MEMS 1049 Final Documentation - Team 1

Project Purpose

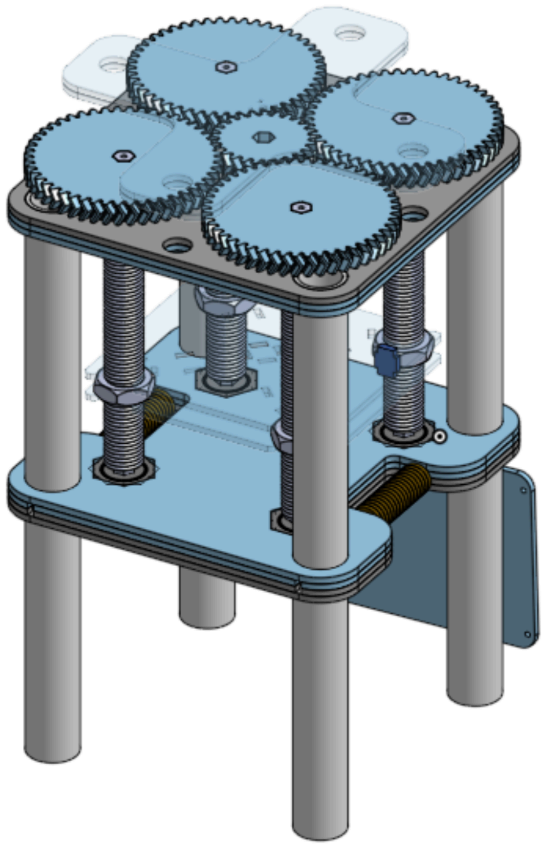
Team #1

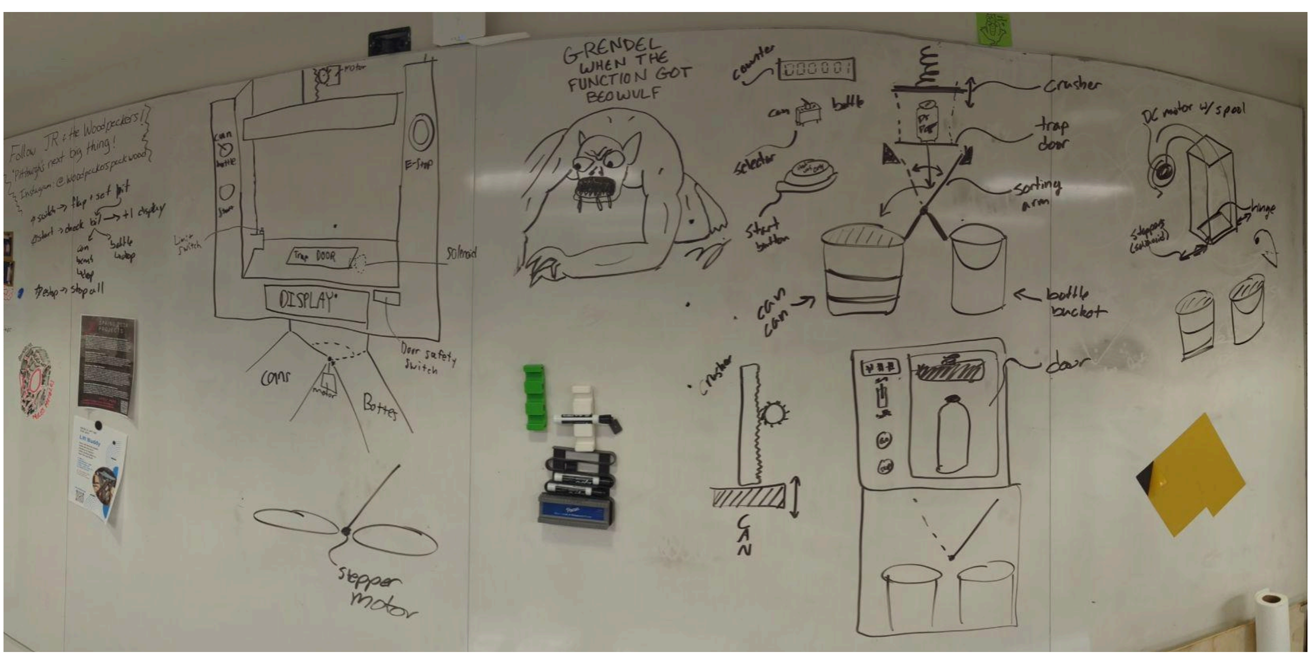
Names: Chris Beatty, Drew Deffenbaugh, Vincent Scaglione

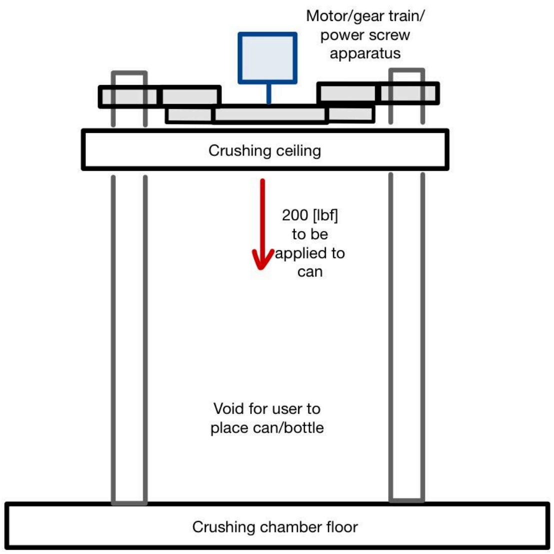
Armed with a Sam's Club membership, a taste for Lacroix, and a borderline problematic Dr Pepper and Diet Coke addiction, Drew, Chris, and Van face the great frontier that each new college semester inevitably becomes. As one may expect, the three had little regard for what happened to the vessels of the soda and soda-in-spirit they consumed on a regular basis; Amidst the semester, several cases worth of carbonated beverages later, they quickly realized that bottles and cans had taken over their homes. Lamenting the laborious process of their disposal, they realized that they could do something to prevent this from happening again. They needed a machine – A machine that would know when a can or bottle is inserted[1], sort between cans and bottles[3] for deposit returns on their yearly trip to Michigan, and compress the volume of each can[2] to limit the number of recycling bags that had to be packed into a car. Knowing themselves well, they also knew that a built-in reward system[5] would keep them consistently utilizing the machine. Additionally, the machine would have to have safety[4] measures to ensure it would be safe for anyone to use.

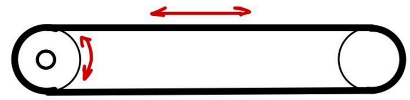
1) Can/Bottle Toggle
2) Can Crusher
3) Sorter
4) E-stop
5) Reward System

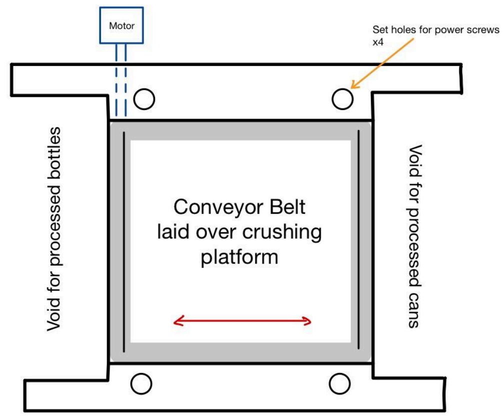
CAD Design & Preliminary Sketches

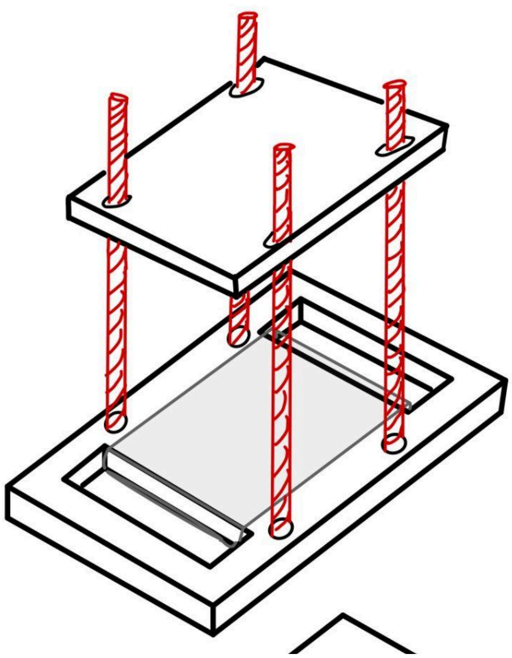


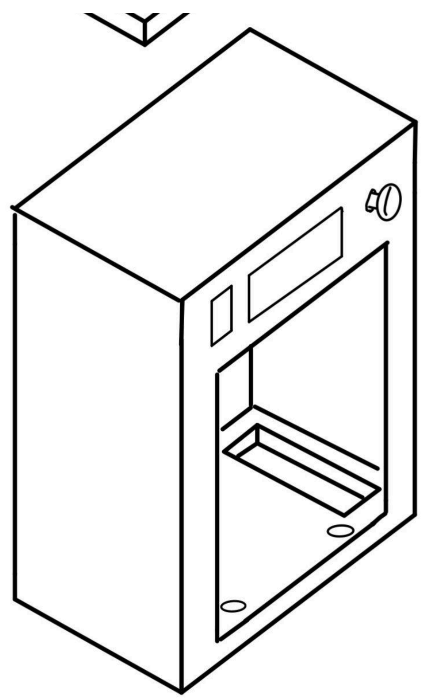



Motor/gear train/
power screw
apparatus
Crushing ceiling
200 [lbf]
to be
applied to
can
Void for user to
place can/bottle
Crushing chamber floor




Motor
Set holes for power screws
x4
Void for processed bottles
Conveyor Belt
laid over crushing
platform
Void for processed cans



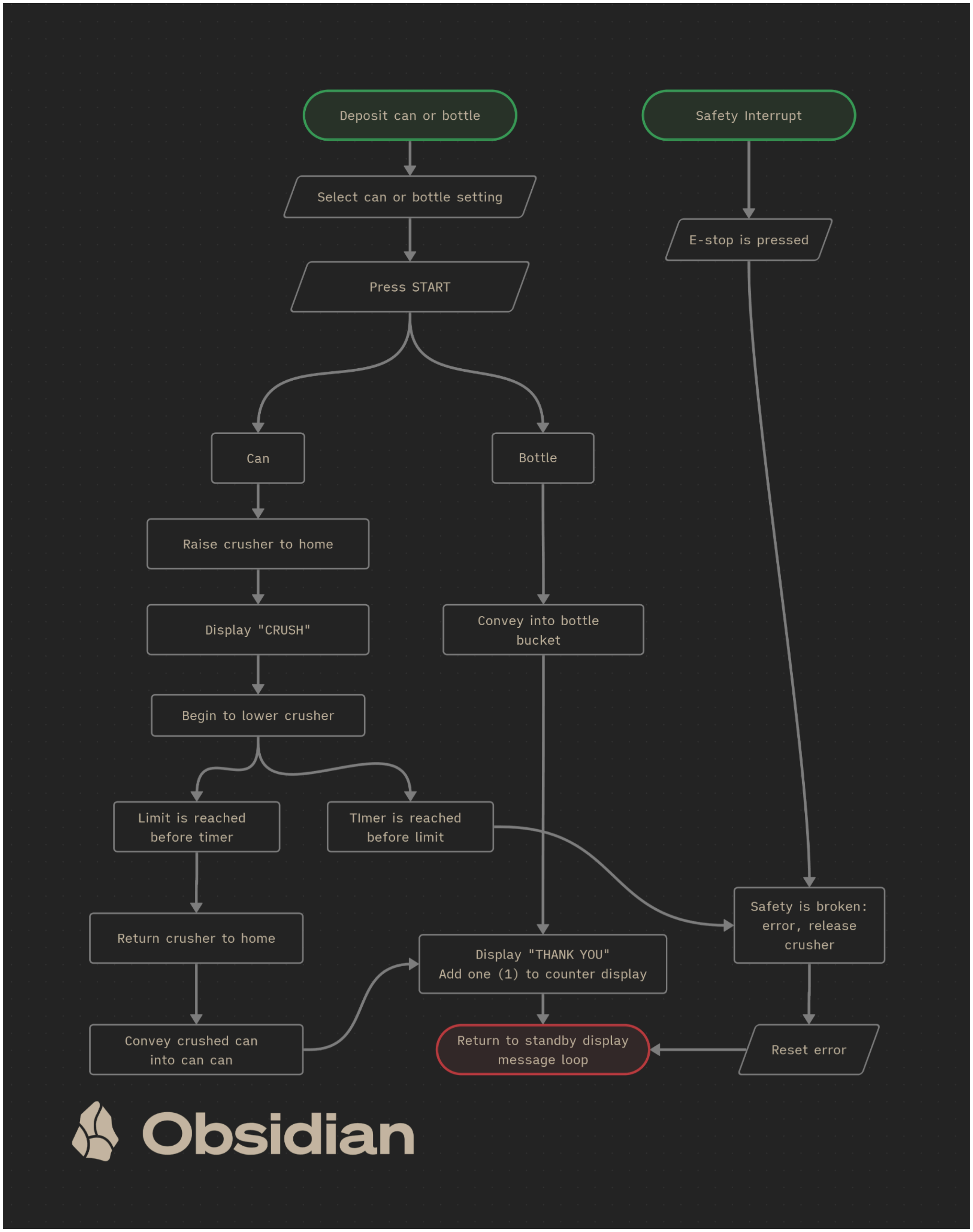


Feature Table

Feature	Description	Mechatronics Element	Effort	Feature Value	Value/Effort Ratio
1. Can/Bottle Detector	This switch has two options associated with it. The switch can either be set to can or bottle and will tell the machine whether or not to use the crusher (crusher will only be actuated if a can is inserted)	Switch	5	5	1
2. Can Crusher	This motor actuates the can crushing mechanism. The motor is connected to some drive-train that pushes down a large plate onto the can and then raises back up	DC Motor	20	35	.75
	The H-Bridge is used to control the direction of the motor to allow for the crusher to both drop and rise with the same motor	H-bridge	10		
	One push button is used as a limit switch for the crusher. When this button is activated, the crusher will automatically start rising back up to not damage the machine or motor, another push button is used to home the crusher and ensure that it always starts from a known distance	Push Button(s)	5		
	This LED is used as a signal to show that the crusher is working to ensure that no one opens the machine during the process	LED	5		
	This LED is used as a signal to show that the crusher safety timeout triggered and stopped the crusher	LED	5		
3. Sorter	This motor actuates the conveyor belt that drops the can/bottle into the recycling bin sorter	DC Motor	15	25	1

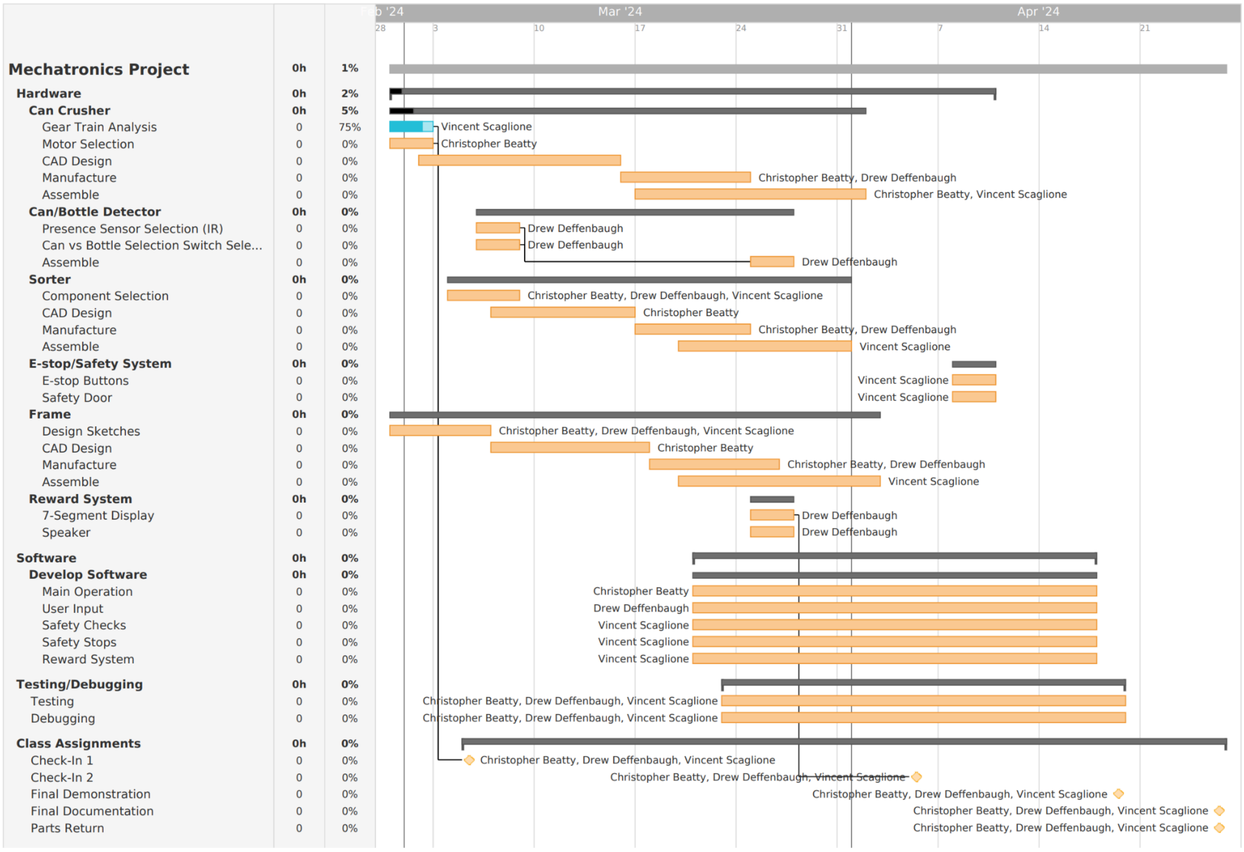
	This H-bridge controls the directionality of the conveyor	H-bridge	10		
4. E-stop	This button/switch is an external button that acts as an e-stop that will stop the machine no matter where in the process it is	Push button/contact switch	0	15	3
	The interrupt function of the microcontroller allows for the system to be constantly polling to see if the door opens, allowing the system to stop working if the door opens	Interrupts	5		
5. Reward System	The 7-segment display shows the number of cans/bottles that have been recycled using this system. This allows users to feel like they are contributing to something and will enjoy the number counting up	7-Segment Display	20	15	0.75
		Total	100		
		Scale Factor	100 %		

Operation Flowchart



Responsibility Breakdown

Preliminary Plan:

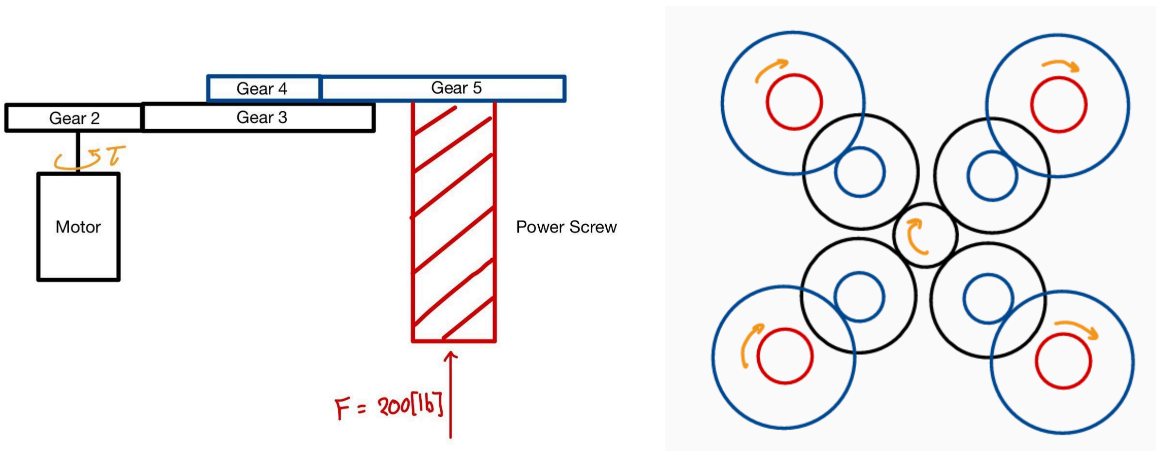


Final Responsibilities:

Group Member	Tasks Accomplished
Drew Deffenbaugh	Seven Segment Display Circuit and Code Lead Mechanical Assembly Frame CAD Design
Chris Beatty	Conveyor Belt Circuit and Code Mechanical Assembly Conveyor CAD Design
Vincent Scaglione	Main Can Crusher Circuit and Code Mechanical Assembly Crushing Plate CAD Design

Motor & Power Electronics Analysis

For this check-in, we focused on a motor analysis for the crusher itself, as it is the focal point of our project. At this stage of the design process, we have settled on using a single motor to drive four identical gear trains, which turn four identical power screws.



Side View of Torque Transmission to Single Power Screw (left), Top view of Four-Way Transmission from Single Motor (right)

For this component, there is no particularly necessary speed threshold, but the necessary torque is extremely important. From some research and testing, we have settled on a required force application of 50 lbs to satisfactorily smash a paper cup; to apply this force within a reasonable budget, we have to rely on a gear train design to amplify the motor's torque. With the power screw and gear analysis, as described in variable form below, we work backward from the necessary force to the required torque to select a motor.

$$T_R = \left(\frac{F*d_m}{2}\right)*\left(\frac{L + \pi f d_m}{\pi d_m - fL}\right) \quad [1]$$

$$m_v = \frac{N_2}{N_3} \quad [2]$$

$$T_M = \frac{T_R * m_v}{\lambda_{total}} \quad [3]$$

Equation 1 uses the lead of the screw (L), diameter of the screw (d_m), friction coefficient (f), and the load the screw pushes against (F) to find the torque required to spin the screw. In this analysis, we are only looking at one of the four lead screws in the design. Therefore the F in equation 1 is a quarter of the actual load on the system. Additionally, the friction coefficient is estimated to be 0.8, the friction coefficient for dry steel on steel. Equation 2 uses the number of teeth on the gears to calculate the transmission ratio for the gear train. Equation 3 uses the torque needed on the screw, transmission ratio, and assumed efficiency to calculate the torque needed from the motor. The efficiency was assumed to be 0.81. We arrived at this value because 0.9 is a common efficiency of gear meshes, and there are two gear meshes in our gear train.

Using values in Table 1 the required gear train input torque is 0.19 [N-m]. Multiplying this value by 4, as there are four lead screws, provides the expected motor torque of 0.78 [N-m] (110.5 [oz-in]). Additional results from the mechanical analysis are shown in Table 2.

Table 1

N2	N3	Mesh Efficiency	Friction
25	48	.9	.8

Table 2

Trans. Ratio	Req. Torque per Screw	Req. Torque per Screw (post-geartrain)	Overall Gear Efficiency
0.4167	0.472[N-m]	0.194 [N-m]	0.81

Following common practice of operating torque being half of stall torque, 5202 Series Yellow Jacket Planetary Gear Motor was selected for the project. This motor has the added benefit of a built in encoder. Its specs are summarized in Table 3 and calculations completed to solve for the expected motion of the final system summarized in Table 4. Using equations 4 - 7 the crushing plate will move at 0.049 [m/min] when loaded and 0.115 [m/min] with no load. This is very slow but is acceptable for a prototype system. A larger motor could be added in the future to achieve the high torque while also a high rotational speed.

$$\%T = \frac{4T_{in}}{T_{stall}} \quad [4]$$

$$n_{motor} = (1 - \%T)(n_{no\ load}) \quad [5]$$

$$n_{screw} = (n_{motor})(m_v) \quad [6]$$

$$v_{crusher} = (L)(n_{screw}) \quad [7]$$

To find the current needed for the motor, the following equation (8) was used to solve for the torque constant. Equation 9 was then used to find the current required based on the torque our motor needs to output.

$$T_{stall} = k_t I_{stall} \quad [8]$$

$$I = \frac{T_{motor}}{k_t} \quad [9]$$

Our required current was found to be 3.87[A]. This is higher than our given H-bridge can supply, thus a more powerful H-bridge will be needed. An H-bridge should be used that can also meet the stall current requirement of 9.2 A to avoid damage and add functionality.

Table 3

Nominal Voltage	No-Load Speed	Stall Torque	Stall Current	Motor Type
12 V	435 RPM	260 oz-in	9.2 A	Brushed DC

Table 4

Screw Rotational Speed	No Load Crusher Speed	Loaded Crusher Speed
20.92 RPM	0.115 m/min (4.53 in/min)	.066 m/min (2.6 in/min)

Final Project Demonstration Video

https://youtu.be/UZjpM7MD528?si=GEWubSHZzEDE7nsx

Final Circuit Schematic