

Spring Final Design Review

Team 10 - David Balogh, Alexander Berman, Aidan Carter, Nick Duncan, Blake Gifford, Olivia Langley, Justin Simoneck, Justin Sayers, Emma Staib, Nicholas Weis, Olivia Wilson

Project Definition & Goal:

- Create half of a pill bottle-filling machine for project sponsors Norwalt and Omega Design which is made up of three separate subsystems that are each responsible for taking in and correctly orienting caps, securing caps to the bottles, and rejecting any bottles that are capped incorrectly.
- The machine must also be able to receive bottles which have been filled with pills by a machine designed by any 'Front-Station' group.
- There is a noticeable gap in the market for automated pill bottle producers. Smaller pill bottle producers need an automated system that is small and cheap.
- The total time required for both the "Front" and "Back" station to complete one cycle must be at least 2 times as fast as a human would be filling a pill bottle.



Background and Benchmarking



Descrambling



Capping



Conveyance



Table of Constraints

Want/ Constraint	Metric	Target Value	Justification
Bottle Handoff	# Bottles Collected successfully	12 Bottles collected successfully	Project Definition and Sponsor [1]
Cap Descrambler	# Caps Descrambled successfully	12 Caps successfully descrambled	Project Definition and Sponsor [1]
Capping	# Caps successfully capped	12 Caps successfully capped	Project Definition and Sponsor [1]
Part Rejector	Must detect if cap is screwed on the bottle correctly, if not the bottle must be removed from the assembly line	No operator intervention is needed as well as must detect EVERY cap that is not screwed on properly	Project Definition and Sponsor [1]
	Height of bottle	Cap must be within a certain range to not be rejected.	
Automation	Must be fully automated	No operator intervention is needed while each station is functioning	Project Definition and Sponsor [1]
Speed of 'Back Station' Process	Time	1/2X manual completion of process.	Project Definition and Sponsor [1]
Compact	Dimensions of all components when not in use	All materials fit in 26" x 20" x 40" storage area.	Project Definition and Sponsor [1]



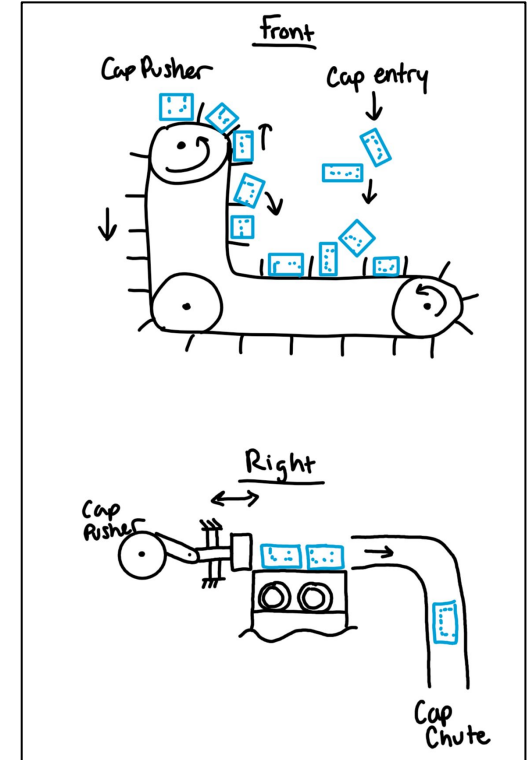
Table of Wants

Priority	Want/ Constraint	Metric	Target Value	Justification
1	Safety	OSHA Transport requirements	Fits within OSHA standards (29 CFR 1910.147,212,217)	Project Definition and Sponsor [1]
		ISO and ASTM safety Standards	Fits within the given standards (ASTM E3106, etc.)	Project Definition and Sponsor [1]
2	Pill Spillage	Number of pills leaving bottles during 'Back Station' process	Minimal error +/- 1 pill from nominal value	Project Definition and Sponsor [1]
3	Minimize Cost	Cost (\$)	20% less than given budget (\$400)	Low cost appeals to potential consumers, especially in competition.
4	Minimal Product Waste	Product waste (lbs)	< 5 lbs Product waste	Project Definition and Sponsor [1]
5	Ease of set up	# People Required to Set up	2 people.	Project Definition and Sponsor [1]



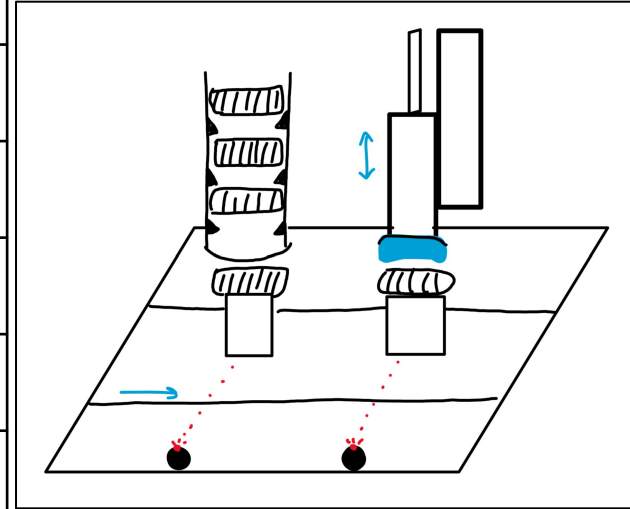
Concept Selection and Generation: Cap Descrambler

Concept	Vertical Conveyor Belt	Ultrasonic Descrambler	Center of Gravity	Rotary Descrambler
Automation	4	3	3	3
Descrambling	4	1	2	2
Speed	5	2	1	2
Low Cost	3	1	2	1
Totals	16	7	8	8



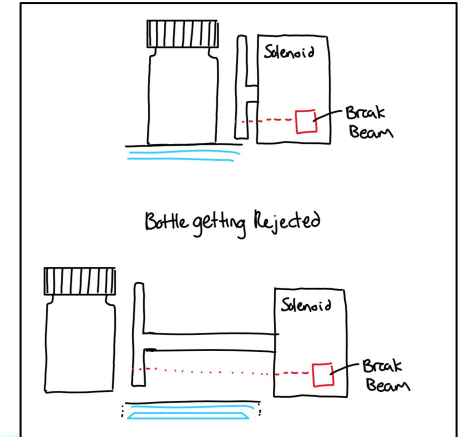
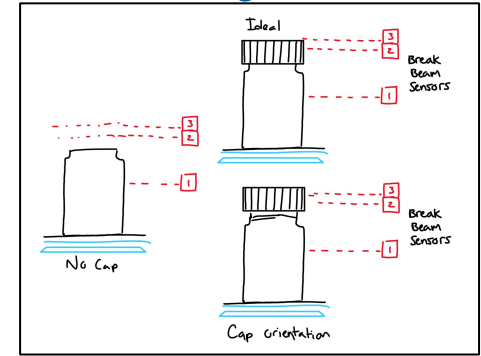
Concept Selection and Generation: Capping Station

Concept	Twister	Rotating Discs	Leading Lines
Compactness	3	1	2
Capping	3	2	1
Speed	2	1	3
Low Cost	3	1	2
Totals	11	5	8

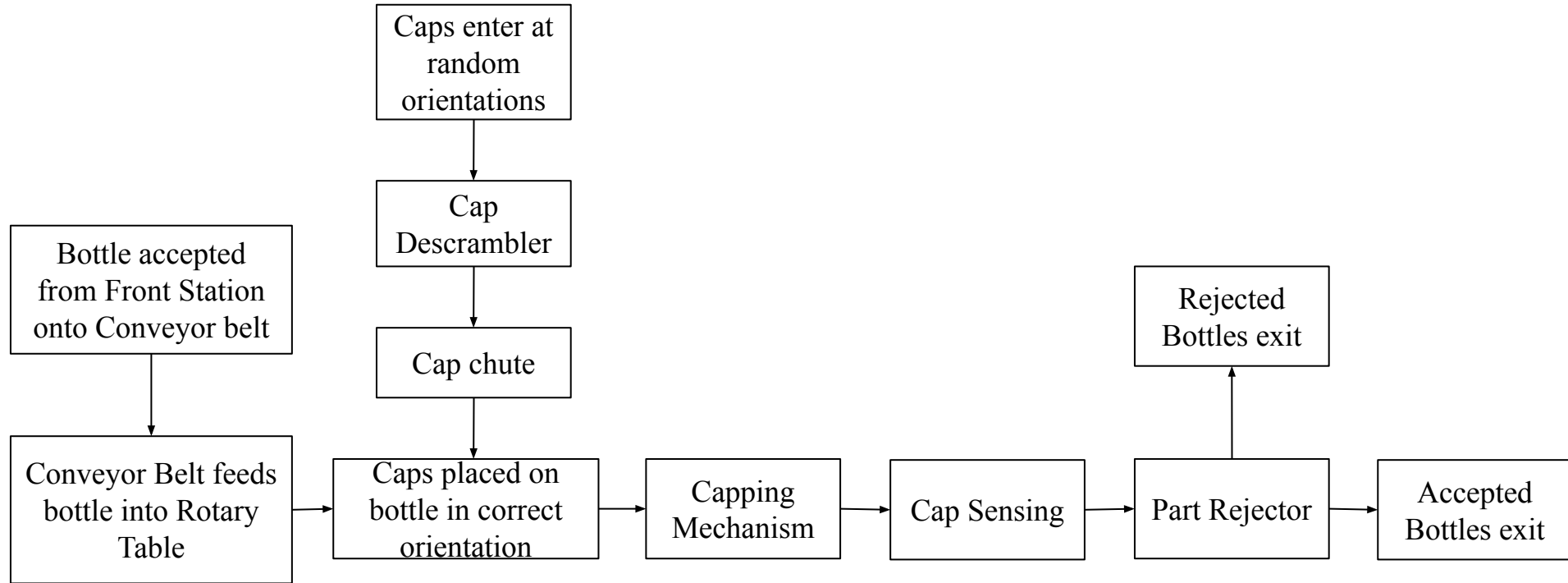


Concept Selection and Generation: Part Rejector

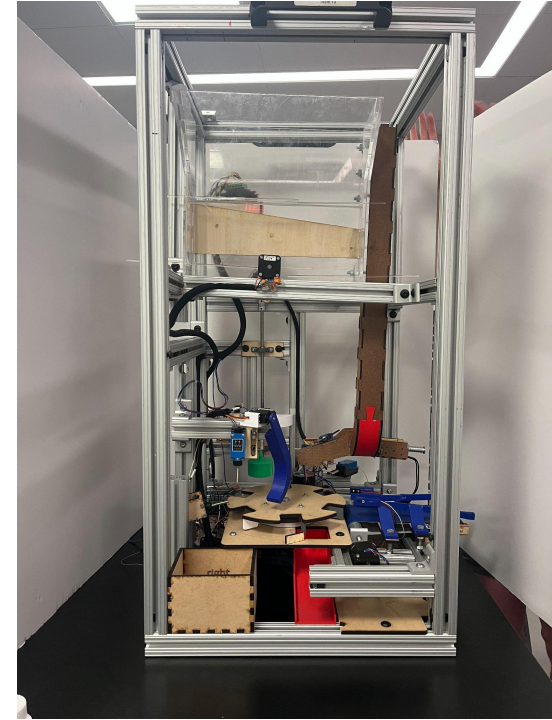
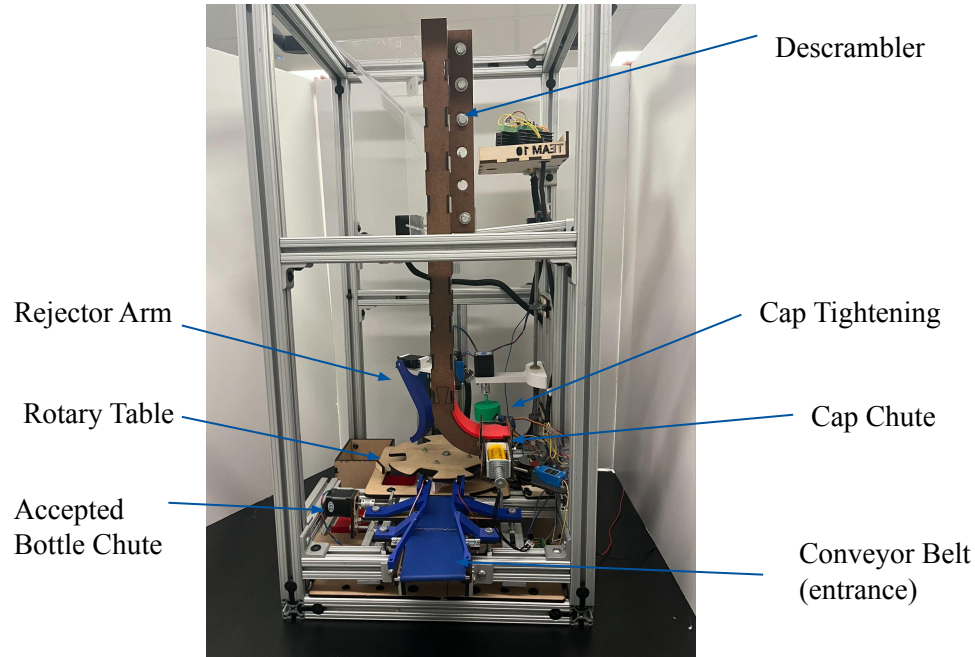
Concept	Break Beam	Solenoid	Vibration	Floor Removal	Pivot
Building Difficulty	3	4	1	2	3
Rejection / Detection	4	4	1	4	3
Speed	5	5	2	3	2
Low Cost	4	4	2	1	4
Totals	16	17	6	10	12



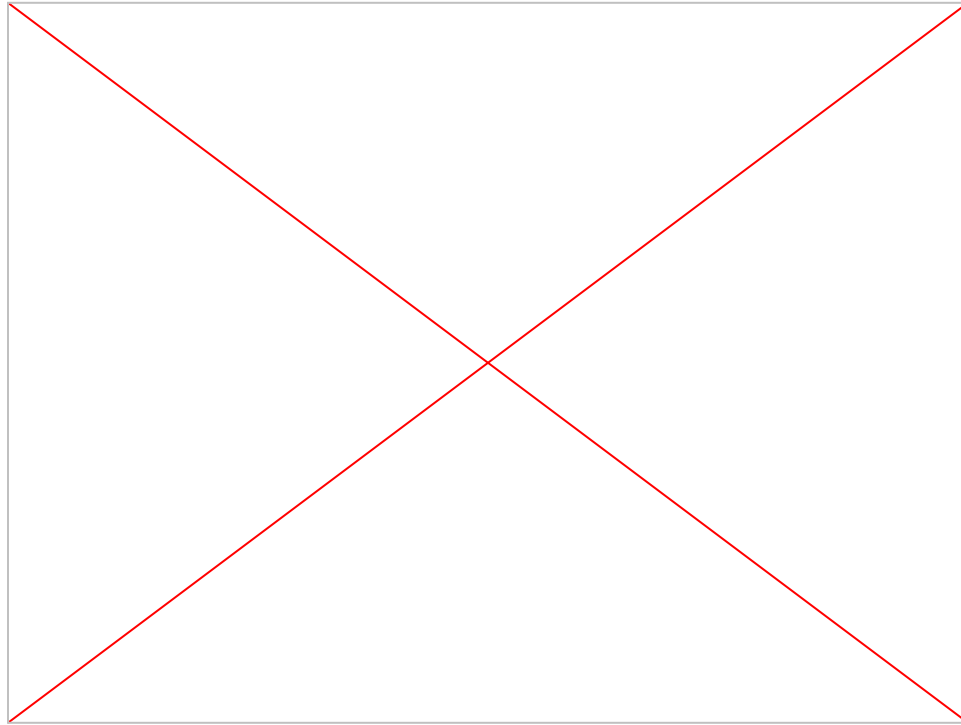
Overview of Final Design



Overview of Final Design

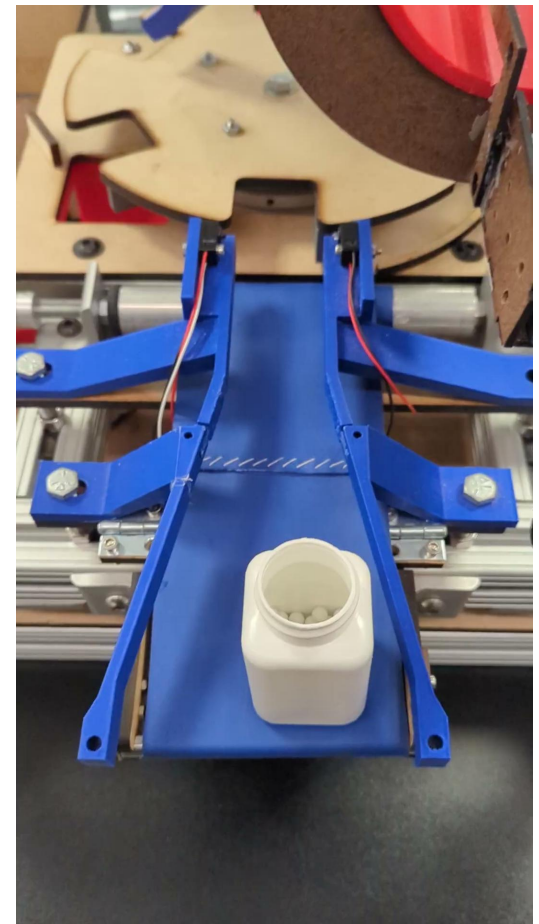


Full Automation



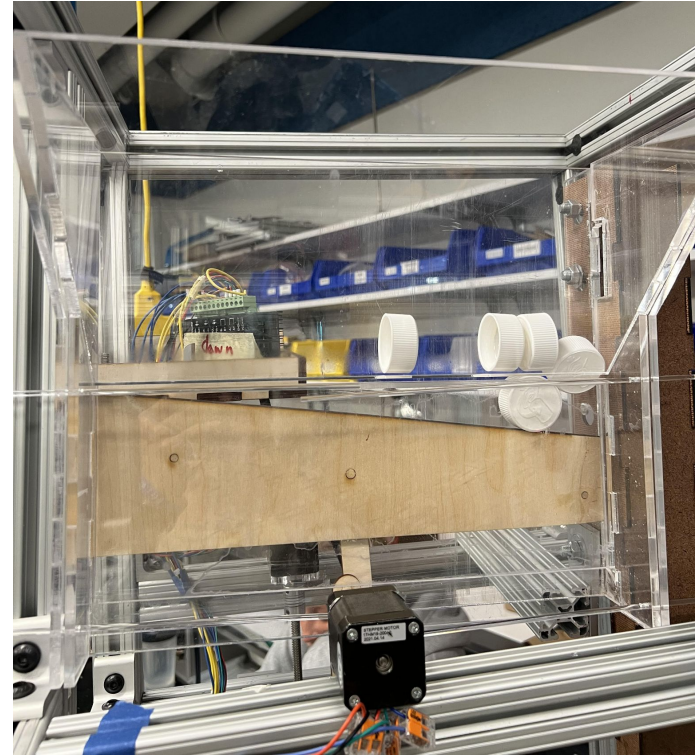
Bottle Acceptor

- Bottles are transported from the front station using a conveyor belt.
- Controlled by a single stepper motor.
- Uses guide rails to move the bottles onto the rotary table.
- Folds into the frame for transport and storage.
- Possible Failure Points: rails fracturing, bottles jamming within the rails.

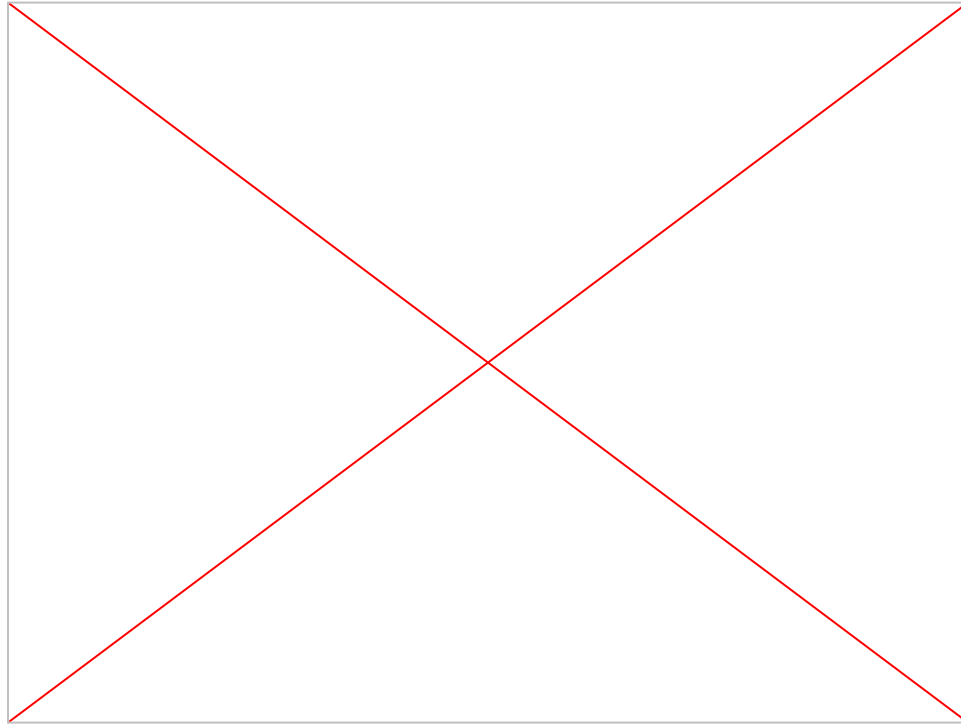


Cap Descrambler

- The descrambler uses the center of gravity of the caps to force them into a single orientation.
- Actuated by a crank-slider mechanism powered by a stepper motor.
- Capable of descrambling 12 caps.
- Possible Failure Points: shaft breaking loose, jamming, unable to descrambler caps in certain orientations.

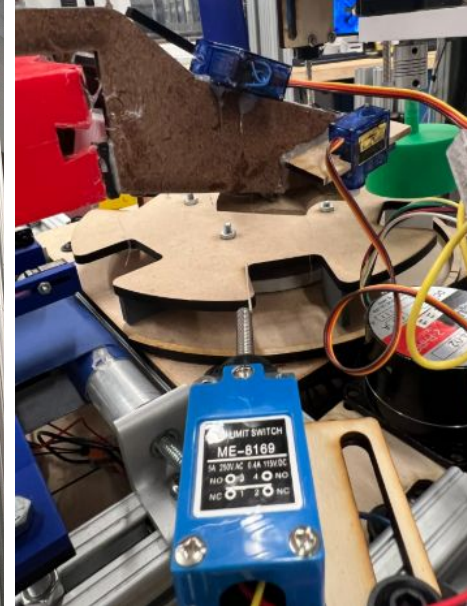


Cap Descrambler Demonstration

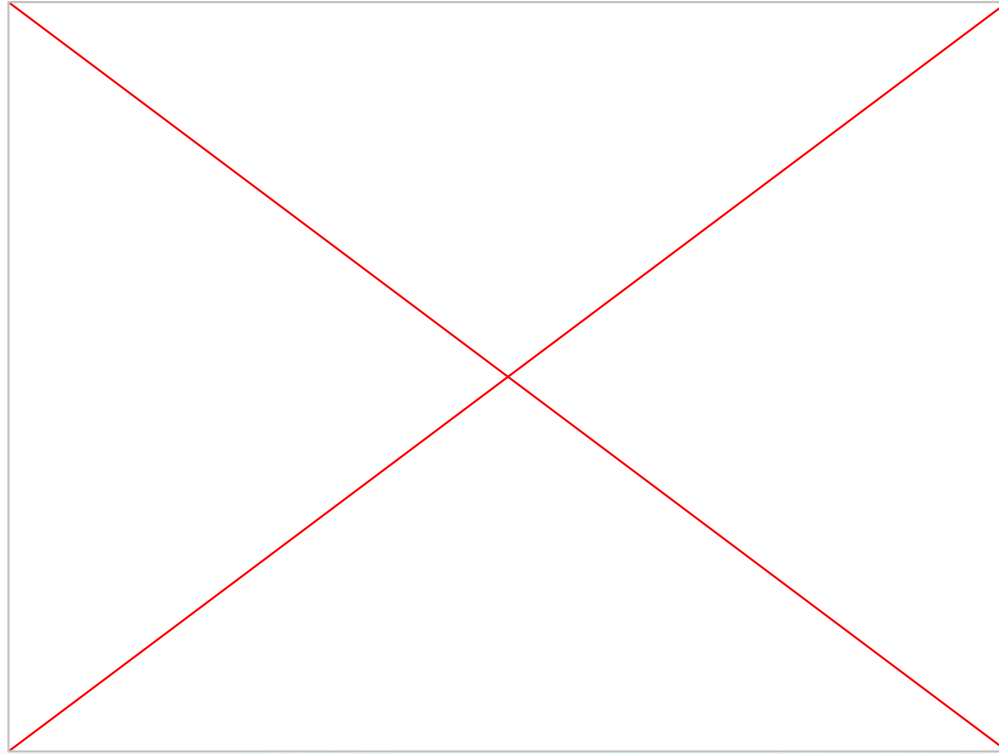


Cap Chute

- Transports caps from the descrambler to the tops of the bottles.
- Uses 12V solenoid and servo motor to place caps on one bottle at a time.
- Bottle hits whisker sensor causing the solenoid to activate and servo to activate after a time delay
- Possible Failure Points: low precision when placing caps, whisker sensor must be placed very accurately.

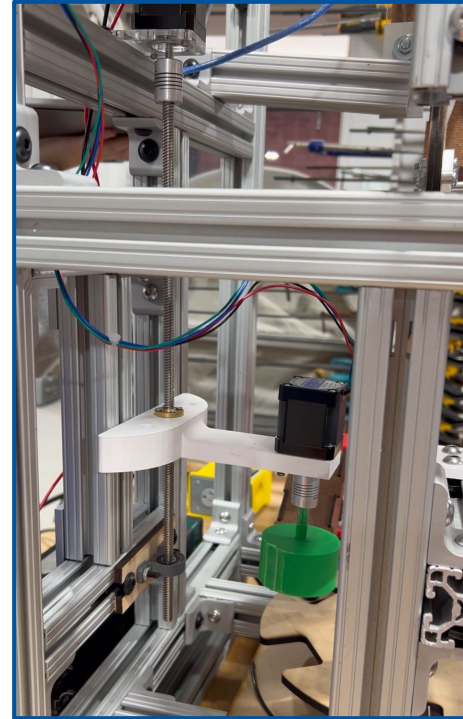


Cap Chute Demonstration

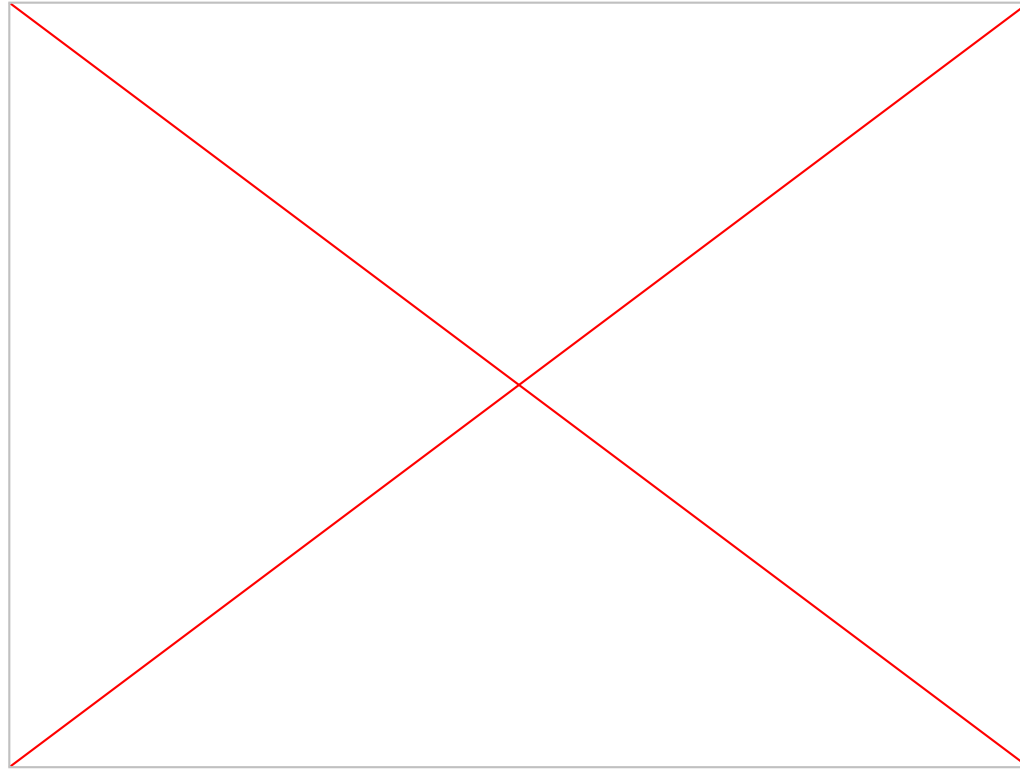


Cap Tightener

- Actively uses friction to tighten caps.
(Rubber insert)
- When system is activated by the position of the rotary table:
 - Lead screw lowers attachment 1 inch
 - 2nd Motor rotates 3 full turns
 - Lead screw brings up attachment 1 inch
- Possible Failure Points: jamming when bottles are out of position, must be properly positioned before activating

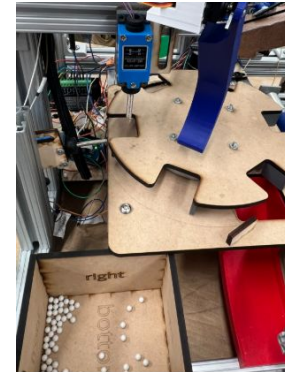
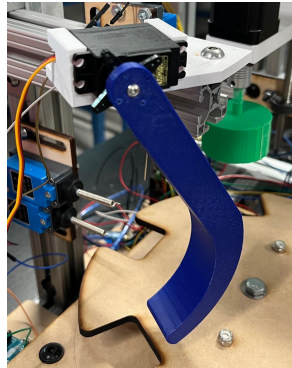
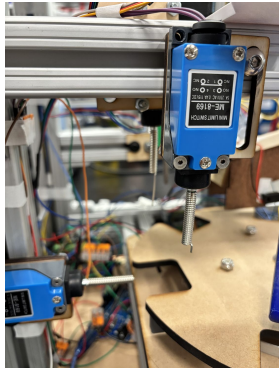


Cap Tightener Demonstration

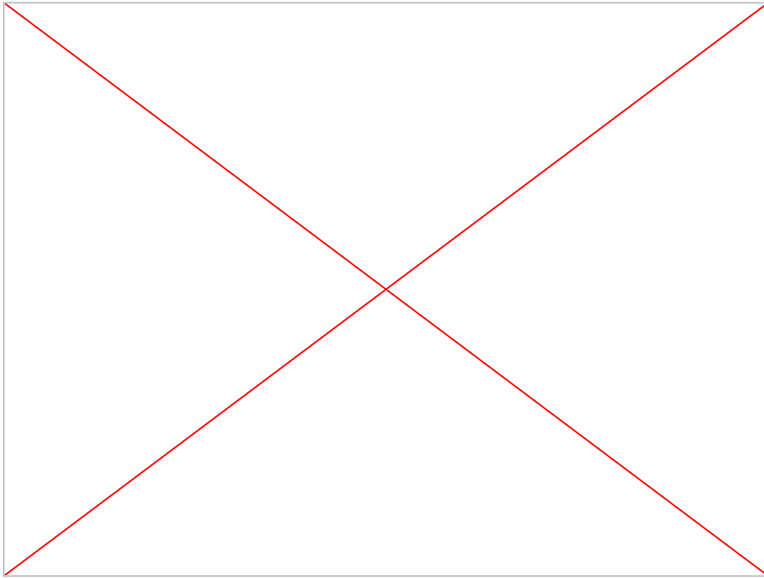


Part Rejector

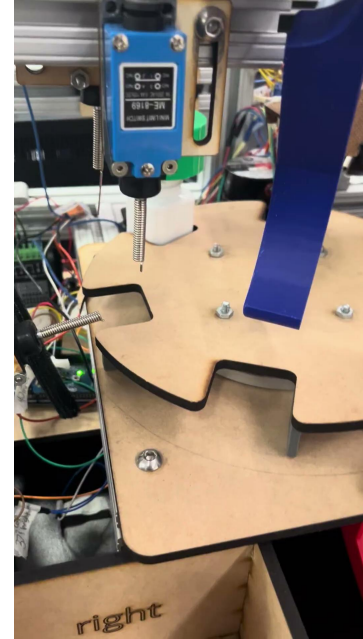
- Whisker sensors detect the presence and height of caps.
- 3D-printed arm powered by servo motor pushes unsatisfactory bottles into a discard bin at the following position.
- Acceptable bottles are allowed to pass to the end chute.
- Possible Failure Points: servo motor mounting fracture, occasional discard of acceptable bottles, whisker sensors cause resistance and disturb bottles.



Part Rejector Demonstration



Accepted



Rejected



Arduino Code

- Code has been combined from all substations into one code.
- 100% automation with one arduino.
- Emergency stop button added into the code for increased safety.
- Each subsystem is in their own function and combined to the large loop for each trial.
- The break beam triggers the start of each subsystem.



Bill of Materials

Part Name	Owner	Fabrication Method	Status	Area/Volume	Units	Price PP	Total Cost	Purpose	Other Notes/Link
Bottle Intake, Conveyance, and ETC									
Motor Bracket (General)	Olivia W	Laser Cut	Complete	3.574 in^2	3	0.1787	\$ 0.54	Allow motor to be connected to 80-20	Editable for needs of different motor lengths
Motor Bracket (Rotary Table)	Blake	Laser Cut	Complete	5.478 in^2	1	0.2739	0.2739	Allow motor to be connected to 80-20	
Rotary Table	David	Laser Cut	Complete	200 in^2	1	10	\$ 10.00	Hold and transport bottles	
Rotary Table	David	Laser Cut	Complete	200 in^2	2	10	\$ 20.00	Hold and transport bottles	
Rotary Table Gaurd	David	Laser Cut	Complete		2	0	\$ -		
Conveyor Belt Guide rails	Alex	3D Print	Complete	6in^3	2	11.76	\$ 23.52	File bottles into a single line for rotary table	
Conveyor Belt extentions	Alex	Laser Cut	Complete	5.82 in^2	6	0.29	\$ 1.74	Extends conveyor belt out past frame	
Conveyer Belt support	Alex	Laser Cut	Complete	36.8 in^2	2	1.84	\$ 3.68	Helps bottles from sagging down on convyor belt	
Accepted Bottles Chute	Blake	3D Print	Complete	4.47 in^3	1	6.71	\$ 6.71	Accepted bottles have a place to go	3.5" x 2" hole needs to be cut in base plate of rotary table
Conveyor Belt Motor Bracket	Aidan	3D Print	Complete	13.744 in^3	1	26.94	26.94	Mounting point to hold the motor that turns the conveyor belt	
Conveyor Belt Split re-print	Emma	Laser Cut	Complete	88.265	1	1.7653	\$1.77	Makes it so the conveyor belt can be compacted so it fits inside when the Plate used to mount electronics at bottom	Custom bracket for conveyor belt motor May need to be sanded down more
Bottom Plate Part 1	Aidan	Laser Cut	Complete	174.884 in^2	1	8.7442	\$ 8.74		
" " Part 2	Aidan	Laser Cut	Complete	183.898 in^2	1	9.1949	\$ 9.19	" "	
Guide Rails	Olivia L	Laser Cut	Complete	2.14 in^2	1	0.0214	\$ 0.02	Guide Rails to hold bottles on rotary table while capping	
Emergency Stop	Olivia W	Purchase	Complete		1		\$ 13.99	Project Requirement	
Wire management	Olivia W	Purchase	Complete		1		\$ 6.79		



Bill of Materials

Capping attachment			Complete							
Capping attachment	Olivia L	3D Print	Complete	3.247 in^3	1	0.55	\$	0.55	Twist on the cap of the bottle	print of PC due to its high tensile strength
Capping attachment	Olivia L	3D Print	Complete	3.7 in^4	1	1	\$	1.00	Twist on the cap of the bottle	print of PC due to its high tensile strength
Bearing Bracket	Olivia W	Laser Cut	Complete	5.227 in^2	2	0.26135	\$	0.52	allow bearings to be connected to the 80-20	
Second Motor holder	Emma	3D Print	Complete	9.807 in^3	1	1.43	\$	1.43	To hold the second motor on the lead screw	
Bearing	Olivia W	Stock Components	Complete	---	2	---	---	---	Hold Lead Screw in Place	
Motor	Olivia W	Stock Components	Complete	---	1	---	---	---		
Motor	Olivia W	Purchase	Complete	---	1	---	\$	13.99	Screw on Cap	Amazon Link
Lead Screw	Olivia W	Stock Components	Complete	---	1	---	---	---		
Break Beam Sensor	Olivia W	Stock Components	Complete	---	1	---	---	---		
Rubber Attachment	Olivia L	Purchase	Complete	---	1	---	\$	5.29	Friction to twist on cap, will be inside the capping attachment	Amazon Link
Electronics Box Base	Olivia W	Laser Cut	Complete	43.127 in^2	1	2.1585	\$	2.16	Hold electronics	
Electronics Box Side 1	Olivia W	Laser Cut	Complete	7.5 in^2	1	0.375	\$	0.38	Hold electronics	
" " Side 2	Olivia W	Laser Cut	Complete	7.5 in^2	1	0.375	\$	0.38	Hold electronics	
" " Side 3/4	Olivia W	Laser Cut	Complete	10 in^2	2	0.5	\$	0.50	Hold electronics	
Cap Descrambler										



Bill of Materials

Cap Descrambler									
Descrambler Body - back panel	Mickey	Laser Cut	Complete	184 in^2	1	9.2	\$	9.20	Contain caps during descrambling
Descrambler Body - front panel	Mickey	Laser Cut	Complete	79.6 in^2	1	3.98	\$	3.98	Contain caps during descrambling
Descrambler Body - inner front panel	Mickey	Laser Cut	Complete	78.0 in^2	1	3.9	\$	3.90	Keeps caps upright when on cap platform
Descrambler Body - right panel outer	Mickey	Laser Cut	Complete	59.7 in^2	1	2.985	\$	2.99	Contain caps during descrambling
Descrambler Body - right panel inner	Mickey	Laser Cut	Complete	35.0 in^2	1	1.75	\$	1.75	Contain caps during descrambling and hold interface in place
Descrambler Body - left panel outer	Mickey	Laser Cut	Complete	43.5 in^2	1	2.175	\$	2.18	Contain caps during descrambling
Descrambler Body - left panel inner	Mickey	Laser Cut	Complete	36.0 in^2	1	1.8	\$	1.80	Contain caps during descrambling and hold interface in place
Descrambler Body - ramp	Mickey	Laser Cut	Complete	120.75 in^2	1	6.0375	\$	6.04	Slide the caps onto the descrambling platform
Descrambler Platform	Mickey	Laser Cut	Complete	67.4 in^2	2	3.37	\$	6.74	Actuates up and down to descramble the caps
Lightweight Platform - Outer	Mickey	Laser Cut	Complete	68.4 in^2	3	3.42	\$	10.00	Actuates up and down to descramble the caps
Lightweight Platform - Inner	Mickey	Laser Cut	Complete	28.6 in^2	3	1.43		\$5.50	Actuates up and down to descramble the caps
Descrambler Cam Drive	Justin Sim	Laser Cut	Complete	27.34 in^2	1	2.734		2.73	Drives the descrambler up and down
Cam Drive Shaft and Mount	Justin Sim	Machine Shop	Complete		1	15		15	Attaches Cam lobe to Motor Coupler
Cap Descrambler Chute	Justin Sav	3D Print	Complete		1	39.2784		39.28	Moves the caps to the bottle
Solenoid	Mickey	Purchase	Complete		1	16.99		16.99	Dispense the caps from the chute to the bottles
Chute vertical shaft	Justin Sav	Laser Cut	Complete	156.7	1	0.05		7.835	Vertical drop in chute after descrambler
Nose Chute	Justin Sav	Laser Cut	Complete	29.15	1	0.05		1.4575	Slanted part that directly puts caps on bottle
Curved section Chute	Justin Sav	3D Print	Complete	5.48	1	1.96		10.7408	Curved Section to deliver caps
Solenoid Housing	Justin Sav	Laser Cut	Complete	16.7	1	0.05		0.835	Housing for mounting solenoid at base of chute
Cap Chute Bottom Piece	Justin Sim	Laser Cut	Complete	4.2	1	0.05		0.21	New cap chute
Cap Chute Top Piece	Justin Sim	Laser Cut	Complete	6.87	1	0.05		0.3435	new cap chute with slot for servo arm
Cap Chute Servo Mount	Justin Sim	Laser Cut	Complete	1.01	1	0.05		0.0505	mount for new servo for swing arm
Cap Chute End Stop	Justin Sim	Laser Cut	Complete	1.17	1	0.05		0.0585	Stops caps from sliding out of chute
Cap Chute Swing Arm	Justin Sim	Laser Cut	Complete	3.23	1	0.05		0.1615	Holds caps and opens when a bottle is below

Currently Assuming 100% Infill

Currently assuming 100% infill

Try to meet requirements for acrylic use

Part has been made in CAD, need to 3D print bottom part, and laser cut vetical chute

[Link](#)

Was originally planned as a unique part, but was attached to the chute.

Bill of Materials

Part	Rejection	David	3D Print	Complete	6.17 in^3	1	\$	1.00	1	Kicks out rejected bottles	
Rejected Bottle Arm	David	3D Print	Complete	2.1 in^3	1	0.24	\$	0.24		Mounts servo in correct position to kick out rejected bottles	Going to be a wierd angle
Servo Mount	Blake	Purchase	Complete		2	9.99	\$	19.98		only need 2, will need to add 3d printed arm to have it work	
Whisker Sensor	Blake	Laser Cut	Complete	4.597 in^2	2	0.22985	\$	0.46		Mounts whisker sensor onto frame	
Whisker Sensor Mount	Blake	3D Print	Complete		1	1.11	\$	1.11		Remove accepted bottles from table	
Accepted Bottles Chute	Nick	Machine Shop	Complete	60 in^2	1	3	\$	3.00		Catch unwanted bottles. eliminate spilling	
Rejection Bin	Nick	3D Print	Complete							Hold Bottles in place for sensors	
Guide Rail											
Stock Parts											
80-20 Rails		Stock Components	Complete	37'-4"							
80-20 L brackets		Stock Components	Complete		25						
Metal Tube - for convayer belt		Stock Components	Complete	d = 1in, L = 7in	2						
Bearings - for convayer belt		Stock Components	Complete	id = 5/16, od = 7	4						
Last Semester Costs		Laser Cut	Complete				\$	5.02			
Rotary Table 1/4"-20, 4in bolt	David	Stock Components	Complete		1					Connect the top of the rotary table to the motor under the base	
Rotary Table M5 bolts	David	Stock Components	Complete		8					Connect the base and top of the rotary table	



Budget

Currently Spent :
\$341.42

- Online Order: \$77.03
- Laser Cut: \$133.88
- 3D Print: \$113.00
- Machine Shop: \$18.00

Remaining:
\$158.58

Cost of Unused Material:
\$46.48



Project Management

- Divide labor based on the team members' strengths and areas needing improvement.
- Organized communication through GroupMe messaging.
- Regular team meeting once a week and subgroup meetings for specific tasks.
- Documents are file-organized using Google Drive for live updates.
- Shared commitment to clear communication when being late or absent.
- Aim to finish assignments a few days before due dates.



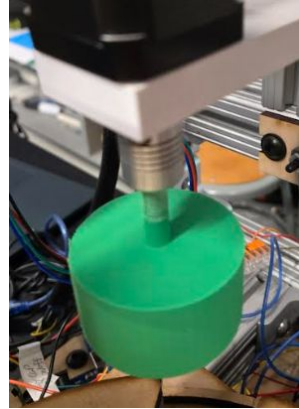
Bottle Capping Device (Back Station)

[illegible]

Mechanical Failure Analysis Overview



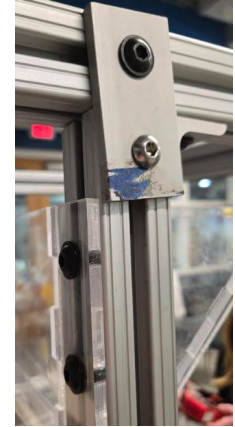
Whisker Sensor
Bracket



Tightener
Motor Shaft



Descrambler Motor
Shaft



Descrambler
Bracket



Fatigue Life - Descrambler Motor Shaft

- The motor shaft on the descrambler is made of a $\frac{1}{4}$ in, 1.375in long wooden dowel.
- The mass of the slider and the torque from the motor generate stress on the shaft.
- The driving torque is 0.28 N-m, and the mass of the slider is 0.25 kg.
- This generates a mean Von Mises stress of 11.2 MPa, and an amplitude of 8.14 MPa.
- Yield factor of safety is 1.7, and infinite life factor of safety is 0.95 from Goodman criterion.
- The shaft will not yield or fracture, but its life is finite.
- Insufficient data on wood to calculate number of cycles to failure.
- From the factor of safety, the lifetime is expected to be close to 1 million cycles.



Completed Testing

MANUAL FILLING:

- One person fills a bottle with exactly 30 pills
- Puts cap on and tightens
- Repeat for 12 bottles

RESULTS:

- Average total time - 5:24
- Average time per bottle - 0:28

AUTOMATED FILLING:

- 12 bottles are sent through back station

RESULTS:

- Average total time - 2:30
- Time for first bottle - 0:47
- Rotation time - 0:10
- Average time per bottle - 0:15



Validation of Constraints

Want/ Constraint	Metric	Target Value	Measured Value	Pass/Fail
Bottle Handoff	# Bottles Collected successfully	12 Bottles collected successfully	Maximum = 12, Average = 12	Pass
Cap Descrambler	# Caps Descrambled successfully	12 Caps successfully descrambled	Maximum = 12, Average = 4	Fail
Capping	# Caps successfully capped	12 Caps successfully capped	Placed on Bottle = 1 Tightened = 12	Fail Pass
Part Rejector	Must detect if cap is screwed on the bottle correctly, if not the bottle must be removed from the assembly line	No operator intervention is needed as well as must detect EVERY cap that is not screwed on properly	Successfully Rejected Maximum = 12, Average = 11	Pass
	Height of bottle	Cap must be within a certain range to not be rejected.	Successfully Allowed Through: Maximum = 12, Average = 11	
Automation	Must be fully automated	No operator intervention is needed while each station is functioning	Can be completed without intervention	Pass
Speed of 'Back Station' Process	Time	1/2X manual completion of process.	Process Time = 40 seconds 1/2X time of manual process	Pass
Compact	Dimensions of all components when not in use	All materials fit in 26" x 20" x 40" storage area.	Volume = 26" x 20" x 40"	Pass



Validation of Wants

Priority	Want/ Constraint	Metric	Target Value	Measured Value	Pass/Fail
1	Safety	OSHA Transport requirements	Fits within OSHA standards (29 CFR 1910.147, 212, 217)	Complies with OSHA Standards	Pass
		ISO and ASTM safety Standards	Fits within the given standards (ASTM E3106, etc.)	Complies with ASTM Standards	Pass
2	Pill Spillage	Number of pills leaving bottles during 'Back Station' process	Minimal error +/- 1 pill from nominal value	0 pills spilled during process	Pass
3	Minimize Cost	Cost (\$)	20% less than given budget (\$400)	\$341 Spent	Pass
4	Minimal Product Waste	Product waste (lbs)	< 5 lbs Product waste	3 lbs of Product Waste	Pass
5	Ease of set up	# People Required to Set up	2 people	Requires at least 2 team members to operate	Pass



Proposed Improvements

- Update Code
 - Most issues with cap chute and part rejector came from the code
 - Descrambler and rotary table can be made more consistent
 - Use gears instead of a belt
- Revise or replace cap chute
 - Add more support to prevent vibrations
 - Replace trap-door with a more precise mechanism
- Replace wooden/hardboard parts with metal, plastic, or acrylic
- Replace descrambler motor to increase torque



Acknowledgments:

Professor Adam Wickenheiser
Omega Design
Norwalt Design
Alex Abrams
Design Studio Staff and TAs

Thank you!