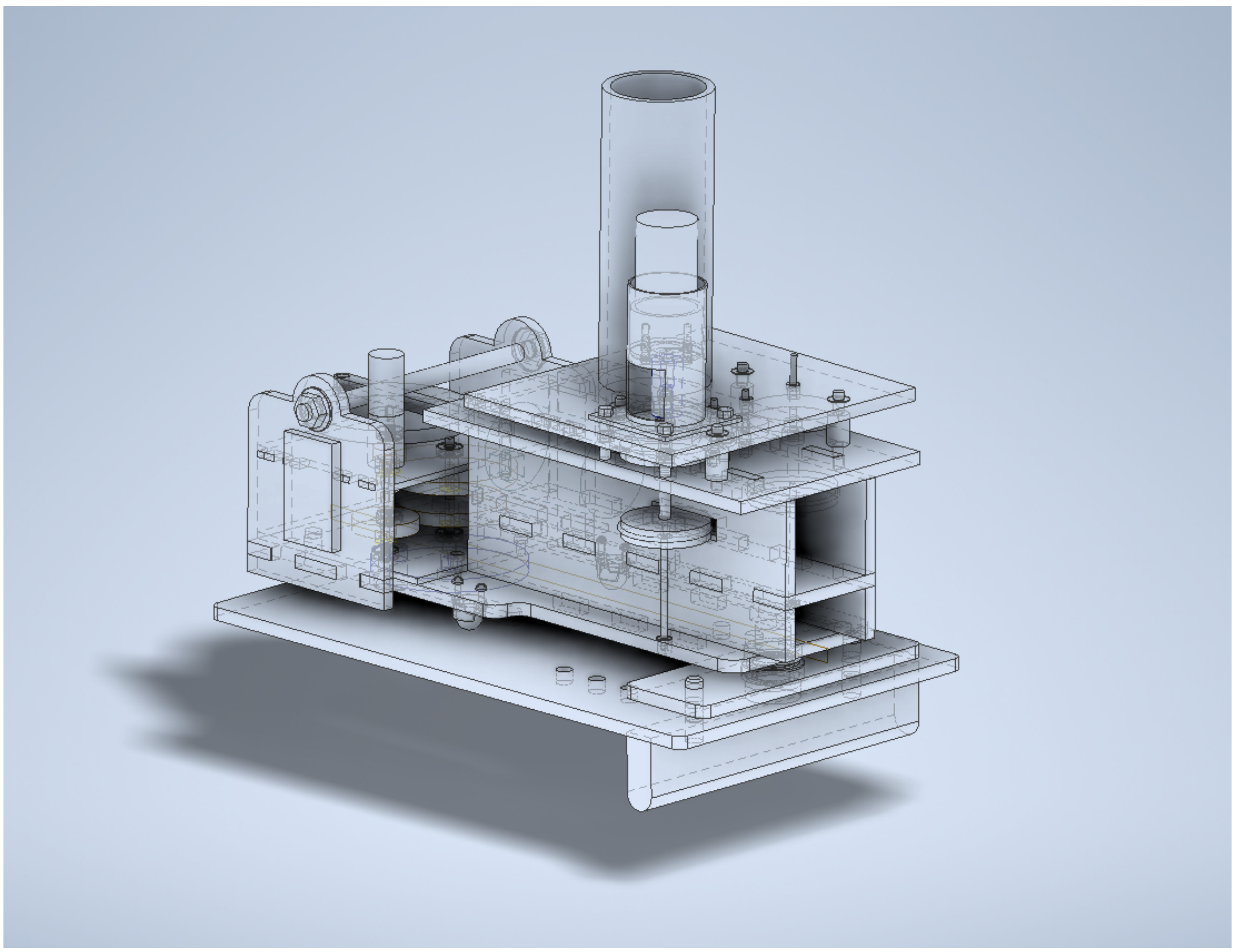
Table Tennis Ball launcher

Group_33_Report



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Appendices

1.0 Introduction

A mechanical assembly is required to automatically launch ping pong balls of a diameter of 40mm over a distance of roughly 1400mm, at three different angles. This ping pong launcher is to be designed as part of an undergraduate Design & Make project.

The following report outlines the design process from five initial concept drawings, to a final design that will be constructed from bespoke parts, as well as pre-made parts that are provided by approved suppliers. In this report, the initial drawings, the records of the meetings and progress can be found, as well as engineering drawings for the final design, and a parts list.

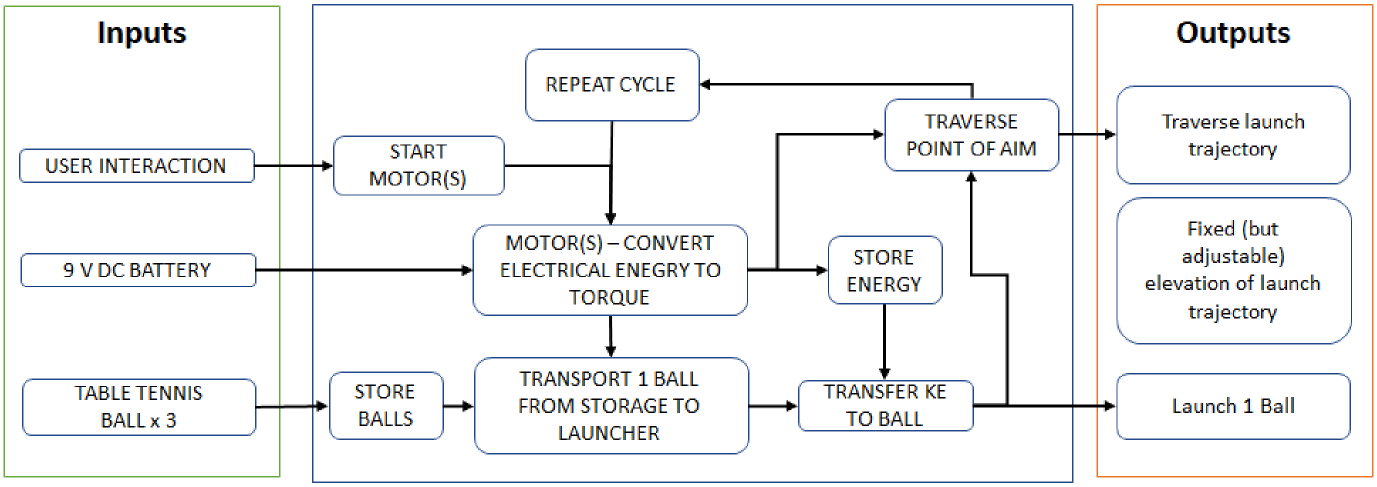
2.0 Specification

Table 1 - Specification points developed from the product brief and client interviews

Group 33		Requirements List Table Tennis Ball Launcher	Issue No	3
			Date	19/03/2021
			Page	1
D/W	**Wt.**	**Requirements**	**Source**	**Modified**
		Geometry		
D		● When Store (mm)d: 380 mm Long, 180 mm wide 300 High.	Brief	19/03/2021
		● In operation:		
D		○ 150 mm maximum extension on the “storage” geometry.	Rod	19/03/2021
D		○ Product must fit within the 300 mm x 750 mm region on the Table Tennis Table.	Brief	19/03/2021
		Kinematics		
D		● Launch a 40mm diameter table tennis ball a distance of 800mm – 1300mm.	Brief	19/03/2021
W	3	● Curved flight trajectory.	Rod	26/03/2021
W	2	● Alter launch angle.	Rod	
		Forces		
D		● No axial or radial loads on motor(s), only torque transferred.	Brief	19/03/2021
D		● Only Motors can be used to transfer Electrical Energy → Kinetic Energy	Brief	19/03/2021
		Energy		
D		● 9V DC Battery.	Rod	19/03/2021
D		● A maximum of 2 motors can run from the battery.	Rod	26/03/2021
		Materials		
W	3	● Internally sourced from the University of Bath workshop.	Brief	19/03/2021
W	3	● Externally sourced from the University of Bath Approved Supplier’s List.	Brief	19/03/2021
D		● Any other source requires university clearance.	Rod	26/03/2021
		Signals		
D D		● No electrical circuit that will change the input to the DC motor(s).	Brief	19/03/2021
D		● Only mechanical elements to provide control.	Brief	19/03/2021
		Safety		
D		● No risk of electrocution.		30/03/2021
D		● No risk of burns.		30/03/2021
W	3	● No risk of cutting.		30/03/2021
D		● Must not topple over under normal operation.		30/03/2021

Group 33		Requirements List Table Tennis Ball Launcher	Issue No	3
			Date	19/03/2021
			Page	2
D/W	Wt.	Requirements	Source	Modified
		Ergonomics		
W	1	● Minimised weight.	Brief	30/03/2021
W	1	● Convenient to displace.		26/03/2021
W	1	● Facilitated re-loading of balls.	Brief	26/03/2021
W	1	● Convenient to alter initial launch angle.	Rod	19/03/2021
		Production		
W	1	● Subcomponents can be produced independently.	Brief	30//03/2021
W	2	● Machine Shop: Lathe, Mill, ect.	Brief	19//03/2021
W	2	● 3D Printer: Technician Assistance	Brief	19//03/2021
		Assembly		
D		● No glue (except for PVC pipe connections).	Brief	19/03/2021
W	2	● Mechanical fasteners.	Rod	26/03/2021
W	2	● Possible to disassemble into main subcomponents.	Rod	30/03/2021
D		● No assembly required by the client, excludes inserting batteries.	Rod	19/03/2021
		Operation		
D		● Two human interactions, one to start and one to stop motor(s).	Rod	19/03/2021
D		● Product must remain stationary (no lateral movement).	Brief	19/03/2021
		● Balls manually loaded.	Rod	19/03/2021
D		● One firing cycle consists of:		19/03/2021
D		One ball fired into each target region one after the other for a total of 3 balls fired.	Brief	
W	3	Cycle Time Period: $5 < T < 18$	Rod	19/03/2021
D		● Product repeats firing cycle until switched off.	Rod	19/03/2021
		● Stand alone product (relative to table tennis table).	Rod	
		Budget		
W	3	● £80.00 from approved supplies (VAT excluded)	Rod	19/03/2021

Functional Analysis



Fig(1): Functional Analysis of Table Tennis Launcher. Used to identify the main sub-functions the Product must produce to meet the specification.

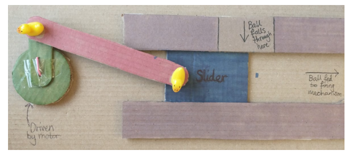
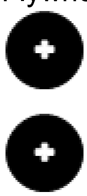
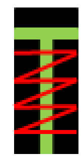
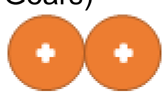
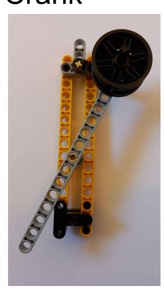
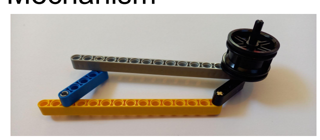
Main Sub-Functions Identified

1. Store balls - Ball Storage for minimum 3 balls.
2. Transport a single ball from the Ball Storage to the launch mechanism.
3. Transfer Kinetic Energy to the ball via a launch mechanism.
4. Traverse the Launch trajectory to the next target zone.
5. Repeat steps 2,3,4 at least 3 times.

These five subfunctions formed the basis for the Morph Board.

Morph Board

Table 2 - Morph board tidied up from the groups ideation process

Table : Morph Board. All team members brought solutions to fub functions, this produced 225 potential paths						
Sub Function		**Solutions**				
1	**Ball Storage**	Tube	Bucket	Funnel		
2	**Feed Mechanism**	Slider and Crank	Scotch Yoke	Slider and Crank 		
3	**Launch Mechanism**	Vertical Flywheels 	Horizontal Flywheels 	Offset Flywheels 	Compressed air from can 	Compressed air from spring 
4	**Traverse Mechanism**	Geneva Mechanism	Intermittent Gears (sheared Gears) 	Slider and Crank 	4-Bar link Mechanism 	Whitworth Quick return

Morph Board Pathways:
These pathways were used to outline the approach each team member should take for their Concept Sketches.

1. **Lani (A):** Tube, Slider and Crank, Horizontal Flywheel.
2. **Vi (B):** Tube, Slider and Crank, Offset Vertical Flywheels.
3. **Vojta (C):** Bucket, Rotating Gate, Compressed air from can.
4. **Ollie (D):** Tube, Scotch Yoke, Compressed air from spring.
5. **Theo (E):** Tube, Scotch Yoke, Vertical flywheels.
6. **Cody (F):** Hopper, Slider and Crank, Vertical flywheels.

3.0 Concept Drawings

Lani's concept sketch of her initial design (A)

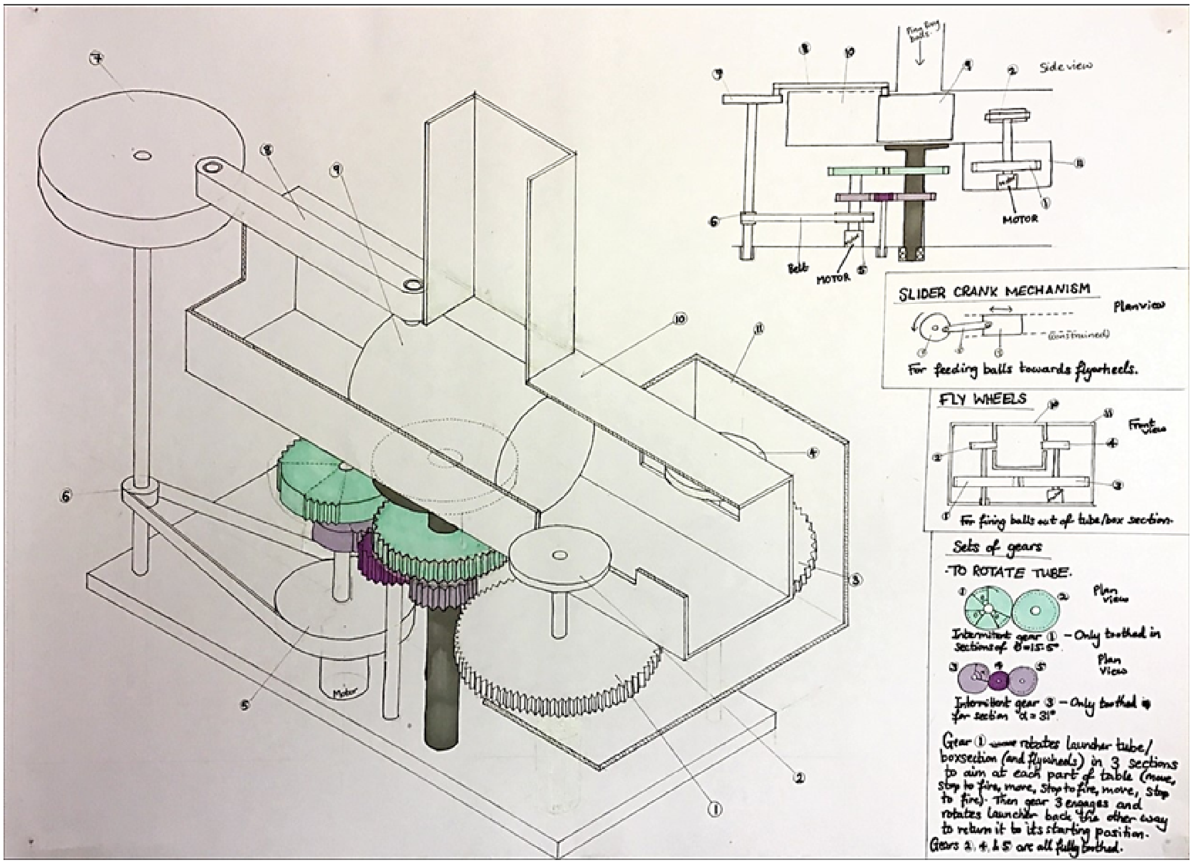


Figure 2 - Lani's annotated concept drawing

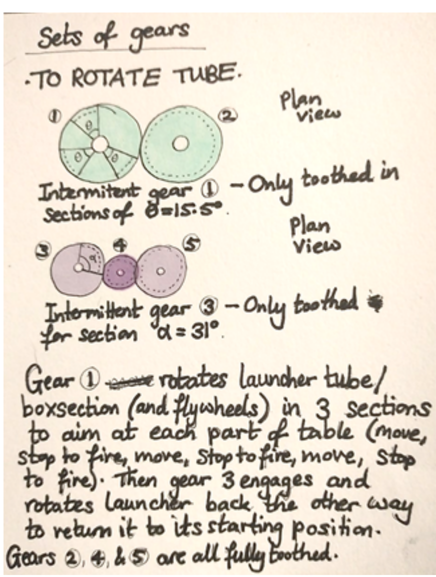


Figure 3 - Magnified image of Lani's gearing system for clarity

Vi’s concept sketch of her initial design (B)

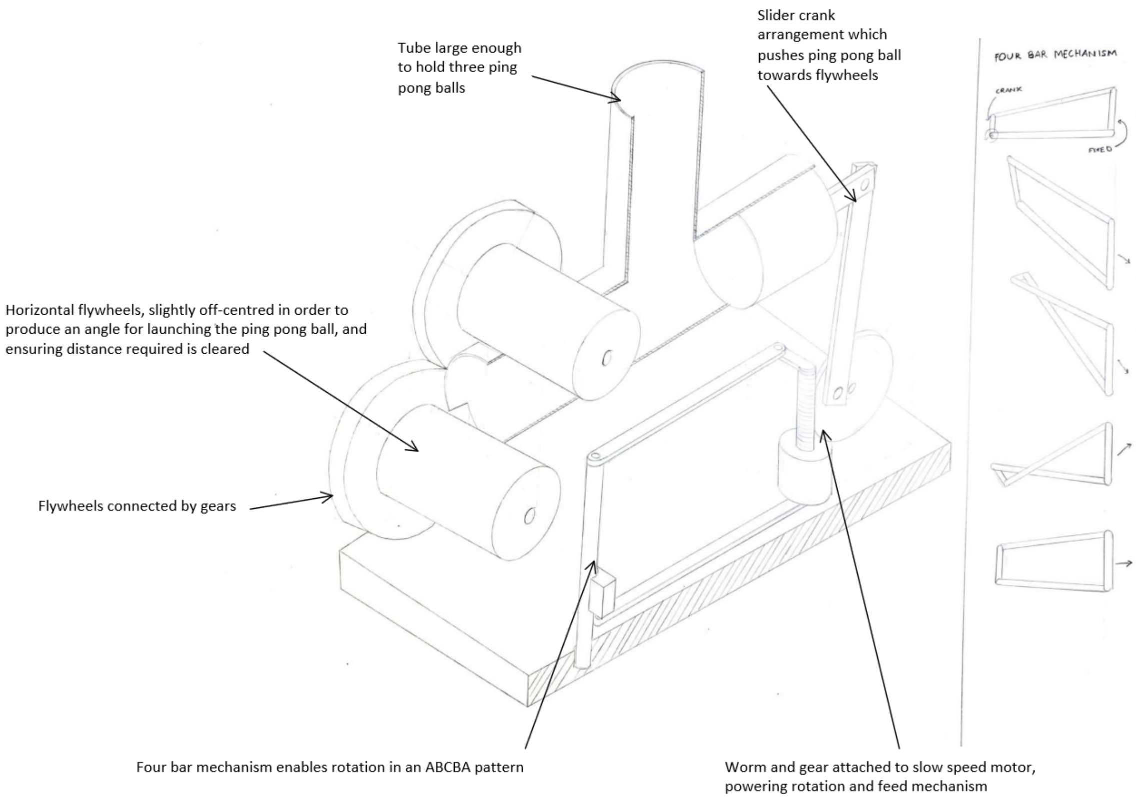


Figure 4 - Vi’s annotated concept drawing

Vojta's concept sketch of his initial design (C)

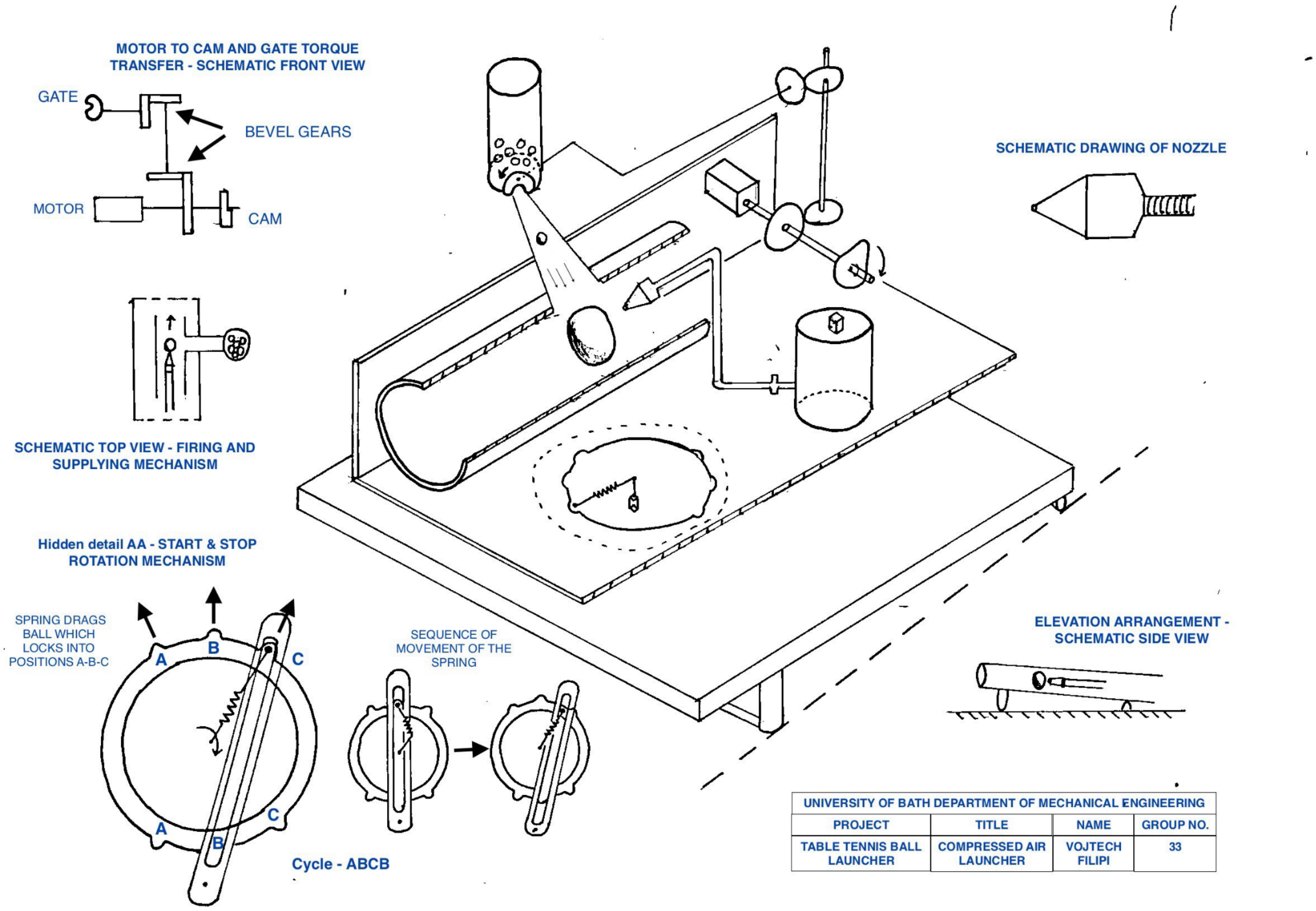


Figure 5 - Vojta's annotated concept drawing

Ollie’s concept sketch of his initial design (D)

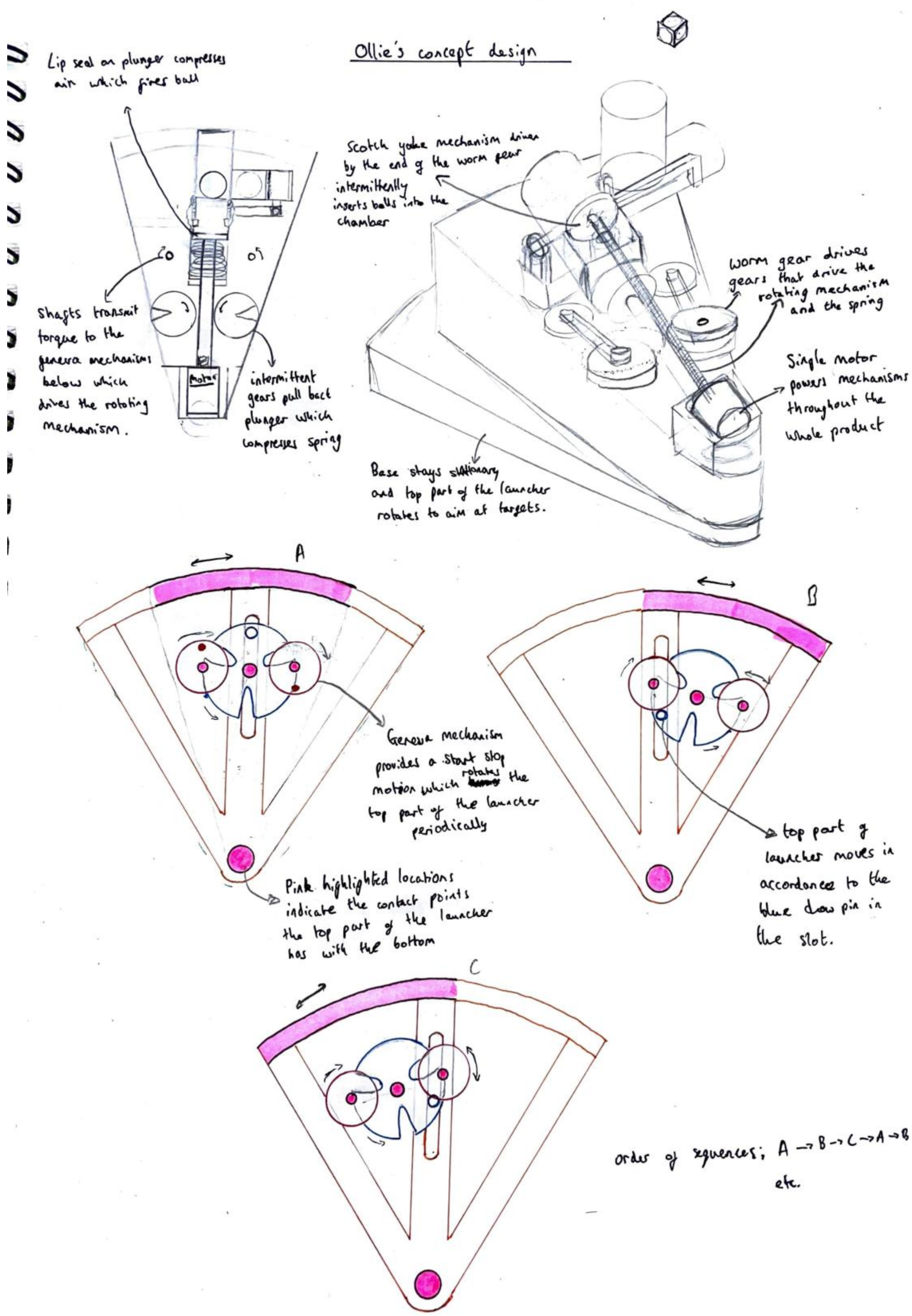


Figure 6 - Ollie’s annotated concept sketch

Theo’s concept sketch of his initial design (E)

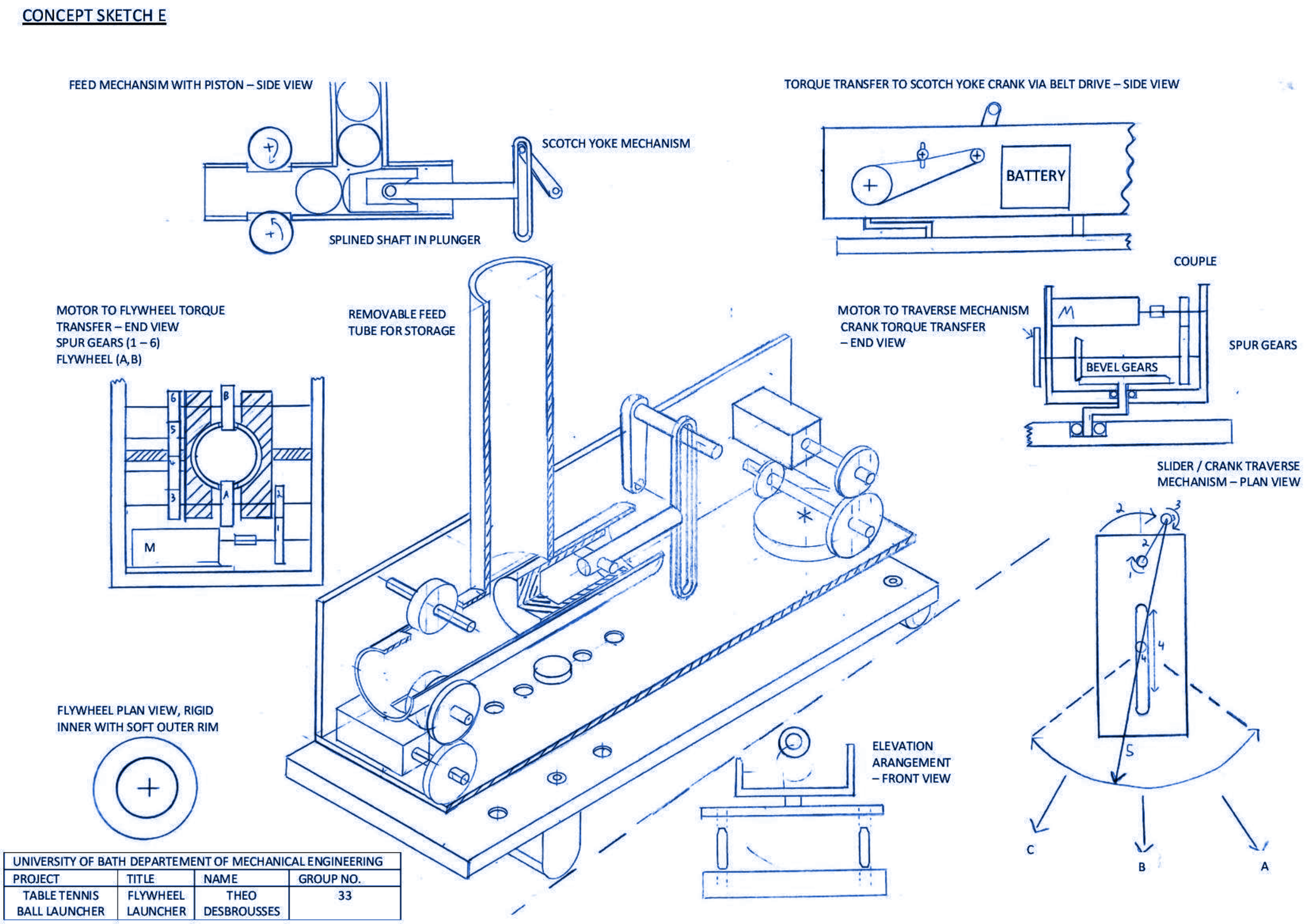


Figure 7 - Theo’s annotated concept sketch

4.0 Evaluation and Rational

The concepts must be evaluated for the following reasons:

- Fine tune ideas and concepts
- Evaluate designs and understand how they can be improved
- Understand a designs strengths and weaknesses
- Determine whether it meets the criteria of the design specification
- To enable the design development phase

For the purpose of our concept scoring, we used the MCDA (multi-criteria decision analysis) method. The method for this is as follows:

1. Determine the criteria based on specification
2. Weight the criteria
3. Score the concepts based on the criteria
4. Calculate weighted score and totals, providing a rank

MCDA Criteria Definitions

1. Ball Storage: How many 40mm balls can the hopper hold before the client must reload the hopper.
2. Feed Mechanism: Transportation of a single ball from Ball storage to launch mechanism.
3. Launch Mechanism: Transfer of kinetic energy to the ball to accelere it into the target area.
4. Traverse: Mechanism that changes the launcher's point of aim, must aim at: A, B, and C, preferably capable of repeated cycles.
5. Simplicity: number of moving parts and ability for fettling
6. Cost: Estimated Cost of material from approved suppliers
7. Reliability: how likely is the concept to provide a smooth transfer of torque and maintain timing.
8. Accuracy: ability of the concept to launch three balls into the three target regions
9. Ease of Manufacture: predominantly based upon the number of bespoke parts, amount of manually operated machining, and required time.

Table 3: MCDA Table. Criteria weighting enables more emphasis to be placed upon criteria deemed more important. Weight ranged from 1 (Low) → 3 (High) and Scoring ranged from 1 (Low) → 4(high)

Criteria	**Weight**	**Lani's (A)**	**Vi's (B)**	**Vojta's (C)**	**Ollie's (D)**	**Théo's (E)**
1. Ball Storage	1	Tube 2	Tube 2	Bucket 4	Tube 2	Tube 2
2. Feed mechanism	3	Slider crank 3	Slider crank 3	Rotating gate 1	Scotch yoke 2	Scotch yoke 2
3. Launch Mechanism	3	Horizontal Flywheels 3	Off centre Horizontal Flywheels 3	Stored Compressed air 1	Air compressed via Springr 3	Vertical Flywheels 3
4. Traverse	3	Gearbox (Spur and intermittent gears) 4	Four bar link mechanism 3	Spring and Whitworth mechanism 2	Geneva and whitworth quick return 3	Slider and crank 3
5. Simplicity	1	3	4	2	2	3
6. Cost	1	4	3	2	2	4
7. Reliability	3	3	4	2	2	3
8. Functionality	2	3	3	4	4	3
10. Ease of manufacture	2	2	3	3	2	3
Total score	76	58	60	40	48	54
Rank		**2**	**1**	**5**	**4**	**3**
% Score		76	79	53	63	71

Analysis of MCDA results

- Ball Storage. The Bucket (C) brings the highest storage capacity, the only downside being the space required to store the bucket due to the specification's geometry restriction.

- Feed mechanism. The rotating gate (C) is the more complex option. Meanwhile, the scotch yoke (D and E) performs the same function as the slider crank (A and B), but with more positional constraints required. Therefore, the slider crank mechanism was chosen.

- Launch mechanism. Whilst compressed air provides more power, the increased complexity, limited amount stored air and associated costs to maintain seals conflict with the specification's £80.00 budget. Therefore, Flywheels were chosen. Their arrangement (horizontal or vertical) was deemed to have little effect and so could be decided on later on in the design development.

- Traverse. All the designs are able to meet the specification wish of a repeating cycle. However, the four bar link mechanism (B) was deemed to be the simplest and so was initially chosen as a starting point for the transverse mechanism.

Concept B both ranked highest and had two of the chosen mechanisms. However, a more effective initial design could be produced by combining ideas from the several concept sketches.

5.0 Design Development

Testing mechanisms

In order to ensure that the design we had created was effective, we modelled some of the mechanisms using cardboard. This gave us an idea how the components could be arranged, and how effective the mechanism was.
This process demonstrated the difficulty of using a four bar link mechanism, and hence enabled us to change this part of the design to a whitworth quick return system early in the development of the design, to make the construction of the machine easier.

Inventor

The use of Inventor was paramount to the development stage of designing the mechanics of the machine. It enabled the visualisation of our ideas, and hence determined what parts would fit, and places where more support may be needed.

Electrical circuit

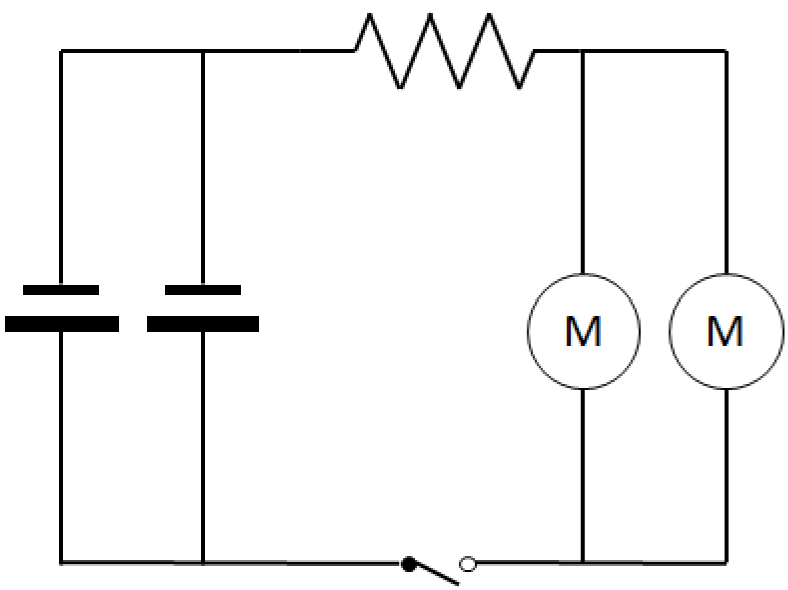


Fig 8 - Circuit Diagram. Parallel arrangement, two motors, one toggle switch, two 9V DC Battery.

- The chosen design uses two 9V batteries mounted in parallel to two motors, also mounted in parallel.
- This ensures both motors receive 9V DC (the specification demanded 9V maximum supply Voltage).
- This arrangement will draw twice the current as a series arrangement and result in more frequent battery changes. However, neither the specification or brief consider current.
- The resistor accounts for the combined wire resistance, as well as any other resistance sources (from motors and internal source) .
- A toggle switch will be used to turn both motors on at the same time. This meets the specification demand for a single client interaction to operate the device.
- The use of two batteries in parallel is to ensure that both motors draw the required current (Current adds up in parallel circuits).
- If only one battery is used, the motors may receive less current and will not be able to reach the required RPM due to a lack of power

6.0 Summary of Meetings

All = Vojta, Lani, Vi, Ollie, Cody, Theo

Table 4 - Summary of meetings

Meeting	1	**Date**	19/03/2021	**Time (GMT)**	12.00 - 13.00
Pre - work	n/a				
Participants	All				
Objectives	Meet and set up Cybernetic Collective discuss Brief and outline Specification				
Meeting	2	**Date**	23/03/2021	**Time (GMT)**	
Pre - work					
Participants	All				
Objectives	Brainstorm and create morphology board				
Meeting	3	**Date**	26/03/2021	**Time (GMT)**	07.00 - 10.00
Pre - work	Create rough sketches				
Participants	5				
Objectives	Compare and finalise individual morph board solutions				
Meeting	4	**Date**	06/04/2021	**Time (GMT)**	
Pre - work	Draw individual concept sketches				
Participants	5				
Objectives	Explain individual concept sketches to each other				

Meeting	5	Date	08/04/2021	Time (GMT)	11
Pre - work					
Participants	5				
Objectives	Use scoring system to rank how well each concept sketch works with the specification				

Meeting	6	Date	11/04/2021	Time (GMT)	
Pre - work					
Participants	5				
Objectives	Do calculations to determine the dimensions of the final design. Set up a shared onedrive file in order to collaborate and create parts in inventor				

Meeting	7	Date	15/04/2021	Time (GMT)	
Pre - work	Determine parts list				
Participants	5				
Objectives	Walk through all assemblies to determine parts list and bearing arrangements.				

Meeting	8	Date	18/04/2021	Time (GMT)	15:30 - 20:30
Pre - work	Complete parts list				
Participants	4				
Objectives	Continue to make parts in inventor in order to create a completed assembly				

Meeting	9	**Date**	20/04/2021	**Time (GMT)**	13:00 - 15:30
Pre - work	Finish base in inventor				
Participants	All				
Objectives	Format the report				

Meeting	10	**Date**	23/04/2021	**Time (GMT)**	09:30-12:00
Pre - work	Continue to work on box section of the launcher in inventor				
Participants	5				
Objectives	Format and complete as much of the report as possible				

Meeting	11	**Date**	25/04/2021	**Time (GMT)**	17:30-19:00
Pre - work					
Participants	4				
Objectives	Finish inventor assembly drawing				

Meeting	12	**Date**	27/04/2021	**Time (GMT)**	14:00 - 17:15
Pre - work					
Participants	5				
Objectives	Complete order sheet/parts list for bespoke and pre-manufactured parts				

Meeting	13	**Date**	28/04/2021	**Time (GMT)**	16:30-19:15
Pre - work	Parts drawings for bespoke parts				
Participants	3				
Objectives	Complete order form and start creating files that can be read by laser cutter or 3D printer				

Meeting	14	**Date**	29/04/2021	**Time (GMT)**	15:00-19.00
Pre - work	Finish orthographic drawings of bespoke parts				
Participants	All				
Objectives	Prepare files that are ready for submission, by formatting them correctly in the folder				

Meeting	15	**Date**	30/04/2021	**Time (GMT)**	9:30-13.15
Pre - work	Finish all parts drawings and files for laser cutter				
Participants	All				
Objectives	Make sure everything is complete and all parts are accounted for				

7.0 Order forms and Cost Calculations

Cost Calculation

Table 5 - Overview of costs

Suppliers	**Total Cost of Components (£)**
University of Bath Supplies (UoB)	17.15
Technobots (TNB)	24.92
Technobots Online (TNBE)	33.13
RS Components (RSC)	1.72
3D Printing Costs (ABS)	4.75
Laser Cutting Costs (MDF)	2.82
Total	**84.49**

3D printing Cost Calculation

Cost (£) = Volume (mm^3) x Density (ABS = 0.00105 g/mm^3) x Cost (£ 0.08 / g) x infill

Piston UOB33019:

62831 x 0.00105 x 0.08 x 0.5 = £ 2.64

50253 x 0.00105 x 0.08 x 0.5 = £2.11

Laser Cutting (MDF) Cost Calculation

Total Area of MDF:

6mm 195,180 mm^2. Costs £7.50, for a 900 mm x 600 mm sheet. Therefore: 2.71

3mm MDF 10,450 mm^2. Costs £5.50 for a 900 mm x 600 mm sheet. Therefore: 0.11

Order Forms

Table 6 - University of Bath supplies order form

Table 6: University Of Bath Supplies Order Form.				
Qty	**Supplier Part no.**	**Description**	**Unit Price £**	**Total £**
5	527-432	M5 x 25 Hex Set Screw	£0.08	£0.39
6	525-903	M5 Nut	£0.02	£0.12
4	560-596	M3 x 10 Pan Head Screw	£0.02	£0.07
5	525-931	M5 Plain Washer	£0.01	£0.04
8	560-338	M3 Plain Washer	£0.01	£0.05
4	560-293	M3 Nut	£0.04	£0.17
2	553-633	M5 x 20 Pan Head Screw	£0.04	£0.07
0.17	SB005300	Mild Steel Round Bar, 5mm Ø x 300mm long (only need 50 mm)	£2.00	£0.34
0.8	SB008300	Mild Steel Round Bar, 8mm Ø x 300mm long (only need 240 mm)	£7.00	£5.60
0.63	SB010300	Mild Steel Round Bar, 10mm Ø x 300mm long (only need 187 mm)	£10.00	£6.30
0.51	SS004300	Silver steel Ground bar, 4mm Ø x 300mm long (only need 152 mm)	£0.86	£0.44
0.5	530-337	Threaded Bar M8 x 300 (only need 150 mm)	£1.98	£0.99
0.52	PVCTUB50	OD 50 mm, Wall Thickness 3.7mm	£3.50	£1.82
0.083	254300	25.4 Ø x 300mm long (only need 25 mm)	£9.00	£0.75
Total:				**£17.15**

Table 7 - RS Components order form

Table 7: RS Components Order Form.				
Qty	**Supplier Part No.**	**Description**	**Unit Price £**	**Total £**
5	270-675	8 x 24 mm Dowel Pin	£0.28	£1.41
2	196-4902	Nitrile Rubber O-ring 38 mm Bore, 42 mm OD	£0.04	£0.08
2	483-1331	M2 x 12 Pan Head Screw (Brass)	£0.05	£0.10
2	530-797	M8 Plain Washer	£0.00	£0.01
2	527-612	M8 Hex Nut	£0.06	£0.12
Total:				**1.72**

Table 8 - Technobots electrical order form

Table 8:Technobots Electrical Order Form				
Qty	**Supplier Part no.**	**Description**	**Unit Price £**	**Total £**
2	1063-090	PP3 9V Battery Holder with flying leads	£0.41	£0.82
1	1450-060	940D51 Planetary Geared Motor 5:1	£15.03	£15.03
1	1450-072	941D2311 Planetary Geared Motor 231:1	£16.52	£16.52
1	1610-110	SPST Miniature Toggle Switch	£0.76	£0.76
Total				**£33.13**

Table 9 - Technobots supplies order form

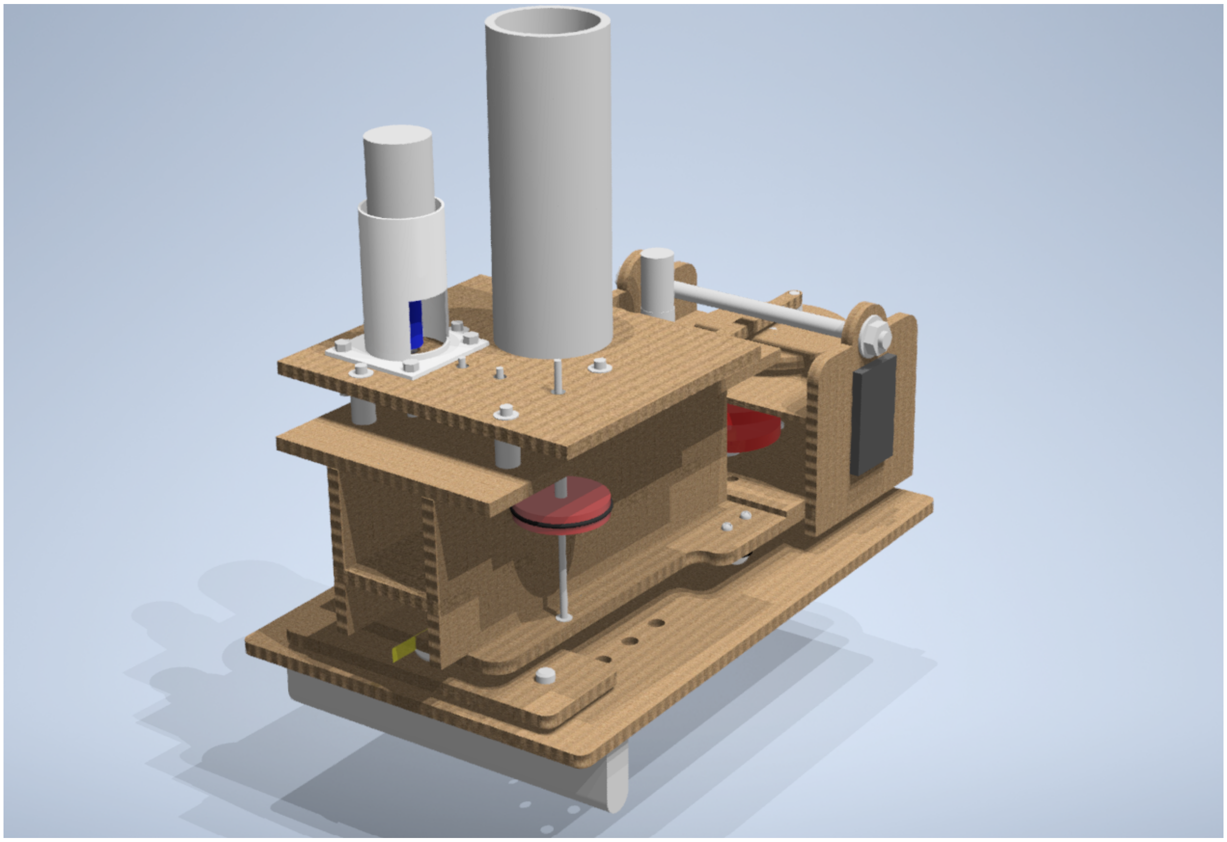
Table 9: Technobots Order Form.				
Qty	**Supplier Part no.**	**Description**	**Unit Price £**	**Total £**
1	4255-206	Bearing ID 15 OD 28	£0.54	£0.54
1	4255-036	Bearing ID 4 OD 9	£0.66	£0.66
7	4255-020	Bearing ID 3 OD 6	£0.66	£4.62
2	4255-126	Bearing ID 5 OD 10	£0.66	£1.32
5	4255-124	Bearing ID 4 OD 12	£0.33	£1.65
1	4600-136	MOD 1, 30 T Gear	£1.18	£1.18
1	4600-133	MOD 1, 15 T Gear	£0.89	£0.89
1	4600-139	MOD 1, 50 T Gear	£1.66	£1.66
1	4600-141	MOD 1, 60 T Gear	£1.79	£1.79
2	4603-032	Polyethylene Wheel 38 x 7.3	£0.61	£1.22
1	4604-049	inline 3-4 mm Shaft Coupling	£3.42	£3.42
1	4604-141	inline 4 - 6 mm Shaft Coupling	£2.00	£2.00
2	4262-111	Ball Caster 1/2 inch plastic ball	£1.42	£2.84
1	4555-707	3 mm circlip (£ 0.90 for 135 piece set)	£0.01	£0.01
6	4555-707	4 mm circlip (£ 0.90 for 135 piece set)	£0.01	£0.06
2	4600-174	Tbot Standard Mod 1 Plastic Gear 38T 2.9 mm Bore	£0.26	£0.52
2	4600-172	Tbot Standard Mod 1 Plastic Gear 18T 2.9 mm Bore	£0.25	£0.50
4	4555-707	5 mm circlip (£ 0.90 for 135 piece set)	£0.01	£0.04
Total				**24.92**

8.0 Conclusion

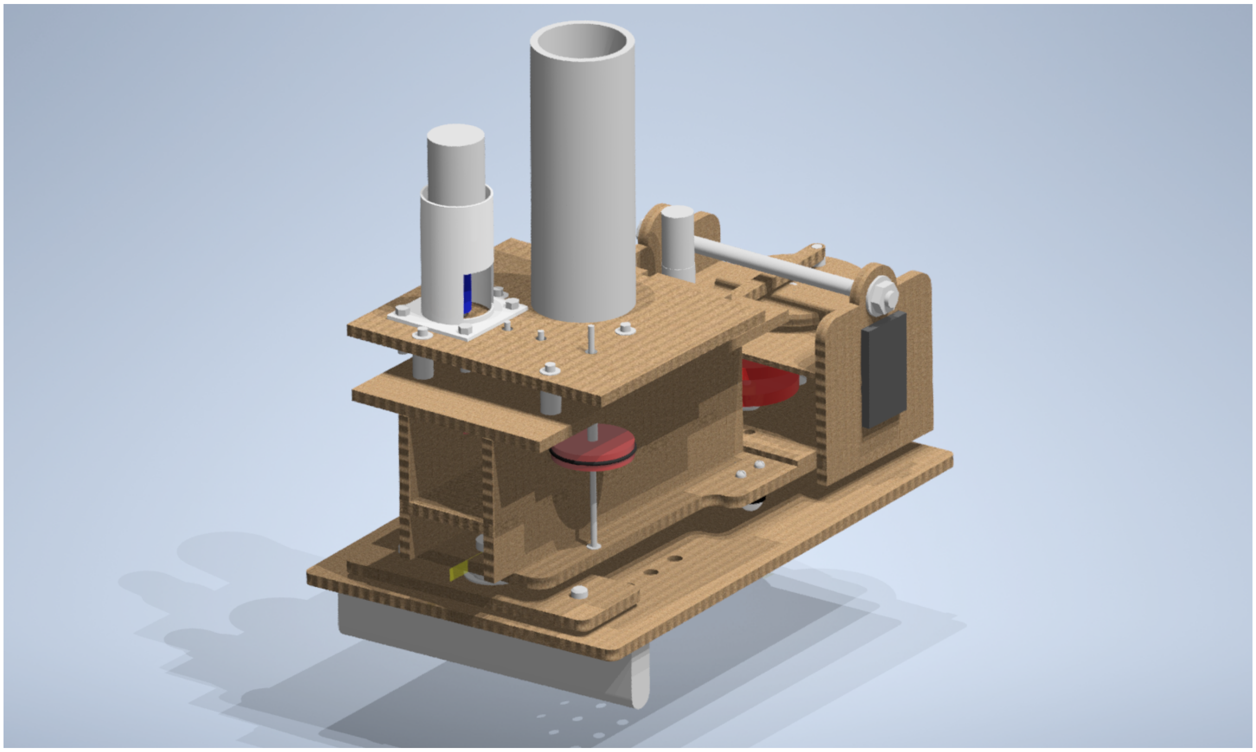
Our design incorporates key features that meet the design specification, and allow our design to be around the £80 budget. We have successfully produced the most efficient design from our initial ideas, by a reliable design process, that has allowed us to produce a final concept that we are proud of, and are keen to create. Some notable features include, the rotating flywheels that are surrounded by o-rings to allow slight compression of the ping pong ball, and hence allow friction to aid the launch of the ball. Additionally, our bespoke parts are designed so that they can easily fit together without the need for any adhesives, and without having to create too many holes for mechanical fastenings. In conclusion, the design we have created is reliable, and efficient, while meeting, and exceeding the requirements of the design specification.

Appendix A - 3D CAD Model

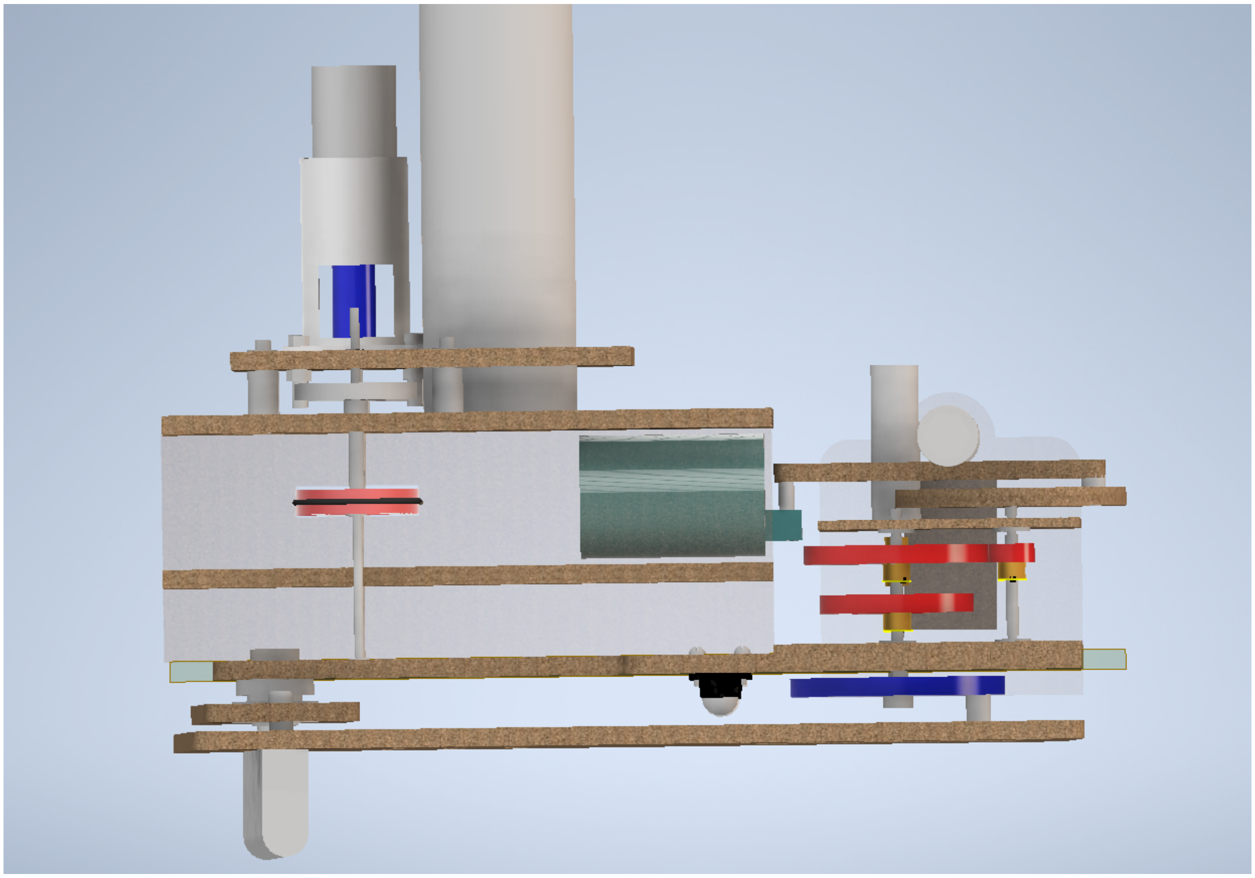
Perspective view full assembly



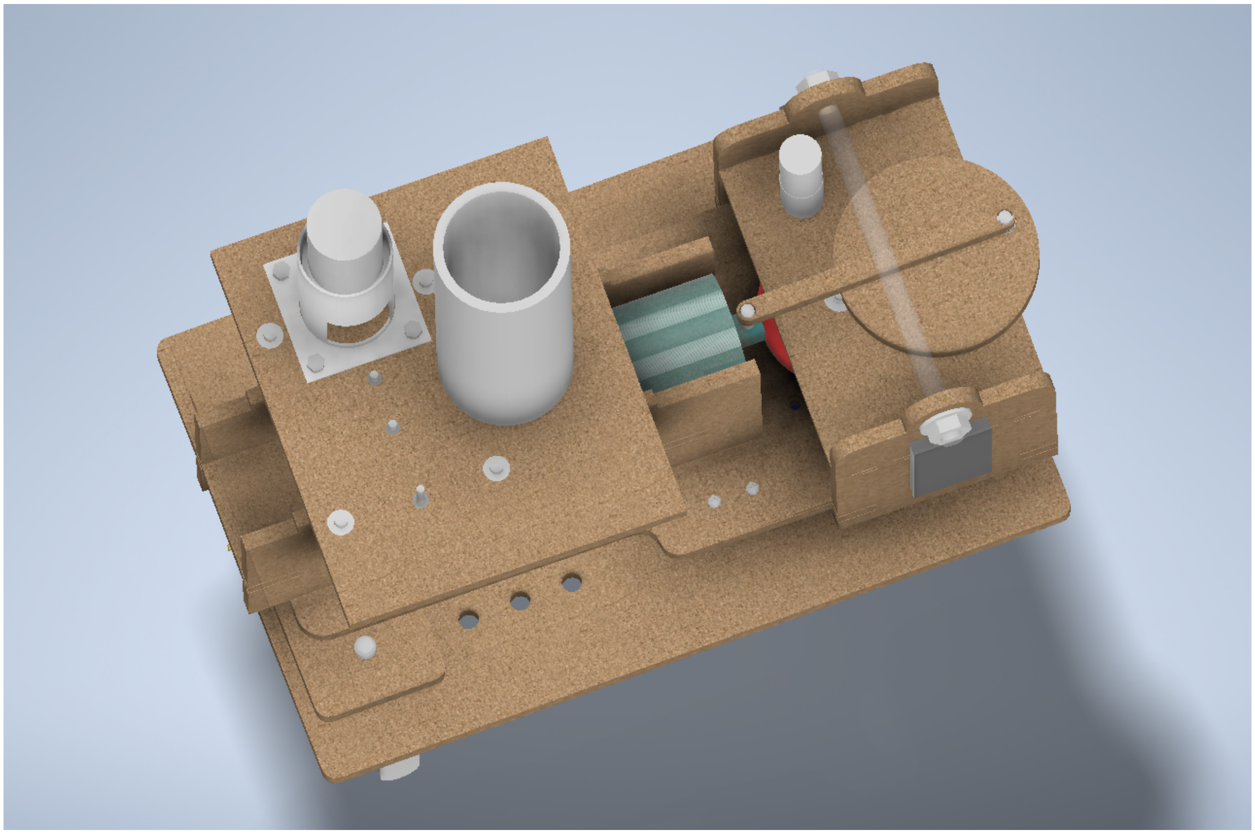
Isometric view full assembly



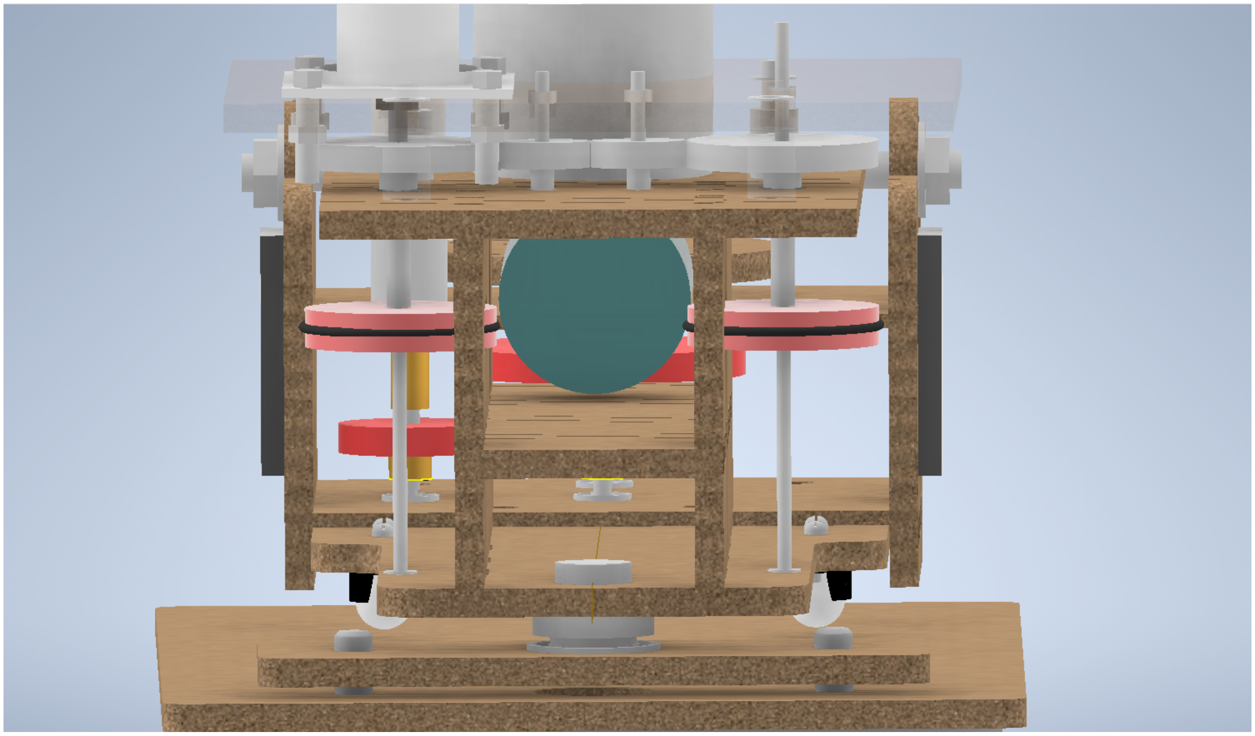
Side view with transparent sides



Top view



<u>Front view</u>



Appendix B - Parts List and Assembly Model

Table 9 - Parts list

REF	PART NO.	QTY	PART NAME	INVENTOR PART NAME	DESCRIPTION
1,13	RSC 270675	4 (2)	20X8 DOWEL PIN		8 x 24 mm Dowel Pin
2	UOB33003	1	BASE BEARING PLATE	Base_Bearing_Plate	6 mm LASER CUT MDF
3	TNB 4255-206	1	BASE BEARING	15 ID 28 OD	
4	TNB 4262-111	2	ROLLER SUPPORT		Ball Caster 1/2 inch plastic ball
6	TNB 4255-124	5	FLOOR BEARING		Bearing ID 4 OD 12
7	UOB33020	1	REAR MOTOR SHAFT	Motor_4mm_Shaft	4 X 32 mm MILLED STEEL SHAFT (SS004300)
8	TNB 4600-136	1	MOD_1_30_T_GEAR		MOD 1 30T GEAR, GRUB SCREW
9	TNB 4600-139	1	MOD_1_50_T_GEAR		MOD 1 50T GEAR, GRUB SCREW
10	TNB 4600-141	1	MOD_1_60_T_GEAR		MOD 1 60T GEAR, GRUB SCREW
11	TNB 4600-133	1	MOD_1_15_T_GEAR		MOD 1 15T GEAR, GRUB SCREW
12	UOB33007	1	WHITWORTH WHEEL	blue_Wheel	6 mm LASER CUT MDF
14	UOB33022	1	TRAVERSE SHAFT	Rotation_4mm_shaft	10 X 65 mm MILLED STEEL SHAFT (SB010300)
15	UOB33010	1	SLIDER WHEEL	Disk_for_Slider	6 mm LASER CUT MDF
16	UOB33031	1	SLIDER WHEEL PIN	Pin For slider	8 X 15 mm MILLED STEEL SHAFT (SB008300)
17	UOB33011	1	SLIDER ARM	Slider_Arm	6 mm LASER CUT MDF
18	UOB33009	1	REAR GEARBOX ROOF	Roof_Bearing_Plate	3 mm LASER CUT MDF
19	UOB33006	1	FLOOR BEARING PLATE	Floor_Bearing_Plate	3 mm LASER CUT MDF
20	UOB33019	1	PISTON	Slider_for_Tow_Bar	3D PRINTED ABS
21	UOB33018	1	PISTON PIN	Tow_Bar_for_Slider	5 X 15 mm MILLED STEEL SHAFT (SB005300)
22	UOB33012	1	BOX SECTION BOTTOM	Box_Pipe_Bottom	6 mm LASER CUT MDF

23	UOB33013	2	BOX SECTION SIDE	Box_Pipe_Side (identical)	6 mm LASER CUT MDF
24	UOB33014	1	BOX SECTION TOP	Box_Pipe_Top	6 mm LASER CUT MDF
25	UOB33005	1	FLOOR	Floor	6 mm LASER CUT MDF
26	UOB33008	2	REAR GEARBOX SIDE	Right Side Plate (Identical)	6 mm LASER CUT MDF
27	TNBE 1450-072	1	ROTATION FEED MOTOR	Rotation feed motor	941D2311 Planetary Geared Motor 231:1
28	UOB33021	1	SLIDER SHAFT	slider_4mm_Shaft	4 X 55 mm MILLED STEEL SHAFT (SS004300)
29	TNB 4604-009	1	REAR MOTOR COUPLE		inline 3-4 mm Shaft Coupling
30	UOB33016	1	GEARBOX ASSEMBLY PIN	Gearbox_Assembly_Pin	150 X 8 mm THREADED SHAFT (530-337)
31	UOB33002	1	BASE	Base	6 mm LASER CUT MDF
32	UOB33004	1	BASE SUPPORT PIN	Base_Support_Pin	25.4 mm MILLED STEEL SHAFT (UOB 254300)
33	UOB33023	1	LEFT FLYWHEEL SHAFT	Flywheel shaft	8 X 120 mm MILLED STEEL SHAFT (SB008300)
34	TNB 4603-032	2	FLYWHEELS		Polyethylene Wheel 38 x 7.3
37	TNB 4600-174	1	LEFT FLYWHEEL GEAR	Flywheel gear	Tbot Mod 1 Plastic Gear 38T 2.9 mm Bore
38	TNB 4255-020	7	3 ID 6 OD BEARING	3mm bearing	Bearing ID 3 OD 6
39	UOB33025	2	FLYWHEEL INNER SHAFT	Shaft for flywheel gear 2s	5 X 30.5 MILLED STEEL SHAFT (SB005300)
40	UOB33028	4	FLYWHEEL GEARBOX DOWEL	Dowel between box top and roof	10 X 30.5 mm MILLED STEEL SHAFT (SB010300)
41	UOB33001	1	ELEVATION SUPPORT	Elevation_Support	
42	TNB 4600-172	2	FLYWHEEL GEAR 2		Tbot Mod 1 Plastic Gear 18T 2.9 mm Bore
43	RSC 196-4902	2	O-RING	O-ring	Nitrile Rubber O-ring 38 mm Bore, 42 mm OD
44	TNBE 1450-060	1	MOTOR FOR FLYWHEELS	Motor for flywheels	940D51 Planetary Geared Motor 5:1
46	UOB33024	1	RIGHT FLYWHEEL SHAFT	4mm flywheel shaft	8 X 120 mm MILLED STEEL SHAFT (SB008300)

47	TNB 4555-707	4	3 mm CIRCLIPS	circlip	3 mm circlip (£ 0.90 for 135 piece set)
48	TNB 4604-141	1	FLYWHEEL SHAFT COUPLE		inline 4 - 6 mm Shaft Coupling
49	TNB 4555-707	4	5 mm CIRCLIPS		5 mm circlip (£ 0.90 for 135 piece set)
50	UOB33027	1	FLYWHEEL MOTOR MOUNT	Flywheel motor mount	3D PRINTED ABS
51	UOB33029	1	BORED FLYWHEEL GEAR	4mm bore flywheel	TNB 4600-174 - with bore drilled wider to be 3.6 mm (for 4mm shaft)
52	TNB 1063-090	2	BATTERY MOUNT		PP3 9V Battery Holder with flying leads
53	RSC 527-612	2	M8 HEX NUT	Gearbox Nut	M8 Hex Nut
54	RSC 530-797	2	M8 WASHER	Gearbox Washer	M8 Plain Washer
57	UOB 527-432	4	M5 HEX SCREW		M5 x 25 Hex Set Screw
58	UOB33015	1	FLYWHEEL GEARBOX ROOF	roof_for_flywheel_gear	6 mm LASER CUT MDF
59	UOB 525-903	4	M5 HEX NUT		M5 Nut
60	UOB PVCTUB50	1	PVC Tube		LENGTH 156, OD 50 mm, t = 3.7mm
	TNBE 1610-111	1	Toggle Switch		SPST Miniature Toggle Switch
	UOB 560-293	4	M3 HEX NUT		M3 Nut
	UOB 560-338	8	M3 WASHER		M3 Plain Washer
	UOB 560-596	4	M3 PAN HEAD SCREW		M3 x 10 Pan Head Screw
	TNB 4555-707	6	4 mm CIRCLIPS		4 mm circlip (£0.90 for 135 piece set)
	TNB 4255-036	1	4 mm BEARING		Bearing ID 4 OD 9
	TNB 4255-126	2	BIG BEARING		ID 5 OD 10

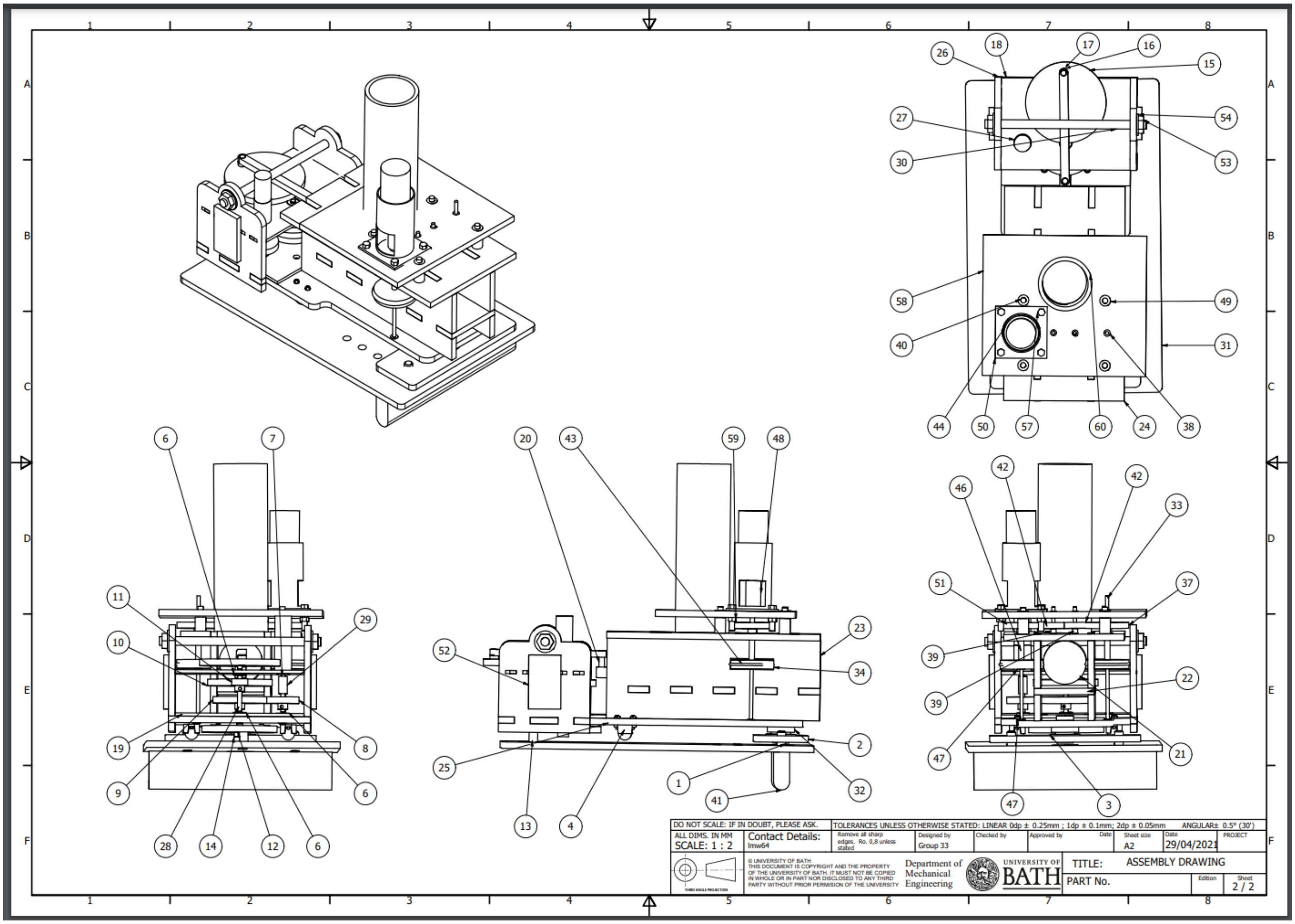


Figure 9 - Balloon referenced assembly drawing

Appendix C - Record of Meetings

1. **Worksession 19/03**

    What did we do last time?
    - This is our first meeting

    Programme
    - Meet each other. Find out information and what individuals can do
    - Explaining the exercise. Creating specifications and requirements list
    - Easy brainstorming. Giving thoughts in the air.
    - Start to think about concept sketches in free time

    Notes

    Our very first meeting went smoothly and well. All people have joined the Teams call which really helped and showed the activity of all members.

    We made a list of all specifications and criterias for each step or part (chapter 2.0).

    We discussed several ideas and agreed to create a collaborative morph board and brainstorm again after that.

    We also agreed on usage of Whatsapp as the communication tool and Miro for the work and operations. The meetings will be often but no on a regular basis.

    What we do next time
    - Complete functional analysis
    - Generate more ideas or things we would like to have there

First meeting of the team
- *Main task: create a specification and begin to generate individual concept sketches*
- *Brainstorming*
- *Create a collaborative morph board*

2. **Worksession 23/03**

    What did we do last time?
    - We had our first meeting.
    - We made a list of requirements and specifications
    - Agreed on using Whatsapp and Miro.

    Programme
    - Complete functional analysis
    - Generate more ideas
    - In free time, make the concept sketches and later be ready to discuss them

    Notes

    We completed the functional analysis. We all know what we expect the machine will do, will be able to do and what it does need to accomplish

    We generated some more ideas. Concretely, for the base rotation and attachment this to the motor (in Miro)

    What to do next time

- Finalise the morph chart
- Explain individual rough design to each other to make sure all concept drawings will be unique and we have a great diversity.

- *Complete functional analysis*
- *Generate more ideas*

3. **Worksession 26/03**

What did we do last time?

- Completed functional analysis
- Generated more ideas especially about the rotation of the base (in Miro)

Programme

- Explain rough designs to each other. Sketches should be unique in most parts.
- Finalise morph chart based on the sketches

Notes

Everybody introduced his/her design and made sure that we have a great diversity in our designs. For example for firing the balls we have horizontal flywheels, vertical flywheels, compressed air, and loaded spring.

Thanks to that we finalise the morph chart.

What to do next time

- Explain finished concepts to each other.

- *Explain rough designs to each other in order to make sure all concept sketches will be unique*
- *Finalise morph board*

4. **Worksession 06/04**

What did we do last time?

- Showed our rough sketches or presented our ideas.
- Finalised the morph chart

Programme

- Explain finished concept sketches to each other
- Critically asked what are advantages and disadvantages of individual parts, how they will be made of, how they operate all together.

Notes

We presented our designs. Some concepts were really nice drawn. We had a critical view to each design but no criticism to the drawer. The whole concept of this work was to try to put on paper as many possible different mechanisms and combinations that it had not been expected that one single design would “win” and we make it without changes.

What to do next time

- Weight all mechanisms used in each design by MCDA chapter 4.0
  - Evaluate MCDA and agree on basic design for the launcher
  - Begin calculations for dimensions
- *Explain concept sketches to each other*

5. **Worksession 08/04**

What did we do last time?

- Presented and evaluated all designs

Programme

- Weight all mechanisms used in each design by MCDA chapter 4.0
- Evaluate MCDA and agree on basic design for the launcher
- Begin calculations for dimensions
- Design layout and mechanisms

Notes

We followed the instructions from lessons and made an MCDA table. Subsequently, we marked all parts in each design and made the rank of all designs.

We chose the best part across all designs and made a final basic design for the launcher

We wrote down some calculations for dimensions

What to do next time

Make sure all things are shared for all members

Begin to create Inventor files for components

Make a start on parts list

- Weigh the mechanisms used in each design to help choose which are best
- Finalize basic design for the launcher
- Design layout and mechanisms
- Begin calculations for dimensions

6. **Worksession 11/04**

What did we do last time?

- Created MCDA table and agreed on final basic design.
- Made layout for the design and mechanisms

Programme

- Have a look to the four bar mechanism and discuss the change
- Set up Inventor. Create files for components.
- Make a start on parts list

Notes

One member made the four bar links at home and after discussion we decided to leave this idea and go for Whitworth quick return mechanism which scored second highest score in MCDA table (Chapter 5.0)

Then, we “finally” started to make the launcher. We created a couple of first parts in Inventor and wrote them down to the parts list. We started with the base.

What to do next time

- Assess all assemblies to identify joining mechanisms
- Determine shoulders and bespoke parts
- Asses what materials will be used for each part

- *Change rotation mechanism to whitworth quick return mechanism*
- *Begin to create inventor files for components*
- *Make a start on parts list*

7. Worksession 15/04

What did we do last time?

- Changed the rotation mechanism to whitworth quick return mechanism
- Began doing Inventor and a parts list

Programme

- Assess all assemblies to identify joining mechanisms
- Determine shoulders and bespoke parts
- Assess what materials will be used for each part

Notes

We assessed all assemblies which we had so far to identify joining mechanisms which will be used in future as well (joining mechanisms also need to be made or bought).

We determined shoulders and bespoke parts (a list of them, dimensions, functions,...) and decided on what material the parts will be and subsequently whether we buy it or make it

What to do next time

- Continue with Inventor
- Begin creating formal report

- *Assess all assemblies to identify joining mechanisms*
- *Determine shoulders and bespoke parts*
- *Assess what materials will be used for each part*

8. Worksession 18/04

What did we do last time?

- Assessed all parts to identify joining mechanisms
- Determined shoulders and bespoke parts and their specifications and functionality

Programme

- Continue with Inventor drawings
- Begin creating formal report

Notes

We finished the base for now and created other parts especially for firing. We began writing the report and put all sketches and photos into it.

What to do next time

- Continue with the Inventor
- Format the report

- *Continue with inventor drawings*
- *Begin creating formal report*

9. Worksession 20/04

What did we do last time?

- We finished the base for now and created other parts especially for firing.
- We began writing the report and put all sketches and photos into it.

Programme

- Continue to work on the inventor file
- Format the report

Notes

We continued on the Inventor files. Finished the firing part and moved to the slider and box.

According to the information given, we formatted the report.

What to do next time

- Continue with the Invento
- Update the report
- *Continue to work on the inventor file*
- *Format the report*

10. Worksession 22/04

What did we do last time?

- Continued on the Inventor files.
- Formatted the report.

Programme

- Continue on the Inventor files

        - Update the report

Notes

- We continued on the Inventor files. Finished the slider and box part and moved to the spur gears. Then we put all assemblies together.
- We updated the report.

What to do next time

- Formulate plan for drawing bespoke parts for submission for 3D printing or laser cutting
- Start to prepare the order sheet

- *inventor*
- *Report*

11. Worksession 25/04

What did we do last time?

- Continued on the Inventor files. Finished the slider and box part and moved to the spur gears.
- Put all assemblies together.
- Updated the report.

Programme

- Formulate plan for drawing bespoke parts for submission for 3D printing or laser cutting
- Start to make an order sheet

Notes

We formulated the plan for drawing bespoke parts …..

We started to make an order sheet form

What to do next time

- Prepare order sheet in the format required
- Make parts drawings for bespoke parts so they can be made in the make process

- *Formulate plan for drawing bespoke parts for submission for 3D printing or laser cutting*
- *Order sheet*

12. Worksession 27/04

What did we do last time?

- Finished assembly on inventor
- Put all assemblies together.

Programme

- Prepare order sheet in the format required

- Make parts drawings for bespoke parts so they can be made in the make process

Notes

To make the bespoke parts drawings, must have a plan view, front view and end view as well as isometric, and make the file format as required for the laser cutter or 3D printer.

What to do next time

- Create cdr and stl files.
- Finish bespoke parts
- Finalise order form and cost calculation

13. Worksession 28/04

What did we do last time?

- Divided up the bespoke parts in order to create orthographic drawings for their construction
- Finished parts list

Programme

- Create appropriate cdr or stl files to have bespoke parts laser cut or 3D printed
- Finish parts drawings for bespoke parts
- Finalise order form and cost calculation
- Changed idea of using bucket to store balls to a tube, in order to minimise weight, and space occupied

Notes

Firstly, we finished all the bespoke parts. Then, we splitted the work and completed the order form and cost calculation, and finalised the funnel method for storing balls that go to the feeder. Lastly, we created some cdr and stl files for bespoke parts laser cut and 3D printed and will continue next time

What to do next time

- Check that the parts list is complete
- Construct the entire assembly drawing during the next meeting.
- Continue on cdr and stl files

14. Worksession 29/04

What did we do last time?

- Completed order form and cost calculation.
- Finalised funnel method for storing balls that go to the feeder
- Continued to translate inventor files into formats readable by 3D printer and laser cutter

Programme

- Check that the parts list is complete
- Finish orthographic drawings for bespoke parts
- Create the 3D assembly that will be shown in the report
- Ensure that the lighting is pleasing

15. Worksession 30/04

What did we do last time

- Assembly drawings
- Parts drawings
- Parts list

Programme

- Ensure all parts are accounted for
- Proof-read report and ensure all sections are completed