01-...**	**14-02-...**	**100%**
10			Limitations of Concept	17 days	23-01-...	14-02-...	100%
11			Market Research	17 days	23-01-...	14-02-...	100%
12			Sustainability Research	17 days	23-01-...	14-02-...	100%
13			EDI Report 1.0	12 days	30-01-...	14-02-...	100%
14			Materials Research	12 days	30-01-...	14-02-...	100%
15			Financial Outline	12 days	30-01-...	14-02-...	100%
16			Risk Assessments	12 days	30-01-...	14-02-...	100%
17			Concept Report Submission	0 days	14-02-...	14-02-...	100%
18			Presentation Practice	5 days	13-02-...	19-02-...	100%
19			Individual Video Submission	0 days	14-02-...	14-02-...	100%
20			Concept Presentation	0 days	20-02-...	20-02-...	100%
21			**PROTOTYPE PHASE**	**65 days**	**30-01-...**	**28-04-...**	**100%**
22			Feedback and Review	40 days	30-01-...	24-03-...	100%
23			Prototype Letter	23 days	20-02-...	22-03-...	100%
24			**Iterating Design**	**35 days**	**30-01-...**	**17-03-...**	**100%**
25			Programming Development	30 days	06-02-...	17-03-...	100%
26			Part Drawings and Modelling	18 days	30-01-...	22-02-...	100%
27			CAD Part Designs	18 days	30-01-...	22-02-...	100%
28			3D Printing	11 days	06-02-...	20-02-...	100%
29			Assembly	11 days	06-02-...	20-02-...	100%
30			Testing Prototype 1.0	6 days	20-02-...	27-02-...	100%
31			Refining Prototype 1.0	11 days	20-02-...	06-03-...	100%
32			Testing Prototype 2.0	6 days	27-02-...	06-03-...	100%
33			**Final Prototype**	**21 days**	**20-02-...**	**20-03-...**	**100%**
37			Examination Week	5 days	20-03-...	24-03-...	100%
38			Technical Drawing and Letter Sub...	0 days	22-03-...	22-03-...	100%
39			Integrated Prototype Test Day	0 days	24-03-...	24-03-...	100%
40			**Collating Feedback 1**	**30 days**	**20-03-...**	**28-04-...**	**100%**
41			Financial Outline Review	30 days	20-03-...	28-04-...	100%
42			Sustainability Outline Review	30 days	20-03-...	28-04-...	100%
43			EDI Report 2.0	30 days	20-03-...	28-04-...	100%
44			**FINAL DESIGN PHASE**	**67 days**	**20-03-...**	**20-06-...**	**82%**
45			**Collating Feedback 2**	**30 days**	**20-03-...**	**29-04-...**	**100%**
46			Design Review	30 days	20-03-...	28-04-...	100%
47			Production Review	30 days	20-03-...	28-04-...	100%
48			**Final Product**	**37 days**	**24-04-...**	**13-06-...**	**63%**
49			CAD	32 days	24-04-...	06-06-...	100%
50			Programming	32 days	24-04-...	06-06-...	80%
51			3D Printing and Laser Cutting	31 days	02-05-...	13-06-...	40%
52			Assembly	25 days	08-05-...	09-06-...	20%
53			**Final Design Report**	**36 days**	**02-05-...**	**20-06-...**	**100%**
54			Financial Report	25 days	02-05-...	05-06-...	100%
55			Sustainability Report	25 days	02-05-...	05-06-...	100%
56			EDI Report	25 days	02-05-...	05-06-...	100%
57			Sub Group Annexes	25 days	02-05-...	05-06-...	100%
58			Production Report	25 days	02-05-...	05-06-...	100%
59			Final Design Report Submission	0 days	06-06-...	06-06-...	100%
60			Individual Video Submission 2	0 days	06-06-...	06-06-...	100%
61			Defence Practice	8 days	06-06-...	15-06-...	0%
62			Group Design Defence	2 days	15-06-...	16-06-...	0%
63			Presentation Preparation	3 days	16-06-...	20-06-...	0%
64			Final Presentation and Test Day	0 days	20-06-...	20-06-...	0%

SUSTAINABILITY REPORT

In line with the Paris Agreement of 2015 as well as recent regulation set out by the IPCC and the EU's ISO 14001, net zero and sustainability was fundamental for our operations. We focused on reducing our emissions to the greatest compressibility possible, then offsetting the rest through investing in a carbon offsetting global portfolio. We can therefore proudly say we are a net zero company. This sustainability report aims to assess the environmental impacts of the sorting machine by doing a carbon footprint analysis. And outline improvements made to make the final product more sustainable.

The machine's main structural components were polylactic acid (PLA) used through 3D printing and medium-density fiberboard (MDF) derived from laser cutting. PLA, a biodegradable and renewable plastic material derived from corn starch, sugarcane, or other natural sources, exhibits a low carbon footprint of 2.4 kg/kg compared to conventional petroleum-based plastics. Moreover, PLA is fully recyclable, thereby minimizing carbon emissions during the product's end-of-life stage. Despite the potential negative environmental impacts, such as soil erosion, associated with commercial wood harvesting leading to deforestation, MDF—presenting a carbon footprint of 1.023 kg/kg—represents a natural, renewable resource that has been employed in diverse applications over centuries. Its biodegradability further supports waste reduction during the product's end-of-life stage. Additionally, a small quantity of polymethyl methacrylate (PMMA), commonly known as Perspex, was used for the machine's window. Although certain chemical constituents of PMMA pose hazards to both human health and the environment, its robustness and durability ensure prolonged service life, reducing the frequency of replacement and waste generation. Furthermore, the PMMA usage was minimal to reduce the damage. The cumulative carbon emissions attributed to the materials used can be found in Scope 3 of Figure 23.

The other 2 scopes were considered in Figure 23. The calculation of manufacturing and on-site emissions of the machine was done in Scope 1. Then the calculation of electricity consumption during the sessions was done in Scope 2.

In terms of the implemented enhancements, the initial focus centered on minimizing both the total material volume utilized and the energy consumption during the machine's operation. For example, the final design of the feeder part used the 180-degree motor instead of the original one mentioned in the concept report. This not only reduced the volume of the feeder, but also reduce the energy consumption as the 180-degree motor is more efficient. On the other hand, according to the carbon emission calculation in Figure 23, use more laser cutter save more energy, and the MDF wood's carbon footprint is lower than the PLA. So that more laser cutting was used for the manufacturing of the machine rather than 3D printing.

Carbon Emission Summary	Electricity(kWh)	Emissions (kgCO_2e)
Scope 1		
3D Printer[1]	10.5	2.0265
Laser Cutter[2]	3.4	0.6562
Total scope 1	13.9	2.6827
Scope 2		
Computer electricity[3]	58	11.194
Machine electricity[4]	0.4	0.0772
Total scope 2	58.4	11.2712
Scope 3		
Materials' carbon footprint[5]		8.43
Materials Transportation[6]		8.63
Total scope 3		17.06
Total Emissions		31.0139
Total Emissions Offset		1,000

FIGURE:23 THE CARBON EMISSION CALCULATION CHART. IT SHOULD BE NOTED THIS ASSESSMENT IS AN APPROXIMATION AND NOT FULLY COMPREHENSIVE.

EDI REPORT

Throughout the project, respect and inclusivity are two topics upheld and found essential in Org2. Although there have been some challenges along the way, such as communication and task clarity, major improvements have been made. Surveys were conducted monthly to check up on how things have been progressing within the team.

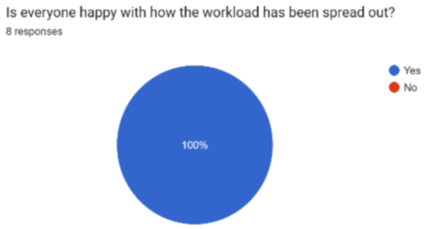


FIGURE 25: DATA TAKEN FROM A SURVEY CONDUCTED IN MID-FEBRUARY.

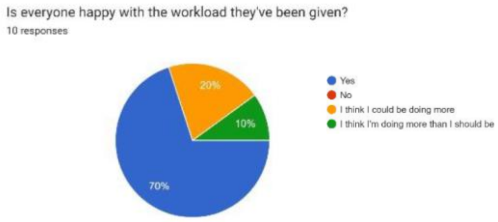


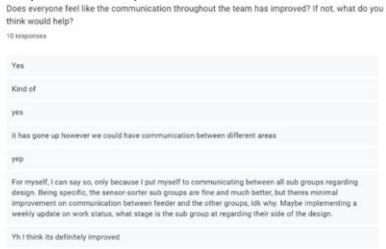
FIGURE 25: DATA TAKEN FROM A SURVEY CONDUCTED MID-MAY.

Starting this report off on a good note, it can be seen when comparing the data that most of the company members are satisfied with how the workload has been spread out

Communication has been a continuing issue within the company, particularly regarding inadequate dialogue involving subgroups in choosing machine part incorporation. This lack of cohesiveness became noticeable during the prototype day when the model differed from the original. Nevertheless, drastic changes were made in early March and mid-May to tackle the problem, resulting in substantial development. Monthly discussions and regular document updates have assisted in solving persistent issues. Other obstacles, such as a lack of organization and irregular tardiness, were also emphasized in conferences, though only by a few members.

In the most recent meeting, it was concluded that whoever was more than half an hour late would be marked as absent (unless it was an emergency). Going back to the other concern that was mentioned, there had also been major improvements in the clarity of what everyone needed to do because of the meetings. In the first survey, it was written that the leadership of the company needed some direction and clearer tasks. Looking at some data below, after discussing this complication there was a refinement in the division of work.

On the plus side, the team introduced the idea of a snack rotor back in early March. This has been proven to improve workplace morale and motivation, which has been great.



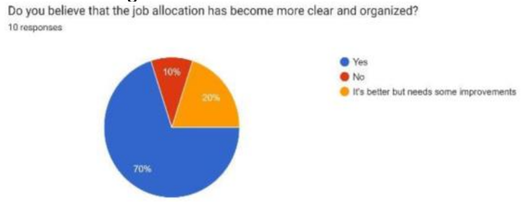


FIGURE 26: DATA TAKEN FROM SURVEY IN MID-MAY OUTLINING FEEDBACK RECIEVED AS WELL AS JOB ALLOCATION SATISFACTION

To summarize, through consistent communication and collaboration, Org2 has continued to uphold the constructive and welcoming environment that is crucial to a successful company. The more time that was spent together, the more open and honest everyone was with one another, which was rewarding for both the project and the group.

FINANCIAL REPORT

We focused on reducing our overall capital spent by primarily focusing on the resources provided to us and only spending when we felt it was fully necessary. It is therefore critical to keep track of how much it costs to construct our final product when we finish our design study and development. Fortunately, we have spent significantly less than the amount allotted to us by the university.

One of the key reasons we were able to spend so little money was the university's provision of free resources. The Arduino Kit given out at the start of the year had the Arduino board and motors, which were essential components of our project. The usage of numerous tools, including the 3D printer, the soldering iron, and the glue gun was also cost-free.

Moving on to our actual expenses, our first purchase was a load cell. This was crucial to our project because it helped us calculate the weight and impulse of a ball over a given time. However, going forward we found this was not the right component for what we required and was not accurate enough. Then, we went on to replace this component with a force sensitive resister which worked much better.

We then bought three 3D printer spools as our subsequent purchase. Even while we could have printed all our components on a single spool, using multiple spools allowed us to print components more quickly by employing multiple printers. Although we did go onto realize we could not use other companies' machines, rendering this purchase as wastage. However, going into the future we will explore reselling these spools second hand or back to the department to return any financial losses.

The bulk of the product was built using MDF as well as some acrylic which has all also been accounted for.

TABLE 1: FULL FINANCIAL BREAKDOWN OF THE PROJECT

Item	Sub-Group	No. of Units	Price per Unit / £	Total price / £
3D Printer Spools	All	2	20	40
Load Cell	Sensor Group	1	11.87	11.87
Acrylic Sheets	Sensor Group	1	2.71	2.71
MDF Sheet (1200x600)	Sensor and Sorter Groups	1	7.74	7.74
MDF Sheet (500x300)	Sensor and Sorter Groups	1	1.78	1.78
Global Portfolio Carbon offsetting	All	1	9	9
Force Sensitive Resistor	Coding/ testing	1	10	10
Total				83.1
Money Left				66.9

Although there were mistakes made in the process, we were well under the budget assigned to us. If this product were to go into mass production, it would be at minimum less than £40 (deducting the load cell and two 3D Printer Spools) proving the cost-effectiveness of our design.

RISK ASSESSMENT

Year 1 Design Study (MATE40003)

Risk assessment form:

Assessment undertaken by:	Felix Watson
Signed:	Felix Watson
Date:	6/06/2023
Assessment review date:	

Risk Assessment for:	Dynamic Stiffness Test Organizer(DSTO)
Task:	Ball identification & sorting machine
Assessment ref. No.	DSTO1

Hazards	Persons at risk	Existing controls	Action needed
Balls can get crushed in machine and create debris	Anyone within range of the machine	N/A	Keep a broom close by
Electrical wires on the ground, people could trip	Anyone within range	N/A	Keep wires out of reach
Malfunction of motors, leading to overheating	Anyone that would want to touch the machine	Make an emergency stop button	Wear gloves when handling machine
Hand injury from feeder	Anyone within range of the machine	N/A	Warning labels
Fire from electrical components	Everyone	Protection circuits	Fire Safety Equipment

ASSESSMENT OF STATUS OF THE PROJECT

Commented [WF1]: Needs to be finished

Overall, the project has come along very nicely, and we believe the product will be finished before the scheduled date. Almost all our parts have been tested individually and refined to mitigate any issues. We can therefore be confident that once all the parts are manufactured and assembled our product will perform as expected. One cause for concern is the integration of the coding and wiring, which has not all been fully combined yet, so there may be further refinement required to get this to work, however, this will not be too much of an issue.

We have designed the product in such a way that if it were to be mass-produced it would be simple and easy thanks to our significant use of machining equipment such as the laser cutter and 3D printer. We have focused on reducing exteriorly sourced components resulting in our overall project being fully built from a couple of Arduino kits, a few different laser cutting sheets and one spool of 3D printing filament as well as a couple of nuts and bolts. This means our product will be perfect for any large-scale just-in-time or continuous manufacturing operation inherently saving on machining and labour costs. Without the mistake of buying the spare 3d-printing spools, our project could have cost as little as £40, proving its scalability.

Our team has learnt a lot from this project, the coding team had little to no C experience prior and has managed to finish the code. Many of the subgroup engineers had little experience using solid works compared with what was expected for this project, so that is a feat to be immensely proud of.

With the current climate and health crisis happening all around us ESG has been a major factor for our decision-making throughout the project. Many of us have never worked together before so initially some individuals found it hard working with others, however, thanks to the amazing efforts of the Equality, Diversity and Inclusion officer, Donya Sharifi, as well as many others in the group. Communication and respect have been a defining triumph within our company, which we are incredibly proud of. As well, sustainability has been a focus in the creation of our product. From the material selection where we avoid metals and focused on renewables and recycled materials for most of the design to the minimalized approach to electrical components within the design. Through our offsetting as well not only have we offset all of our own emissions but we have also offset emissions for everyother company without our cohort and possibly half of next cohorts (assuming they have similar emissions to us).

APPENDIX

Part's List

Part Title	No. Rep	Part No.	Prod Method	Material	Designer Name	Engineer Sign Off
SORTER						
Ex Base	1	[001]	Laser Cut	MDF	Adele Morgan Delarboulas	
Ex-x Side 1	1	[002]	Laser Cut	MDF	Adele Morgan Delarboulas	
Ex-x Side 2	1	[003]	Laser Cut	MDF	Adele Morgan Delarboulas	
Ex-x Side 3	1	[004]	Laser Cut	MDF	Adele Morgan Delarboulas	
Ex-I Side (W-M)	1	[005]	Laser Cut	MDF	Adele Morgan Delarboulas	
Ex-x Side (M)	1	[006]	Laser Cut	MDF	Adele Morgan Delarboulas	
M Holder	1	[007]	3D Print	PLA	Donya Sharifi	
Ex-x Junction 1	1	[008]	3D Print	PLA	Adele Morgan Delarboulas	
Ex-x Junction 2	1	[009]	3D Print	PLA	Adele Morgan Delarboulas	
Ex-I Side (M)	1	[010]	Laser Cut	MDF	Adele Morgan Delarboulas	
Ex-I Box-Junction 2	1	[011]	3D Print	PLA	Adele Morgan Delarboulas	
Ex-I Box-Junction 1	1	[012]	3D Print	PLA	Adele Morgan Delarboulas	
Junction-Box Side 2	1	[013]	Laser Cut	MDF	Adele Morgan Delarboulas	
Junction-Box Side 1	1	[014]	Laser Cut	MDF	Adele Morgan Delarboulas	
Border Guards	3	[015]	3D Print	PLA	Adele Morgan Delarboulas	
G-Clip	3	[016]	3D Print	PLA	Donya Sharifi	
Gear Ex	3	[017]	3D Print	PLA	Donya Sharifi	
Gear Attachment	2	[018]	Laser Cut	MDF	Donya Sharifi	
Gear M	1	[019]	3D Print	PLA	Donya Sharifi	
R-Plate	1	[020]	3D Print	PLA	Adele Morgan Delarboulas	
Border Guard Junction	1	[021]	3D Print	PLA	Adele Morgan Delarboulas	
Top Part	2	[022]	Laser Cut	MDF	Adele Morgan Delarboulas	
Box base	1	[023]	Laser Cut	MDF	Rishi Karthikeyan	
Box Side	4	[024]	Laser Cut	MDF	Rishi Karthikeyan	
Box Intersection	2	[025]	Laser Cut	MDF	Rishi Karthikeyan	
SENSOR						
Top Part	1	[026]	Laser Cut	MDF	Geronimo Lauzan	
Left Piece	1	[027]	Laser Cut	MDF	Geronimo Lauzan	
Right Piece	1	[028]	Laser Cut	MDF	Mervyn Ochoa-Dugoy	
Front Piece	1	[029]	Laser Cut	MDF	Mervyn Ochoa-Dugoy	
Back Piece	1	[030]	Laser Cut	MDF	Mervyn Ochoa-Dugoy	
Testing Plate	1	[031]	3D Print	PLA	Mervyn Ochoa-Dugoy	
Pear Cam	1	[032]	3D Print	PLA	Mervyn Ochoa-Dugoy	
Follower	1	[033]	3D Print	PLA	Mervyn Ochoa-Dugoy	
Support Rod	1	[034]	3D Print	PLA	Mervyn Ochoa-Dugoy	
Support Block	1	[035]	3D Print	PLA	Mervyn Ochoa-Dugoy	
FEEDER						

Roller	4	[036]	3D Print	PLA	Charles Li / Bubi Zhou
Shield	1	[037]	3D Print	PLA	Bubi Zhou
Rotor	1	[038]	3D Print	PLA	Charles Li
Front Piece	1	[039]	Laser Cut	PMMA	Bubi Zhou
Motor Mount	1	[040]	3D Print	PLA	Bubi Zhou

Ball Category	Mass (g +/- 0.1g)			Average Mass (g)
	Trial 1	Trial 2	Trial 3	
Soft & Light	0.5	0.5	0.5	0.5
Hard & Light	0.5	0.5	0.5	0.5
Soft & Heavy	22	22	21	21.7
Hard & Heavy	32	32	33	32.3

FIGURE:27 TABLE SHOWING MEASUREMENTS OF THE MASS OF THE GIVEN BALLS WE HAVE SO THAT WE COULD SELECT THE CORRECT LOAD CELL TO BUY

Ball Category	Diameter (mm +- 0.005mm)			Average Diameter (mm	Average Radius (mm
	Trial 1	Trial 2	Trial 3		
Soft & Light	43.86	42.19	41.78	42.61	21.31
Hard & Light	47.31	47.42	47.54	47.42	23.71
Soft & Heavy	48.6	48.79	48.83	48.74	24.37
Hard & Heavy	43.68	43.52	43.7	43.63	21.82

FIGURE:28 TABLE SHOWING MEASUREMENTS OF DIAMETER

Production Record

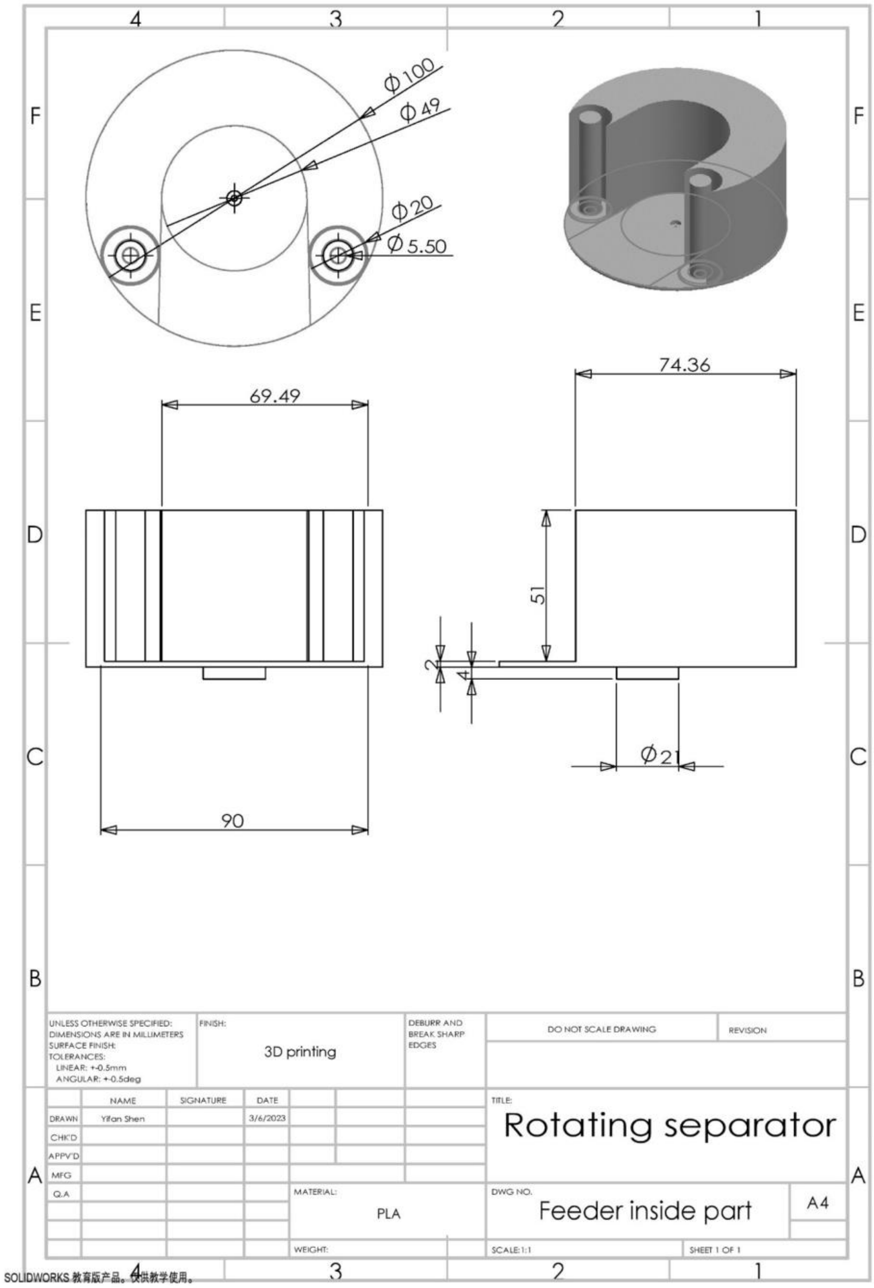
	Part Name	Drawing Files	Repetitions	Serial Number	Production Method	Material	Date	Start	Finish	Settings	Produced	Comments
Sorter	Ex Base - Final	Ex Base.SLDPRT	1	[C8-1301]	Laser Cut	MDF					N	
	Ex-x Side 1 - Final	Ex-x Side 1.SLDPRT	1	[C8-1302]	Laser Cut	MDF					N	
	Ex-x Side 2 - Final	Ex-x Side 2.SLDPRT	1	[C8-1303]	Laser Cut	MDF					N	
	Ex-x Side 3 - Final	Ex-x Side 3.SLDPRT	1	[C8-1304]	Laser Cut	MDF					N	
	Ex-l Side (W-M) - Final	Ex-l Side (W-M).SLDPRT	1	[C8-1305]	Laser Cut	MDF					N	
	Ex-x Side (M) - Final	Ex-x Side (M).SLDPRT	1	[C8-1306]	Laser Cut	MDF					N	
	M Holder - Final	M Holder.SLDPRT	1	[C8-1307]	3D Print	PLA					N	
	Ex-x Junction 1 - Final	Ex-x Junction 1.SLDPRT	1	[C8-1308]	3D Print	PLA					N	
	Ex-x Junction 2 - Final	Ex-x Junction 2.SLDPRT	1	[C8-1309]	3D Print	PLA					N	
	Ex-l Side (M) - Final	Ex-l Side (M).SLDPRT	1	[C8-1310]	Laser Cut	MDF					N	
	Ex-l Box-Junction 1 - Final	Ex-l Box-Junction 1.SLDPRT	1	[C8-1311]	3D Print	PLA					N	
	Ex-l Box-Junction 2 - Final	Ex-l Box-Junction 2.SLDPRT	1	[C8-1312]	3D Print	PLA					N	
	Junction-Box Side 2 - Final	Junction-Box Side 2.SLDPRT	1	[C8-1313]	Laser Cut	MDF					N	
	Junction-Box Side 1 - Final	Junction-Box Side 1.SLDPRT	1	[C8-1314]	Laser Cut	MDF					N	
	Border Guards - Final	Border Guards.SLDPRT	3	[C8-1315]	3D Print	PLA					N	
	G-Clip - Final	G-Clip.SLDPRT	3	[C8-1316]	3D Print	PLA					N	
	Gear Ex - Final	Gear Ex.SLDPRT	3	[C8-1317]	3D Print	PLA					N	
	Gear Attachment - Final	Gear Attachment.SLDPRT	2	[C8-1318]	Laser Cut	MDF					N	
	Gear M - Final	Gear M.SLDPRT	1	[C8-1319]	3D Print	PLA					N	
	R-Plate - Final	R-Plate.SLDPRT	1	[C8-1320]	3D Print	PLA					N	
	Border Guard Junction - Final	Border Guard Junction.SLDPRT	1	[C8-1321]	3D Print	PLA					N	
	Top Part - Final	Top Part.SLDPRT	2	[C8-1322]	Laser Cut	MDF					N	
	Box Base - Final	Box Base.SLDPRT	1	[C8-1323]	Laser Cut	MDF					N	
	Box Side - Final	Box Side.SLDPRT	4	[C8-1324]	Laser Cut	MDF					N	
	Box Intersection - Final	Box Intersection.SLDPRT	2	[C8-1325]	Laser Cut	MDF					N	
	Ex Base - Final Prototype	Ex Base.SLDPRT	1	[C8-1201]	Laser Cut	Cardboard	05/06/2023	13:23	14:16		Y	
	Ex-x Side 1 - Final Prototype	Ex-x Side 1.SLDPRT	1	[C8-1202]	Laser Cut	Cardboard	05/06/2023	13:23	14:16		Y	
	Ex-x Side 2 - Final Prototype	Ex-x Side 2.SLDPRT	1	[C8-1203]	Laser Cut	Cardboard	05/06/2023	13:23	14:16		Y	
	Ex-x Side 3 - Final Prototype	Ex-x Side 3.SLDPRT	1	[C8-1204]	Laser Cut	Cardboard	05/06/2023	13:23	14:16		Y	
	Ex-l Side (W-M) - Final Prototype	Ex-l Side (W-M).SLDPRT	1	[C8-1205]	Laser Cut	Cardboard	05/06/2023	13:23	14:16		Y	
	Ex-x Side (M) - Final Prototype	Ex-x Side (M).SLDPRT	1	[C8-1206]	Laser Cut	Cardboard	05/06/2023	13:23	14:16		Y	
	Ex-l Side (M) - Final Prototype	Ex-l Side (M).SLDPRT	1	[C8-1207]	Laser Cut	Cardboard	05/06/2023	13:23	14:16		Y	
	Junction-Box Side 2 - Final Prototype	Junction-Box Side 2.SLDPRT	1	[C8-1208]	Laser Cut	Cardboard	05/06/2023	13:23	14:16		Y	
	Junction-Box Side 1 - Final Prototype	Junction-Box Side 1.SLDPRT	1	[C8-1209]	Laser Cut	Cardboard	05/06/2023	13:23	14:16		Y	
	Gear Attachment - Final Prototype	Gear Attachment.SLDPRT	2	[C8-1210]	Laser Cut	Cardboard	05/06/2023	13:23	14:16		Y	
	Top Part - Final Prototype	Top Part.SLDPRT	2	[C8-1211]	Laser Cut	Cardboard	05/06/2023	13:23	14:16		Y	
	Box Base - Final Prototype	Box Base.SLDPRT	1	[C8-1212]	Laser Cut	Cardboard	05/06/2023	13:23	14:16		Y	
	Box Side - Final Prototype	Box Side.SLDPRT	4	[C8-1213]	Laser Cut	Cardboard	05/06/2023	13:23	14:16		Y	
	Box Intersection - Final Prototype	Box Intersection.SLDPRT	2	[C8-1214]	Laser Cut	Cardboard	05/06/2023	13:23	14:16		Y	
	Base Box - Prototype	sorting box.SLDPRT	1	[C8-1101]	Laser Cut	Cardboard	23/03/2023	11:13	11:47		Y	
	Section Divider 1 - Prototype	cross x2.SLDPRT	2	[C8-1102]	Laser Cut	Cardboard	23/03/2023	11:13	11:47		Y	
	Section Divider 2 - Prototype	cross x1.SLDPRT	1	[C8-1103]	Laser Cut	Cardboard	23/03/2023	11:13	11:47		Y	
	Side Pane 1 - Prototype	side pane 2.0 x2.SLDPRT	2	[C8-1104]	Laser Cut	Cardboard	23/03/2023	11:13	11:47		Y	
	Side Pane 2 - Prototype	side pane 3.0.SLDPRT	2	[C8-1105]	Laser Cut	Cardboard	23/03/2023	11:13	11:47		Y	
	Combined Plate - Prototype	Teethed Exterior Whole.SLDPRT	1	[C8-1106]	3D Print	PLA	13/03/2023	02:31	End of Day		Y	
	Pinion Gear for Motor - Prototype	Pinion Gear For Motor x1.SLDPRT	1	[C8-1110]	3D Print	PLA	13/03/2023	02:31	End of Day		Y	
	Pinion Gear for Case - Prototype	Pinion Gear For Case x3.SLDPRT	3	[C8-1111]	3D Print	PLA	13/03/2023	02:31	End of Day		Y	
	Motor Holder - Prototype	motor holder.SLDPRT	1	[C8-1112]	3D Print	PLA	13/03/2023	02:31	End of Day		Y	
	Gear Holder - Prototype	gear holder x3.SLDPRT	3	[C8-1113]	3D Print	PLA	13/03/2023	02:31	End of Day		Y	
Sensor	Top Part - Final	Top Part.SLDPRT	1	[C8-2301]	Laser Cut	MDF					N	
	Left Piece - Final	Left Piece.SLDPRT	1	[C8-2302]	Laser Cut	MDF					N	
	Right Piece - Final	Right Piece.SLDPRT	1	[C8-2303]	Laser Cut	MDF					N	
	Front Piece - Final	Front Piece.SLDPRT	1	[C8-2304]	Laser Cut	MDF					N	
	Back Piece - Final	Back Piece.SLDPRT	1	[C8-2305]	Laser Cut	MDF					N	
	Testing Plate - Final	Testing Plate.SLDPRT	1	[C8-2306]	3D Print	PLA					N	
	Pear Cam - Final	Pear Cam.SLDPRT	1	[C8-2307]	3D Print	PLA	22/05/2023	14:42	End of Day		Y	
	Follower - Final	Follower.SLDPRT	1	[C8-2308]	3D Print	PLA	22/05/2023	14:42	End of Day		Y	
	Support Rod - Final	Support Rod.SLDPRT	1	[C8-2309]	3D Print	PLA	22/05/2023	14:42	End of Day		Y	
	Support Block - Final	Support Block.SLDPRT	1	[C8-2310]	3D Print	PLA	22/05/2023	14:42	End of Day		Y	
	Top Part - Final Protoype	Top Part.SLDPRT	1	[C8-2201]	Laser Cut	Cardboard	30/05/2023	14:34	15:03		Y	
	Left Piece - Final Prototype	Left Piece.SLDPRT	1	[C8-2202]	Laser Cut	Cardboard	30/05/2023	14:34	15:03		Y	
	Right Piece - Final Prototype	Right Piece.SLDPRT	1	[C8-2203]	Laser Cut	Cardboard	30/05/2023	14:34	15:03		Y	
	Front Piece - Final Prototype	Front Piece.SLDPRT	1	[C8-2204]	Laser Cut	Cardboard	30/05/2023	14:34	15:03		Y	
	Back Piece - Final Prototype	Back Piece.SLDPRT	1	[C8-2205]	Laser Cut	Cardboard	30/05/2023	14:34	15:03		Y	
	Back Piece - Prototype	Back piece.SLDPRT	1	[C8-2101]	Laser Cut	Cardboard	13/03/2023	13:22	14:12		Y	
	Base Piece - Prototype	Base piece.SLDPRT	1	[C8-2102]	Laser Cut	Cardboard	13/03/2023	13:22	14:12		Y	
	Front Piece - Prototype	Front piece.SLDPRT	1	[C8-2103]	Laser Cut	Cardboard	13/03/2023	13:22	14:12		Y	
	Top Piece - Prototype	Top piece.SLDPRT	1	[C8-2104]	Laser Cut	Cardboard	13/03/2023	13:22	14:12		Y	
	Upper Left Piece - Prototype	Upper left piece.SLDPRT	1	[C8-2105]	Laser Cut	Cardboard	13/03/2023	13:22	14:12		Y	
	Upper Right Piece - Prototype	Upper right piece.SLDPRT	1	[C8-2106]	Laser Cut	Cardboard	13/03/2023	13:22	14:12		Y	
	Lower Left Piece - Prototype'	Lower left piece.SLDPRT	1	[C8-2107]	Laser Cut	Cardboard	13/03/2023	13:22	14:12		Y	
	Lowe Right Piece - Prototype'	Lower right piece.SLDPRT	1	[C8-2108]	Laser Cut	Cardboard	13/03/2023	13:22	14:12		Y	
	Test Plate - Prototype	Test plate.SLDPRT	1	[C8-2109]	Laser Cut	MDF	13/03/2023	13:22	14:12		Y	
	Support Block - Prototype	Support block.SLDPRT	2	[C8-2111]	Laser Cut	MDF	13/03/2023	13:22	14:12		Y	
	Follower - Prototype	Follower.SLDPRT	1	[C8-2112]	Laser Cut	MDF	13/03/2023	13:22	14:12		Y	
	Snail Cam - Prototype	Snail cam.SLDPRT	1	[C8-2113]	Laser Cut	MDF	13/03/2023	13:22	14:12		Y	
	Support Rod - Prototype	Support rod.SLDPRT	1	[C8-2114]	3D Print	PLA	10/03/2023	12:31	16:22		Y	
	Trapdoor - Prototype	Trapdoor 80x80mm.SLDPRT	1	[C8-2115]	3D Print	PLA	10/03/2023	12:31	16:22		Y	
	Feeder Connection - Prototype	Feeder connection.SLDPRT	1	[C8-2116]	3D Print	PLA	10/03/2023	12:31	16:22		Y	
	Bumper - Prototype	Bumper.SLDPRT	1	[C8-2117]	3D Print	PLA	10/03/2023	12:31	16:22		Y	
Feeder	Rotor - Prototype	rotor.SLDPRT	1	[C8-3101]	3D Print	PLA	09/03/2023	16:09	End of Day		Y	
	Shell Main Body - Prototype	shell main body.SLDPRT	1	[C8-3102]	3D Print	PLA	09/03/2023	16:09	End of Day		Y	
	Shell Top Cover - Prototype	shell top cover.SLDPRT	1	[C8-3103]	3D Print	PLA	09/03/2023	16:09	End of Day		Y	
	Feeder Shell - Prototype	feeder shell trimmed.SLDPRT	1	[C8-3104]	3D Print	PLA	07/03/2023	15:30	End of Day		Y	
	Feeder Shell Lid - Prototype	Feeder Part3(circular shield).SLDPRT	1	[C8-3105]	3D Print	PLA	08/03/2023	11:00	14:00		Y	
	Rotating Separator - Prototype 1	Feeder Part4(inside part).SLDPRT	1	[C8-3106]	3D Print	PLA	29/02/2023	15:00	End of Day		Y	
	Rotating Separator - Prototype 2	inside part roller.SLDPRT	1	[C8-3107]	3D Print	PLA	09/05/2023	16:30	End of Day		Y	
	Rotating Separator - Prototype 3	inside part roller.SLDPRT	1	[C8-3108]	3D Print	PLA	23/05/2023	16:00	End of Day		Y	
	Feeder Motor Mount - Final	feeder Motor mount.SLDDRW	1	[C8-3301]	3D Print	PLA					N	
	Rotating Separator - Final	Feeder inside part.SLDDRW	1	[C8-3302]	3D Print	PLA	30/05/2023	16:00	End of Day		Y	
	Shell Lid - Final	Feeder shell.SLDDRW	1	[C8-3303]	Laser Cut	PMMA					N	
	Separator Rollers - Final	shell roller.SLDDRW	2	[C8-3304]	3D Print	PLA					N	

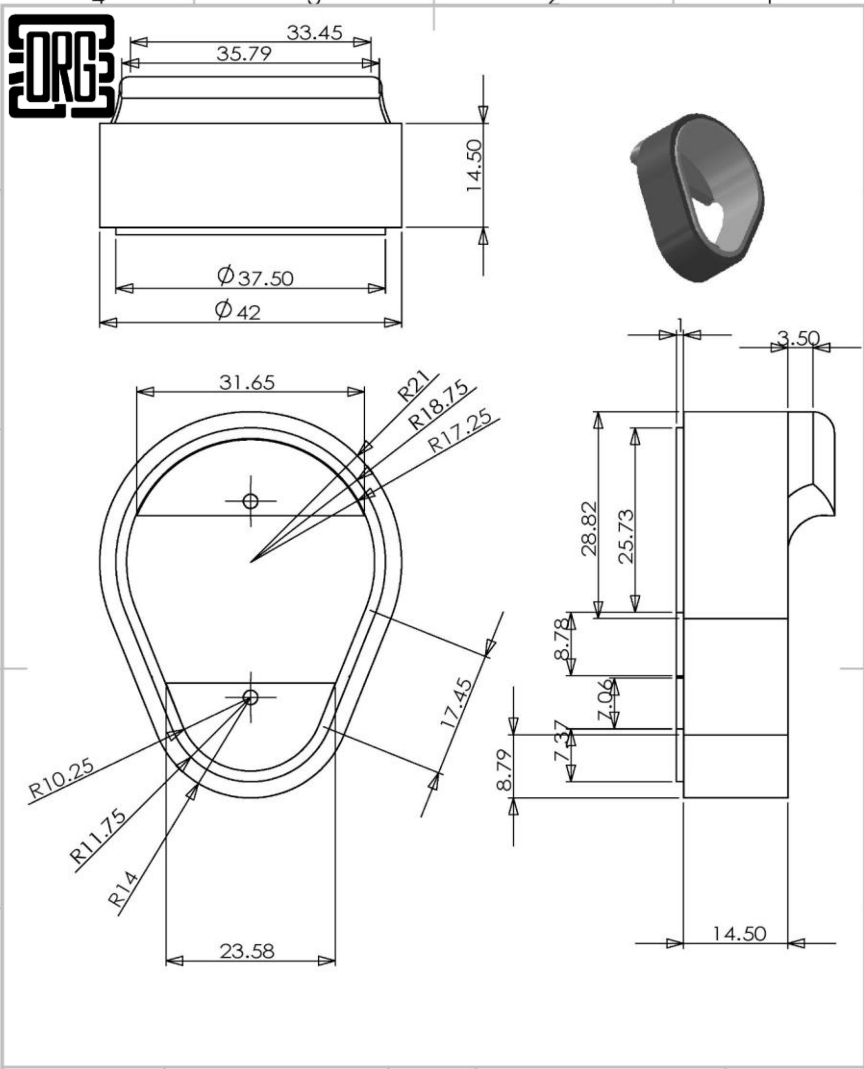
Serial Number Explanation:
[Company Number- Subgroup-Phase-Number] eg. [C8-1302]

Subgroup:
Sorter: 1
Sensor: 2
Feeder: 3

Phase:
Initial Prototyping: 1
Final Prototype: 2
Final Product: 3

TECHNICAL DRAWINGS





UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR: +-0.5mm
ANGULAR: +-0.5deg

FINISH: 3D printing

DEBURR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	Yifan Shen		3/6/2023
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE: Feeder motor mount

MATERIAL: PLA

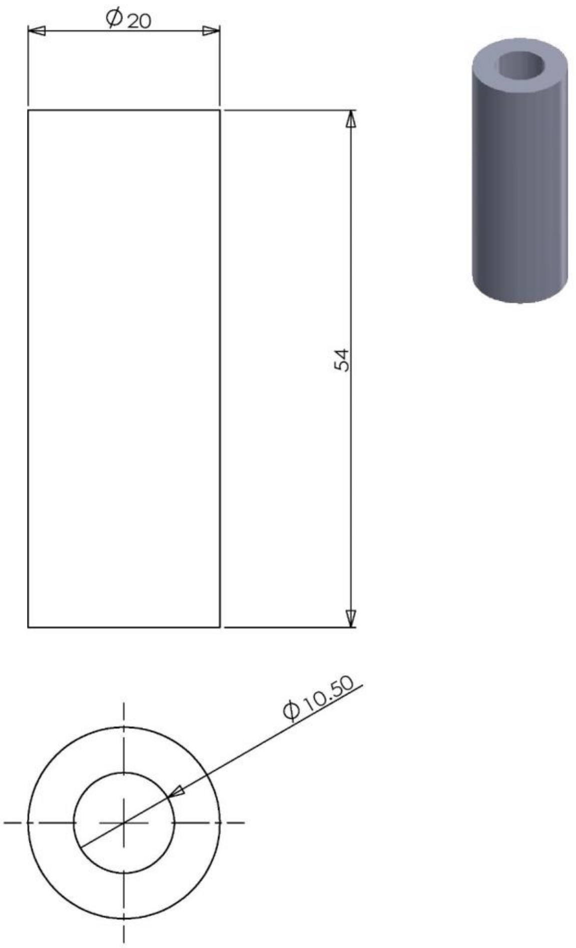
DWG NO. feeder Motor mount

A4

WEIGHT:

SCALE:2:1

SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR: +-0.5mm
ANGULAR: +-0.5deg

FINISH: 3D printing

DEBURR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	Yifan Shen		3/6/2023
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE: Feeder shell roller

MATERIAL: PLA

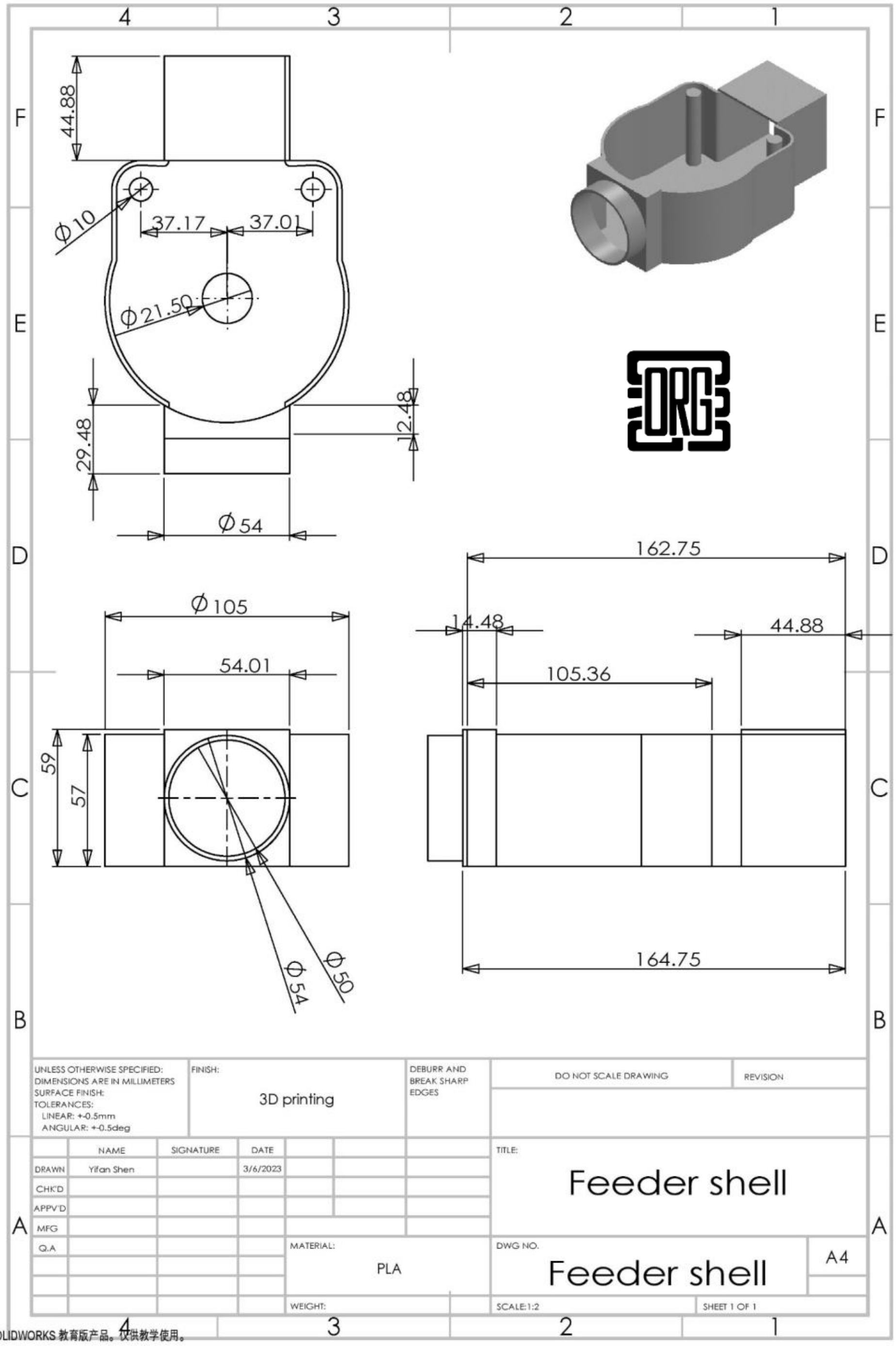
DWG NO. shell roller

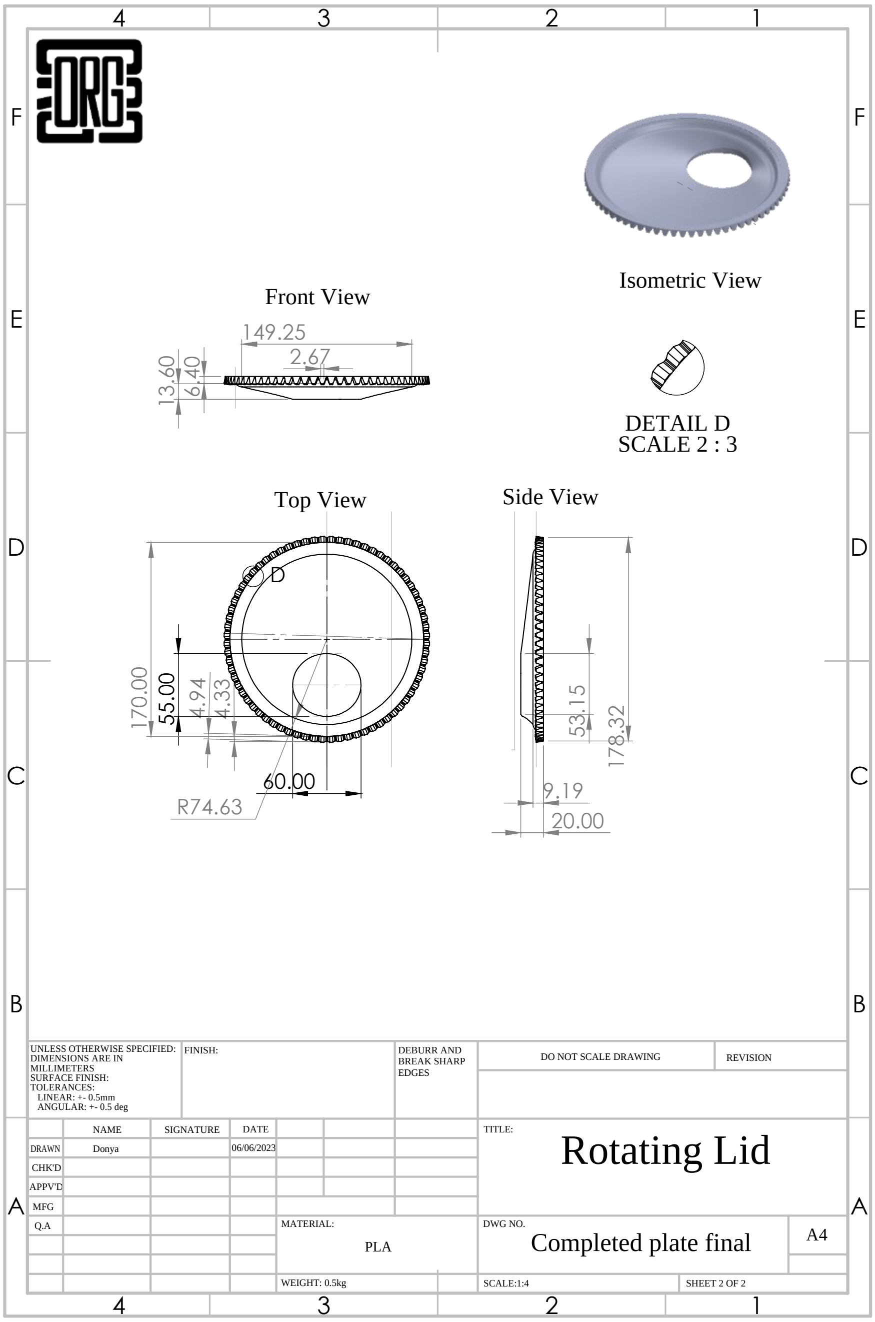
A4

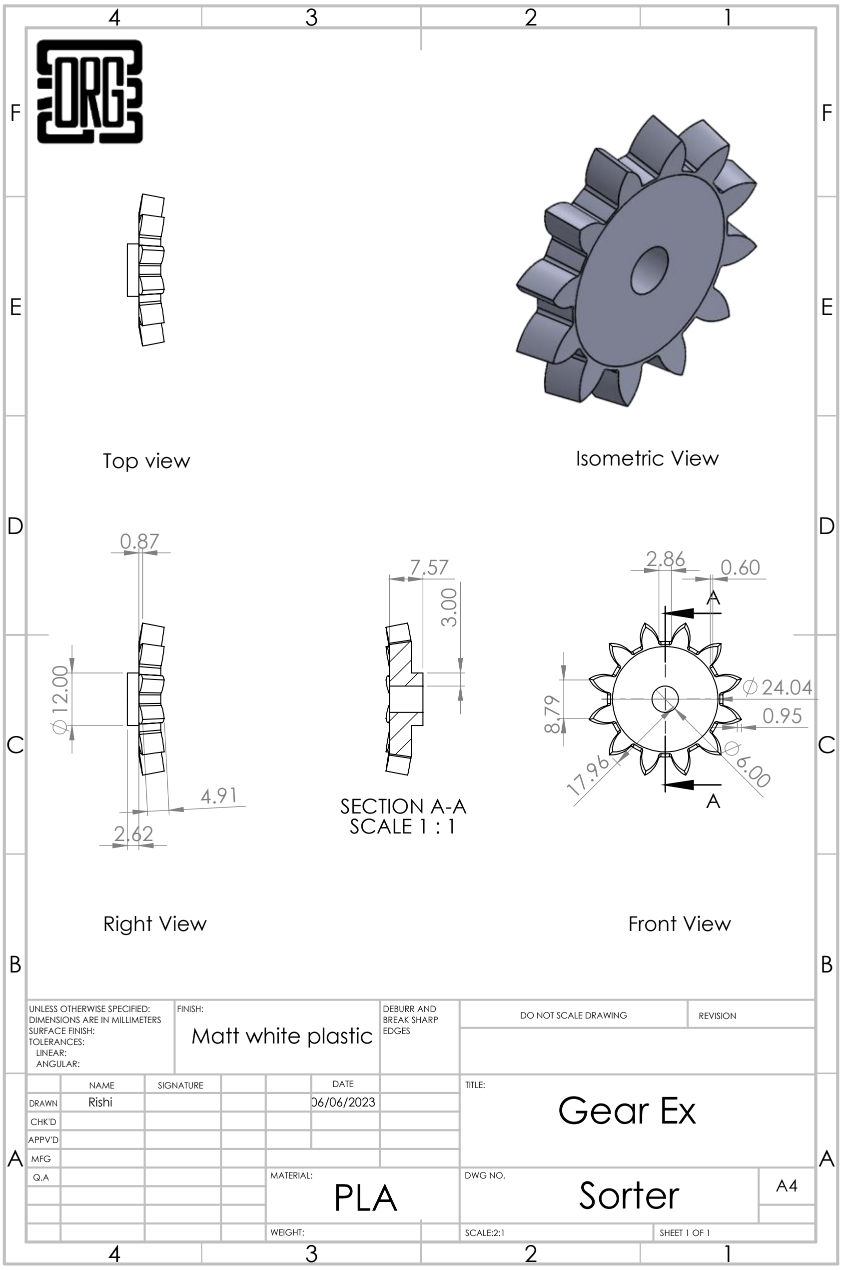
WEIGHT:

SCALE:2:1

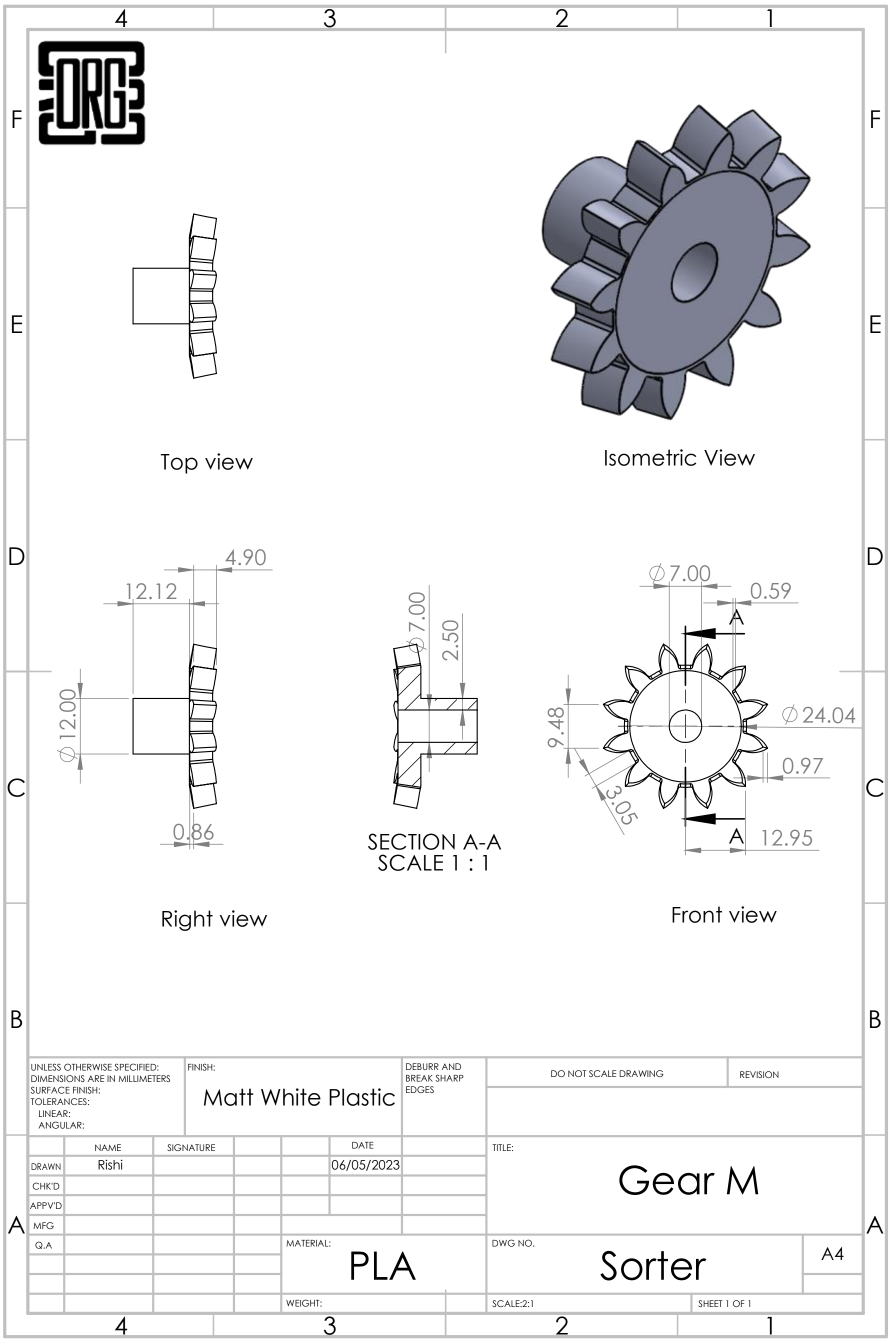
SHEET 1 OF 1

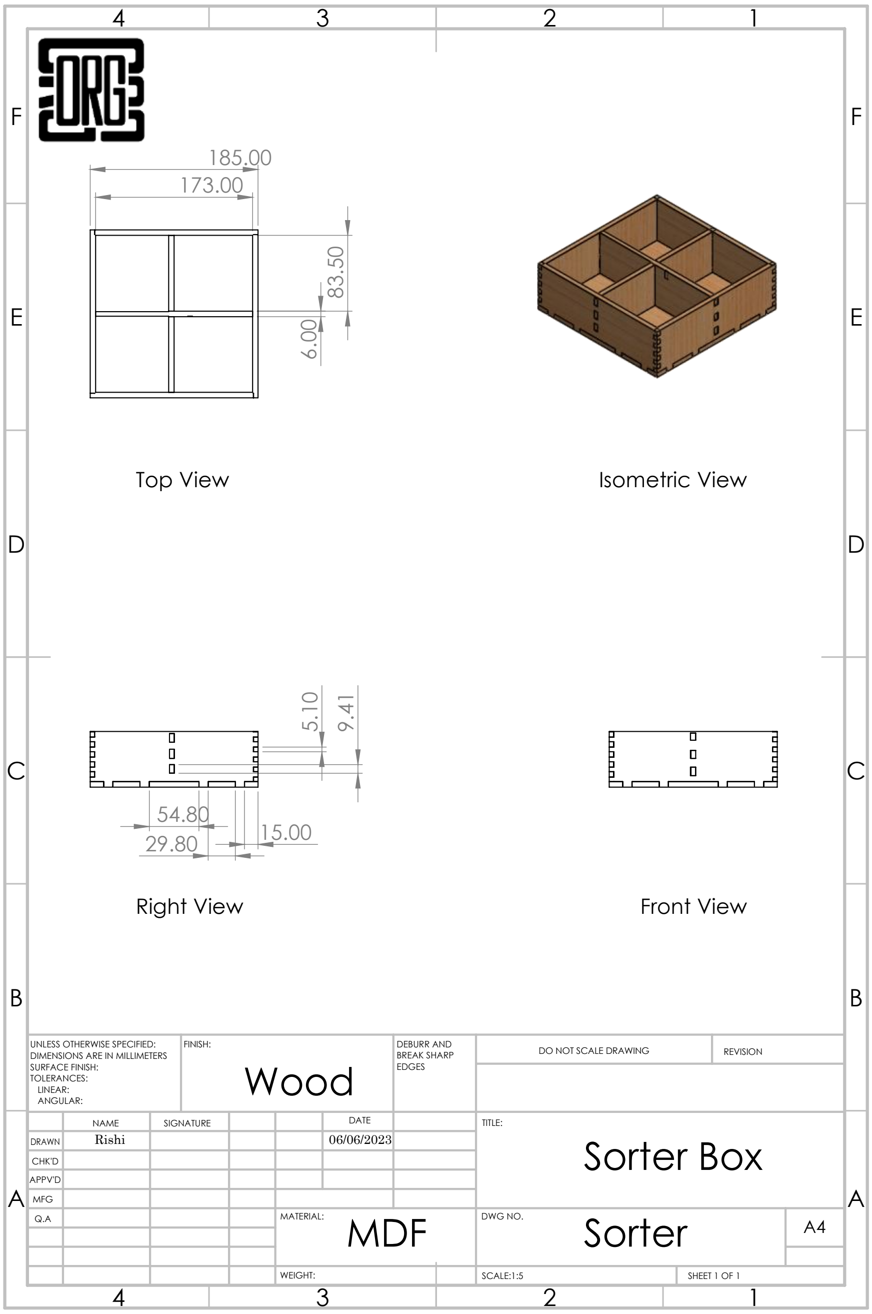

44.88
Ø10
37.17
37.01
Ø21.50
29.48
12.48
Ø54
Ø105
54.01
59
57
Ø54
Ø50
162.75
14.48
44.88
105.36
164.75
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR: +-0.5mm
ANGULAR: +-0.5deg
FINISH:
3D printing
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
Yifan Shen
3/6/2023
CHK'D
APPV'D
MFG
Q.A
TITLE:
Feeder shell
MATERIAL:
PLA
DWG NO.
Feeder shell
A4
WEIGHT:
SCALE:1:2
SHEET 1 OF 1


Front View
Isometric View
DETAIL D
SCALE 2 : 3
Top View
Side View
149.25
2.67
13.60
6.40
170.00
55.00
4.94
4.33
60.00
R74.63
53.15
178.32
9.19
20.00
D
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR: +- 0.5mm
ANGULAR: +- 0.5 deg
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
Donya
06/06/2023
CHK'D
APPV'D
MFG
Q.A
TITLE:
Rotating Lid
MATERIAL:
PLA
DWG NO.
Completed plate final
A4
WEIGHT: 0.5kg
SCALE:1:4
SHEET 2 OF 2

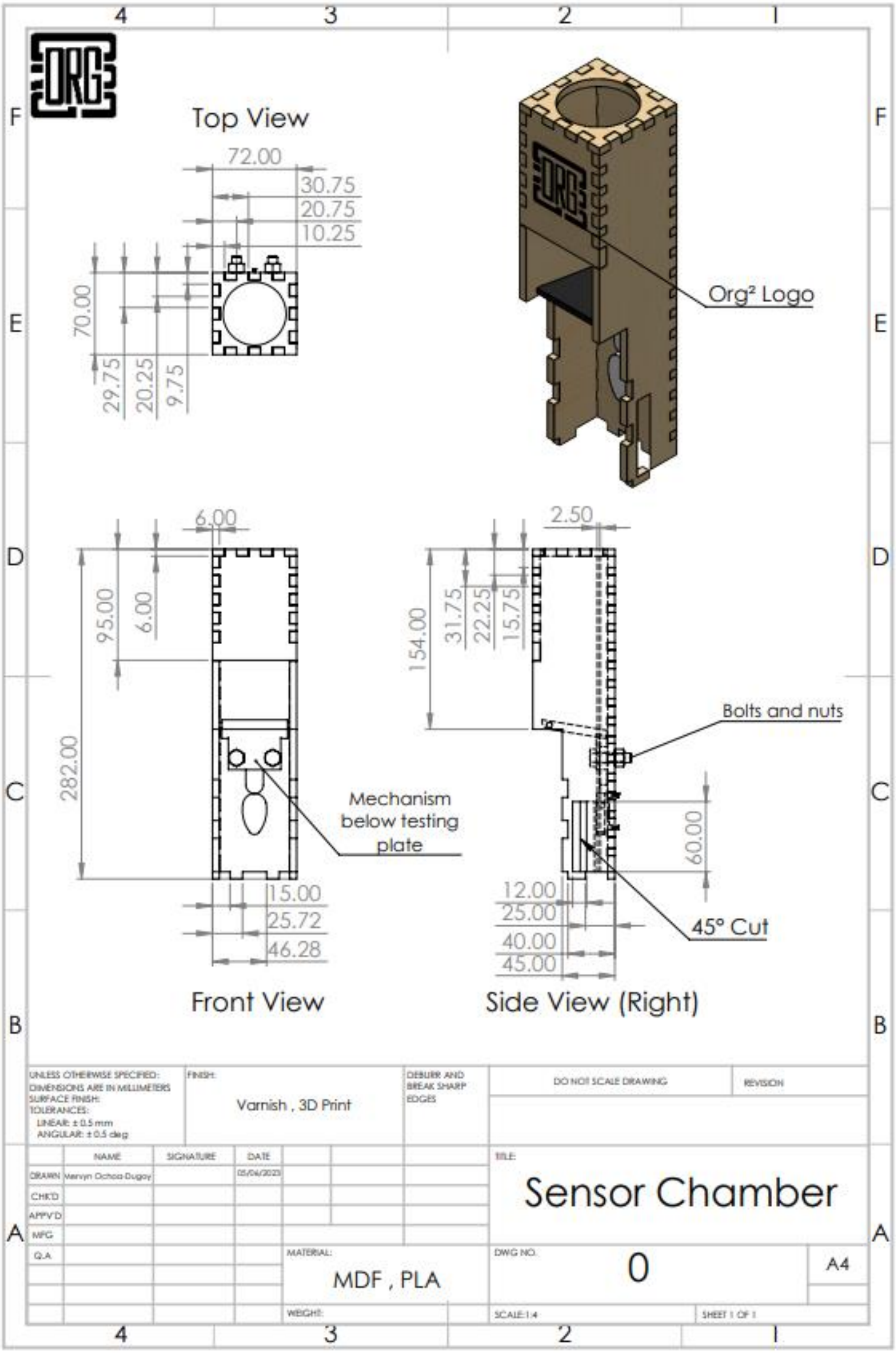


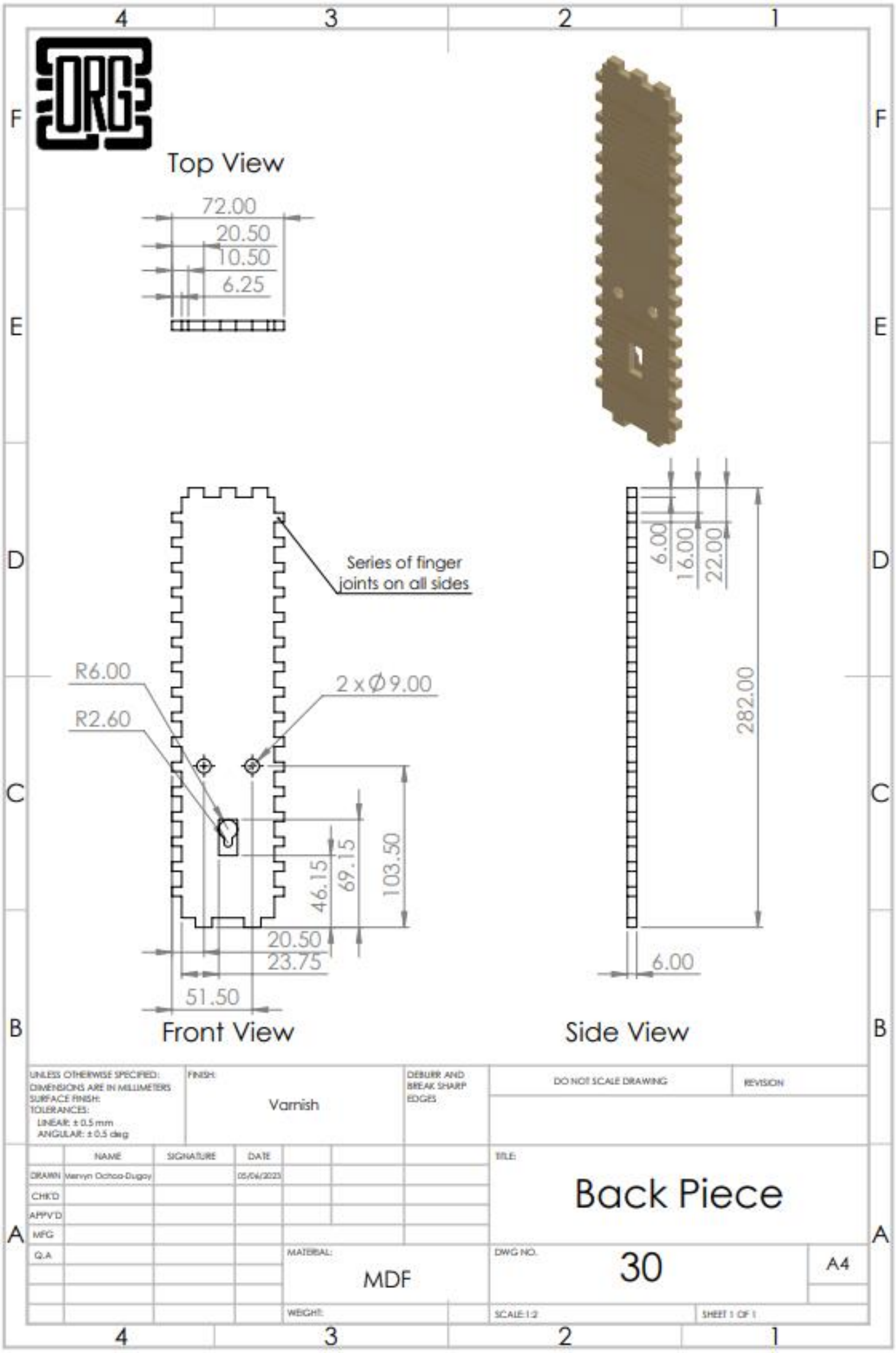
Top view
Isometric View
0.87
7.57
3.00
2.86
0.60
A
Ø 12.00
Ø 24.04
0.95
8.79
17.96
Ø 6.00
4.91
2.62
SECTION A-A
SCALE 1 : 1
Right View
Front View
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
Matt white plastic
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
Rishi
06/06/2023
CHK'D
APPV'D
MFG
Q.A
TITLE:
Gear Ex
MATERIAL:
PLA
DWG NO.
Sorter
A4
WEIGHT:
SCALE:2:1
SHEET 1 OF 1

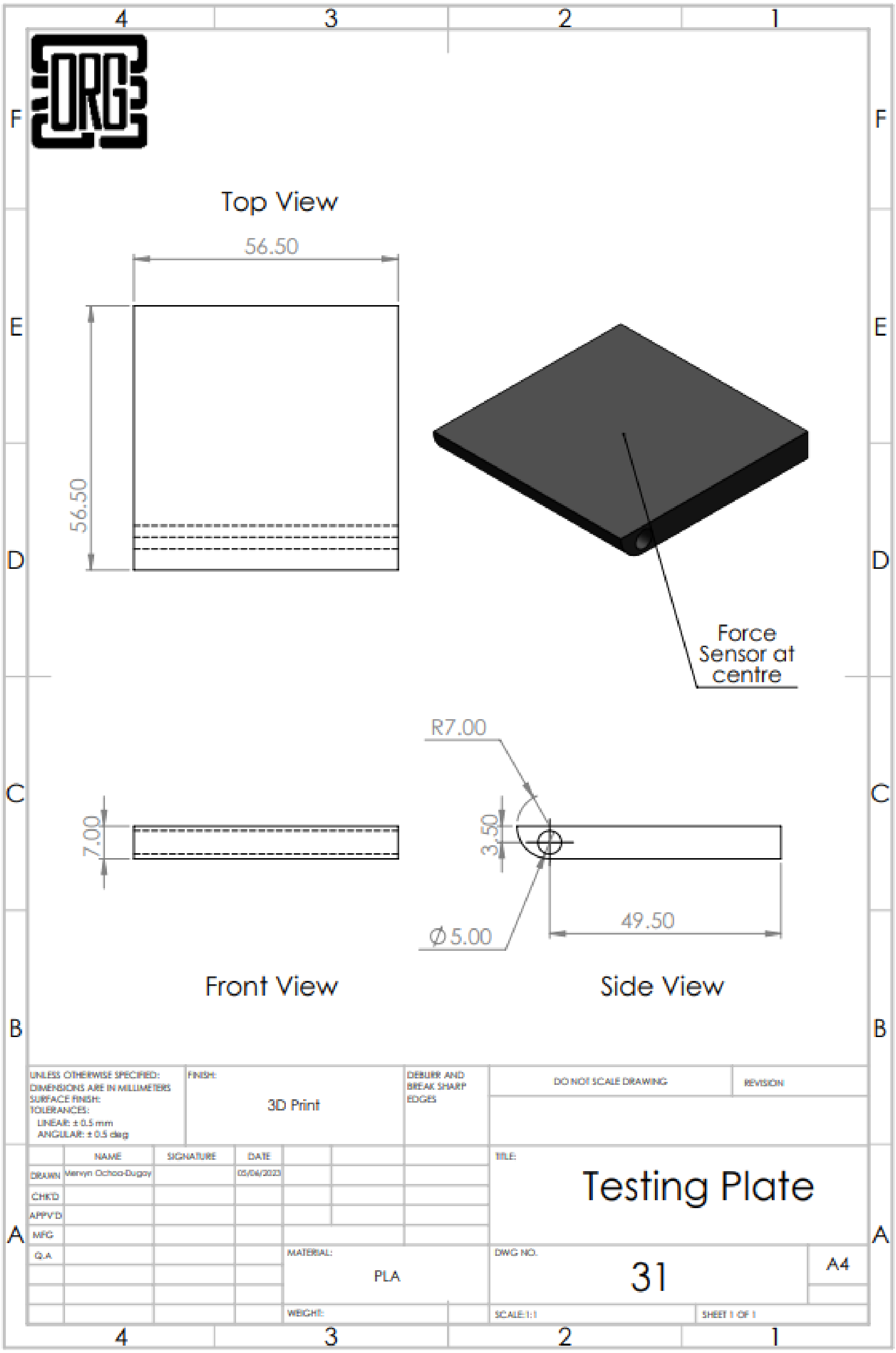

Top view
Isometric View
4.90
12.12
∅12.00
0.86
Right view
∅7.00
2.50
SECTION A-A
SCALE 1 : 1
∅7.00
0.59
A
9.48
∅24.04
0.97
3.05
12.95
Front view
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
Matt White Plastic
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
Rishi
06/05/2023
CHK'D
APPV'D
MFG
Q.A
TITLE:
Gear M
MATERIAL:
PLA
DWG NO.
Sorter
A4
WEIGHT:
SCALE:2:1
SHEET 1 OF 1

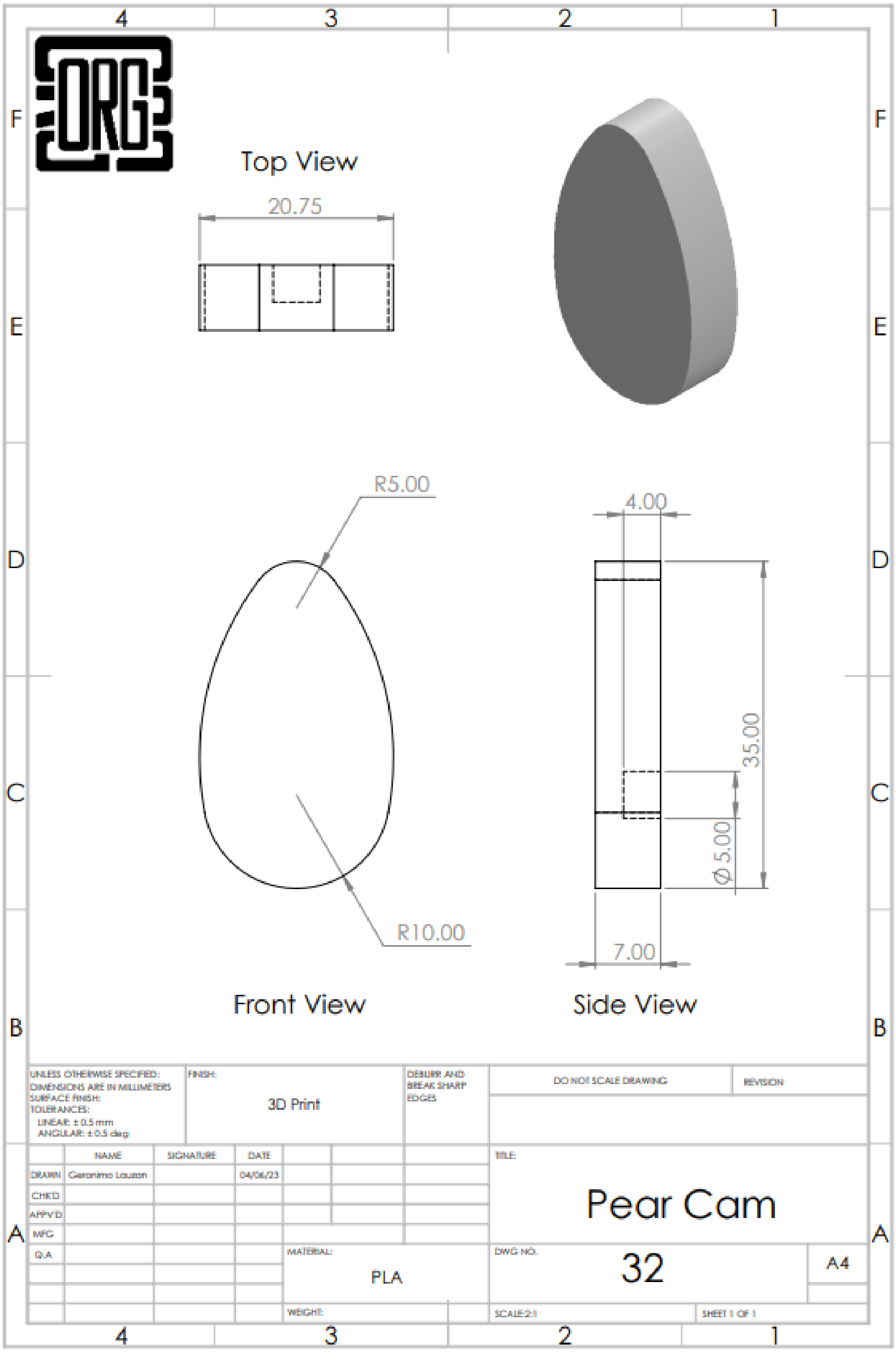


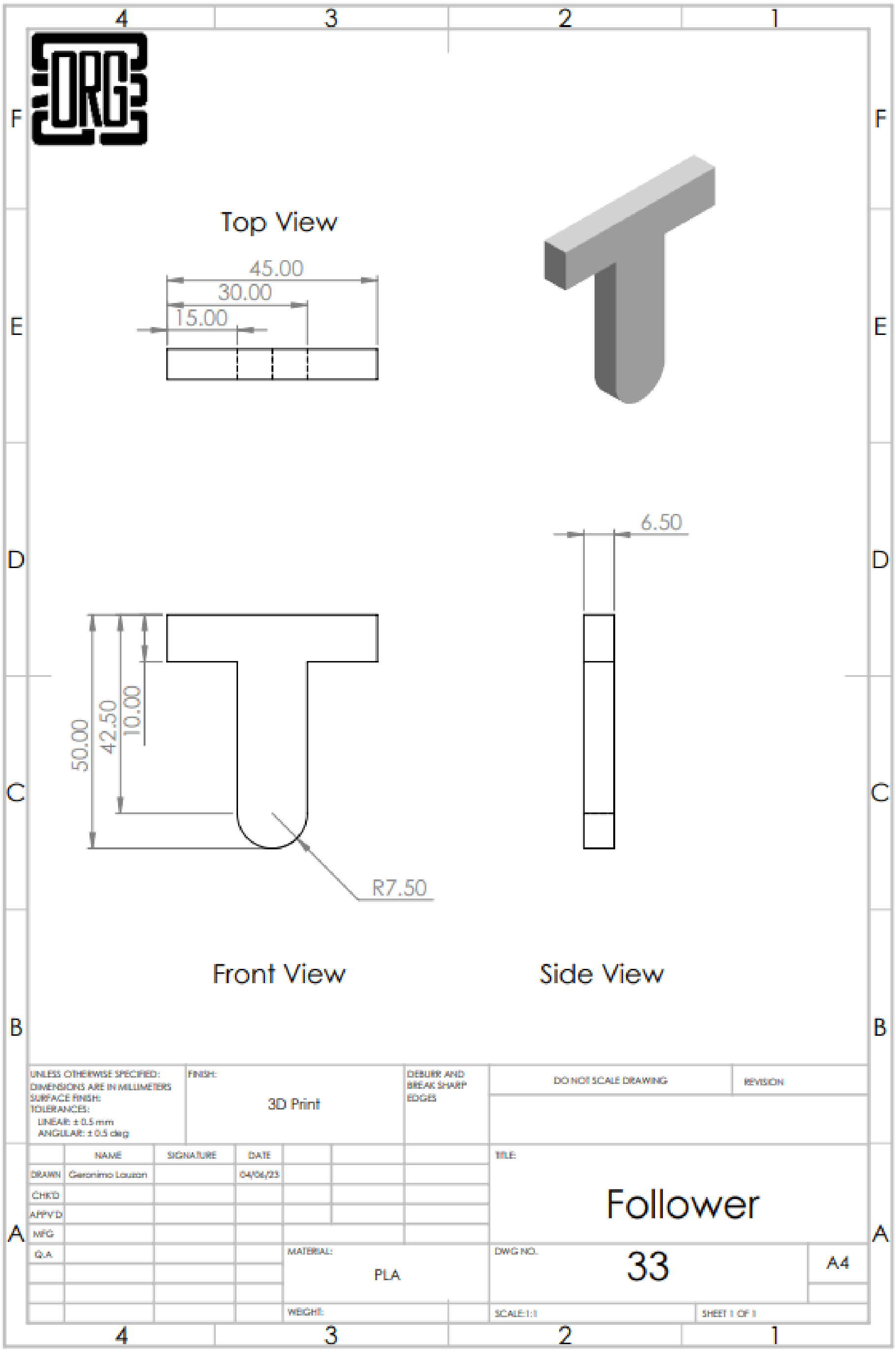
4
3
2
1
F
E
D
C
B
A
185.00
173.00
83.50
6.00
Top View
Isometric View
5.10
9.41
54.80
29.80
15.00
Right View
Front View
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
Wood
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
Rishi
06/06/2023
CHK'D
APPV'D
MFG
Q.A
TITLE:
Sorter Box
MATERIAL:
MDF
DWG NO.
Sorter
A4
WEIGHT:
SCALE:1:5
SHEET 1 OF 1

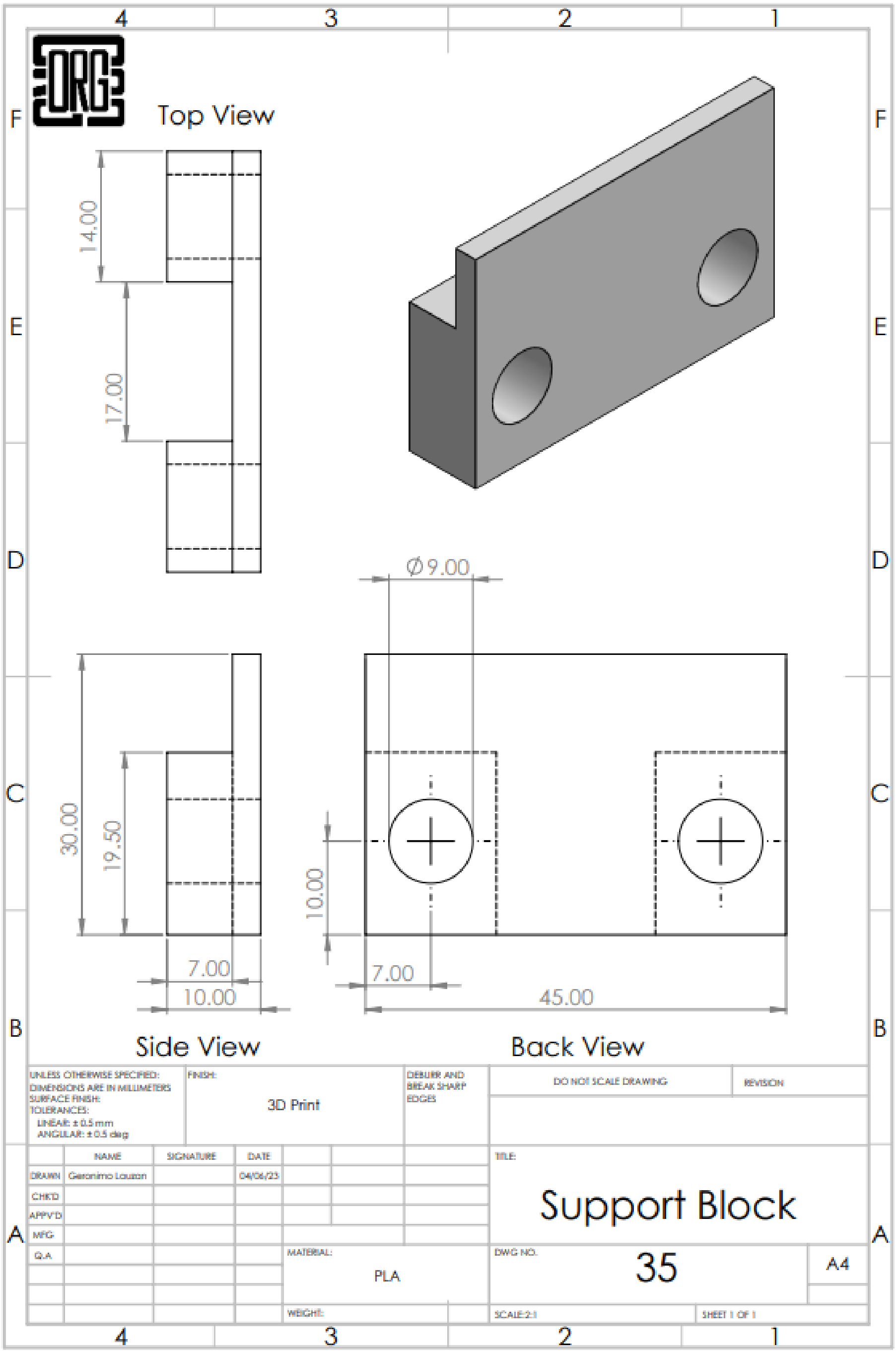

Top View
72.00
30.75
20.75
10.25
70.00
29.75
20.25
9.75
Org² Logo
6.00
95.00
6.00
282.00
Mechanism
below testing
plate
15.00
25.72
46.28
Front View
2.50
154.00
31.75
22.25
15.75
Bolts and nuts
60.00
12.00
25.00
40.00
45.00
45° Cut
Side View (Right)
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR: ± 0.5 mm
ANGULAR: ± 0.5 deg
FINISH:
Varnish , 3D Print
DEBURR AND
BREAK SHARP
EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
Sensor Chamber
MATERIAL:
MDF , PLA
DWG NO.
0
A4
WEIGHT:
SCALE:1:4
SHEET 1 OF 1


Top View
72.00
20.50
10.50
6.25
Series of finger joints on all sides
R6.00
R2.60
2 x Ø9.00
46.15
69.15
103.50
20.50
23.75
51.50
Front View
6.00
16.00
22.00
282.00
6.00
Side View
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR: ± 0.5 mm
ANGULAR: ± 0.5 deg
FINISH:
Varnish
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
Mervyn Ochoa-Dugay
05/06/2023
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
MDF
WEIGHT:
TITLE:
Back Piece
DWG NO.
30
A4
SCALE 1:2
SHEET 1 OF 1


Top View
56.50
56.50
Force Sensor at centre
R7.00
3.50
Ø 5.00
49.50
7.00
Front View
Side View
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR: ± 0.5 mm
ANGULAR: ± 0.5 deg
FINISH:
3D Print
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
Mervyn Ochoa-Dugay
05/06/2023
CHK'D
APPV'D
MFG
Q.A
TITLE:
Testing Plate
MATERIAL:
PLA
DWG NO.
31
A4
WEIGHT:
SCALE:1:1
SHEET 1 OF 1


Top View
20.75
R5.00
4.00
35.00
Ø 5.00
R10.00
7.00
Front View
Side View
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR: ± 0.5 mm
ANGULAR: ± 0.5 deg
FINISH:
3D Print
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
Geronimo Lauzon
04/06/23
CHK'D
APPV'D
MFG
Q.A
TITLE:
Pear Cam
MATERIAL:
PLA
DWG NO.
32
A4
WEIGHT:
SCALE:2:1
SHEET 1 OF 1


Top View
45.00
30.00
15.00
6.50
50.00
42.50
10.00
R7.50
Front View
Side View
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR: ± 0.5 mm
ANGULAR: ± 0.5 deg
FINISH:
3D Print
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
Geronimo Lauzon
04/06/23
CHK'D
APPV'D
MFG
Q.A
TITLE:
Follower
MATERIAL:
PLA
DWG NO.
33
A4
WEIGHT:
SCALE:1:1
SHEET 1 OF 1


Top View
14.00
17.00
Ø9.00
30.00
19.50
10.00
7.00
10.00
7.00
45.00
Side View
Back View
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR: ± 0.5 mm
ANGULAR: ± 0.5 deg
FINISH:
3D Print
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
Geronimo Lauzon
04/06/23
CHK'D
APPV'D
MFG
Q.A
TITLE:
Support Block
MATERIAL:
PLA
DWG NO.
35
A4
WEIGHT:
SCALE:2:1
SHEET 1 OF 1

Coding Appendix

Firmware.ino

```
#include "Arduino.h"
#include "FSR.h"
#include "ReadForce.h"
#include <Stepper.h>
#include <Servo.h>
#include <Keypad.h>


#define FSRSQUARE_PIN_1 A10

int heavy;
int stiff;

float maxForce = 0;

FSR fsrSquare(FSRSQUARE_PIN_1);
ReadForce readForce(20, FSRSQUARE_PIN_1);

const int timeout = 100000;
char menuOption = 0;
long time0;
bool isHard;
bool isHeavy;
//Keyboard setup
const byte ROWS = 4; //four rows
const byte COLS = 4; //four columns
char keys[ROWS][COLS] = {
  {'1','2','A','3'},
  {'4','5','B','6'},
  {'7','8','C','9'},
  {'*','0','D','#'}
};

byte rowPins[ROWS] = {24, 26, 28, 30}; //connect to the row pinouts of the keypad
byte colPins[COLS] = {32, 34, 36, 38}; //connect to the column pinouts of the keypad

Keypad keypad = Keypad( makeKeymap(keys), rowPins, colPins, ROWS, COLS );

// change this to the number of steps on your motor
#define STEPS 100

//define the number of steps for a full rotation of the servo motors
int StepsPerRevolution = 2048;
int motSpeed = 10;

// create an instance of the stepper class, specifying
// the number of steps of the motor and the pins it's
// attached to
Stepper stepper(STEPS, 8, 9, 10, 11);
Stepper stepper2(STEPS, 17, 16, 15, 14);
Servo feed_servo;
Servo test_servo;

int previous = 0;

void setup()
{
    analogReference(EXTERNAL);
    Serial.begin(115200);
    while (!Serial) ;
    Serial.println("start");
    stepper.setSpeed(200);
    stepper2.setSpeed(200);
    feed_servo.attach(4);
    test_servo.attach(5);
```

```
    test_servo.attach(5);
    delay(100);

}

void loop()
{
  char key = keypad.getKey();

  if (key){
    Serial.println(key);
  }

  if (key == '#') {
    for (int i = 0; i < 1; i++ ){
      readForce.taken = false;
//    delay(1000);
      feed_servo.write(0);
      delay(2000);
      feed_servo.write(180);
      delay(2000);
      test_servo.write(0);
      delay(2000);
      test_servo.write(180);
      delay(2000);
      while (readForce.taken == false){
        readForce.takeForce();
      }
      if (readForce.isHard == true){
        stiff = 1;
      }else{
        stiff = 0;
      }
      if (readForce.isHeavy == true)
      {
        stepper.step(StepsPerRevolution * (1+stiff));
        Serial.println(1+stiff);
      }else {
        stepper.step(StepsPerRevolution * (3 + stiff));
        Serial.println(3 + stiff);
      }
    }
  }
    if (millis() - time0 > timeout)
    {
      return;
    }

}
```

AnalogReader.cpp

```
#include "AnalogReader.h"

#include <Arduino.h>

AnalogReader::AnalogReader(const int pin) : m_pin(pin) {}

//read analog pin value
int AnalogReader::read()
{
    return analogRead(m_pin);
}
```

AnalogReader.h

```
#ifndef _ANALOG_READER_H
#define _ANALOG_READER_H

class AnalogReader
{
    public:
        AnalogReader(const int pin);
        int read();

    private:
        const int m_pin;
};
#endif //_ANALOG_READER_H
```

FSR.cpp

```
#include "FSR.h"
#include <Arduino.h>


FSR::FSR(const int pin) : AnalogReader(pin), Vcc(5), res(100)
{
    pinMode(pin, INPUT);
    analogReference(EXTERNAL);
}

//resistance (Ohms) of sensor
float FSR::getResistance()
{
    float senVoltage = read() * Vcc / 1023;
    return res * (Vcc / senVoltage - 1);
}

//use curve to find force
float FSR::getForce()
{
    float resistance = getResistance();
    //calculate force using curve broken into two parts of different slope
    if (resistance <= 600)
        return (1.0 / resistance - 0.00075) / 0.00000032639;
    else
        return (1.0 / resistance)  / 0.000000642857;
}
```

FSR.h

```
#ifndef _FSR_H_
#define _FSR_H_

#include "AnalogReader.h"

class FSR : public AnalogReader {
 public:
  FSR(const int pin);
  float getResistance();
  float getForce();
  float Vcc, res;

};

#endif // _FSR_H_
```

ReadForce.cpp

```
#include <Arduino.h>
#include "ReadForce.h"
#include "FSR.h"


ReadForce::ReadForce(float thresh, int pin)
{
  threshold = thresh;
  FSRSQUARE_PIN_1 = pin;
}

void ReadForce::begin()
{
  analogReference(EXTERNAL);
}

void ReadForce::printResult()
{

  if (maxForce < 500){
    Serial.println("Soft Light");
    isHard = false;
    isHeavy = false;
  }else if(maxForce < 2000){
    Serial.println("Hard Light");
    isHard = true;
    isHeavy = false;
  } else{
    if(totalT > 7){
      Serial.println("Soft Heavy");
      isHard = false;
      isHeavy = true;
    }else{
```

```
      Serial.println("Hard Heavy");
      isHard = true;
      isHeavy = true;
    }
  }
}

void ReadForce::takeForce()
{
  FSR fsrSquare(FSRSQUARE_PIN_1);
  float fsrSquareForce = fsrSquare.getForce();
  int Force = int(fsrSquareForce);
  if (fsrSquareForce > threshold){
        if (aboveT == false){
          aboveT = true;
          startT = int(millis());
          Serial.println("Above threshold");
        }
        if (fsrSquareForce > maxForce){
          maxForce = fsrSquareForce;

        }
      }
      else{
          if (aboveT == true){;
            finishT = int(millis());
            totalT = finishT - startT;
            aboveT = false;
            Serial.println("Below Threshold");
            Serial.print("Max Force:");
            Serial.println(maxForce);
            Serial.print("Time: ");
            Serial.println(totalT);
            printResult();
            maxForce = 0;
            taken = true;
            delay(1000);
          }
        }
}
```

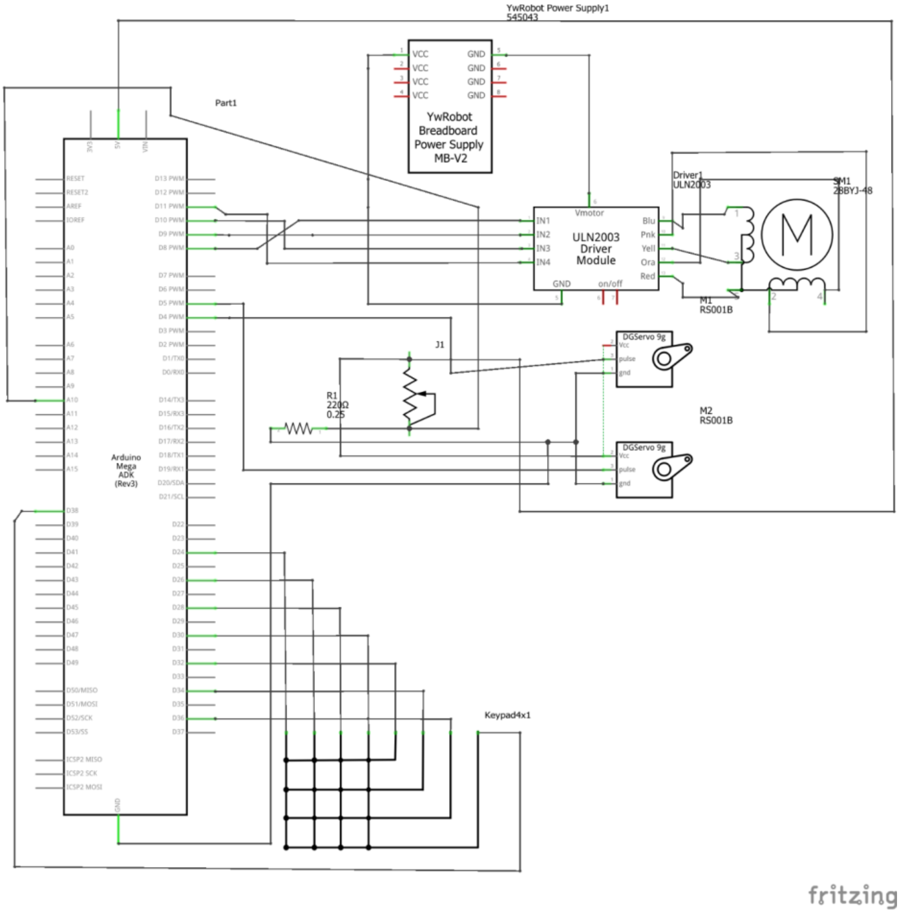
ReadForce.h

```
#ifndef ReadForce_h
#define ReadForce_h

#include "Arduino.h"

class ReadForce
{
  public:
    ReadForce(float thresh, int pin);
    float threshold;
    bool isHard;
    bool isHeavy;
    bool taken;
    void begin();
    void printResult();
    void takeForce();
  private:
    bool aboveT;
    int startT;
    int finishT;
    int totalT;
    float fsrSquareForce;
    int FSRSQUARE_PIN_1;
    float maxForce;
};
#endif
```

Circuit schematic



carbon footprint™

This certificate acknowledges that

Org^2

offset

1 tonne of carbon dioxide

by supporting

a Global Portfolio of
Verified Carbon Reduction Projects

6 June 2023

Helping to combat climate change
and sustain our environment for future generations

John Buckley
Managing Director, Carbon Footprint Ltd
www.carbonfootprint.com