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Honors Research Projects

The Dr. Gary B. and Pamela S. Williams Honors College

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Chocolate Bar Wrapping Machine

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Chocolate Bar Wrapping Machine

Honors Senior Design Project

Final Design Report

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Executive Summary:

Gilbert Chocolates has proposed to manufacture a machine to wrap chocolate bars. This machine is intended to replace two people wrapping the chocolate bars by hand, which is a time consuming method. This is especially apparent between October and January when the workers are working long hours in preparation for the Christmas rush of customers. Currently wrapping a bar takes about a minute and Gilbert Chocolates wants this time reduced down to 20-30 seconds. The budget for this project is set at $1000, and is being funded by the company. This machine needs to fit in a cubic foot of space and weigh under 30 pounds for storage purposes. This device can be either purely mechanical with manual input, or it may use step motors and a controller.

This project pulls from our knowledge in kinematics, dynamics, 3D modeling, tolerance analysis, material selection, manufacturing techniques, and design of components. From doing this project we will learn how to apply all of these concepts together to solve real world problems. This project will encompass the design, manufacturing of a prototype, and optimization of the chocolate bar wrapping machine in hopes that the price of manufacturing chocolate bars can be reduced for Gilbert Chocolates.

The final presentation of this project will include a working prototype, a report, and a presentation. The project will be presented at the Engineering Senior Design Project day. The machine will be operated and displayed at this event.

Chapter 1: Introduction & Background

Background

Gilbert Chocolates, which is based out of Jackson, MI, has requested we design a chocolate wrapping machine for their chocolate bars. However, chocolate bars are not the primary form of chocolate they sell, so buying an automatic machine for $7,000 is uneconomical. Thus, the target goal is $1,000 dollars. Currently, the company wraps the bars by hand, which takes about 1 minute. Our machine must be able to wrap both the aluminium foil and paper sleeve around the bar in 20-30 seconds. To achieve this, the machine must have a short setup time, and a short wrapping time. Also, there is a lack of consistency when wrapping by hand, and the machine is designed to not make mistakes, which would require re-wrapping.

Operation

The machine is designed to require little to no training and decrease the wrapping time of the bars. First the bar is loaded into position with the foil and paper beneath it. The worker then spins the bar into the machine where the foil will be wrapped. The worker manually inputs energy into the system which will begin folding the foil. After the foil wrapping is completed, a new bar is placed onto the loading point. As the recently wrapped bar is spun out of the machine, a gear will contact a gear track, causing the paper to be folded around the bar. The worker can then tape the paper and remove the fully wrapped bar.

Product Definition

Our machine is designed to wrap chocolate bars in foil and paper. To do this, two levers and a combination of gears will be used to fold the wrappers over the bars. The planned cost of manufacturing is between $500-$1000. To allow for easy storage and movement to a work area, the footprint of the whole machine will be under 12”x 12”x 12.” Initially, the machine will be designed to wrap chocolate bars that are 2”x 4.5” for Gilbert Chocolates. This could be modified to wrap larger or smaller bars for other companies and marketed to other small chocolate businesses.

Chapter 2: Conceptual Design

Preliminary Design Brief

In order to increase production of chocolate bars and save money, Gilbert Chocolates has requested that a machine be designed and manufactured to wrap their chocolate bar products. This machine should be able to wrap both the inner foil and the outer paper sleeve in a manner that makes repeatable and neat folds, while being quicker than wrapping by hand. To make this machine as easy as possible to use and reduce costs we are using a manually operated approach. This will eliminate tedious human movements of folding with a simple human movement to drive a mechanism that will precisely fold the wrapper around the chocolate bar.

Expanded Design Brief

Gilbert Chocolates has contacted our design team to design and manufacture a product capable of wrapping both the outer paper stock sleeves and the inner metallic foil for their chocolate bars. Currently, they wrap these chocolate bars by hand, but have found that this method is time consuming as well as it tends to yield inconsistent folds. It has also been requested that the machine to be restrained to under a cubic foot of space.

Looking at other methods used to wrap chocolate bars we found that most are highly automated turn key operations that can be in excess of $10,000. With the budget of $1000 and the needs of Gilbert Chocolates in mind, we have decided to not use an automated approach but rather a simple mechanized operation driven by manual input. This makes it simple to use, easy to manufacture and repair, and able to fold precisely in a quick manner.

As simple mechanical machine will keep the budget and the footprint small enough to be within Gilbert Chocolates' restrictions where an automated system would fail. It is also going to be fast enough to beat the 30 seconds needed by manually wrapping, while making even more precise folds. Thus this machine should be able to help Gilbert produce more and better looking chocolate bars, while reducing their overall cost.

Structure Diagrams

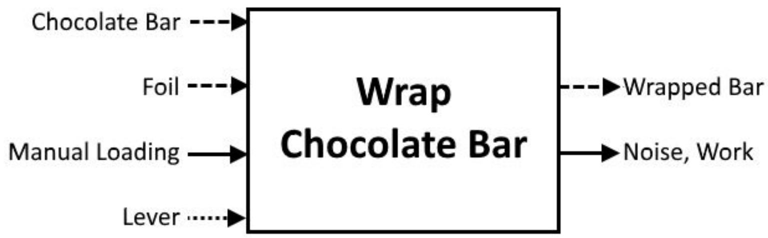

Figure 1: Overall Function Structure Diagram

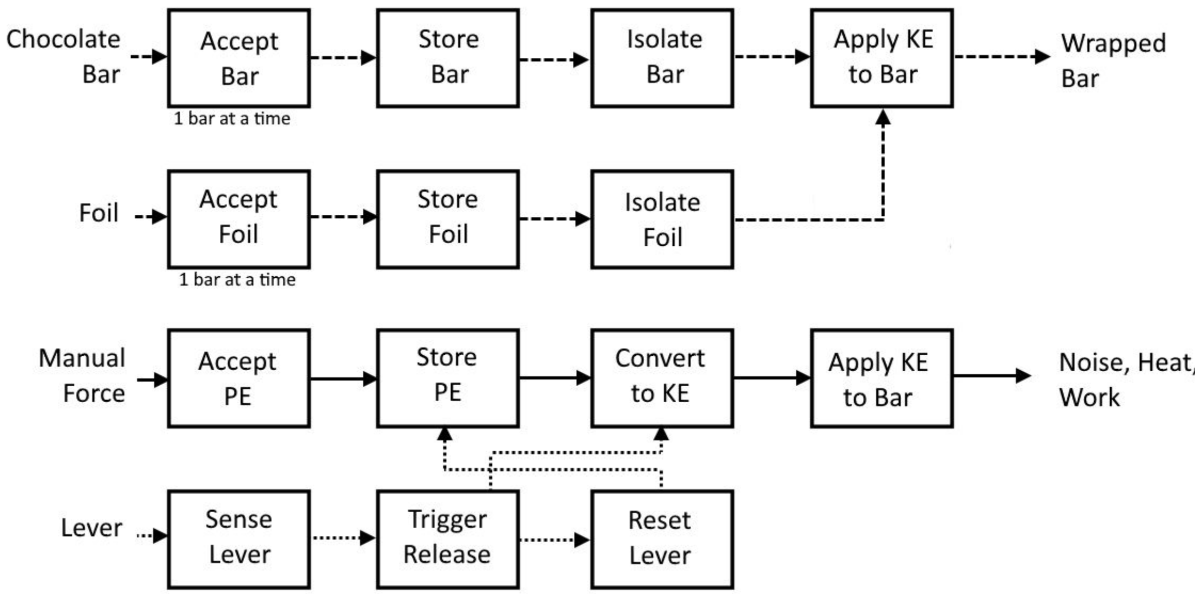

Figure 2: Detailed Function Structure Diagrams

From these four function diagrams, we developed six distinct categories for our machine to satisfy. Manual input is how the operator will directly interact with the machine, putting the necessary energy to wrap the bar. Energy storage is how the motion of the manual input is stored in the machine until the wrapping occurs. Manual trigger is how the operator will release the stored energy, ultimately wrapping the bar. Loading method is how the bar will reach the wrapping zone. The wrapping method is how the foil will actually be wrapped around the chocolate bar. Then the unloading method will be how the finished bar will be removed from the machine.

While we developed several ideas on the storage and trigger methods, we also included the option of no storage or trigger. In those cases the manual input directly drives the wrapping action of the machine. Also, while the company specified a specifically mechanical machine, we included the option of an electrically driven computer setup. This was incase the computer method developed fell within the price and size limits the company gave us.

Morphological Chart					
Manual Input	**Energy Storage**	**Manual Trigger**	**Loading Method**	**Wrapping Method**	**Unloading Method**
Crank	NONE	NONE	Hand	Wiper	Piston
Lever	Torsional	Button	Piston	Hinged Flap	Hand
Slot	Axial	Switch	Ramp	Piston	Tilt
Pump	Hanging Weight	Controller	Spinning Tray	Choco-flip	Spinning Tray
Electric Motor	NONE	Knob	Roller	NONE	Trap Door

Figure 3: Morphological Chart

From the chart above, we developed eight different possible combinations of the above options. They are shown in Figure 4 below.

Combinations						
A)	Crank	Torsion	Switch	Piston	Flap	Piston
B)	Lever	Weight	Button	Ramp	Piston	Tilt
C)	Slot	Axial	Swtch	Tray	Wiper	Tray
D)	Motor	None	Controller	Roller	Choco-Flip	Tilt
E)	Pump	Weight	Knob	Tray	Piston	Tilt
F)	Lever	None	None	Hand	Flap	Hand
G)	Slot	None	None	Tray	Wiper	Tray

Figure 4: Combinations of Morphological Chart

We then ranked the eight categories in terms of their importance. We weighted them in two different ways, a standard ranking as well as an objective tree weighing scale. The first method was a standard order of what we determined to be the most important. The second method placed an additional weighting scale with the added level of objective vs subjective categories.

Each ranking system developed similar weighted values, placing safety, footprint and consistency at the top.

Category	Ranking
Safety	1
Footprint	2
Manufacturability	3
Consistent	4
Cycle Time	5
Cost	6
Ease of Use	7
Longevity	8

Figure 5: Ranking System

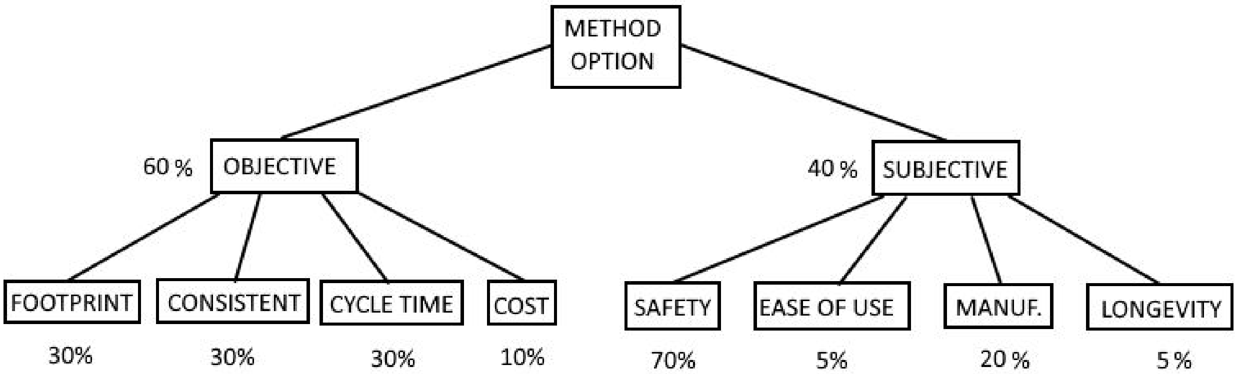

Figure 6: Objective Tree

Figure 7 shows the scores of each design for each category based on the ratings we gave them. These scores are summed up and graphed in Figure 8.

Weighted Decision Matrix								
Combo	**Safety**	**Footprint**	**Manuf.**	**Consist.**	**Cycle T.**	**Cost**	**EOU**	**Longev.**
	8	7	6	5	4	3	2	1
A)	3 / 24	4 / 28	3 / 18	4 / 20	4 / 16	2 / 6	3 / 6	2 / 2
B)	3 / 24	3 / 21	2 / 12	2 / 10	3 / 12	2 / 6	4 / 8	4 / 4
C)	4 / 32	4 / 28	4 / 24	4 / 20	4 / 16	3 / 9	4 / 8	3 / 3
D)	5 / 40	2 / 14	1 / 6	1 / 5	2 / 8	1 / 3	5 / 10	1 / 1
E)	2 / 16	1 / 7	2 / 12	3 / 15	3 / 12	2 / 6	2 / 4	2 / 2
F)	2 / 16	5 / 35	5 / 30	5 / 25	3 / 12	5 / 15	3 / 6	5 / 5
G)	3 / 24	5 / 35	5 / 30	4 / 20	4 / 16	5 / 15	4 / 8	5 / 5

Figure 7: Weighted Decision Matrix

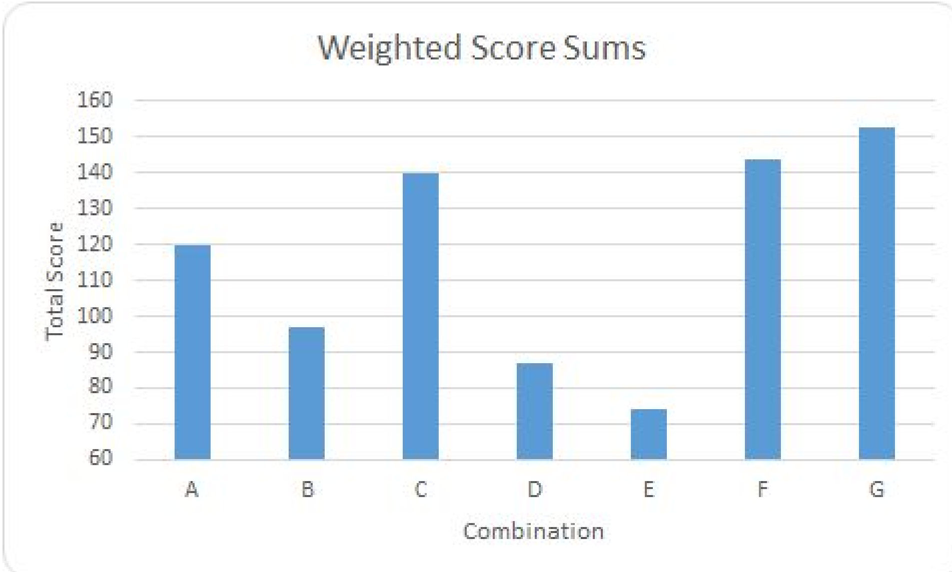

Figure 8: Weighted Score Sums

In Figure 8, higher scores correlate to better performance, based upon the needs and corresponding ratings given above. From the weighted decision matrix, it was determined that option G would satisfy our needs the best, although options F and C are still worth consideration.

Chapter 3: Embodiment Design

Schematic Diagram

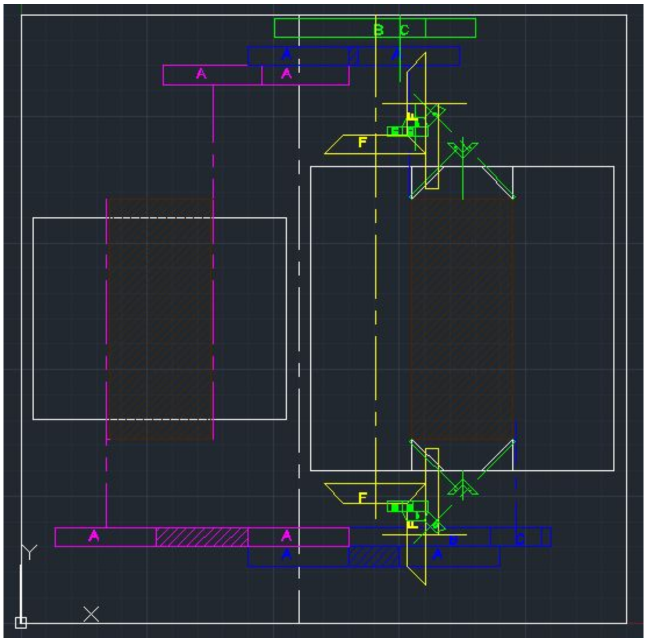

Figure 9: Top view schematic

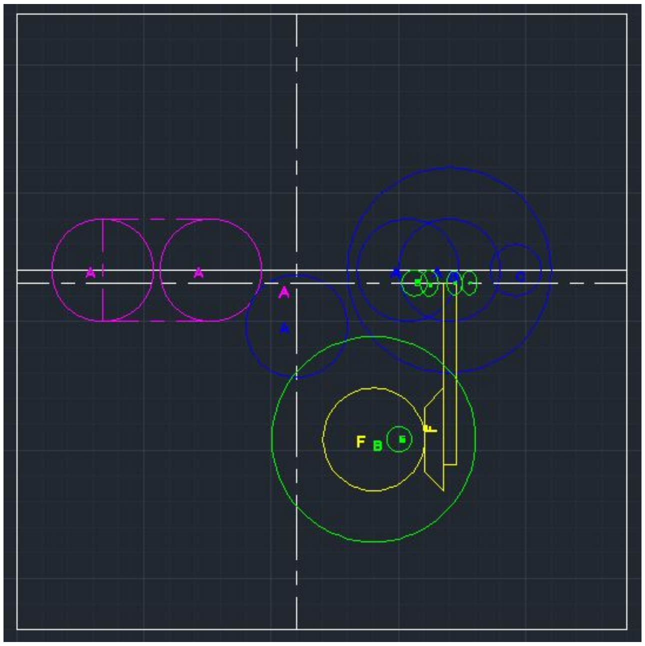

Figure 10: Side view schematic

Embodiment Rules and Principles

There are 3 rules and 3 principles for Embodiment Design:

Rules

Clarity is the first rule of embodiment design. Clarity must be used to prevent the product from being misused, damaged, or from operating incorrectly. For our design, we put several systems into place to prevent any of the mistakes listed below. First we wanted to prevent the paper or foil from being misplaced while the machine is operated. To do so, the flaps will be labeled, and a slight etch will be cut into the machine. Second, we needed to prevent them from turning the lever the wrong way, wrong time, or at the wrong speed. To do this, each lever will be labeled with a number and an arrow indicating the direction it should be pulled. To keep them from pulling the lever too fast, a rotational damper will be included in the system.

The second rule of embodiment design is simplicity. The purpose of simplicity is to prevent confusion. In this case, our primary concern was reducing the confusion for the untrained operators, as well as the technician repairing the machine. Thus, we attempted to minimize the number of levers the operator would need to pull. Furthermore, we tried to use the same gears as frequently as possible to reduce the part numbers. Finally, the gears will be color coded and will be able to “snap-on” to the rods to make gear replacement easier.

The last rule is safety. There are three types of safety: Direct, indirect, and warning. Direct is when no danger is present. Indirect is when the danger is covered in some sort of cage. Warning is when the operator is simply warned that there is danger, but little to no preventive measures can be made. In our case, we used a combination of direct and indirect safety. Our primary concern was pinch points that could hurt fingers or catch hair. To avoid these problems, most of the gears will be below the operating zone, and any gears gears level with the zone will be covered in a cage.

We also addressed the principles of embodiment design. The first rule is the division of tasks. For this machine, the gears and belts will be used to turn the shafts to transmit the force through the machine and fold the paper and foil. The supports will hold the gears, and will allow the gears and shafts to turn in place. The next principle is self-help. The gears will snap into place, the gears will be cut with the necessary number of teeth. Furthermore, the gears will mesh with each other, which will hold them in the desired position. Finally, the last principle is stability, which is achieved by even distribution of gears on a shaft, and a bottom heavy design to reduce wobbling or rocking.

FMEA

For every design, a Failure Mode Effects Analysis must be performed. The purpose of doing so is to predict possible failures that could occur during the operation of our product. By doing so, we can create control systems to prevent or reduce the effects of the failure.

FMEA				
Potential Failure	**Potential Effects**	**Severity**	**Causes**	**Current Controls**
Does not wrap the bar well	• Frustrated Customer • Time spent rewrapping	5	• Lever pulled too fast • Minor gear jamming	• Rotational Damper • Gearbox access for visual verification
Wraps the bar to slowly	• Annoyed Customer • More time required to wrap the same amount of bars	3	• Lever pulled to slow • Internal resistance • Minor jamming	• Manager's opinion
Does not wrap the bar at all	• Customer upset that the product does perform its stated function • Wastes time • Product objective not achieved	7	• Major jamming • Broken gear • Foil or paper not in position	• Visual Verification • Gear replacement
Breaks the chocolate bar	• Upset Customer • Loss of product and profit • Refund demanded	9	• Lever pulled too fast • Lever pulled too far	• Rotational Damper • Lever stop bar
Broken Gear	• Frustrated Customer • Time spent replacing gears • Material for new gear • Suspension of production		• Lever pulled too fast • Lever pulled too far • Gears weren't meshed • Material Fatigue	• Rotational Damper • Lever stop bar • Gear ratio analysis • 3D printed parts are quicker to replace

Figure 11: FMEA Analysis

Preliminary Material Selection

For the preliminary material selection, we had to determine what to used based on three factors: cost, reproducibility, wear resistance, and weight. Furthermore, because these materials will be in close proximity to food, the materials must be deemed food safe, as determined by the USDA.

First we determined that the gears would be 3d printed instead of machined, because many of the gear would need to be custom made, which would increase the cost. Because metal based 3d printers are expensive, it was quickly determined we should use a plastic. Our initial plan was to use the common 3d printing material, ABS plastic, but it is not food-safe. However, PLA filament, which is also commonly used, is food safe, has high strength, and is relatively cheap. Thus for the gears we determined that PLA filament would be the best prototype material

Second, we needed to determine the material for the frame. We wanted to keep costs low and the weight down. Because the frame should undergo little stress, having high strength was deemed unnecessary, but we didn't want a material that was porous, which would encourage bacteria growth. We decided on aluminum because it is food-safe, relatively low weight, low cost, and non-porous.

Numerical Calculations

Calculate Pitch: $P = \frac{P_d * \Pi}{N}$ where $P_d = pitch\ diameter$ and $N = number\ of\ teeth$

Standard Spur Gear: $P = \frac{2.04*\Pi}{24} = .267$

Planetary gears

Sun: $P = \frac{2*\Pi}{36} = .175$

Solar: $P = \frac{4*\Pi}{72} = .175$

Satellite: $P = \frac{1*\Pi}{18} = .175$

22.5° angled gear : $P = \frac{.5*\Pi}{12} = .131$

Calculate Gear Ratio: $R = \frac{P_{d1}}{P_{d2}} = \frac{N_1}{N_2}$

Solar/Satellite: $R = \frac{72}{18} = 4$

Sun/Satellite: $R = \frac{36}{18} = 2$

Calculate the pitch length of the timing belts: $Lp = (2 * C) + 1.57 * (D_1 + D_2) + \frac{(D_1 - D_2)^2}{4C}$

, where $Lp = pitch\ length$, $D_1 = pitch\ diameter\ of\ the\ first\ gear$, $D_2 = pitch\ diameter\ of\ the\ second\ gear$, and $C = distance\ between\ centers$

Shaft A to Shaft C: $Lp = (2 * 3.8) + (1.57 * (1.528 + 1.528)) + 0 = 12.4\ inches$

Shaft A to Shaft H: $Lp = (2 * 2.88) + (1.57 * (1.528 + 1.528)) + 0 = 10.6\ inches$

Shaft A to Shaft F: $Lp = (2 * 4.8) + (1.57 * (1.528 + 1.528)) + 0 = 14.4\ inches$

Vertical Belts: $Lp = (2 * 2.75) + (1.57 * (1.528 + 1.528)) + 0 = 6.96\ inches$

Shafts are labeled in black text on Figure 16.

Gear Direction Layout

Due to the small forces in the system, no force analysis was done on the gears within the system. However, the direction of forces still needed to be determine. The following figures illustrate how the subsystems transmit forces and interact with each other. The black arrow shows the direction of the input force, and the colored arrows show the direction of the related gears.

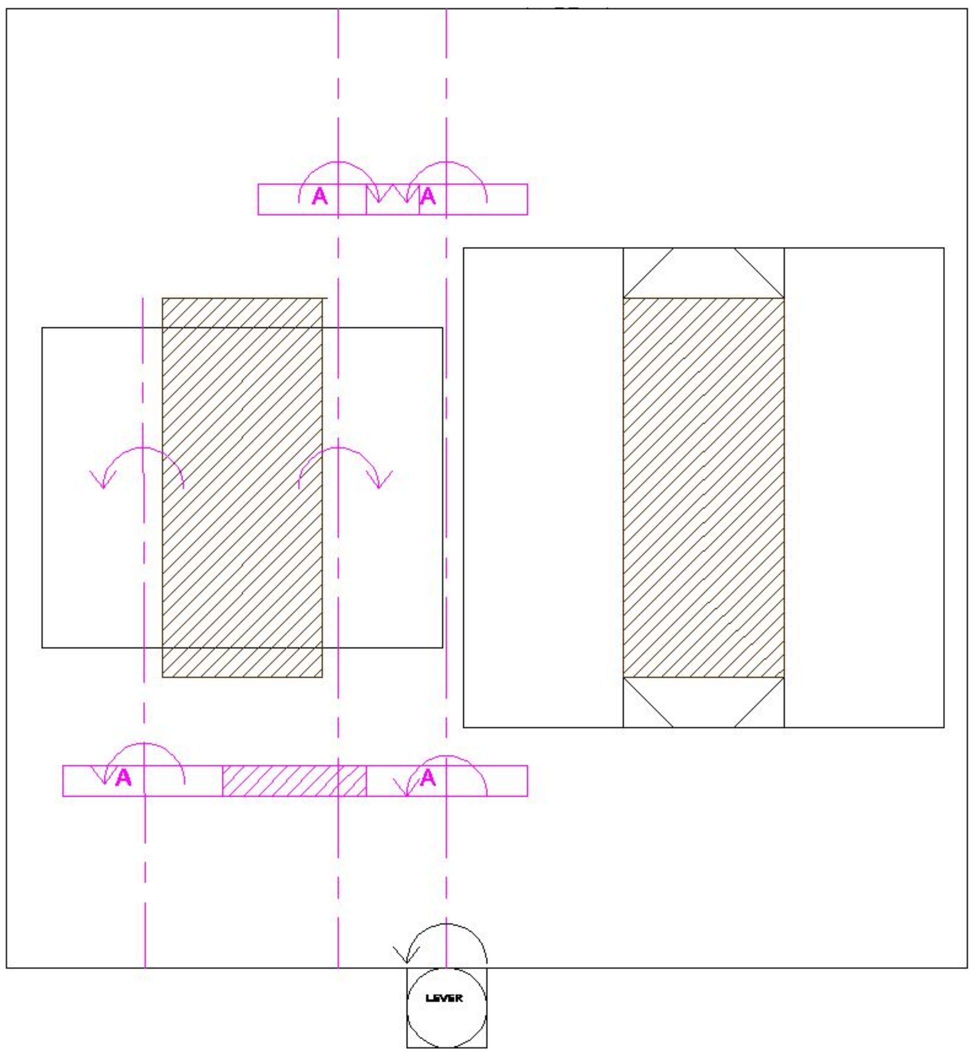

Figure 12: Paper Folding System using Lever 1

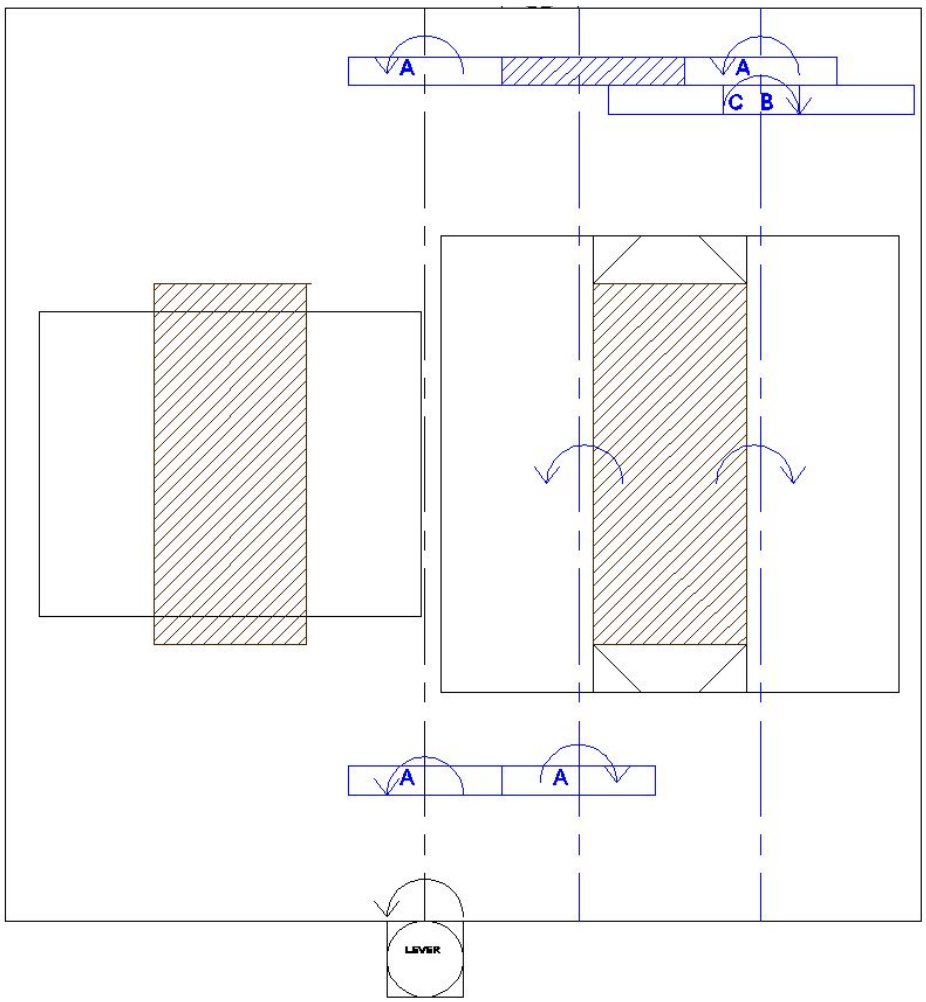

Figure 13: Long Direction Paper Folding System using Lever 1

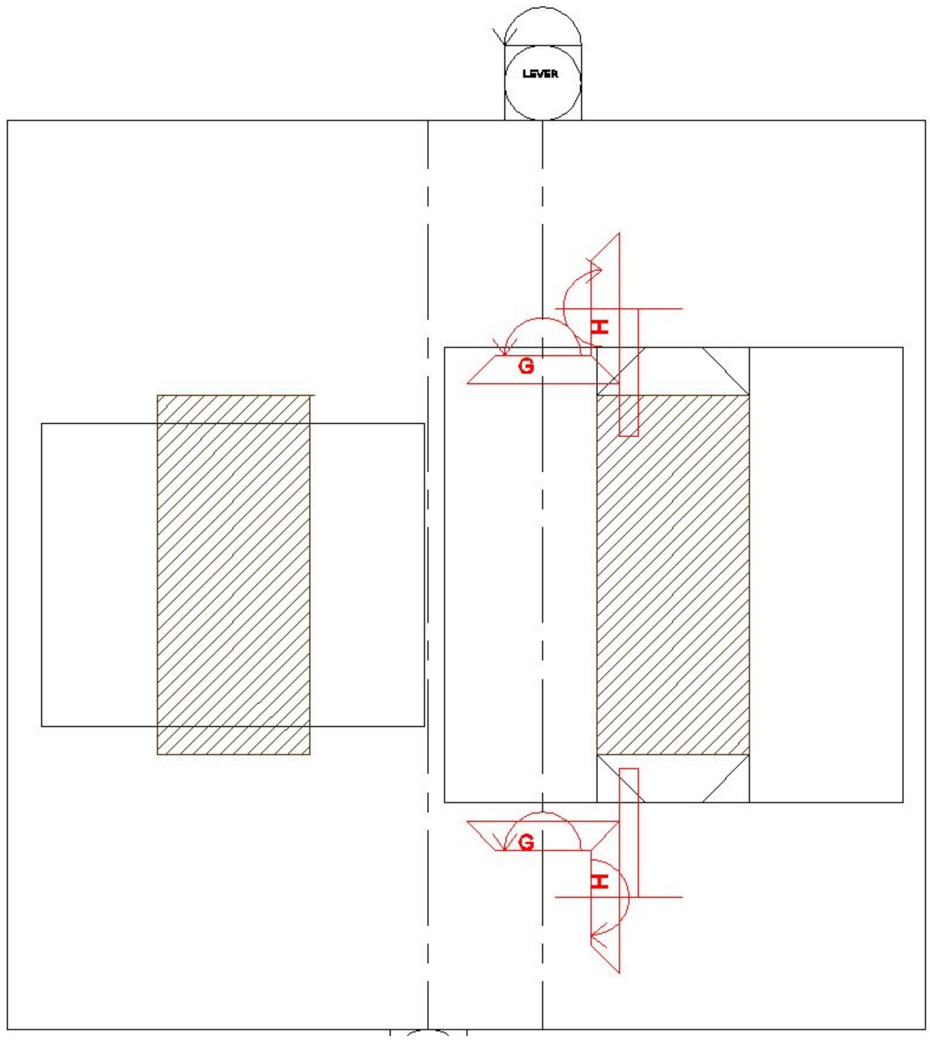

Figure 14: Short Direction Paper Folding System using Lever 2

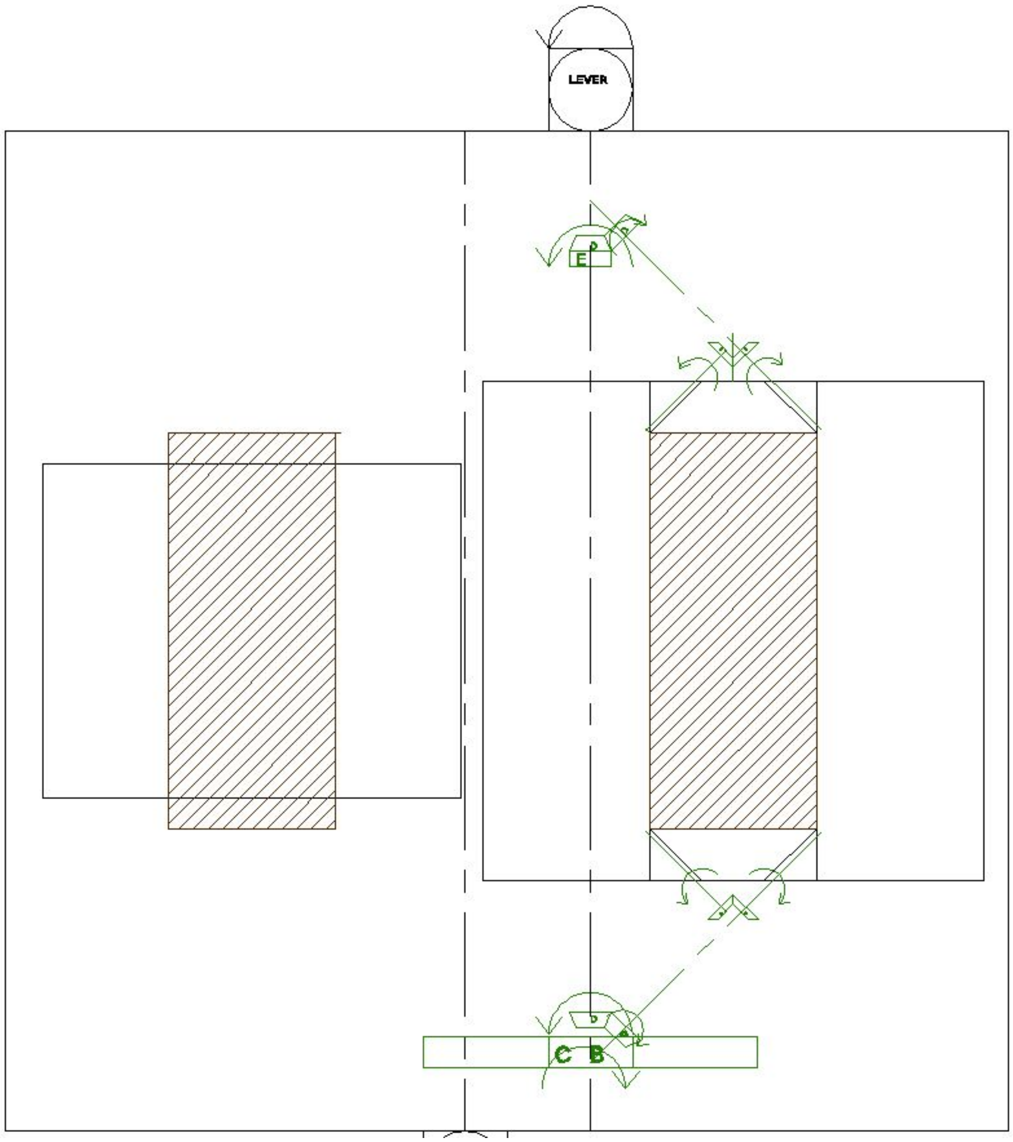

Figure 15: Angled Direction Paper Folding System using Lever 2

Layout Drawings

The following figures depict the general gear, pulley, and axle layout. The colored letters label the gears, the black letters label the shafts.

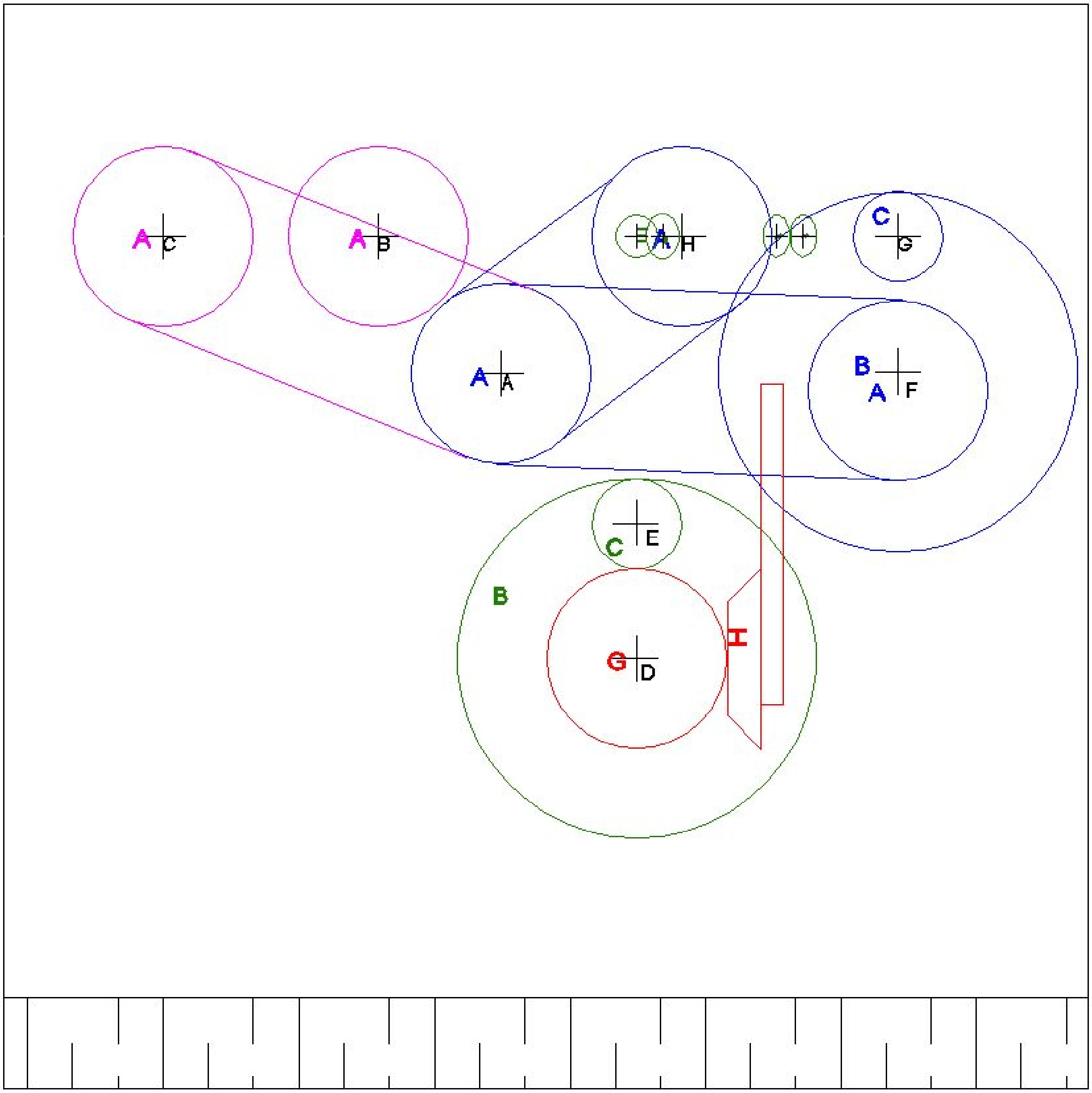

Figure 16: Basic Layout Rightside

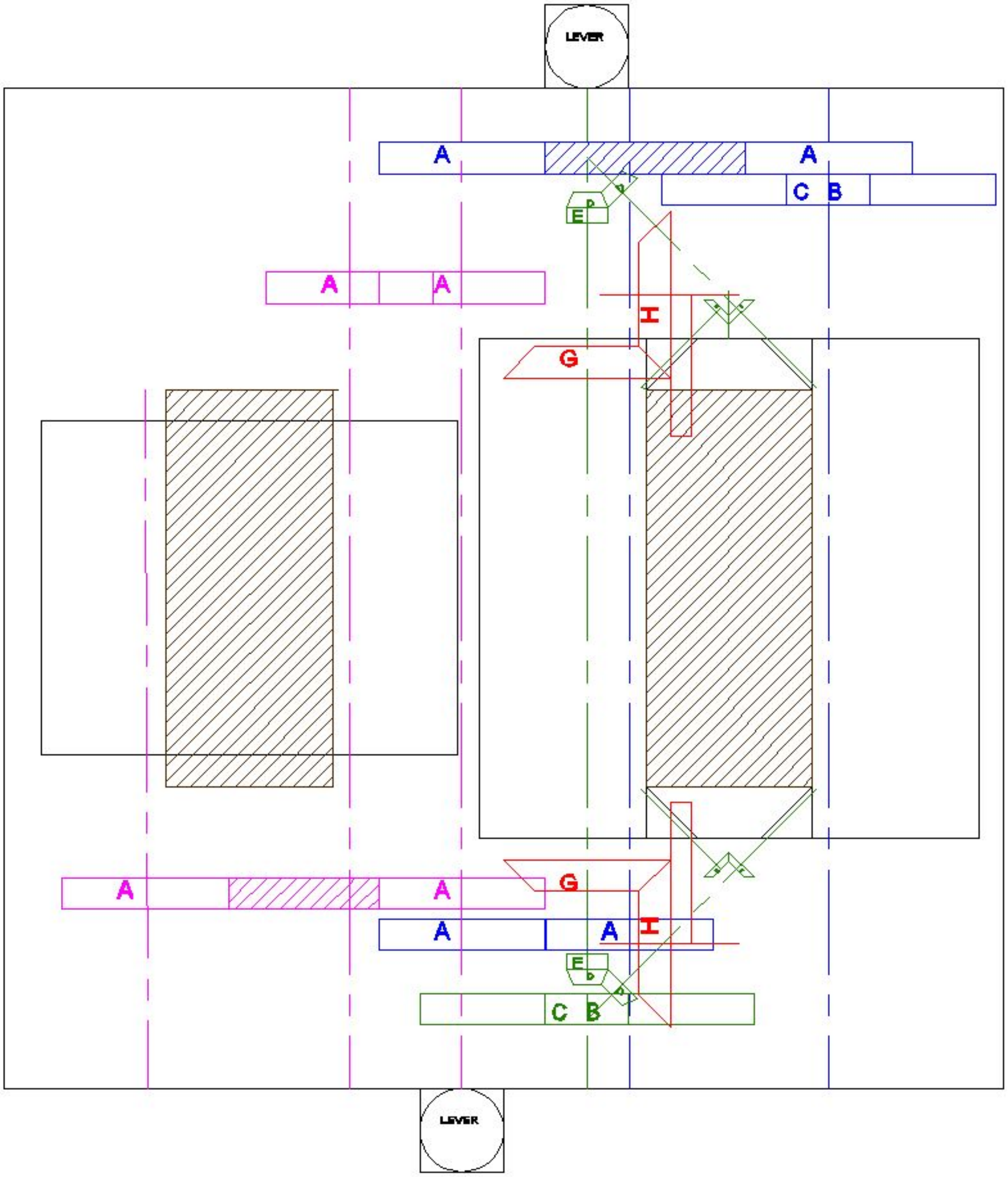

Figure 17: Basic Layout Top

Chapter 4: Detail Design

Standard Components from Catalogues
The following table shows the items that were able to be bought directly from a catalogue and used in our machine.

Standard Materials Used		
Name	Catalogue	Item Number
XML 18 Teeth Pulley	SDP/SI	A 6T16-018SF2508
XL 24 Teet Pulley	McMaster Carr	57105k22
Plastic Bevel Gear 18 Teeth	McMaster Carr	7297K11
Nylon Sleeve 5/16"	McMaster Carr	6389K114
Nylon Sleeve 5/16" Flanged	McMaster Carr	6294K436
Shaft Clamp 5/16	McMaster Carr	9434T16
XL Belt 62T	SDP/SI	A 6R 3-062037
XL Belt 72T	SDP/SI	A_6R_3-053037
XL Belt 53T	SDP/SI	A_6R_3-072037
MXL Belt 87T	SDP/SI	A_6Z16-087037
Junction Box	Jet	SC121208NK
Aluminum Hinge 2"	McMaster Carr	1609A5
Lever Arm	McMaster Carr	6303K400
Rubber Feet	McMaster Carr	9540K842

Figure 18: Standard Materials Used

Explanation of Calculations

There were three major factors that needed to be calculated. These were pitch, gear ratios based upon desired turn speeds, and belt lengths and the corresponding number of teeth. The pitch needed to be calculated so that the gears would mesh properly and turn each other. To calculate the pitch, we used

$$P = \frac{P_d * \Pi}{N} \text{ where } P_d = pitch\ diameter \text{ and } N = number\ of\ teeth$$

Since we were able to adjust the pitch diameter and the number of teeth, we could manipulate the pitch to match on each gear. However, the number of teeth and the pitch diameter had to be set on the planetary gears so we achieved the desired gear ratio, using

$$R = \frac{P_{d1}}{P_{d2}} = \frac{N_1}{N_2}$$

In our situation, we needed a gear ratio of two between the satellite and the sun gear, and a gear ratio of four between the satellite and the solar gear. Finally, we needed to calculate the number of teeth on our belts. To calculate we used

$$Lp = (2 * C) + 1.57 * (D_1 + D_2) + \frac{(D_1 - D_2)^2}{4C}$$, where $Lp = pitch\ length$,

$D_1 = pitch\ diameter\ of\ the\ first\ gear$, $D_2 = pitch\ diameter\ of\ the\ second\ gear$, and

$C = distance\ between\ centers$

At this point, the pitch had been calculated, the pitch diameter had been set, and so all we needed was to determine the necessary belt length.

Materials and Manufacturing Methods Used

Our machine consisted of several materials and methods of manufacturing. The majority of our more complex parts (e.g. the planetary gears and angled gear supports) were 3D printed using a food safe PLA filament. For other complex parts that were either too large to print like the gear covers, or required a less porous material than is possible on a 3D printer like the flaps, the use of a molded food safe resin was used. To do this a prototype part was made, either using a 3D printer in the case of the flaps or MDF for the gear cover, then a two part silicon solution was poured around the part to make a mold. Once dried the part was removed from the mold and then a 2 part resin was poured into the mold to produce the desired part after curing for 24 hours.

Less complex parts were able to be machined out of aluminum. The axle supports were made from 1 x 0.25” aluminum bar stock and 1 x 0.125” angle stock. These were simply cut down to length, had appropriate holes drilled on a drill press, and then deburred. A similar method was made to make the lever mounts out of a 2” diameter aluminum round stock. To make the table top of the machine, we used the steel top that was supplied with the junction box. We then drilled small holes in each corner and used a rotary cutting tool to cut out the desired shape.

Part Drawings

Gear Information	
Number of Teeth	24
Pitch Diameter (in)	2.043
Root Diameter (in)	1.719
Pitch	0.267
Pressure Angle (deg)	25
OD (in)	2.12
ID (in)	0.33

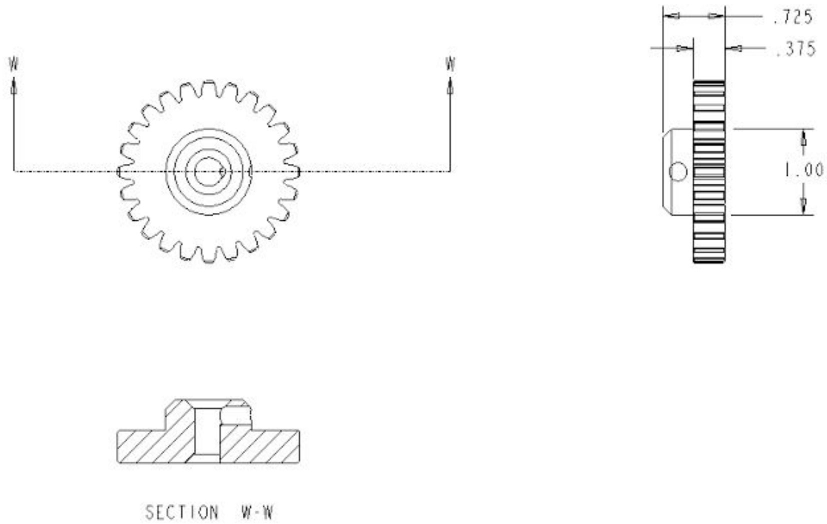

Figure 19: Gear A

Gear Information (inner)	
Number of Teeth	36
Pitch Diameter (in)	2
Root Diameter (in)	1.791
Pitch	0.175
Pressure Angle (deg)	25
OD (in)	2.1
ID (in)	0.33

Gear Information (outer)	
Number of Teeth	72
Pitch Diameter (in)	4
Root Diameter (in)	3.901
Pitch	0.175
Pressure Angle (deg)	25
OD (in)	4.15
ID (in)	0.33

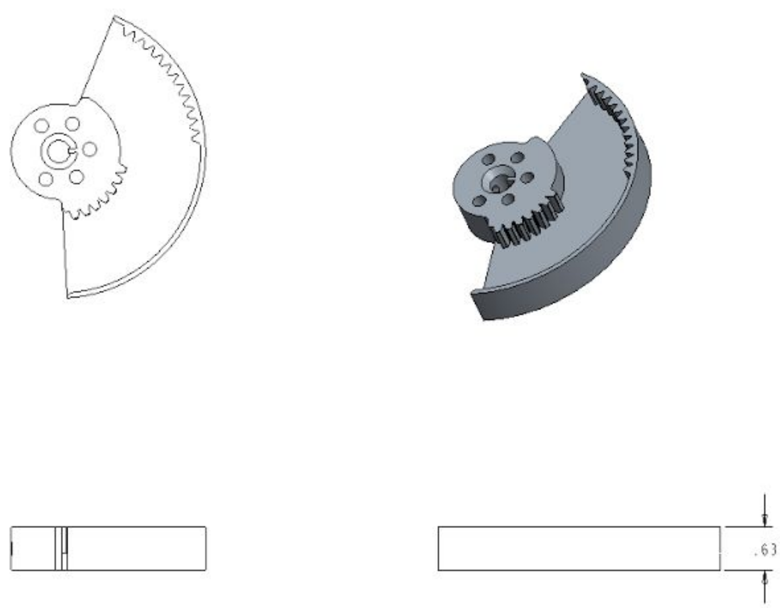

Figure 20: Planetary Gear B

Gear Information	
Number of Teeth	18
Pitch Diameter (in)	1
Root Diameter (in)	0.8515
Pitch	0.175
Pressure Angle (deg)	25
OD (in)	1.1
ID (in)	0.33

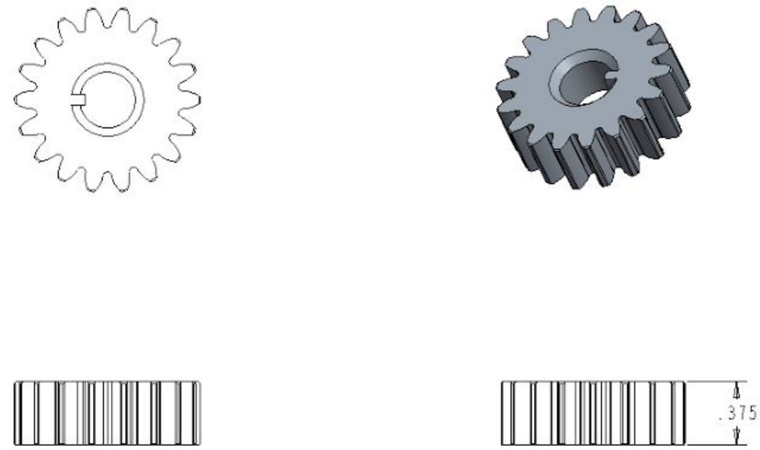

Figure 21: Planetary Gear C

Gear Information	
Number of Teeth	12
Pitch Diameter (in)	0.5
Root Diameter (in)	0.38
Pitch	0.131
Pressure Angle (deg)	25
OD (in)	0.59
ID (in)	0.125
Bevel Angle (deg)	22.5

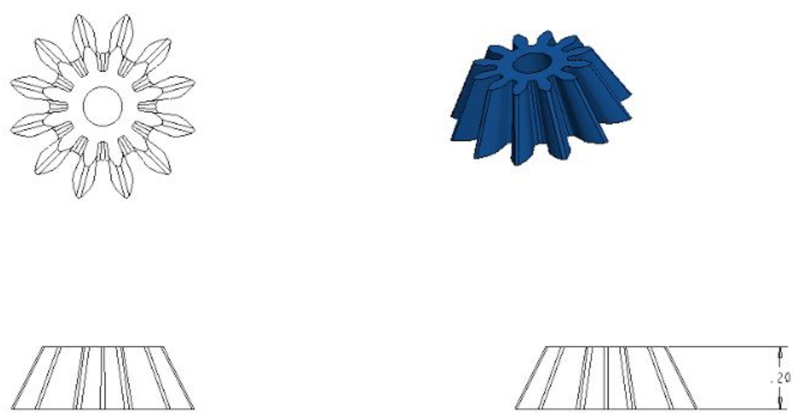

Figure 22: Bevel Gear D

Gear Information	
Number of Teeth	12
Actual Teeth Amount	3
Pitch Diameter (in)	1.77
Root Diameter (in)	1.68
Pitch	0.463
Pressure Angle (deg)	25
OD (in)	1.97
ID (in)	0.33
Bevel Angle (deg)	45

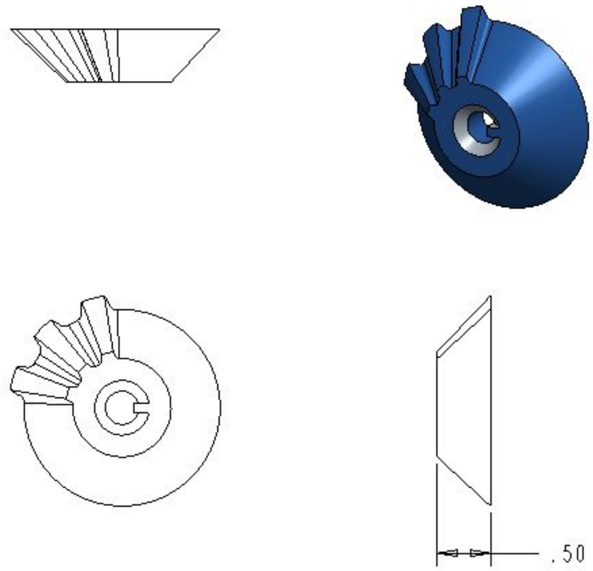

Figure 23: Bevel Gear G

Gear Information	
Number of Teeth	12
Pitch Diameter (in)	1.77
Root Diameter (in)	1.68
Pitch	0.463
Pressure Angle (deg)	25
OD (in)	1.97
ID (in)	0.33
Bevel Angle (deg)	45

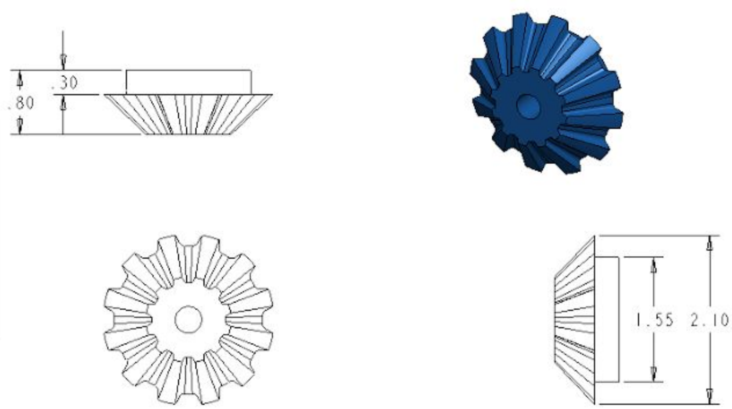

Figure 24: Bevel Gear H

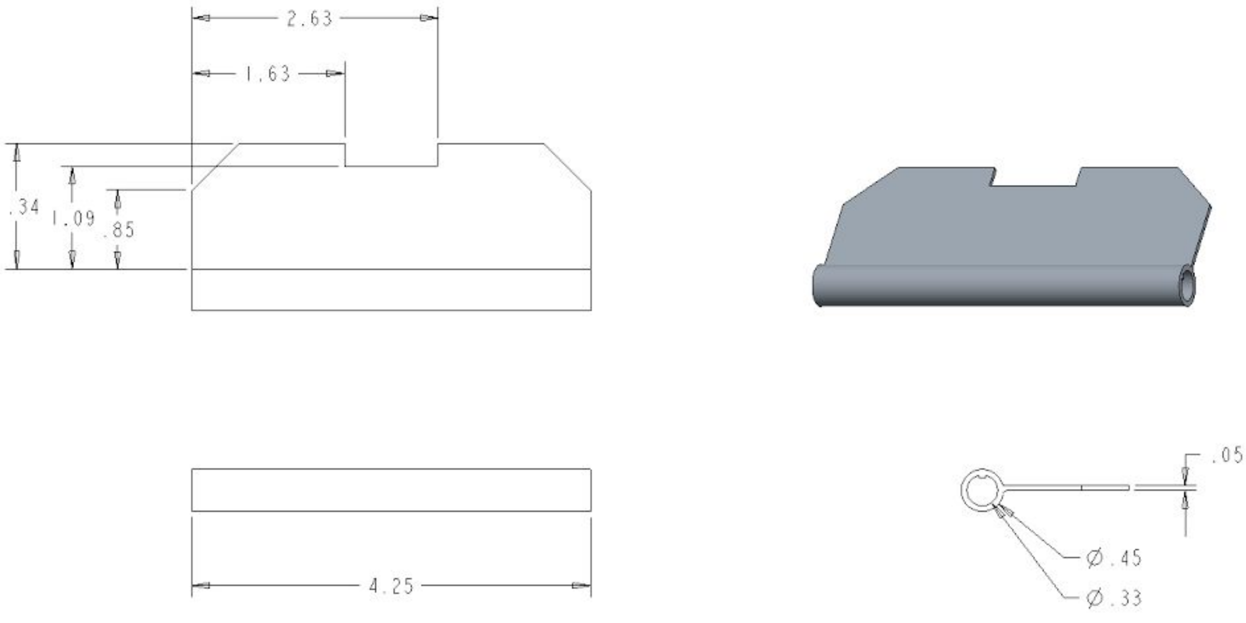

Figure 25: Large Paper Flap

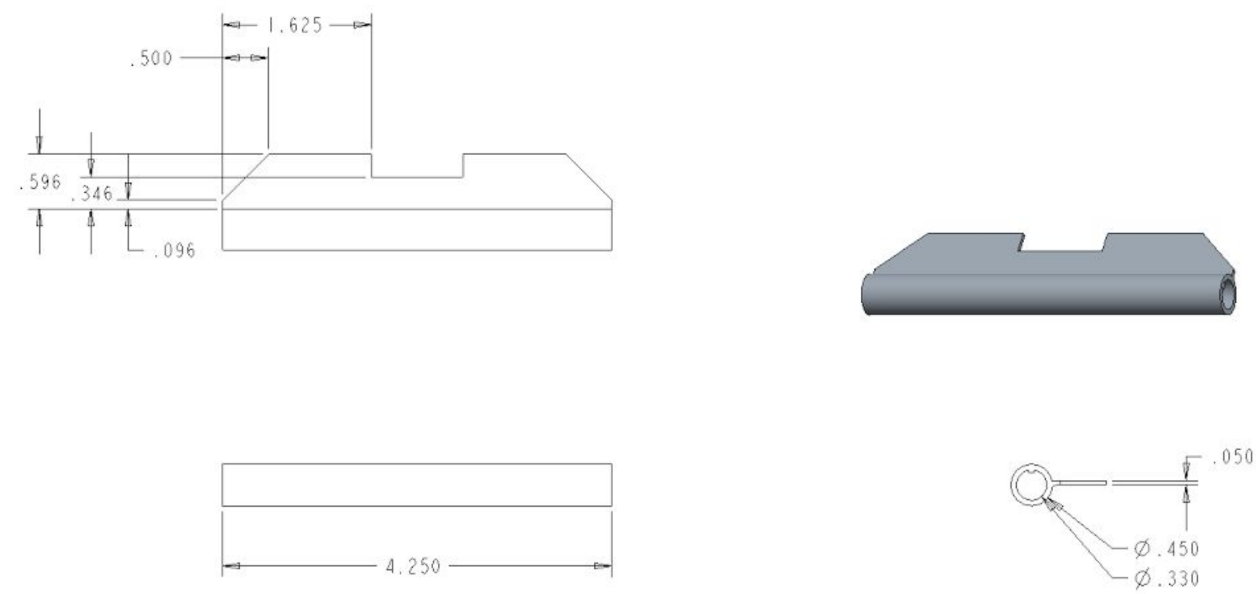

Figure 26: Short Paper Flap

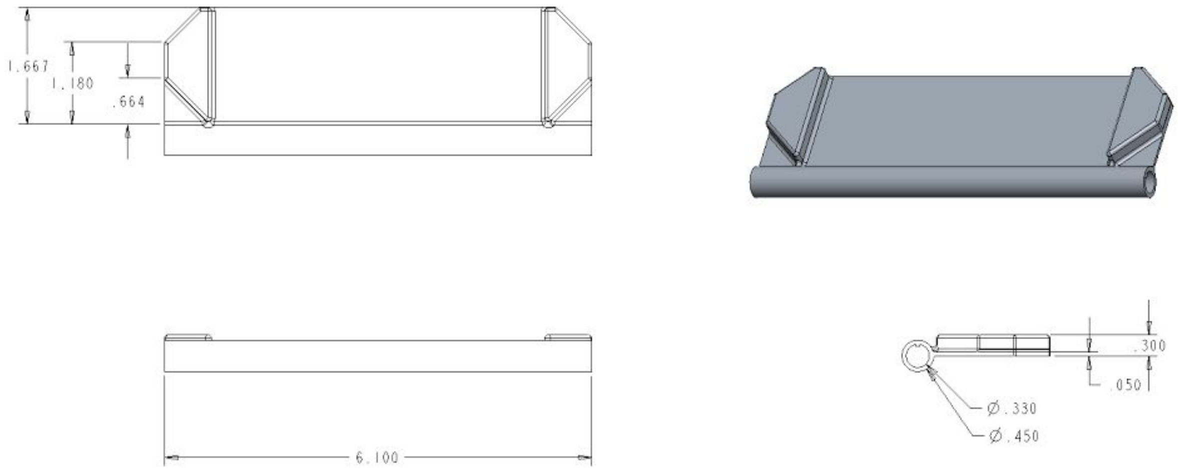

Figure 27: Long Foil Flap

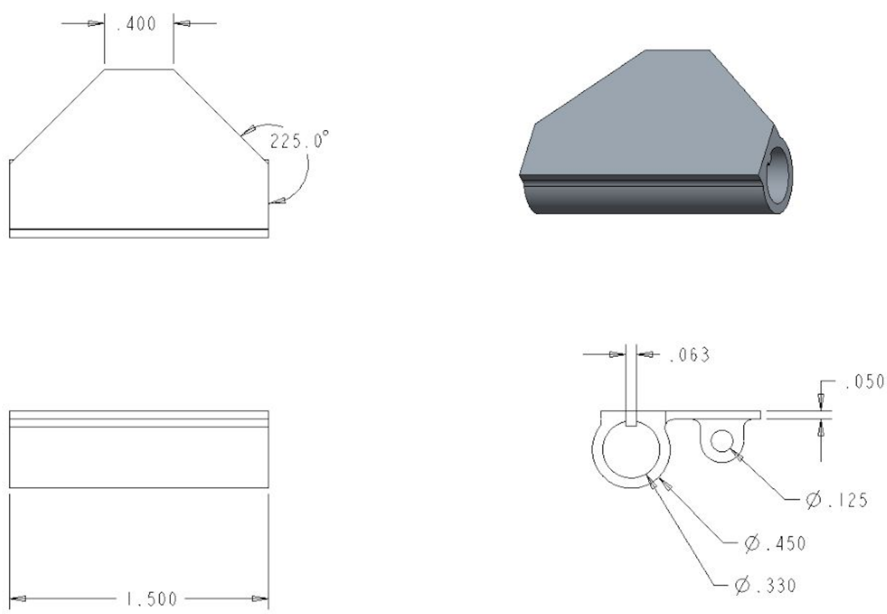

Figure 28: Short Paper Flap

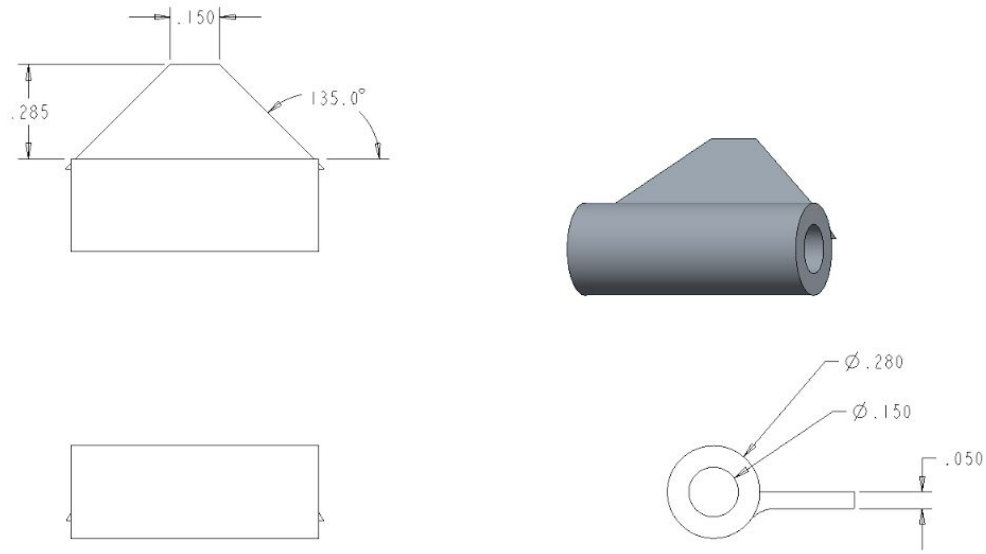

Figure 29: Angle Flap

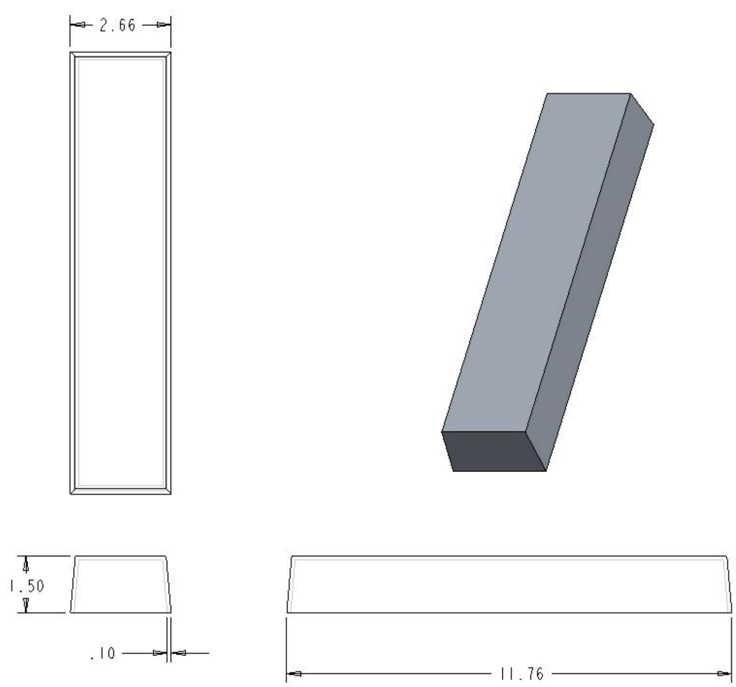

Figure 30: Gear Cover

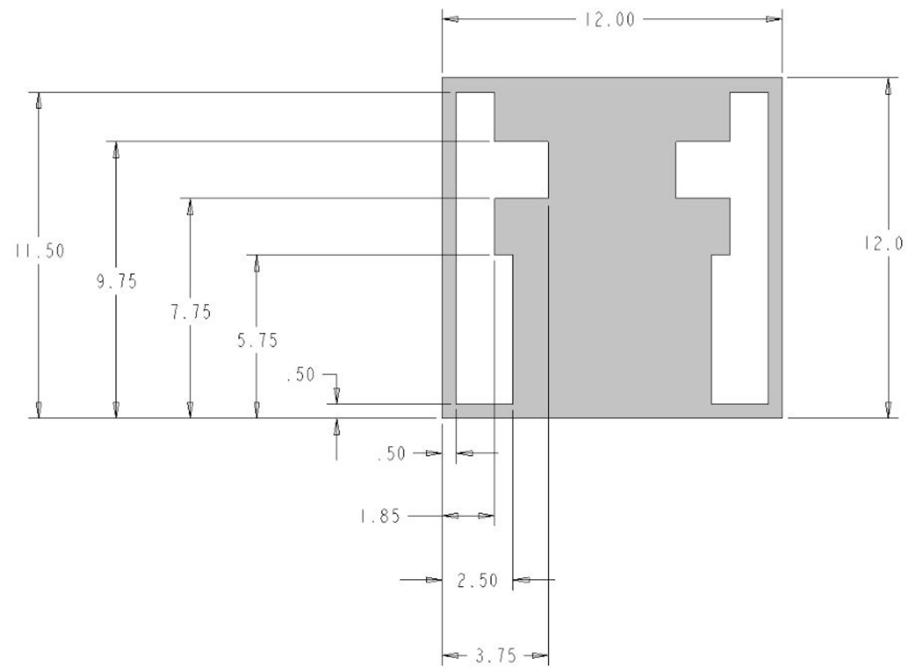

Figure 31: Table Top

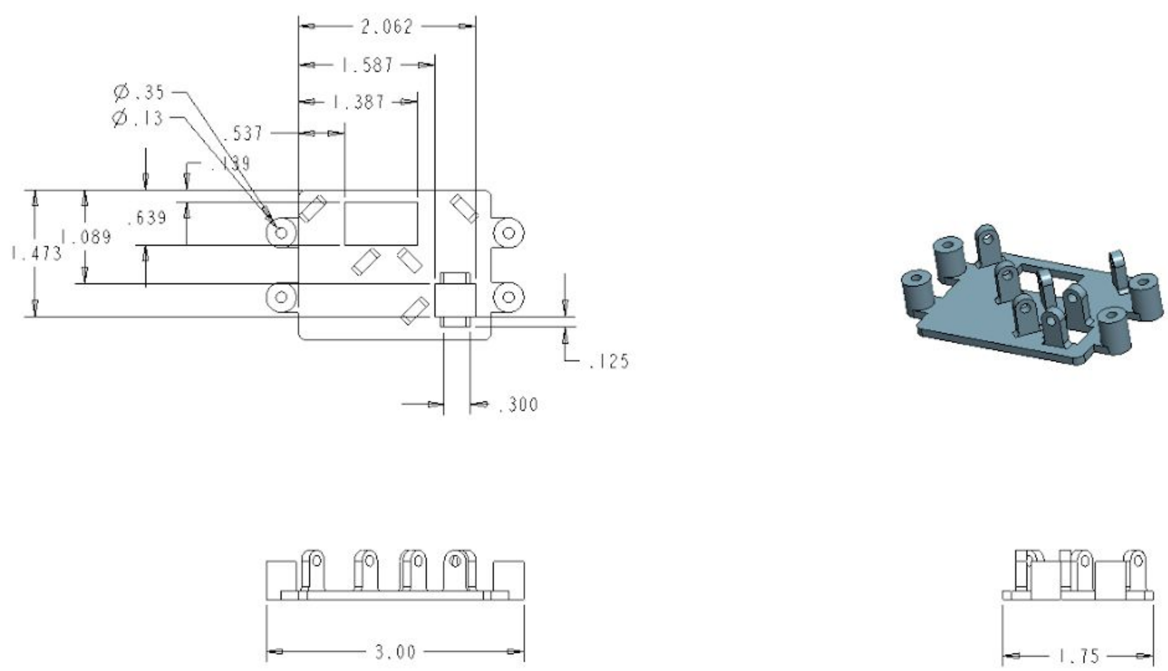

Figure 32: Angled Gear and Flap Support

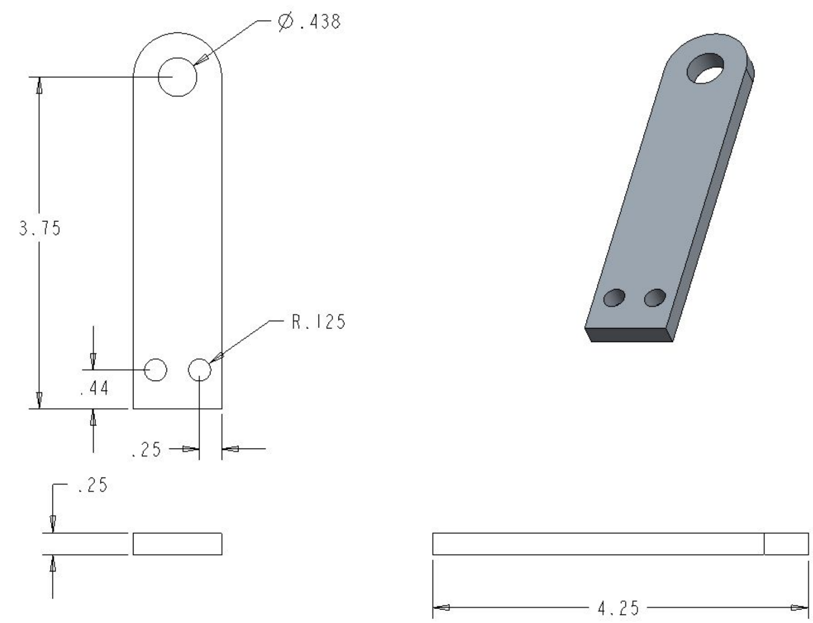

Figure 33: Single Axle Support

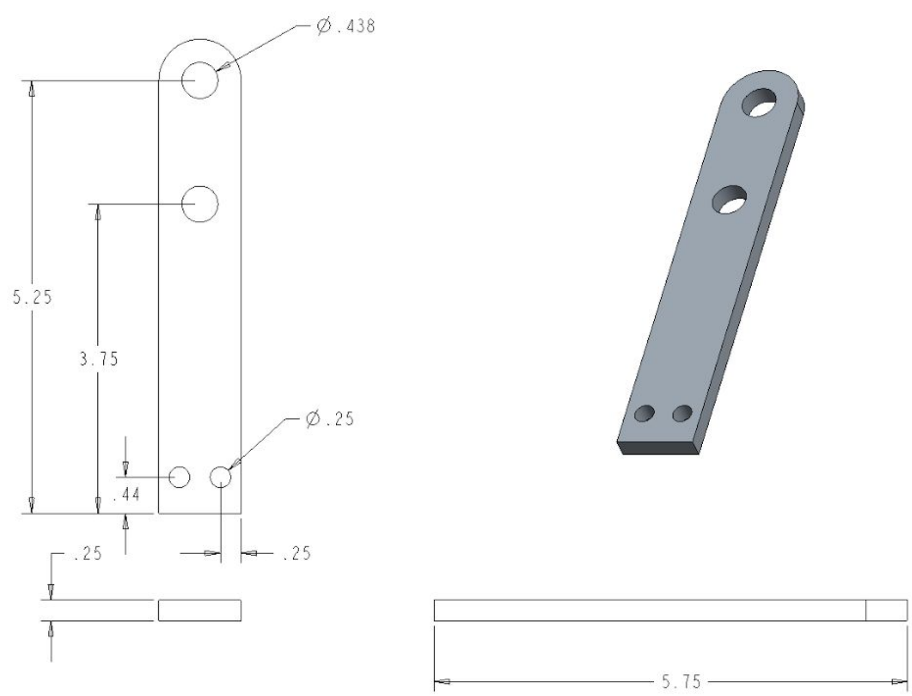

Figure 34: Double Axle Support

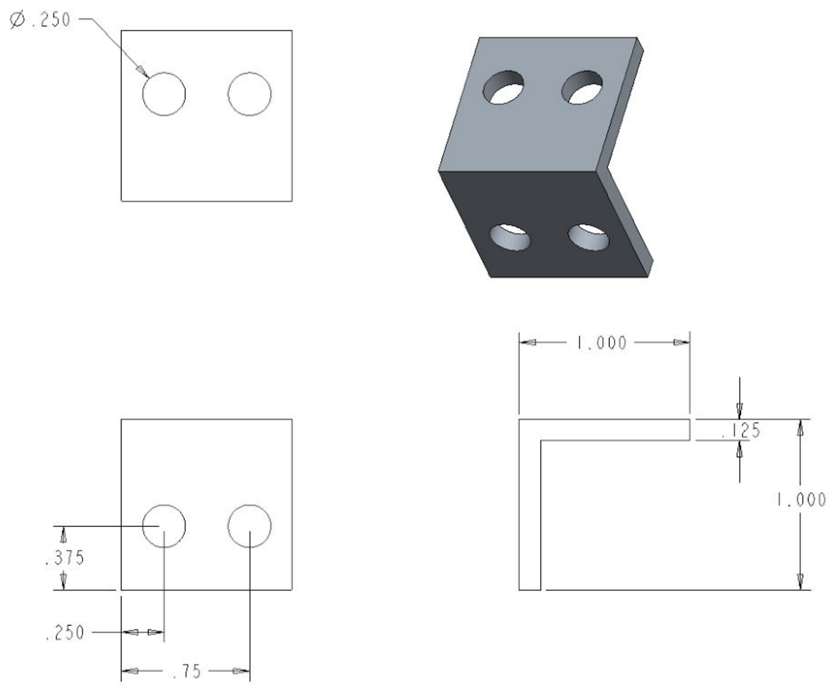

Figure 35: Angle bracket for axle support

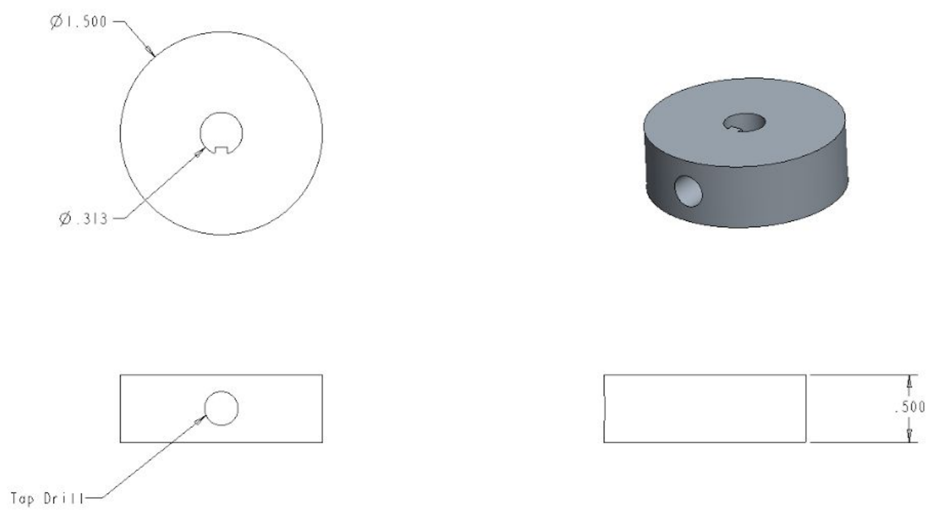

Figure 36: Lever mount

Assembly Drawings

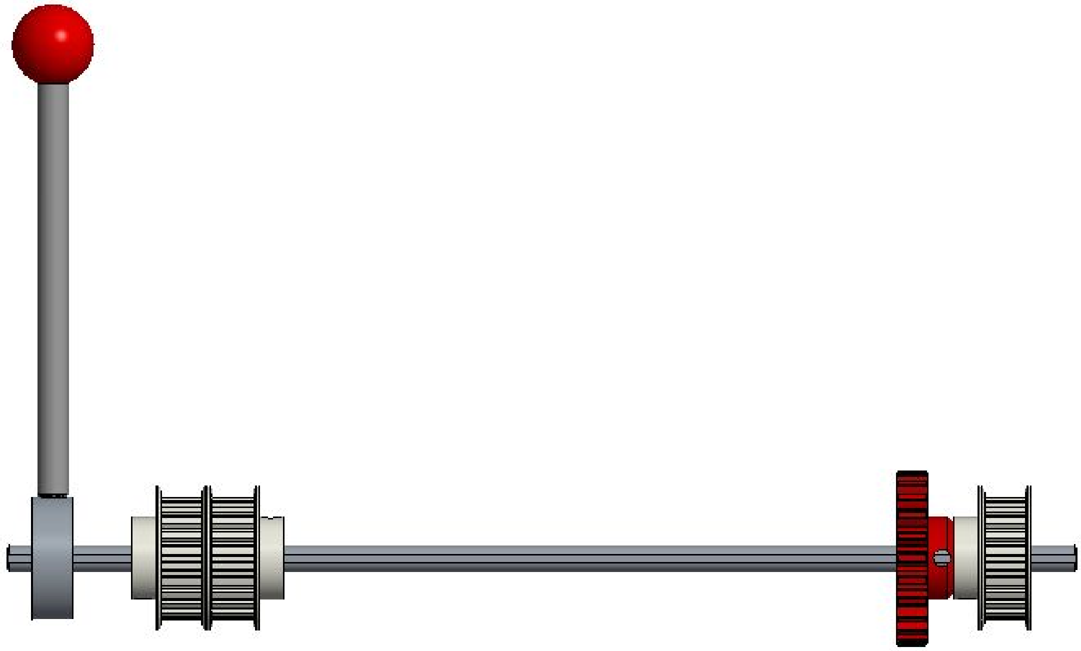

Figure 37: Drive Shaft A Assembly

Figure 38: Drive Shaft B Assembly

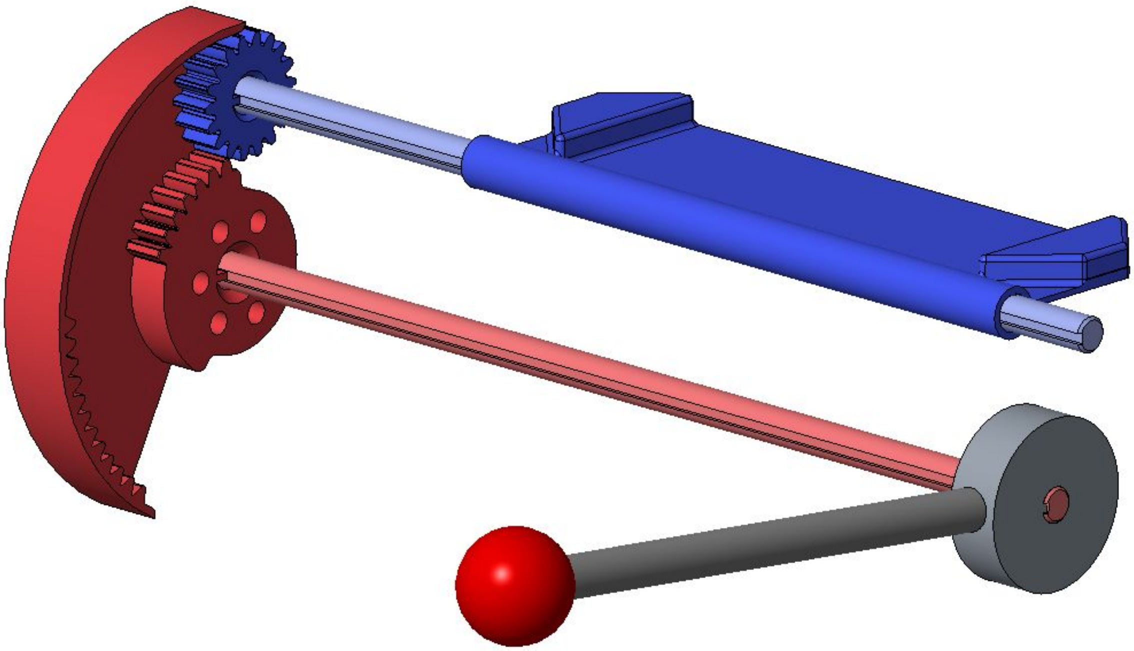

Figure 39: Planetary Gear Assembly

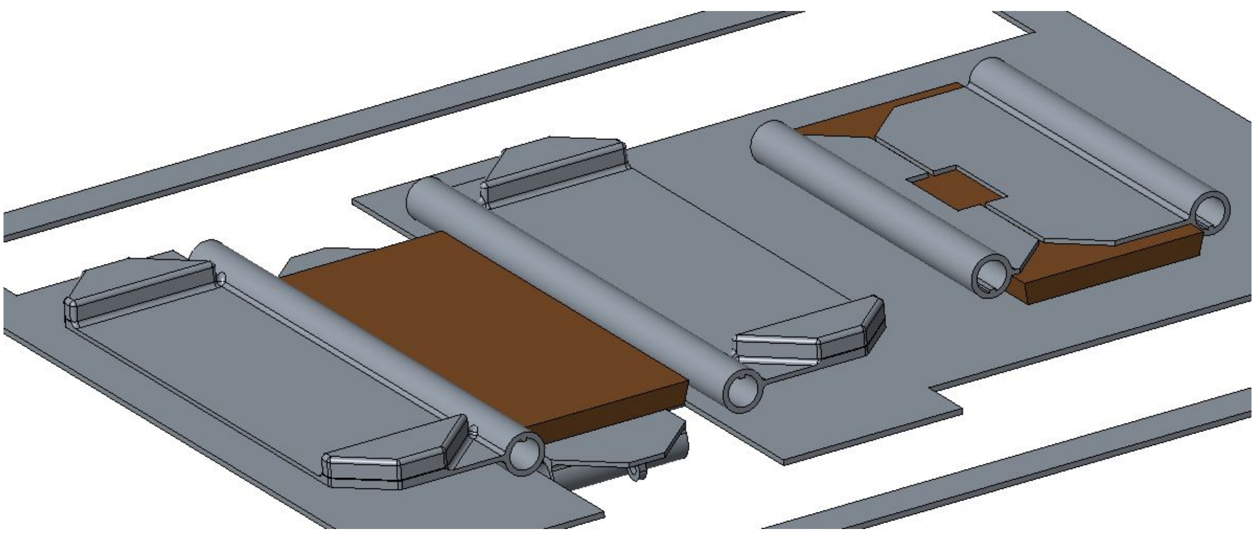

Figure 40: Table Flap Assembly

Exploded View Drawings

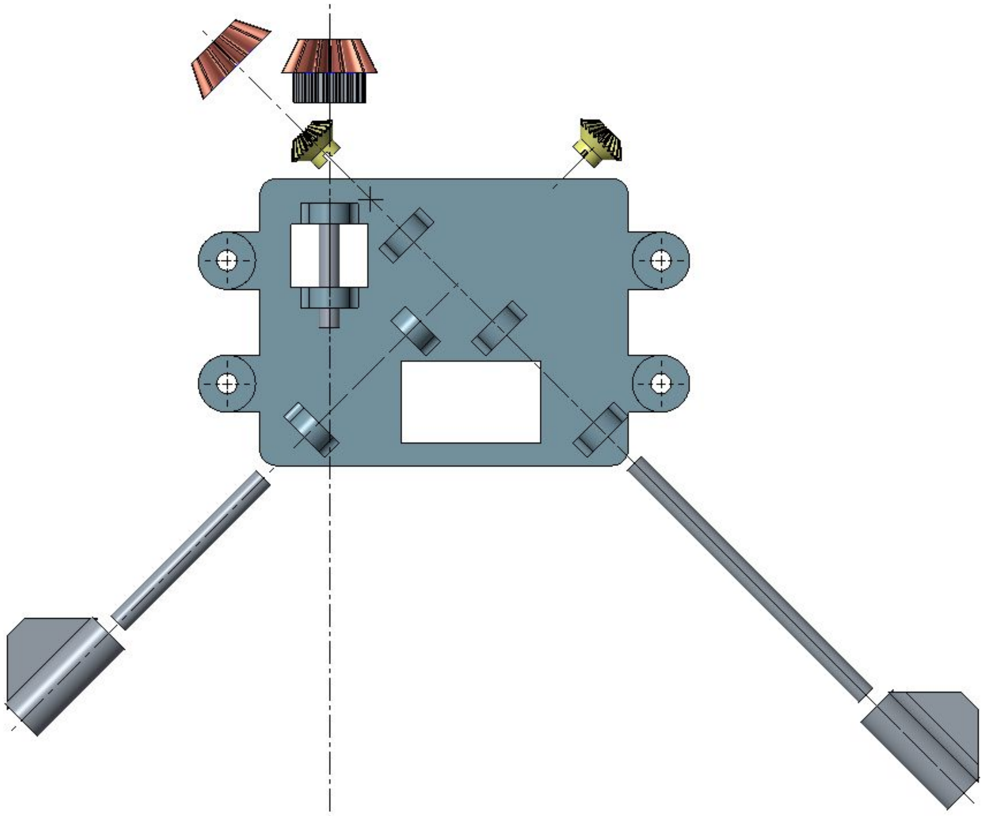

Figure 41: Angular Bracket Exploded View

Chapter 5: Discussion

With the design we selected, numerous gear calculations were needed to ensure correct operation of the machine. With our two levers, we had to accurately deliver the 180° of motion required to the flaps. For the long side of the foil flaps, we had to achieve 180° of motion both forward and back in one lever turn, for only one of the flaps. We designed it this way to prevent the two long foil flaps for colliding into each other. This is why the planetary gear was design. With the correct number of teeth and pitch on each gear in the set, the first flap folds in and comes back out before the second flap folds in.

Because most gears are produced through stamping, we decided to use the on-campus 3D-printer to print the non-standard ones. Also, more of the complex parts that were not easily machinable were printed. This included the planetary gear set, Gear A, each flap, and most of the angular flap assembly. By using the 3D printers, we were able to create otherwise cost-prohibitive parts for significantly cheaper.

A prototype was built to test out the motion of the rods and gears. We used ¼" plywood to build the first unit, for easy assembly and dimensional trials. This was the unit that was showcased at the Senior Design Day Presentations. While the prototype was not quite a looks-like and functions-like model, it was able to show the inner workings of the gears to observers.

The actual machine is to be built shortly after the prototype is completed. It will be the final product that Gilbert Chocolates receives, and could potentially be marketed to other small businesses. The final product costs $430 to manufacture, and with further development, could potentially be reduced further.

Chapter 6: Conclusion

This project was begun with the intent of designing a machine capable of decreasing the time needed for Gilbert Chocolate's employees to wrap candy bars. By doing so, the workers could spend more time producing more chocolate to sell. Furthermore, the machine needed to be affordable for a small business, and needed to easily moveable for when it was needed.

The importance of all of these design criteria cannot be overstated. If the machine failed to reduce the time required to wrap the bars, the machine serves little benefit over wrapping by hand. Furthermore, if the machine costs well over $1000 dollars, the payback time may be undesirable. With further research and development, these machines could be improved and optimized for Gilbert Chocolates, but also for other small chocolate businesses. As the product is optimized, the cost of manufacturing can be reduced, making it more beneficial for more companies, and reducing their payback time.

We believe that this machine achieved its purpose. The price was below the stated price requirement, it reduces the time required to wrap the bars, and is contained within a cubic foot. We also believe that this product is marketable to other small chocolate businesses looking to reduce wrapping time without spending an exorbitant amount of money on a machine way beyond their product capabilities.

Appendix

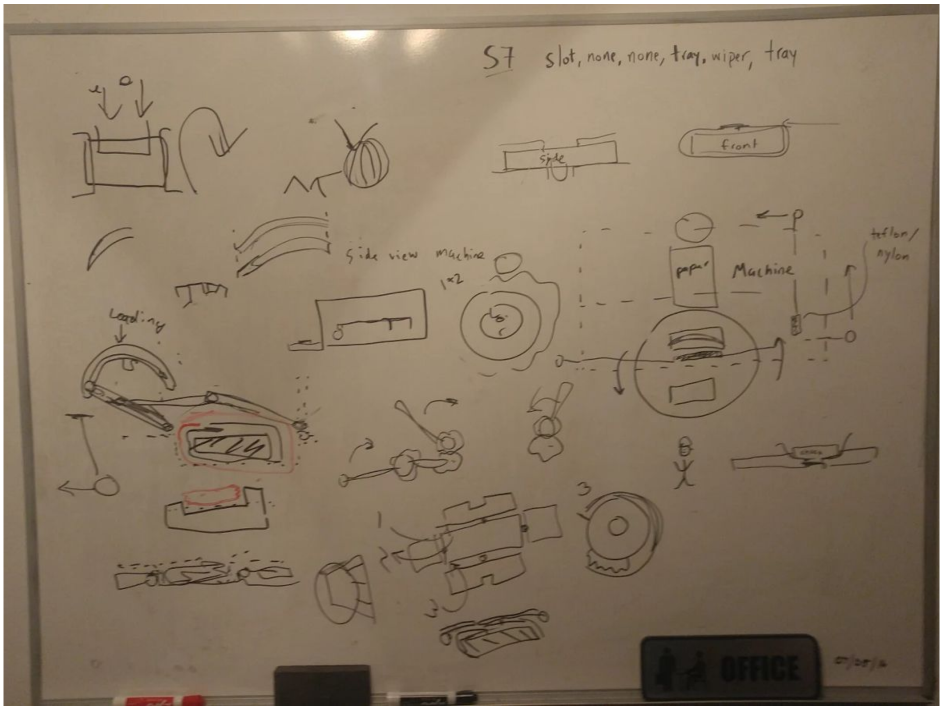

Figure 42: Concept drawings for solution 7

Common Name	Exact Name/Prt #	Qty	Process	Description	Cost (per piece)	Total Cost
			Gears			
Gear A	-	2	3D Print (Makerbot)	Common gear used throughout machine	$0.00	$0.00
Gear B	-	2	3D Print (Makerbot)	Planetary gear	$0.00	$0.00
Gear C	-	2	3D Print (uPrint)	Gear that sits inside Gear B	$20.00	$40.00
Gear D	-	4	3D Print (uPrint)	22.5 bevel gear	$6.00	$24.00
Gear E	A 6T16-018SF2508	4	Purch	Belted gear to angled flaps	$4.76	$19.04
Gear F	7297K11	4	Purch	Small 45 bevel gear to angle flaps	$5.19	$20.76
Gear G	-	2	3D Print (Makerbot)	45 bevel gear with teeth removed	$0.00	$0.00
Gear H	-	2	3D Print (Makerbot)	45 bevel gear with all teeth and nub for piston	$0.00	$0.00
Belt Pulley	57105k22	6	Purch	Pulley for belt driven shafts	$8.20	$49.20
			Shafts & Sleeves			
Drive Shaft	1570K23	2	Purch	13" length; dia = 5/16"; attaches to lever; cut to length	$13.10	$26.20
Shaft A	1570K23	5	Purch	10" length; dia = 5/16"; connects to flap; cut to length	$10.08	$50.38
Shaft B	1570K23	3	Purch	3" length; dia = 5/16"; where Gear H sit; cut to length	$3.02	$9.07
Shaft C	1570K23	2	Purch	2" length; dia = 5/16"; where Gear H sit; cut to length	$2.02	$4.03
Shaft D	-	2	Purch	2" length; dia = 1/8";	$0.13	$0.26
Shaft E	-	2	Purch	1.25" length; dia = 1/8"	$0.08	$0.17
Shaft F	-	2	Purch	.75" length; dia = 1/8"	$0.05	$0.10
Nylon Sleeve 5/16"	6389K114	17	Purch	Provides a low friction surface for the shafts	$0.73	$12.41
Nylon Sleeve 5/16"	6294K436	6	Purch	Provides a low friction surface for the shafts, now with flange	$1.14	$6.84
Shaft Clamp 5/16	9434T16	12	Purch	Holds shaft and sleeve in place	$0.09	$1.04

Flaps						
Paper Flap Short	-	1	3D Print (Makerbot)	Flap for short side of paper; keyed out center to allow taping	$0.00	$0.00
Paper Flap Long	-	1	3D Print (Makerbot)	Flap for long side of paper; keyed out center to allow taping	$0.00	$0.00
Long Flap	-	2	3D Print (Makerbot)	Flap with raised ends to fold flat to bottom of bar	$0.00	$0.00
Angle Flap	-	4	3D Print (Makerbot)	Flap for triangle fold	$0.00	$0.00
Short Flap	-	2	3D Print (Makerbot)	Flap for smaller end of bar	$0.00	$0.00
Alum. Piston Arm	-	2	Machined	Connects to short flap to engage flap	$0.37	$0.74
Belts						
XL Belt 62T	A 6R 3-062037	1	Purch	Meshes with Gear A	$6.84	$6.84
XL Belt 72T	A 6R 3-053037	1	Purch	Meshes with Gear A	$6.59	$6.59
XL Belt 53T	A 6R 3-072037	1	Purch	Meshes with Gear A	$7.11	$7.11
MXL Belt 87T	A 6Z16-087037	2	Purch	Meshes with Gear D	$5.21	$10.42
Frame						
Junction Box	SC121208NK	1	Purch	1 sq. ft steel box used as support and container	$38.86	$38.86
Alum. Shaft Support	8975K596	2	Machined	Supports mid span and ends of some shafts	$0.73	$1.46
Alum. Duo Shaft Support	8975K596	2	Machined	Supports 2 rods at same time	$0.96	$1.91
Cover Alum. Hinge	1609A5	4	Purch	Hinges to connect the gear covers to the junction box	$2.44	$9.76
Gear Cover	-	2	Mold	Attaches to Top Frame via hinges; encloses gears for safety	$2.25	$4.50
Angle Bracket	8982K4	5	Purch	Connects Shaft Supports to Frame	$0.24	$1.20
Misc.						
3/64 Dowel Pin	97155A112	10	Purch	Help lock gears and flaps to shafts	$0.06	$0.60
Lever Arm	6303K400	2	Purch	Engages entire machine	$6.55	$13.10
Silicon Molding	OOMOO 25	1	Purch	Used to make a mold	$25.00	$25.00

Food Safe Resin	Max Clear 24OZ	1	Purch	Epoxy resin used to mold food safe flaps and gear covers	$24.41	$24.41
Super Glue	75445A47	1	Purch	Used to glue small parts together and to rods	$3.42	$3.42
Rubber Feet	9540K842	16	Purch	Used on bottom of machine and on lever stoppers	$0.13	$2.08
Aluminum 0.08" Shim	89015K191	12		Elevates axles to proper hieght	$0.16	$1.92
Fasteners						
M4 x 14	90A150	20	Purch		0.0984	$1.97
M5 x 20	91290A242	12	Purch		0.1209	$1.45
M4 Set Screws	91290A242	10	Purch		0.0402	$0.40
M4 Threaded Inserts	94180A353	20	Purch		0.17	$3.40

Figure 43: BOM

Total Expenditures
$430.63

Figure 44: Total Expenditures