SourceAmerica Design Challenge
Accessible Kitting and Packaging Station

Final Design Review (FDR)

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Abstract

This document entails our research, design, proposed development, and testing process for solving the 2020 SourceAmerica collegiate design challenge. Our team, “Just Kitting”, is composed of four Mechanical Engineering students from California Polytechnic San Luis Obispo. The design challenge requires us to create a device that will help improve the quality of life and productivity of people with disabilities working in the kitting and packaging industry. This document includes our background research and information received from various interviews with our sponsor and others who have experience working with disabilities. Using this information, we refined our problem statement to focus on individuals with disabilities that affect their fine motor skills because many procedures in the kitting and packaging industry are heavily reliant on the dexterity of the user. We tailored our ideation process, decision matrices, concept prototypes, and design justification around this target demographic. This process resulted in the final design of our workstation which provides an innovate and efficient way to bag and package five types of items. In addition, this design requires simple push-pull motions to reduce the dexterity required to create a kit. We have outlined our manufacturing and design verification plans to proceed with this design, along with a breakdown of our projected costs to implement a functional prototype.

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1. Introduction

Our team is named "Just Kitting" and consists of 4 members who are all fourth-year Cal Poly San Luis Obispo mechanical engineering students: Ashley Humpal, Christopher Tan, Kyle Chuang, and Keanau Robin. We are working on a project sponsored by Source America. SourceAmerica is an organization that connects people with disabilities to industry-leading products and services to increase employment opportunities. They host an annual design tournament which challenges teams of high school and college students to create a product that improves the quality of life for people with disabilities.

Our team competed in the 2021 SourceAmerica Design Challenge and specifically in the kitting and packaging event, which challenged students to create an assistive device which helps users package a combination of small, medium and large items into a bag with folded instructions. Once these basic requirements were met, our team explored secondary challenge requirements such as automation, heat-sealing the bags, ergonomics, and aesthetics.

This report consists of multiple sections that documents our complete design process. The Background section discusses the different types of research conducted such as customer, product, and research on regulations. The Objectives section discusses the needs and wants of our sponsor as well as project specifications. Our Concept Design section examines our ideation and design process. Our Final Design section details our final overall design. The Manufacturing section explains how the verification prototype was made. The Design Verification section discusses how we verified our design to meet all our specifications, our tests and results, and any evaluations or challenges we found. The Project Management section outlines our design process throughout the year and discusses what worked well and what might we do differently in future projects. Finally, the Conclusion provides a summary and reflection on the project and provides recommendations for any reader that would like to pursue this topic further.

2. Background

The first week of research consisted of understanding the process of kitting, and what factors need to be considered in this process. Kitting is often a step included in the assembly process when individual pieces of parts are delivered and assembled in presorted kits to be more efficient with item inventory. (Hanson, Robin). The kits are put into packages, assigned to a specific assembly station, and stored there (Günther). Kitting enables less time allocated for finding parts in the assembly process and reduces the time it takes for the assembler. There are two types of kitting strategies: static and traveling. In static kitting strategy, kits get sorted in small logistical areas and then get loaded and delivered to stations. In traveling kitting strategy, kits get delivered to the first station and get moved together with the assembling products (Zhou).

Kitting has several manual aspects such as material handling operations like picking parts and counting, so human error may be prevalent. In terms of quality assurance, there are many errors to look out for, such as: part identification error where the wrong part is inserted into the kit or a missing part type error where one of the key parts is just missing from the kit (Caputo). This research better helped us understand the process of kitting as well as the issues that we should look out for. It prompted us to focus on the human error side of the project and try to account for that. Specifically, we wanted to address the errors those with motor functionality issues may have and try to ease the process of kitting for them.

2.1 Customer Research

To begin our research, we met with SourceAmerica's productivity manager, Charissa Garcia, for an informational interview. She informed us that due to safety concerns amidst the COVID-19 outbreak, all design challenges have been converted to a generalized online format (Garcia). As a result, we will not develop a product for a specific company or person (as has been done in previous years), but rather, that we are designing a product to assist people with disabilities working in the kitting and packaging field as a whole. Every disability is unique which creates a challenge creating a standardized product. Because of this, we chose to focus our research on specific impairments caused by disabilities (deafness, blindness, and/or fine motor control) instead of addressing the disabilities themselves.

In an interview with Manjot Kaur, an ex-Amazon warehouse employee, she told us that the major issue that her deaf co-workers face is not so much with the physical labor of the packaging but rather the communication aspect of the job. Ms. Kaur said that unless the co-workers knew sign language, deaf employees could not communicate (Kaur). This became a major block for deaf workers, as it prevented them from being promoted to managerial positions. Since this was outside the scope of our initial project, we chose not to consider people with hearing disabilities in our target demographic.

Next, we researched people with vision impairments working in the kitting and packaging industry. Lighthouse for the Blind is a company based in Saint Louis, Missouri that employs individuals who are legally blind to work in kitting and packaging processes (STLlighthouse). About 93% of their workforce is legally blind and current accommodations include magnifying glasses, increased font sizes, and large monitors which magnify any online text. We determined that while vision impairments present an issue to these workers, reasonable solutions currently exist to help remedy the problem, so we did not consider them in our target demographic.

Finally, we researched people with disabilities that affect their fine motor control. We found that this impairment was the most common amongst assembly line workers as it encompasses such a wide range of disabilities. Additionally, there are currently no widely available products which assist people with dexterity impairments in the kitting and packaging industry, so there is a need for this product. Workers without disabilities could also benefit from this product. By eliminating the need for fine motor control, a product could increase efficiency and productivity of the user across the board.

We found that this increase in productivity is crucial to our design. In an interview with Jamie Thompson of North Bay Industries, she explained that employers that hold certificates issued under section 14(c) of the Federal Fair Labor Standards Act are authorized to pay subminimum wages to worker with disabilities that impair their productivity for the work they perform. ("14(c) Certificate Holders"). It is unsustainable for a company to employ a person operating at a fraction of the expected efficiency, which is what this act was meant to rectify since the only alternative for many of these people is unemployment. Instead, this act was met with heavy opposition as many argued that it was unfair for anyone to be paid less than minimum wage (Thompson). Jamie expressed that this pushback has essentially killed the sustainability of operating kitting and packing warehouses that employ people with disabilities, leading to many facilities closing down including North Bay Industries, who closed their kitting and packaging warehouse in 2017. Thus, if our team could produce a product that drastically improves the efficiency of workers, we might be able to save a dying market.

2.2 Product Research

The biggest roadblock facing this challenge is the wide range of users that the product will encounter. Every disability is different, which made finding comparable assistive products hard to find, especially for a niche industry like kitting and packaging. We found products that help people with disabilities and could also help in kitting. Magnifying glass that are mounted could allow people to read better (see Figure 1.), access ramps that could help people with motor issues (see Figure 2.), pressure relief cushions are designed to reduce peak pressure zones on skin, usually by spreading the patient's weight out over a larger surface area. They are often also designed to minimize 'shear' and friction' forces (see Figure 3.), and an electrically powered wheelchair to help people with limited motor ability.

Figure 1. Rectangular Magnifying Glass

Figure 2. Access Ramps

Figure 3. Pressure Relief Cushions

Figure 4. Electrically Powered Wheelchair with Postural Support

After extensive research scouring the internet for competitive products, we only found commercial products that are tangentially related to our project like the FlexQube which is an automated modular cart that is designed to improve workflow in heavy assembly lines (“Flexible Material Handling Carts”) (see Figure 5). Thus, we decided to transition our research towards previous SourceAmerica design challenges in kitting and packaging.

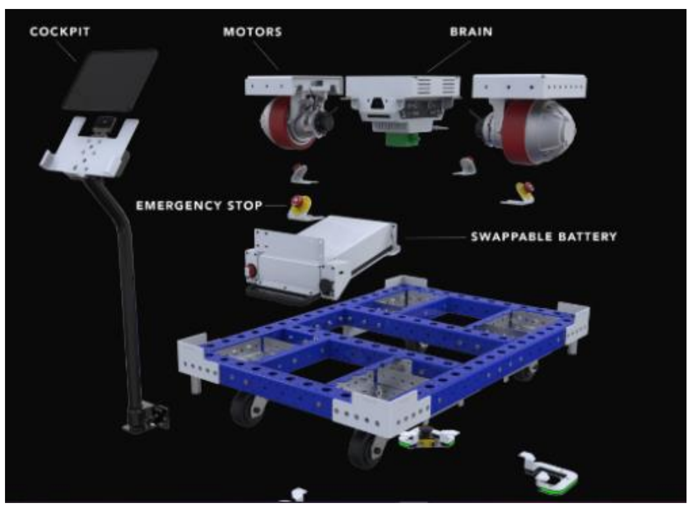


Figure 5. Summary of competitive products. FlexQube is a modular, automated cart that assists larger packaging and manufacturing operations.

We found three similar projects in “Sort-A-Screw” (see Figure 6), “The Coffee Cube” (see Figure 7), and a product for Weaver Industries ProPak (see Figure 8). “Sort-A-Screw” is a table-top screw sorting device that was developed by Copely High School. It uses premade color-coded templates to help the user sort screws. After all the items have been placed in the template, the user turns a lever which automatically consolidates them into a bag. Scales were included and used for quality control (“Sort-A-Screw Team1827-Copely High School”). We determined that this workstation will be the most comparable to the product we will develop, as it provides a simple way to sort miscellaneous parts and package them into individualized bags.

Figure 6. “Sort-a-Screw” is a desktop station that assists with kitting and packaging for different types of screws.

Figure 7. The “Coffee Cube” is an invention created to simplify the bagging process of coffee beans.

Figure 8. The sorting station was designed for Weaver Industries ProPak to assist in the production and packaging of Fomo nozzles.

The next product we found was another table-top invention by Copely High School. This device included an automated press which improved the efficiency of the kitting process. This was combined with a sorting and counting workstation that improved packing accuracy and efficiency. In total, this product doubled ProPak's productivity specifically by automating the hardest parts of the process ("SourceAmerica Design Challenge 2015-16 – Team #1503"). We may consider automation for hard parts of the kitting and packaging process, but since we do not have a direct sponsor to work with, it may be difficult to create a standardized automation process.

The last product we found was the "Coffee Cube" which was a product developed specifically for Erin Baldwin, a cashier with down syndrome from a small coffee roasting company in Westminster, MD. Erin struggled with efficiently packaging beans into bags, so this SourceAmerica team created a device which automatically measures the correct portions of coffee beans and dispenses it into a bag. As an ode to their user, the team painted their product red, which is Erin's favorite color (SIC SA #Team1814). This team showcased the importance of user-centered design in their product, which is something we must consider throughout the entire production process.

As part of the technical research, existing patents were examined to gain a better understanding of what solutions have already been presented within the general field of kitting and packaging. Since the patent research was done with a sole purpose of understanding the kitting and packaging industry, these patents do not connect to one specific solution. Instead, the patent research includes a wide variety of solutions that we examined. A list of our initial patent findings within the kitting and packaging industry is listed in Table 1.

After our initial patent research, the first patent found involved a method and system of robotic transfer devices that kit parts for manufacturing processes. Essentially, this system consisted of a robotic transfer device in between each stage of a kitting process (i.e. part supply structure, part staging structure, manufacturing kit holder, etc.).

The second patent was a 3-D printed packaging system. This patent involved designated areas for an item to be scanned and given a customized packaging model. The model was created via a computer device that took the scan of the item and transfers the model to the 3D printer. Once the 3D printer receives the model, it automatically prints the model.

Table 1. List of relevant patents.

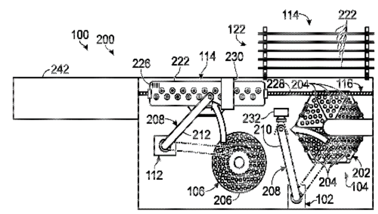
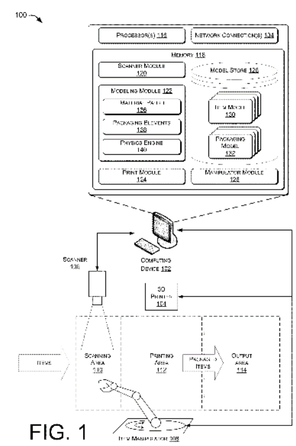
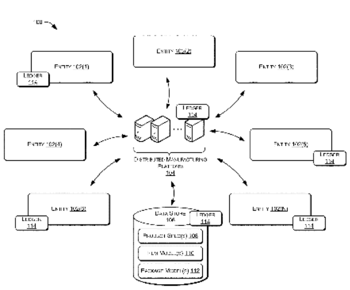
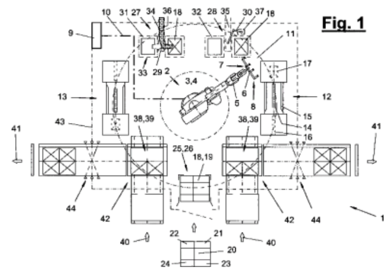
Patent Name	Patent Number	Description	Drawing
Methods and systems for kitting parts for manufacturing processes	US 20170348857 A1	This patent includes a process that starts with a robotic transfer device that transfers parts from the part supply structure to the part staging structure. Then, a second robotic transfer device transfers parts from the part staging structure to a manufacturing kit holder. This patent is specifically for kitting parts within manufacturing process (Vasquez).	
3-D Printed Packaging	US 20160122043 A1	This patent includes a scanning area, computer device, and 3D printer. So, the item first goes into the scanning area. Then, the computer device (which is communicatively coupled to the 3D printer) obtains a packaging model off of the scan of the item. Finally, the 3D printer gets that model and prints it up (Divine).	
Blockchain Enabled Packaging	US 20180096175 A1	This patent considers the entire supply chain. A distributed ledger or blockchain may be used to record transactions, execute smart contracts, and perform other operations to increase transparency and integrity of supply chain. Blockchain enabled packaging can be used to track movement and conditions of packages from manufacture, through transit, to delivery (Schmeling).	

Table 1(continued). List of relevant patents.

Patent Name	Patent Number	Description	Drawing
Packaging device	DE 202010000056 U1	This patent focuses on a filling and loading process that involves a multi-axis moveable handling device in the middle of a working/packaging area. Within its surroundings, there is a supply of foldable containers, one or more filling and/or loading stations, and one or more delivery points. Look at image in the link for a better understanding (Packaging device).	

The third patent involved a blockchain packaging system. This patent would consider the entire supply chain, not just the packaging service. The blockchain is potentially used to record transactions, execute smart contracts, and perform other operations to increase transparency between every portion of the entire supply chain.

Finally, the last patent focuses on a filling and loading process with a multi-axis moveable handling device in the center of a packaging station. Within the surroundings of the packaging station, there is a supply of foldable containers, multiple loading stations, and one or more delivery points. The central idea of this patent is the multi-axis moveable handling device that carries out majority of the packaging process.

2.3 Standards and Regulations

OSHA's (Occupational Safety and Health Administration) policy regarding the employment of individuals are:

1. If an employee can perform their job function in a manner which does not pose a safety hazard to themselves or others, the fact they have a disability is irrelevant.
2. To strive for working conditions which will safeguard the safety and health of all workers, including those with special needs and limitations.

OSHA's general safety regulations include:

1. Proper work practices are factored into determining the time requirements for an employee to perform a task.
2. Employees performing physical work have adequate periodic rest breaks to avoid fatigue levels that could result in greater risk of accidents and reduced quality of work.
3. Newly hired employees receive general ergonomics training and task-specific training.

OSHA's materials handling safety include:

1. Loose/unboxed materials which might fall from a pile are properly stacked by blocking, interlocking, or limiting the height of the pile to prevent falling hazards.
2. Bags, containers, bundles, etc. are stored in tiers that are stacked, blocked, interlocked, and limited in height so that they are stable and secure to prevent sliding or collapse.

3. Storage areas are kept free from accumulation of materials that could lead to tripping, fire, explosion, or pest infestations.
4. Excessive vegetation is removed from building entrances, work, or traffic areas to prevent possible trip or fall hazards due to visual obstructions.
5. Covers and/or guardrails are provided to protect personnel from the hazards of stair openings in floors, meter or equipment pits and similar hazards.

ASTM (American Society for Testing and Materials) packaging standards states:

> ASTM's paper and packaging standards are instrumental in the evaluation and testing of the physical, mechanical, and chemical properties of various pulp, paper, and paperboard materials that are processed primarily to make containers, shipping boxes and parcels, and other packaging and labeling products. These standards help to identify characteristics such as chemical content, acidity or alkalinity, tensile breaking strength, peel adhesion, and water, oil, and tear resistance, among others. Also, these paper and packaging standards help papermaking plants, packaging and shipping companies, and other producers and end-users of paper materials and products in the proper processing and assessment procedures to ensure their quality towards efficient commercial use.

OSHA’s materials handling safety include:

1. Loose/unboxed materials which might fall from a pile are properly stacked by blocking, interlocking, or limiting the height of the pile to prevent falling hazards.
2. Bags, containers, bundles, etc. are stored in tiers that are stacked, blocked, interlocked, and limited in height so that they are stable and secure to prevent sliding or collapse.
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5. Covers and/or guardrails are provided to protect personnel from the hazards of stair openings in floors, meter or equipment pits and similar hazards.

3. Objectives

People with dexterity issues in the kitting and packaging assembly line need a way to even out the efficiency gap between them and workers without disabilities since the majority of the packaging procedures require two properly functioning hands to maintain high efficiency and quality. Our project will focus on addressing this issue and creating a product that will satisfy our customer.

Our product will essentially be a workstation as shown in our Boundary Diagram in Figure 1. The boundary dictates what is outside our control (outside the dotted line) and what we have influence on. We will create a workstation that enables its user to efficiently take part in the kitting process even with motor function disabilities. As pictured in the figure, there are kitting and packaging materials in the center of the table which the user will be working with. We will create a device that will assist the user in doing kitting tasks that focus on dexterity. We have control over the components within the workstation that we design.

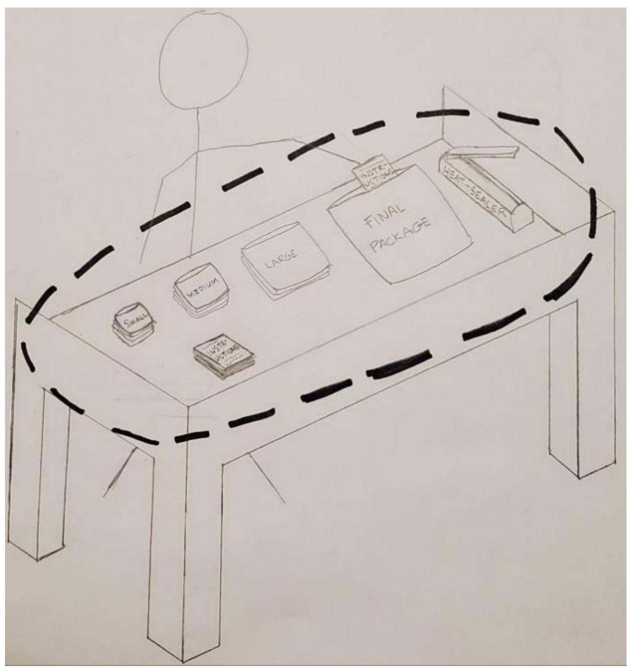


Figure 9. Boundary Diagram

3.1 Needs and Wants Table

In order to build a prototype that concisely addresses our sponsor's concerns as well as their main objectives they wanted to achieve, a needs and wants table was necessary.

Table 2. SourceAmerica Needs and Wants Table

Needs	Wants
Individual bags of items placed into one larger bag	Ease of use
Each bag is sealed then placed into a sealed larger bag	Aesthetics

Table 2(continued). SourceAmerica Needs and Wants Table

Needs	Wants
Hold two kinds of five small items	Heat sealed bags
Hold two kinds of three medium items	Robust
Hold one kind of one large item	Can be used ambidextrously or one handed
Holds paper instructions	Cheap
Labels on each bag and the larger bag	Increase Productivity
	Easy to construct
	Lightweight

Table 2 lists the needs and wants of our product from our sponsor. SourceAmerica is sponsoring this tournament which has its own requirements. Our workstation needs to hold two kinds of five small items, two kinds of three medium items, and one kind of one large item. It also has requirements of bags being placed in other bags. After conversing with Charissa of SourceAmerica we were able to identify their wants. We realized they wanted something easy to use, robust, and somewhat aesthetically pleasing, among the many other wants listed in Table 2.

3.2 QFD House of Quality

Quality Function Deployment is a way to define the problems and specifications, which are summarized in a House of Quality diagram, shown in Appendix A. The house of quality has a section for who, how, now, what, and how much, as well as sections for how these elements interact with one another. The "who" section listed the four parties that would benefit from this project: the workers without disabilities, workers with motor functionality issues, the company the product is for, and the manufacturer that will be producing this product. The "what" section described the needs and wants for the product as the customer sees them. The "how" section showed quantifiable, testable specifications that can be used to check how well the product meets the customer needs. When comparing the "how" and "what" sections, each need/want was assigned a priority based on how much the different customers would value it. The "now" section contains products that are like our projects, which were also checked against the customer needs. The "how much" section provides a target quantity for each specification. The interaction between the "how" and "how much" section comprises most of the specifications table shown in Table 3. The section between "how" and "what" shows the correlation between each specification and the customer needs.

3.3 Specifications Table

From the House of Quality, we determined what engineering specifications were required to succeed in the SourceAmerica kitting and packaging design challenge. Customer wants and needs were taken into consideration when developing the specifications. Some specifications were explicitly stated in the design challenge description as well (i.e. bag count, label check, and paper instructions on each bag). For details on which customer needs/wants to relate to each individual specification, look at the House of Quality in Appendix A.

Table 3 is the specifications table that includes the tolerance, risk level, and compliance method on top of the actual list of specifications. The risk for each specification is measured by High (H), Medium (M), and Low (L). The compliance are methods to meet the engineering specifications and are measured by Inspection (I), Testing(T), Analysis (A), and Similarity (S). Testing will be conducted as follows:

1. The bag count specifications will be conducted by testing the production on the workstation. This specification is important because the user needs to have the right number of bags as there is a specific number of required items on each different bag.
2. Label check specifications for the bags will be conducted with the workstation with a user labeling each bag. Each bag must be labeled so that customers can identify what each bag contains.
3. Item counter specifications will be conducted by testing the workstation. The workstation will have a template counter to count each item. There is a required number of specific items that each bag needs to contain to be able to be accepted for customer distribution.
4. Hold paper instructions specifications will be conducted by testing the workstation. The user of the workstation must place one paper instruction on the final bag that contains all the bags of items so that customers are able to understand and use each bags and items.
5. The survey specifications will be conducted by distributing surveys to our fellow classmates, groupmates, or any relevant users/customers. The survey is important as we want to get feedbacks on how the workstation have improved the users productivity and how to improve the workstation.
6. Heat sealed bags specification will be conducted by the workstation when we have a heat sealer implanted on the workstation. It is important for each bag to be sealed before packaging.
7. A durability test will be conducted on our product by applying a certain amount of stress onto it and observing the effects. The durability of the workstation is important because it will be hectic in the industry and the workstation needs to withstand impacts with any items or people.
8. Comparative dexterity analysis will be conducted by comparing the time it takes for workers with motor ability issues and workers without motor ability issues to complete the task using our product. We are targeting a 50% increase in efficiency, as well as a relatively small difference in time between both groups of workers. This process is similar to the Time to Complete Task specification, where we aim to have the workers complete the task within 5 minutes.
9. Cost will be calculated when purchasing each product and an estimate cost for the production cost. The cost is detrimental because if the cost is too high, there won’t be any manufacturers to make the workstation and the demand from the buyers will be low.
10. Time to complete task will be measured with the workstation. We will complete all the requirements needed to pack the final product and measure the time. We will repeat this 50 times to calculate the average time to complete the task.
11. Construction survey will be done when creating the workstation. We will create a prototype workstation and measure the time of how long it takes. The construction will be important as if it takes too long to construct the workstation then manufacturers would not be inclined to make it.
12. Weight will simply be measured using a weighing scale and making sure it is within the tolerance listed in Table 3.

Table 3. Engineering Specifications Table

Spec. #	Parameter Description	Requirement/Target	Tolerance	Risk	Compliance
1	Bag Count	4 bags	1%	L	I
2	Label Check	1 excluded bag label out of 100 bags	Max	L	I
3	Item Counter	1 excluded bag out of 100 bags	Max	L	T, I
4	Hold Paper? (Y/N)	1 excluded paper instruction out of 100 bags	Max	L	I
5	User Survey	75% Positive Reviews	Min	M	T
6	Heat Sealed Bags? (Y/N)	1 non-heat-sealed bag out of 100 bags	Max	H	I
7	Durability test	3-year life span	Min	H	A
8	Comparative Dexterity Analysis	50% efficiency increase	Min	H	T, I, A
9	Cost	$250	Max	M	A
10	Time to Complete Task	5 minutes/task	Max	M	T
11	Construction Survey	Constructable by manufacturer within 5 hours	Max	H	T
12	Weight	50 lbs	Max	M	A

4. Concept Design

This concept design chapter provides an overview of our design process. We started this process by analyzing the needs and wants listed in the design challenge and refined them through functional decomposition. Once the functions of our product were identified, we conducted numerous ideation sessions to generate designs for each function and used series of decision matrices to select our best ideas for each function. We then created multiple system concept designs which were then compared in a weighted decision matrix to select our top design. Concept prototypes were created for each subsystem to demonstrate feasibility and functionality through basic testing. Once a design direction was finalized, we created a CAD model of our design which helped us visualize the operation and workflow of the system. Finally, we considered potential concerns and hazards with our design as well as how we plan to address them.

4.1 Functional Decomposition

One of our first steps in the ideation process was a function decomposition. Functional decomposition is a set of steps in which you separate your primary function into sub-functions, which are then separated into basic functions if necessary. The main function of our project was to enable various people to kit items. This was formulated with a focus on workers with dexterity issues. In Figure 10, we organized the primary function into eight total sub-functions. Each sub-function represents a specific function within our system that is key to the overall operation of the system.

4.2 Ideation

We used a series of individual and group brainstorming in and out of lab to create multiple ideas for each sub-function. These ideas are shown in Appendix B. For these initial ideas, we carried out each idea session with no regard to the feasibility of the ideas. Each idea was either written on paper or drawn in the whiteboard feature on Zoom. We made sure to come up with at least five ideas for each sub-function, but many of the sub-functions have far more than five.

The ideation sessions consisted of individual ideation and group ideation in Zoom. For the individual ideation, each of us would spend some time out of the lab session creating new ideas for each function. For the group ideation, we conducted these sessions in lab and used the whiteboard feature to draw our ideas. We each took time to draw on the whiteboard and give brief descriptions for each of our ideas once the whiteboard was full.

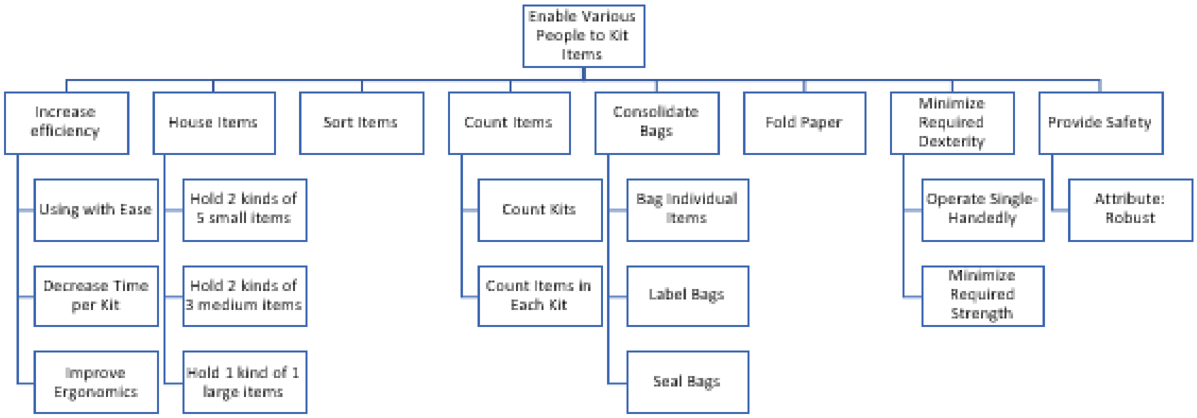


Figure 10. Functional Decomposition Function Tree

From the multiple ideation sessions, we each chose ten ideas and created concept models for each of those ideas. This process was intended to give us a better understanding of the feasibility of each chosen idea, as well as to communicate our ideas to one another. Once the concept models were created, we each chose five out of the ten concept models that we felt were more ideal, feasible, and, overall, better for our design moving forward. Each member's top five concept models are shown in Appendix C.

4.3 Pugh Matrices

We wanted a way to compare our different ideas and rate each idea per function. To do this, we created Pugh Matrices. We set one standard idea as our datum and rated the rest of the ideas as being the same (s), better (+), or worse (-) for that function. The different ratings were then added up to come up with a final score to compare which ideas were better overall. Ideas that received a rank of same were scored as 0, better as +1, and worse as –1. We learned that some ideas were great in concept but were too expensive, very delicate, or difficult to construct. We wanted a workstation that could assist the users, increase safety, and be manufacturable. We picked 3 to 5 ideas from the Pugh matrices that had a high score into the morphological matrix. There is a total of 8 Pugh Matrices in the Appendix D, one for each function in the Functional Decomposition.

4.4 Morphological Matrix

We wanted to combine all our ideas and group them by function and to do this we created a morphological matrix shown in Appendix E. It displays the various ideas for each aspect or function of the workstation. We added ideas from the Pugh matrices to each of the 8 function sections in our system, from the functional decomposition, in our morphological matrix. Full concepts for the workstation were generated from the matrix by choosing one idea in each column to create an idea sketch for the weighted decision matrix.

4.5 System Level Concept Designs

Figure 11 incorporates a top-down system with its housing and sorting systems. Items will be housed in a container and then fall through the 2-shelf sorter. Figure 11 also includes other components such as the heat sealer and paper folder that are spread throughout the workstation. After using the sorting system, the user will physically move the items to the bagging station, then to the paper folding station, and finally to the heat-sealing station. This idea incorporates all necessary components needed in the workstation; however, it is not the most efficient. Additionally, it utilizes an automated bagger which is expensive and not feasible for our design constraints.

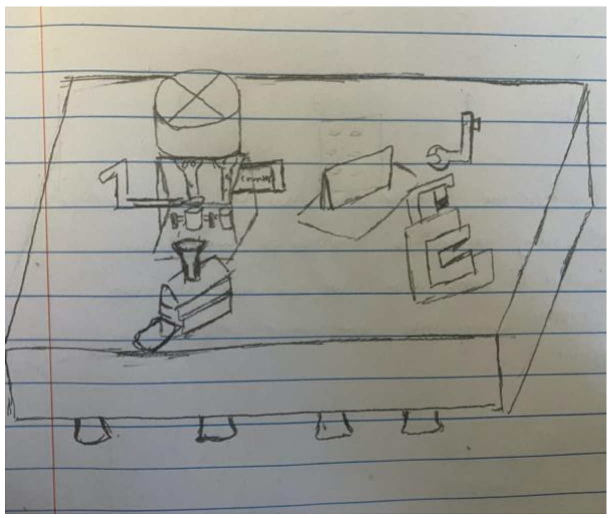


Figure 11. System concept Idea by Ashley

Figure 12, shown below, was a left to right sorter system and incorporates a template sorter to help users who cannot count. It includes a funnel where items could fall through after a foot pedal is pressed. There the users can grab each individual bag and placed them into the final bag where it will be heat sealed. There will be a rotating item holder on the right, where it will contain all the items. The idea incorporates necessary components for each function however, the workflow is a bit limited and does not increase the ease of use and does not print labels.

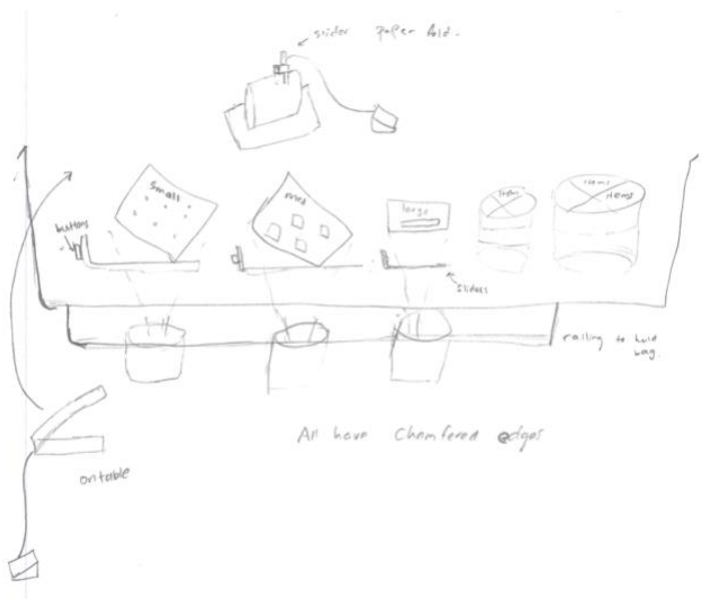


Figure 12. System concept Idea by Chris

Figure 13 includes a pinball sorter where items are sorted and slide down up until they fall into the digital scanner. The purpose of the digital scanner is to allow the user to count the items and make sure each bag holds the correct number of items. After exiting the digital scanner, the items drop into their designated bags. The bags are held by a bag grabber that is operated by a foot pedal, which minimizes the required dexterity. On the side of the workstation, there is a heat sealer operated by a foot pedal, rotatable item holder, and a paper folding device. One advantage about this idea is the top-down concept from the pinball sorter, digital scanner, and bag grabber. However, the downside to this idea is the lack of multiple bagging stations.

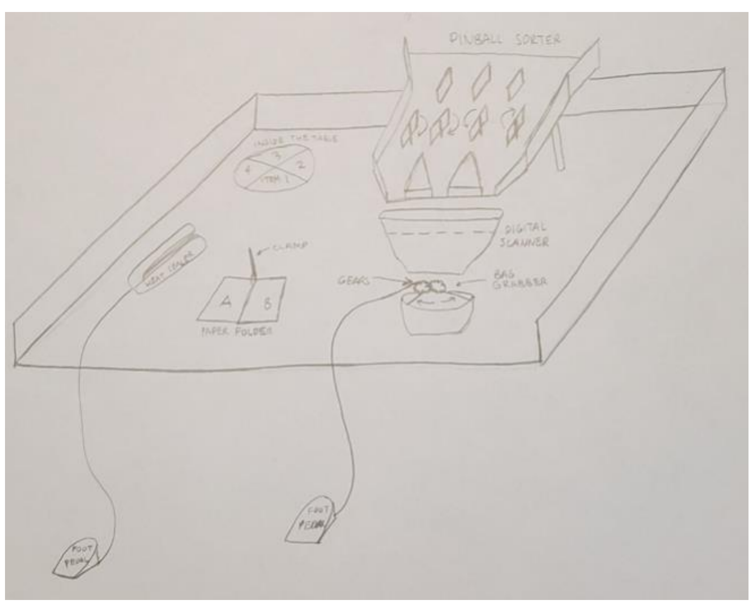


Figure 13. System concept Idea by Keanau

Figure 14 is a worktable that also features a top-down workflow similar to Figure 11 and Figure 13 with key features such as funnels and foot pedals which assist user with limited dexterity. A template sorter is located at the top of the system which assists the user in counting and holding the items. The items are then dropped into separate Ziplock bags. A foot pedal-operated roller system is used to seal the bags and is then dropped into the final bag. A similar roller apparatus seals the final bag, which is then dropped in the collection basket. A scale is used for a final test of quality control. This design efficiently bags and consolidates the items, however, it utilizes Ziplock bags instead of heat-sealed bags. Also, this design does not label bags or folding paper instructions.

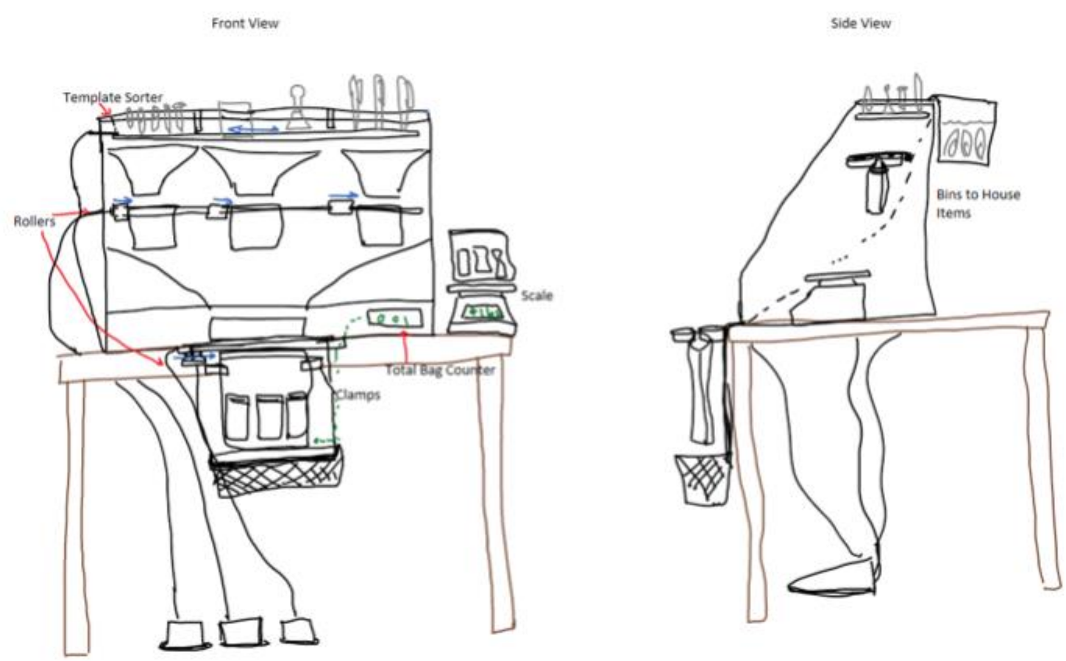


Figure 14. System concept Idea by Kyle

4.6 Weighted Decision Matrix

The purpose of the weighted matrix was to assess all our major ideas against one another to choose what would work the best. In the weighted matrix we explored four different concept system ideas and rated them on a scale 1-5 (bad to good) against our specifications. We drew our specifications from the needs and wants of our sponsor. The score was then multiplied by the allocated weight for that specification and added to the total score of the idea. Based on scores, Idea #1 ranked the best however as a team we felt that the process could be organized better and so we went with the second highest ranked idea which was Idea #4.

We decided that the Idea #4 will be able to sort items and place them on their respective bags, consolidate the bags, and seal them efficiently. It is also relatively easy to use, robust, and it will increase the productivity. However, the design is not that easy to construct and relatively heavy. We will incorporate a top-down system so that our process is much more efficient, and the user must put less effort into moving kit items. At the top we will have a sorting system that leads down to a bagging and sealing station and finally to a counter to check for quality assurance. Although this idea did not score the highest in the weighted decision matrix, shown in Table 4, we still plan on following this design direction since it makes the most sense and seems the most efficient.

Table 4. Weighted Decision Matrix

		Idea 1		Idea 2		Idea 3		Idea 4	
Specification	**Weight**	**Score**	**Total**	**Score**	**Total**	**Score**	**Total**	**Score**	**Total**
Consolidate Bags	8	3	24	3	24	3	24	5	40
Prints Label on each bag and Larger bag	7	1	7	1	7	1	7	1	7
Hold 2 kinds of 5 small items	7	5	35	5	35	5	35	5	35
Hold 2 kinds of 3 medium items	7	5	35	5	35	5	35	5	35
Hold 1 kind of large item	7	5	35	5	35	5	35	5	35
Hold paper instructions	7	1	7	2	14	3	21	1	7
Ease of Use	9	4	36	3	27	3	27	4	36
Aesthetics	5	3	15	3	15	4	20	3	15
Heat Sealed Bags	6	5	30	4	24	3	18	1	6
Robust	7	3	21	3	21	3	21	3	21
Can be used left or right handed	6	4	24	4	24	4	24	5	30
Cheap	5	3	15	3	15	3	15	4	20
Increase productivity	9	4	36	4	36	3	27	4	36
Easy to Consruct	4	3	12	3	12	2	8	2	8
Lightweight	5	2	10	3	15	2	10	2	10
Total			**342**		**339**		**327**		**341**

4.7 Concept Prototypes

Our packaging station design includes a series of subsystems that encapsulate each function of the station. These subsystems include the following: sorting system, bag holder and output device, bag opening device, heat sealing device, quality control and user interface system, and the paper folding device. Each system is crucial in the complete process of the packaging station. The subsequent sections will go into more detail regarding each system's functionality.

4.7.1 Sorting System

The sorting system consists of two identical plates with one placed above the other. Each identical plate has slots in the shape of the object that is to be placed in them. The items are placed in the top template in the holes and the bottom plate has a clamp with a tab attached to it (modeled as a wooden stick in the prototype) so that it can be shifted over. When the bottom plate is shifted over enough that its holes align with the holes of the top plate, items can fall through down the chute into the next system.

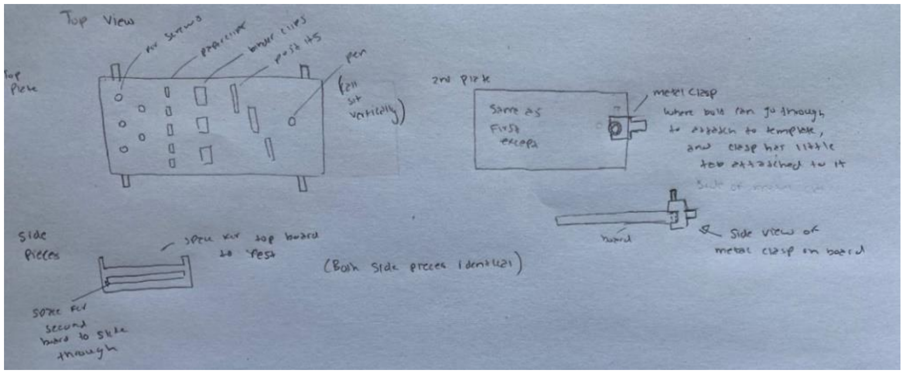


Figure 15. Sorting System Schematic


Figure 16. Sorting System

4.7.2 Bag Holder and Output Device

The bagging device will feature a pre-opened bag rolls that are already pre-made by bagging companies. The bagging device will be mounted on the back of the workstation and there will be an opening on the wall surface of the workstation that ejects the bags.

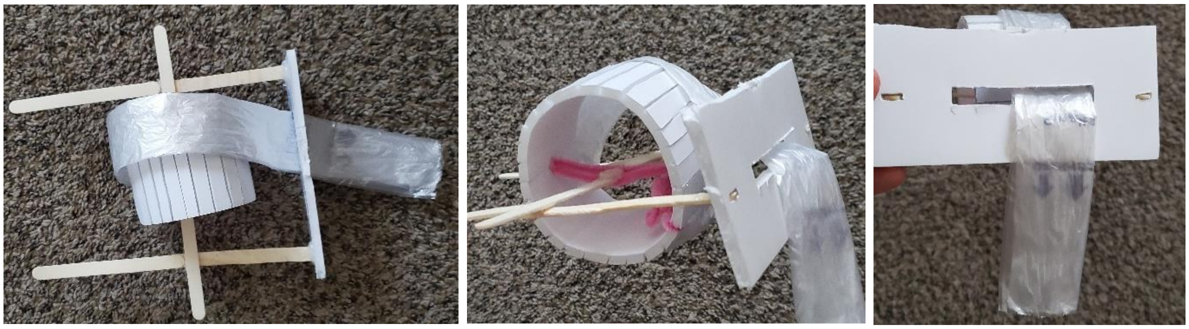


Figure 17. Bag Holder Device

4.7.3 Bag Opening Device

In Figure 18, there is a side view and isometric view of the bag opening device. In this prototype, the handle and hook device maintain a horizontal orientation due to the weight distribution of the device. Ideally, in the CAD model and the final design, this device should be in that orientation due to the stopping mechanism, not its weight distribution. Also, the length of the hook should be edited to make it align with the front side of the open end of the bag. When the bag is fully opened by the hook, the device maintains that vertical orientation due to the locking mechanism.

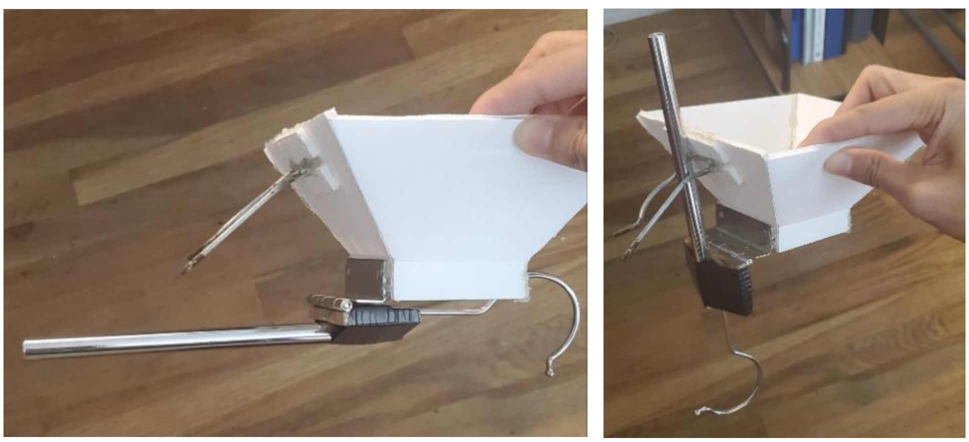


Figure 18. Bag Opening Device

4.7.4 Heat Sealing Device

The impulse heat sealer can be seen in Figure 19. On the left, the device is completely open for the bag to slide through the gap. On the right, the device is closed, which is the position it is held in once it has heat sealed the bag. Once the bag is in the gap and positioned for sealing, the handle will be pushed down by the user. Ideally, one handle will be pushed down for all five bagging stations to achieve simultaneous sealing. As can be seen, the handle and heat sealer will be connected via a pivot point, as opposed to the handle being pushed straight downwards to the heat sealer. Also, the heat sealer will be rotated into a horizontal orientation so the bag can slide into the gap.

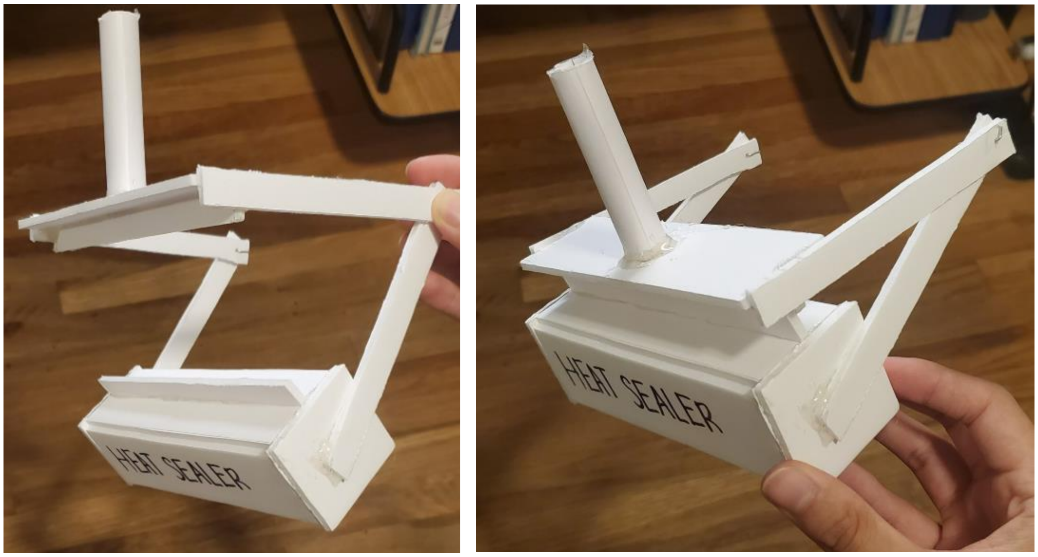


Figure 19. Heat Sealing Device

4.7.5 Quality Control and User Interface

The collection basket will feature a scale for quality control. This will send information to a display screen which will read the current weight read by the scale and will include additional information including tracking productivity of the user as well as total kit count for the user during their shift.

Figure 20. Scale Counter Device

4.7.6 Folding Paper Device

The paper would go on top of the folding surface and centered. Then, the clamp on the top would clamp down on the paper. One surface of the device would be pushed down against the paper while the clamp is pressed on top of the paper to prevent it from sliding out of the device.

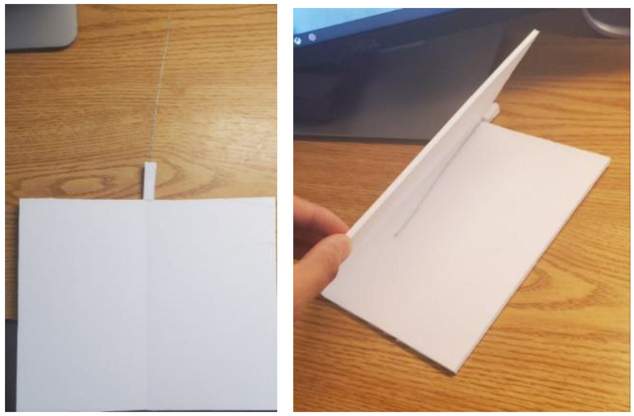


Figure 21. Folding Paper Device

4.8 Concept Design Process

Based on the weighted matrix, we decided that Idea #4 will be able to sort items and place them on their respective bags, consolidate the bags, and seal them in the most effective manner. After compiling our concept prototypes, we developed an initial concept design which incorporated a top-down system so that our process is much more efficient, and the user must put less effort into moving kit items. Figure 22 shows a picture of this design. The estimated size of this workstation is 2 ft in length, 1.5 ft in width, and 2 ft in height. More images of this CAD model are included in Appendix F.

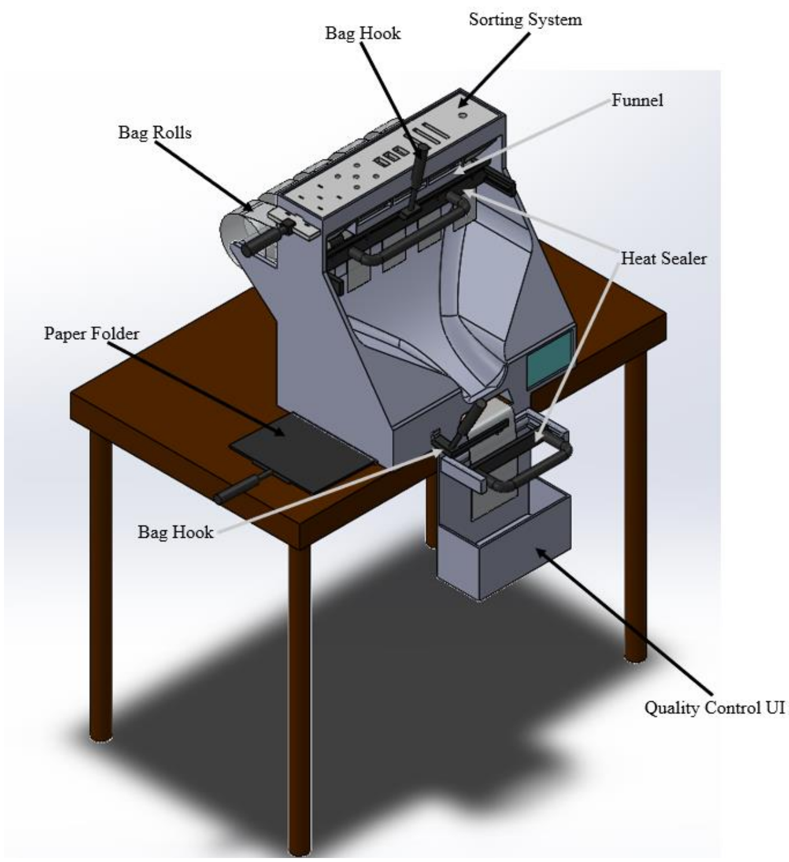


Figure 22. Isometric view of our first concept design.

We presented this design in a preliminary design review with our peers and advisor in our senior project class and received important feedback and design recommendations. A key design critique we received was regarding the height of the workstation. With the workstation sitting at 2ft tall, we had assumed that the worker would be standing during operation. Our peers recommended changing the design to accommodate users who are sitting since this is often how it is done in industry. Additionally, we learned that our proposed bag opening system was highly flawed. To open the bags, we ideally need a linear motion to pull the bag open but since this design has the hooks on a hinge, the rotational motion would be highly inefficient. We took these recommendations into account for the next iteration of our design as shown in Figure 23. This model proposed a more horizontal oriented workstation by placing the final packaging station to the right of the main body as well as condensing the height of the workstation to accommodate sitting users. This estimated size of this workstation is 34 inches in length, 11 inches in width and 12 inches in height. More images of this CAD model are included in Appendix F.

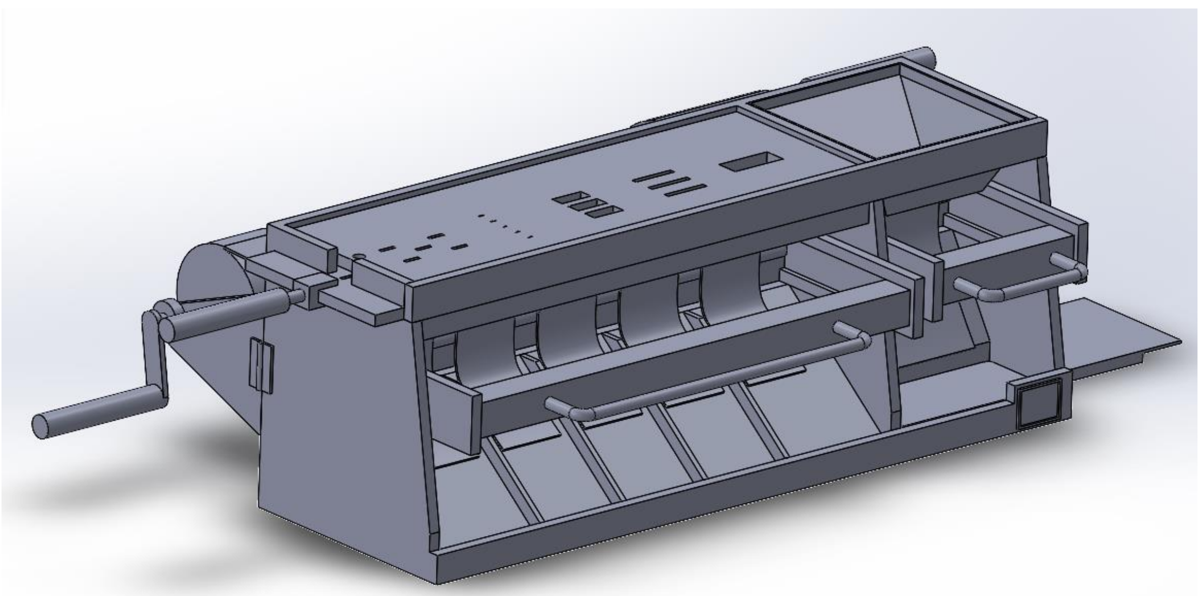


Figure 23. Isometric view of our second concept design.

We once again, presented our second concept design to our senior project class for an interim design review. Our peers confirmed that a 12" height for the workstation was sufficient for a person sitting. They also suggested adding a mirror above it to provide additional assistance which we implemented in our next design.

Additionally, our peers expressed multiple concerns related to safety and durability. Since the bags are being held off the back of the workstation, they were concerned about the workstation tipping. We conducted hand calculations shown in Appendix O which determined that the weight of the workstation would have to be 111 lbs. That weight was unacceptable for our standards. Because we did not want to constrain the user by bolting the workstation to the table, we had to consider an alternative design which moved the bag rolls from the back of the workstation to the top, above the sorting system. This design is shown in Figure 24 with more pictures shown in Appendix H.

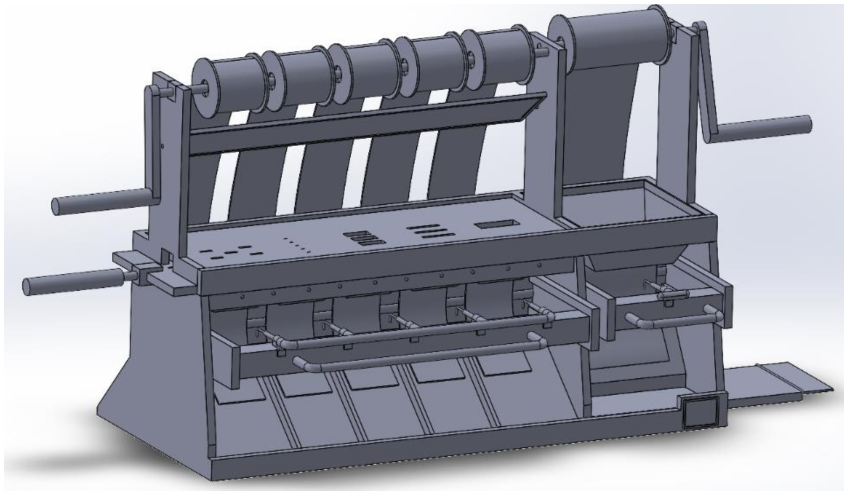


Figure 24. Isometric view of our third concept design.

This design incorporates the changes from the interim design review. The bag rolls have been moved to the top at 10” from the top of the station and centered which helps counteract tipping. Additionally, we widened the base to 15 inches. Other key features of this design include the addition of rollers attached to the workstation which help facilitate the sliding motion of the lower template plate. This design also exhibits our hooking system which we determined will be operated using metal hooks sliding through a pivoting collar.

This was our leading design until we ordered a roll of bags for testing. We severely underestimated the size of the bag rolls. In the prior iterations of our concept design, we had estimated the diameter of each bag roll to be 3”.

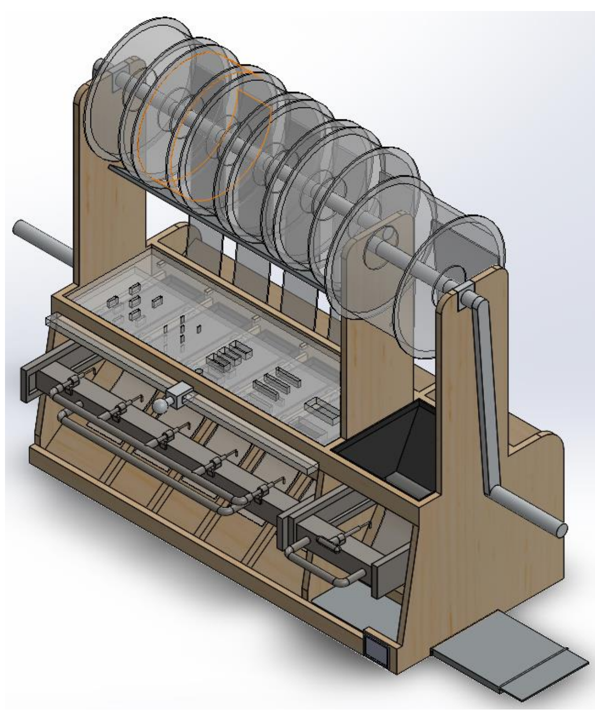


Figure 25. Isometric view of our fourth concept design.

Upon arrival, the bag roll was at a diameter of 10" which caused an issue fitting in our concept design. This design, Figure 25, had to incorporate this change by increasing the height at which the bag rolls were held up to 14.25" from the top. This added height concerned us, so we conducted additional static hand calculations to determine tipping conditions (see the hand calculations in Appendix O). From these calculations, we determined that the workstation would have to weigh a minimum of 44lbs to prevent tipping.

Additionally, we revised the height of the crank handles to 12" above the table as this seemed to improve ergonomics. This change forced us to rethink the sorting system as now the crank handles would interfere with the sorter handle. We accounted for this change by reworking the sorter to slide forwards and backwards instead of left to right. Not only did this solve the conflicting handles, but it also simplified the motion to another push/pull motion. This repetitive motion further reduces the dexterity required to operate the workstation. More pictures of the fourth concept design can be found in Appendix I.

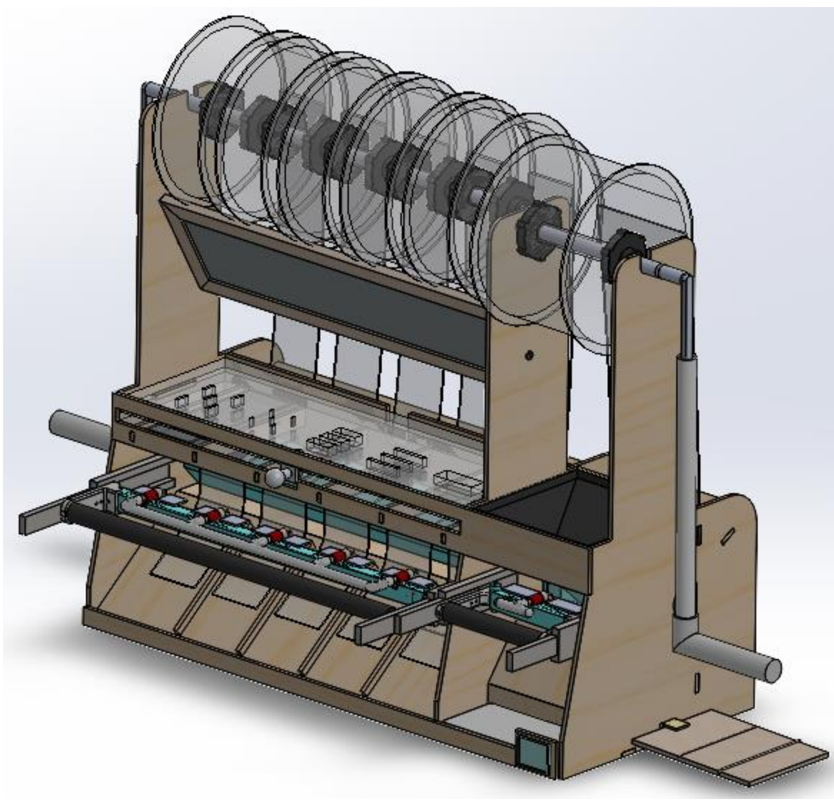


Figure 26. Isometric view of our fifth concept design

This design, Figure 26, incorporates changes to the housing of our workstation. This design will allow the housing to be attachable and detachable by using slots that are located in the housing. With this design, the workstation will be more portable. More pictures of the fifth concept design can be found in Appendix J. The final concept design will be discussed in further detail in Section 5.

4.9 Design Justification

For the ideation phase, we primarily used engineering judgement to design. Because our project is very dependent on testing, it is difficult to gain customer feedback since specific motor disability is quite important. Additionally, since our prototype has not been completed yet we are unable to run preliminary tests. However, we were able to use our judgement. Our final design includes only simple motions like a sliding and pushing so it was not necessary to do a dynamic forces analysis since the exerted force is limited. The primary arm and shoulder muscles can exert about 24lbf while people with dexterity issues can exert about 10lbf of motion. Our workstation will allow simple motion and reduce the amount of force needed as most of the motion will only allow horizontal motion or a simple lever.

4.10 Preliminary Design Risk

There are multiple risks associated with this design for the user. One risk is the heat sealer because if the user is not careful, they could hurt themselves. To prevent this, we want to use an impulse heat sealer. We decided to use an impulse heat sealer because the impulse sealer only uses a brief pulse of electricity to provide a high level of heat for a few seconds, however, the constant heat sealers provide a constant source of heat and therefore the constant heat sealers also allow for much higher levels of heat than impulse sealers because of the constant source.

Another issue is the stability of the workstation. If the user is not careful, they could accidently hit the workstation or tip it over so that it falls. To negate this risk, we will have attachable knobs to the bottom of the workstation that can be used to fasten and secure it to the table.

Table 5. Design Hazard Checklist

Y	N	
✓		1. Will any part of the design create hazardous revolving, reciprocating, running, shearing, punching, pressing, squeezing, drawing, cutting, rolling, mixing or similar action, including pinch points and sheer points?
	✓	2. Can any part of the design undergo high accelerations/decelerations?
	✓	3. Will the system have any large moving masses or large forces?
	✓	4. Will the system produce a projectile?
✓		5. Would it be possible for the system to fall under gravity creating injury?
	✓	6. Will a user be exposed to overhanging weights as part of the design?
	✓	7. Will the system have any sharp edges?
	✓	8. Will any part of the electrical systems not be grounded?
✓		9. Will there be any large batteries or electrical voltage in the system above 40 V?
	✓	10. Will there be any stored energy in the system such as batteries, flywheels, hanging weights or pressurized fluids?
	✓	11. Will there be any explosive or flammable liquids, gases, or dust fuel as part of the system?
	✓	12. Will the user of the design be required to exert any abnormal effort or physical posture during the use of the design?
	✓	13. Will there be any materials known to be hazardous to humans involved in either the design or the manufacturing of the design?
	✓	14. Can the system generate high levels of noise?
	✓	15. Will the device/system be exposed to extreme environmental conditions such as fog, humidity, cold, high temperatures, etc.?
✓		16. Is it possible for the system to be used in an unsafe manner?
	✓	17. Will there be any other potential hazards not listed above? If yes, please explain on reverse.

5. Final Design

This section considers the functionality of each of the major subsystems of our kitting workstation. It contains relevant information on part and material choice, safety, and design justification. It further discusses the overall final design and cost analysis. The final design is shown in Figure 27.

5.1 Overall Selected Design

The overall selected design for our kitting workstation focuses on creating a more efficient kitting process for people with dexterity issues. The workstation will be composed of several key components; these includes the template sorter, pre-opened bags, heat sealer, and the user interface system. All the major components and subsystems will be assembled on the housing and the final overall design will be as shown in Figure 27.

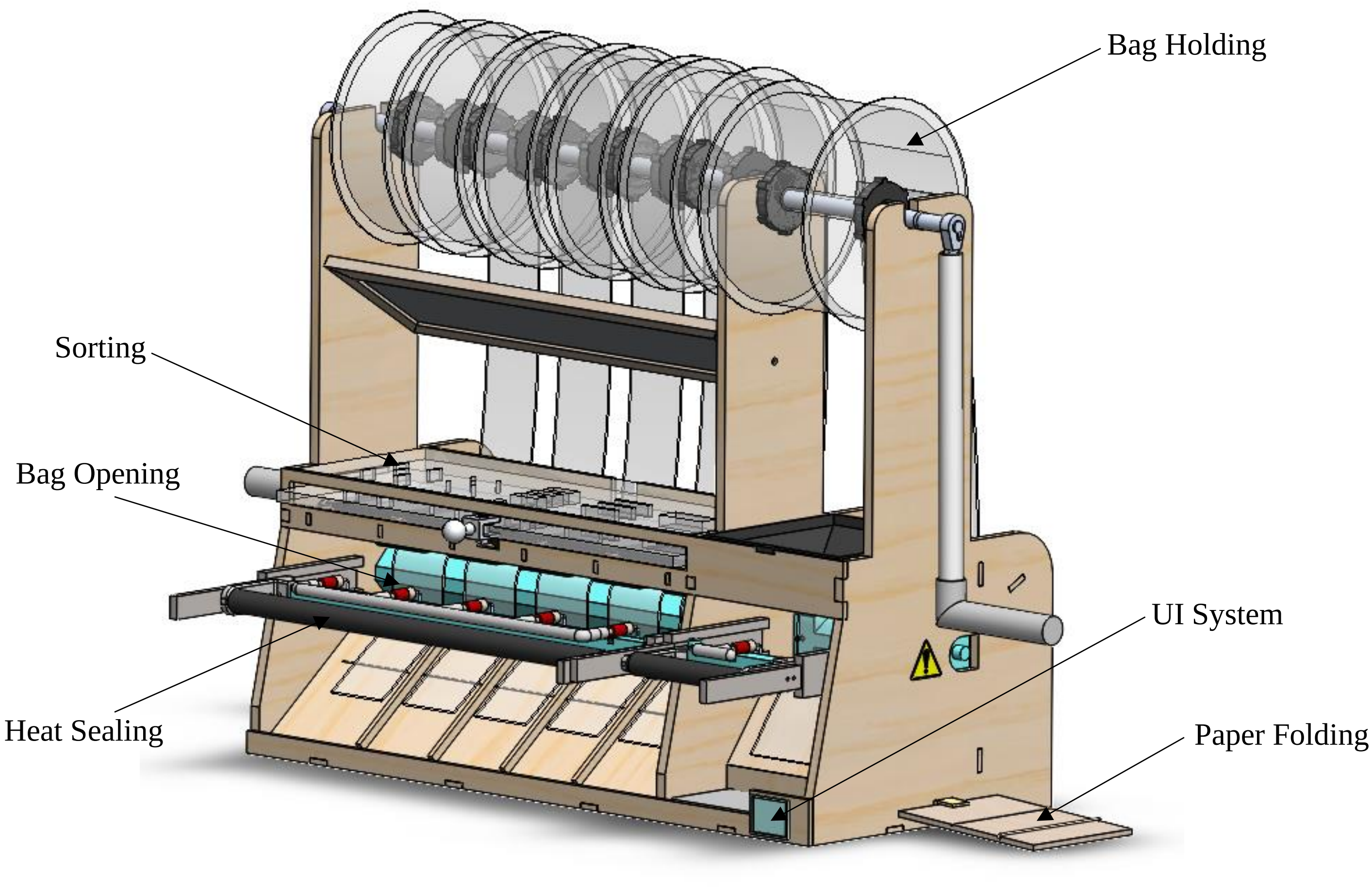


Figure 27. Overall Selected Design

The workstation consists of 5 subassemblies: sorting, bag holding, bag opening, heat sealing, paper folding, and UI system.

5.2 Major Subsystems Components

The components for each subsystem are chosen specifically for durability and cost. Each subsystem has specific components which will be explained below.

5.2.1 Housing

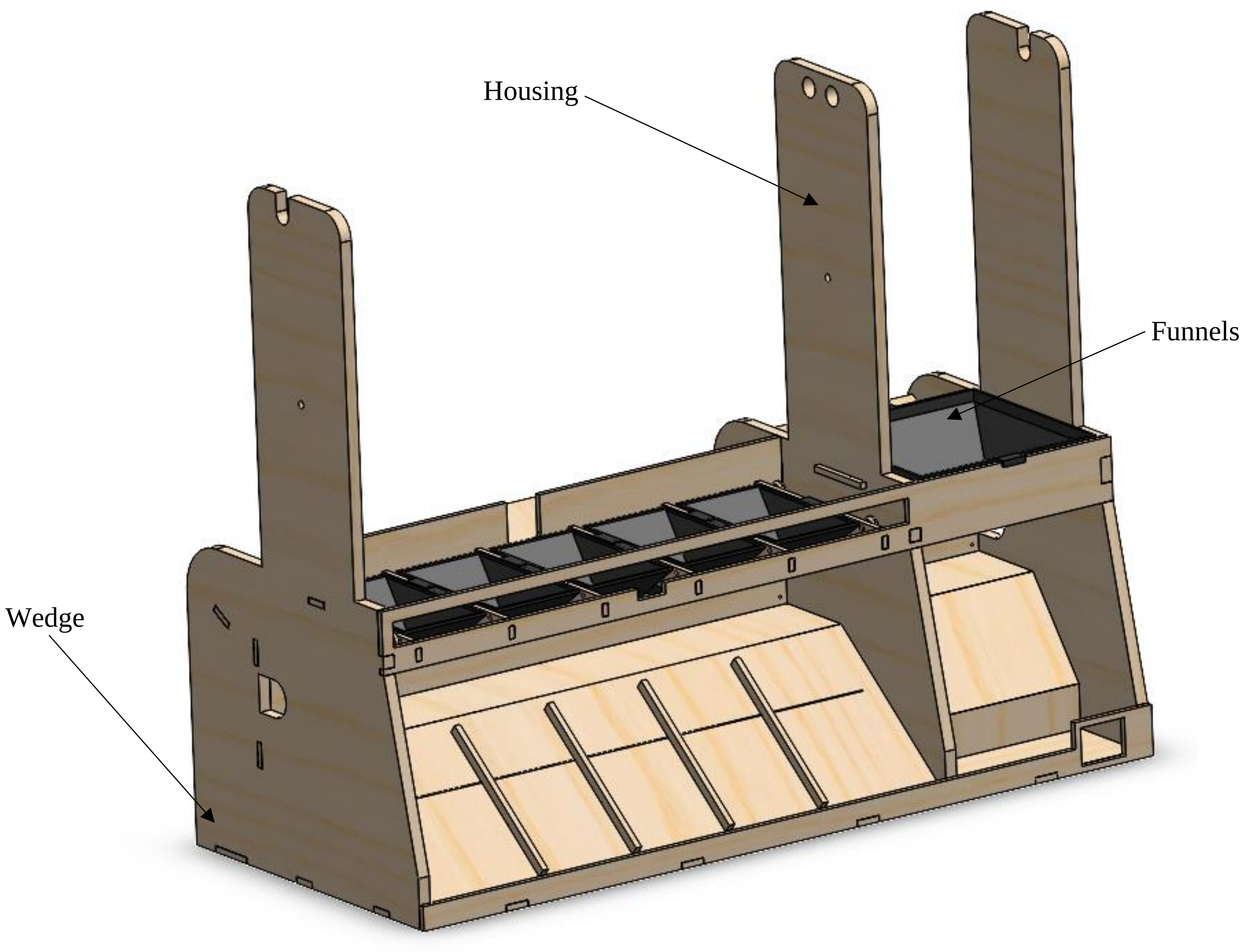


Figure 28. Housing

The housing system will house all the other subsystems and provide casing for the kitting workstation. This system includes all the interconnecting walls and funnels that are used to transport items. There will be walls for the back, sides, and base of the kitting station. The walls are all made of birch plywood since that is a sturdy material that can take our desired load.

5.2.2 Sorting System

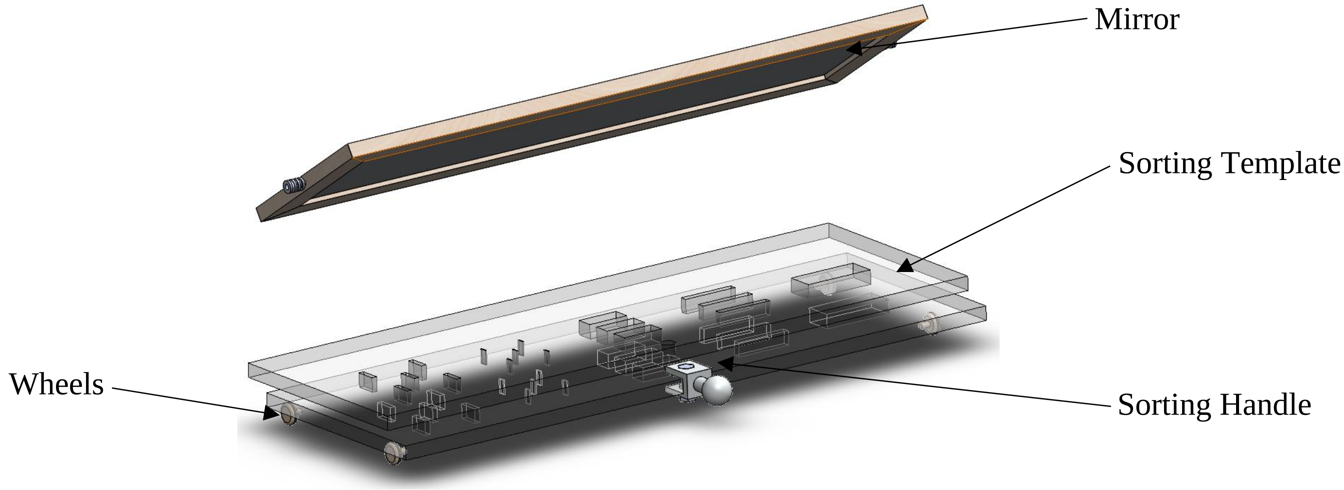


Figure 29. Sorting System and Mirror

The sorting system sorts items that the user places in it. This system consists of 2 sorting templates made from acrylic, plastic wheels to slide the sorting template on and a handle assembly to move the bottom template. Acrylic was chosen as it is easy to laser cut and relatively inexpensive, and wood was chosen as it is sturdy enough to hold the plates up. The top sorting template will have holes that can be used for item placement. The user places items into their designated holes, and when all items are placed, they use the handle to move the bottom plate so that its holes align with those of the top's. When the holes align, items can fall through and into the funnels and get transported to the bag holding system.

5.2.3 Bag Holding System

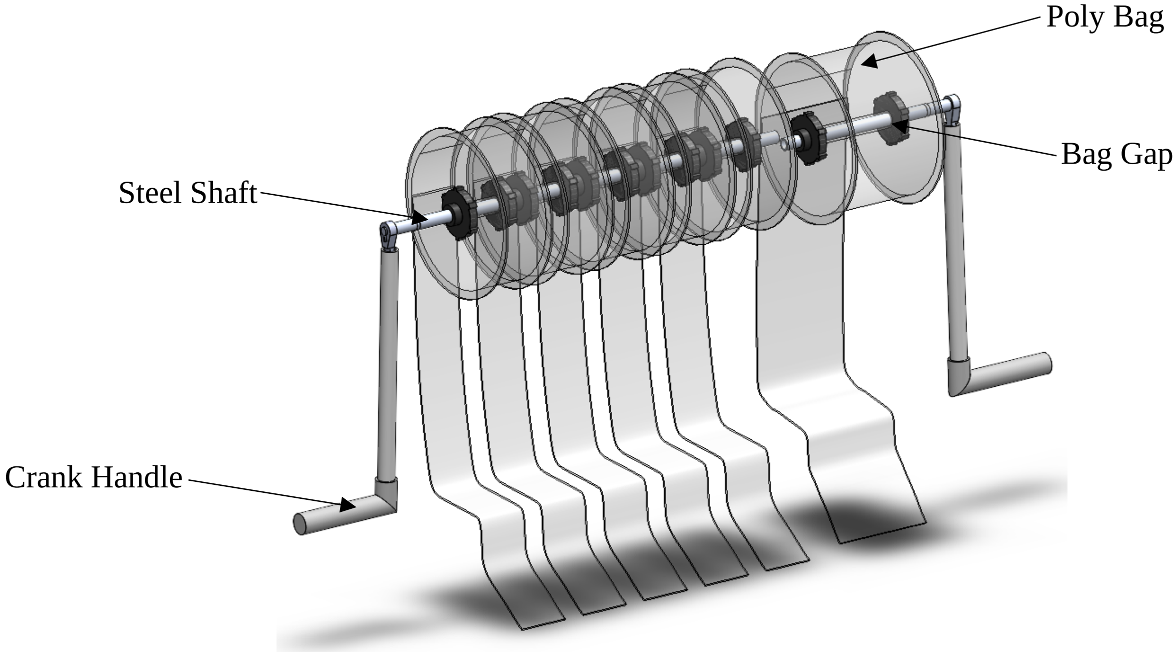


Figure 30. Bag Holding System

Our team chose to have a low-carbon hollow steel round tubes with an inner diameter of 0.9” for the shaft to hold the pre-opened poly bags. The hollow steel round tubes have approximately the same yield strength as aluminum, a higher young’s modulus, and are cheaper than aluminum as shown in Table 6. It is important in this case as the hollow steel tubes must not bend due to the weight of the bags and its relative affordability was a factor in our specifications table.

Table 6. Comparison of Shaft Materials

Material	Yield Strength (psi)	Young’s Modulus (ksi)	Price Estimate ($/6ft)
Aluminum 6061	46000	10000	22.24
Low-Carbon Steel	45000	29000	10.31

The bag holding system is located above the rest of the systems to prevent tipping. To accurately verify that the system does not tip, static hand calculations were made to calculate the minimum weight of the system when given a maximum pushing force of 24 lbf on the crank handle. For more information on the hand calculations, refer to Appendix O. Through these calculations, the minimum weight of the system must be approximately 88 lbf to prevent tipping.

5.2.4 Bag Opening System

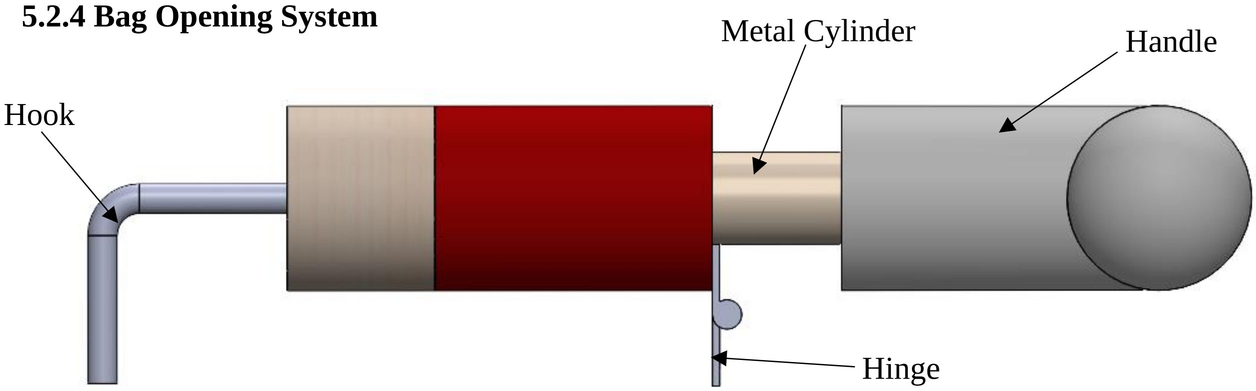


Figure 31. Hooking System

L-shaped hooks were chosen for the bag opening system to get an angle on the open end of the bag, which allows us to insert the edge of the hook into the bag with ease. With the metal cylinder sliding in and out of the clamp collar, the user is able to push and pull the hooking system to perform the bag opening action. The handle will be 3D-printed to ensure that we created a handle that fits with the cylinder. Along with that, the long handle that attaches all five bag opening systems in the left side of our workstation is not something that is commonly manufactured, which is another reason why we 3D-printed these handles.

5.2.5 Heat Sealing System

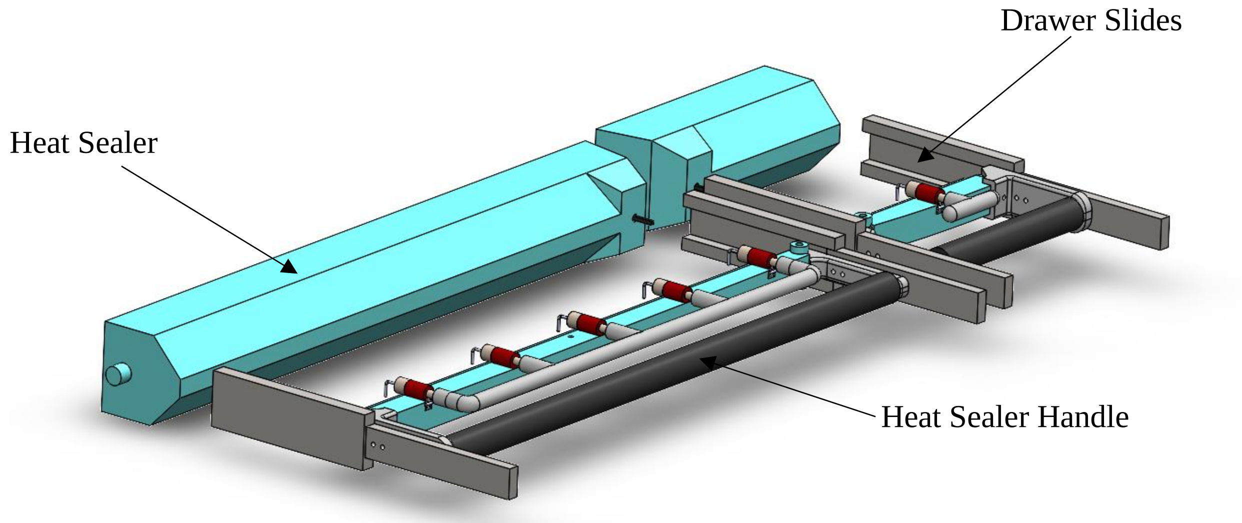


Figure 32. Heat Sealing System

Impulse heat sealers were chosen for this workstation as they provide more safety for the users than normal heat sealers. Any impulse heat sealers would work for our workstation, however the workstation will require one 20” impulse heat sealer and one 4” impulse heat sealer.

5.2.6 UI System

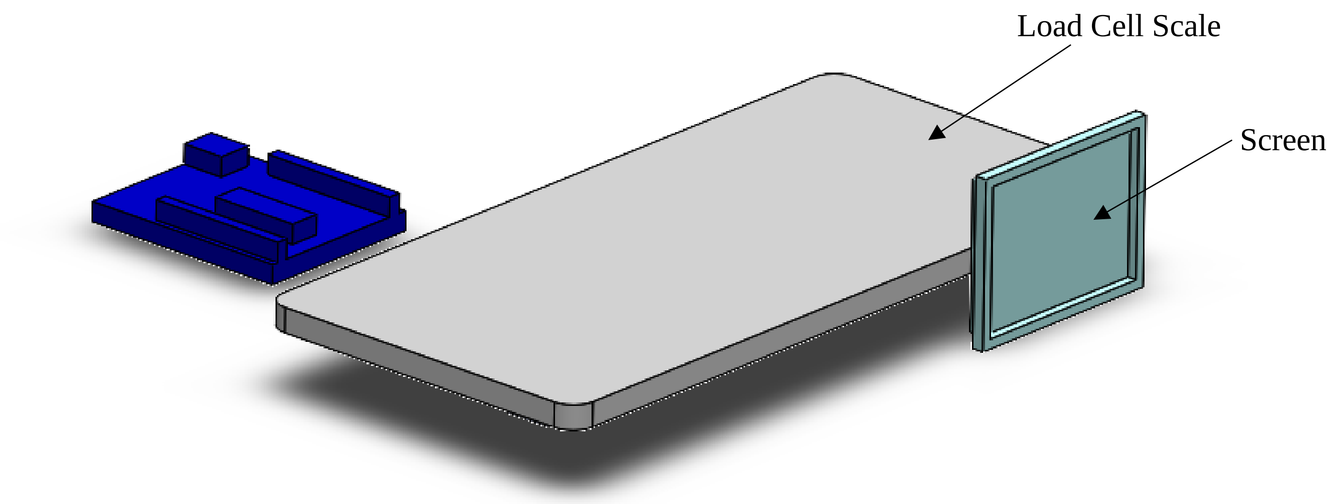


Figure 33. UI System and Load Scale

Building a load cell scale from scratch will provide us with more flexibility for the functionality of our design. A common kitchen scale also uses a load cell, however, it would be difficult to modify the software to calibrate or adapt it to our needs. By building it from scratch, we can make the system and scale plate to fit our system and modify calibration display information easily using the Arduino. Additionally, there is an online step by step guide on how to configure and build this system design.

5.2.7 Paper Folding System

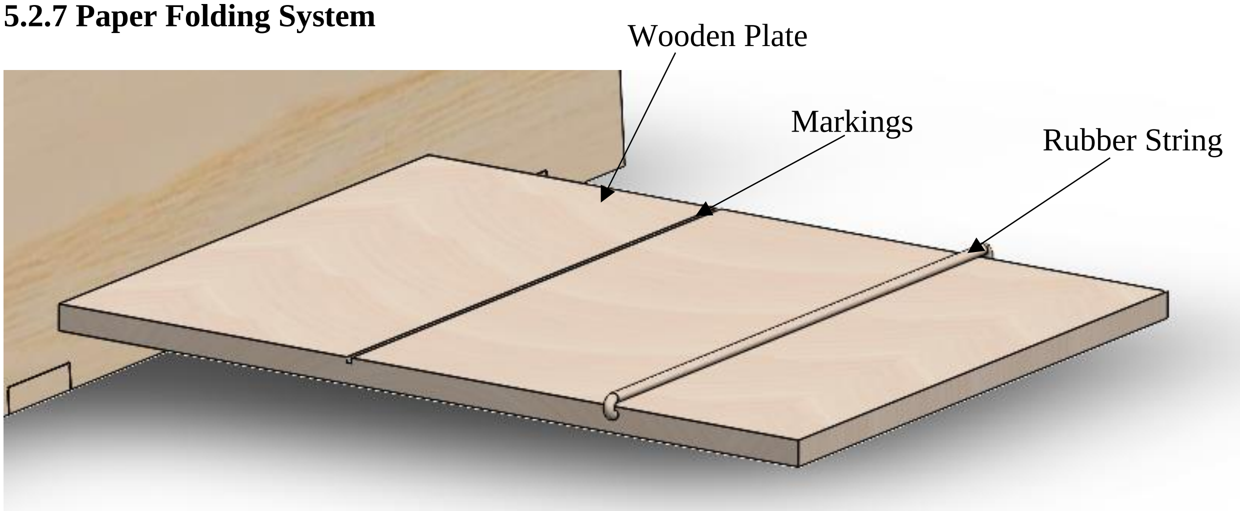


Figure 34. Paper Folding System

The paper folding system is used to help fold paper instructions for the item bags. The system consists of a wooden plate with a lip at the end and a rubber string to hold a piece of paper in it. The plate will contain inch markings so the user can determine where they want to make their paper fold. The paper will be slid into the rubber string and will be folded on the rubber string to create a fold, the process can be repeated to make the paper smaller.

5.3 Structural Prototype

The CAD model and drawing package can be seen in Appendix P. We decided to create a structural prototype where it will be a close representative of the overall concept design, however the structural prototype only has a single top-down column. It shows the key subsystems of our workstation which are the housing, sorting, bag holding, bag opening, and heat sealing as we had limited budget and time. Our team built a structural prototype for a fit test and to physically inspect the sizing of key components in our workstation shown in Figure 33.

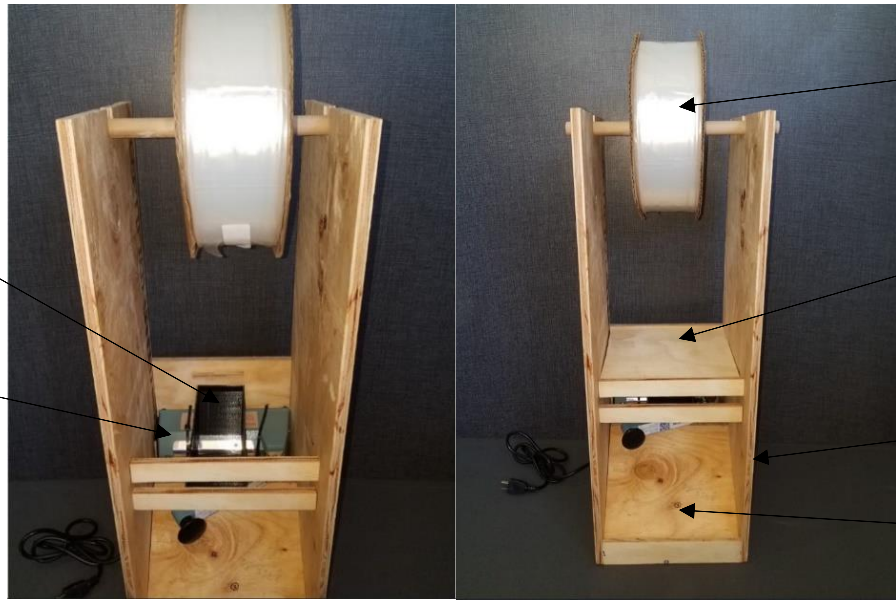


Figure 35. Structural Prototype

From our structural prototype, we learned that the funnel needs readjusting because the items do not fall into the bag and this makes it harder for users to bag the items. We also found that the heat sealer is placed too far back in our structural prototype and it will make it harder for users to heat seal the bags.

5.4 Material and Geometry Justification

For the design justifications, we went through and justified the key specifications that required any hand calculations and finite element analyses (FEAs). For the first specification, we decided to analyze what weight the overall design needed to be to prevent it from tipping. We did this by doing statics hand calculations. According to the Canadian Centre for occupational Health and Safety (CCOHS), the average pushing force is 29lbf. To complete the statics hand calculation, we also needed the center of mass of the design. To get a rough estimation, we used the center of mass of the CAD model in SolidWorks which assumes that all the parts are the same material. With all these known values, the minimum design weight came out to 44lbf to prevent the design from tipping. For further information on the statics hand calculations, see Appendix O.

After the static hand calculations, there were a couple FEAs we needed to consider. The first FEA was to test for any displacement within the shaft holding the bags. After applying the force representing the weight of the bag rolls on the shaft, we saw a maximum displacement of 2 thousandth of an inch which can be seen in Figure 36.

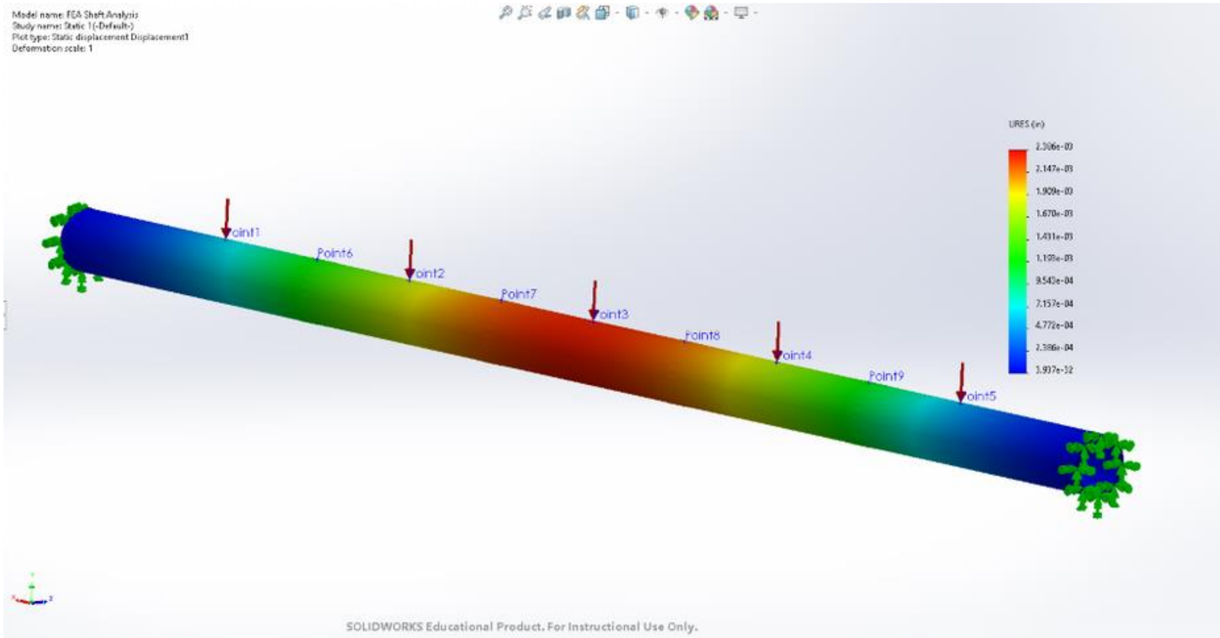


Figure 36. FEA for Bag Holding Shaft

The next FEA determined the appropriate thickness of the housing. Originally, we had the thickness at half of an inch. We felt that it was potentially too thick and a waste of money. So, we ran an FEA with the half inch housing thickness and a quarter of an inch housing thickness.

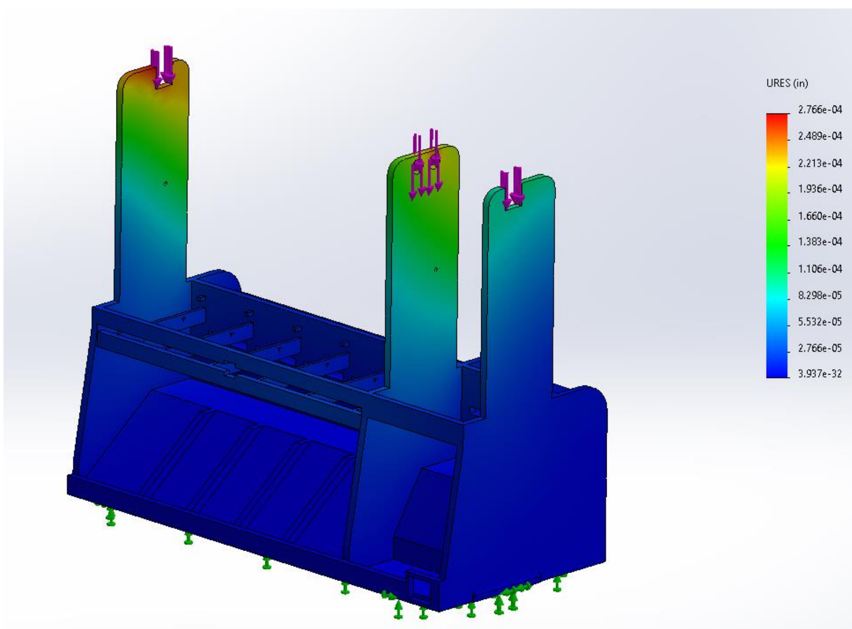


Figure 37. FEA for 0.5in Housing Thickness

As seen from Figure 37, there were forces that mimicked the weight of the bag rolls applied on top of the support beams of the housing. The maximum displacement came out as 0.2 thousandth of an inch, which confirmed that the half inch thickness was not necessary.

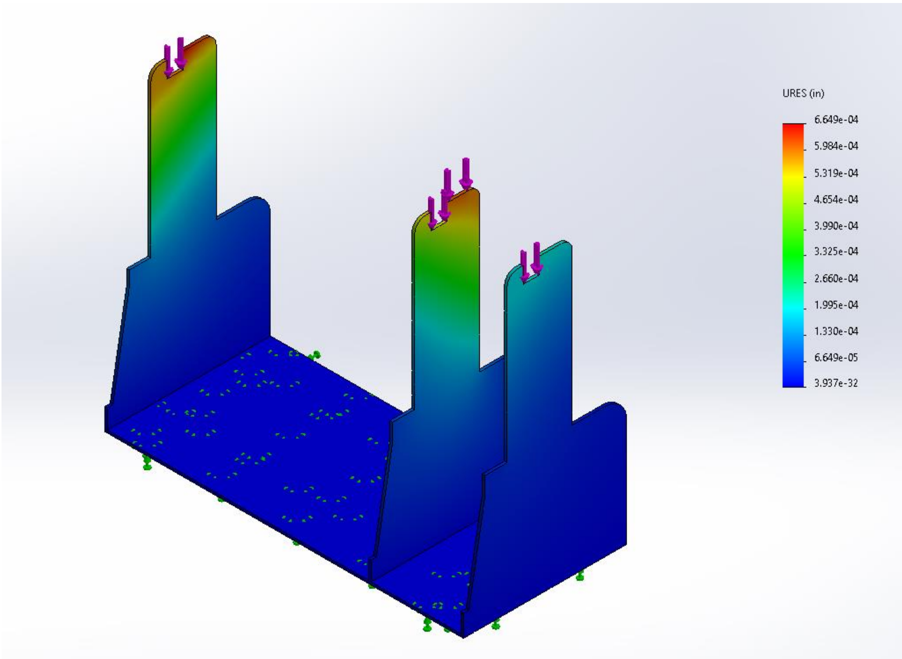


Figure 38. FEA for 0.25in Housing Thickness

We decreased the thickness to a quarter of an inch and performed a new FEA with the same forces. The maximum displacement came out to be 0.6 thousandth of an inch. This small displacement gave us the confidence to go with the quarter inch thickness for the housing.

5.5 Safety, Maintenance, and Replacement Considerations

The safety of the user is of the upmost importance. Our team reviewed the safety of the design by creating a Failure Modes and Effects Analysis attached in Appendix Q and 2D statics calculation, which is attached in Appendix O. This process investigates how the design will fail and considers how this might affect the customers. The potential failure modes we focused on were potential user injury from the bag holding shaft breaking. To prevent this we chose materials that would be able to withstand the given loads.

Other safety precautions that are considered are – edges of the workstations are to be rounded, no exposed wiring from the heat sealer, a wedge is to be placed in the housing so that it would prevent tipping, simple push and pull design for the kitting steps are kept constant throughout the workstation, and a small angle for cranks. To mitigate damage to the heat sealers or to the users, we will enclose the heat sealers in a housing that will prevent it from falling.

The components that will require replacements are the pre-opened poly bag rolls. The bags are used to kit and package items, therefore bag roll replacements will be necessary. It will depend on the number of bags the users use in each day, but an average replacement of the bag rolls every one to two months is required. The team believes that other components should last a lot longer. According to Sealers 101, the heat sealer wire can last to about 5000 seals. The poly bags will have 2500-4000 bags per roll and only require replacement. We believe the housing and other components will last as long as it is not physically abused. Their part number, vendor location, and email for customer support for each vendor will all be accessible in the drawing package which is available at Appendix P.

5.6 Cost Analysis Summary

After sourcing components and compiling their prices, the total cost of the system came out to around $850, which excludes labor cost. The bulk of the system's cost come from the cost of the bag rolls, heat sealers, PLA spool, and wood for the housing. All bolts and connectors for the system are based on standard sizes. Table 7 shows the approximate cost for each subsystem. For more detailed cost analysis, refer to Appendix M for the Indented Bill of Material of the Final Design.

Table 7. Summary of Costs for Overall Design

Subsystem	Approximate Cost
Housing	$113
Sorting System	$94
Bag Holding System	$248
Bag Opening System	$98
Heat Sealing System	$168
Paper Folding System	$32
UI System	$66
Hardware and Fasteners	$30
Total	$849

Since this project has been allocated a budget of $500, the team has created a design prototype that implements the workstation, however, it is a single column top-down system. It implements every subsystem that is in the workstation and also reduces manufacturing cost as we had a limited budget. The total cost of the structural prototype is about $212 and a summary of the prototype costs can be found in Table 8.

Table 8. Summary of Costs for Structural Prototype

Component	Approximate Cost
Plywood for the housing and templates	$70
Wood dowel for shaft	$2
Crank Handle	$5
Clear Pre-Opened AutoBags on Roll 4x4x1.5 mil Roll:4000	$40
Heat Sealer	$40
6” Drawer Railing	$15
PLA	$20
Hardware and Fasteners	$20
Total	$212

6. Manufacturing

This kitting workstation design was created to allow users with dexterity impairments to package items and improve the productivity rate. To test this, we built a prototype that would test our key systems including the housing, sorting, bag holding, bag opening, heat sealing, and the paper folding system. Some key components such as the heat sealers and pre-opened poly bags were raw materials purchased from third-party manufacturers. The other components were fabricated from raw materials. Please note that in reference to steps involving 3D printing, all was done using a personally owned 3D printer, so no facilities are listed for this assembly process. Additionally, all steps involving manufacturing processes such as the Waterjet, Belt Sander, Vertical Bandsaw, and Table Saw were all conducted in Mustang 60, while the minor processes such as drilling or attaching components was done in Bonderson.

6.1 Material Procurement

Key components such as the heat sealer and pre-opened poly bags were purchased from third-party manufacturers. The heat sealers and PLA for 3D printing are commonly available from online retailer Amazon. The pre-opened poly bags are commonly available from online retailers with the same sizing and dimensions but in our case, we purchased them from US Poly Pack. The plywood, acrylic, drawer slides, screws, knob, nuts, and bolts were purchased from Home Depot or Lowe's. All manufacturing processes did not require outsourcing. The final budget of our prototype is $340 which included tax and shipping.

6.2 Housing

This system will contain all funnels and interconnecting walls that house all the subsystems.

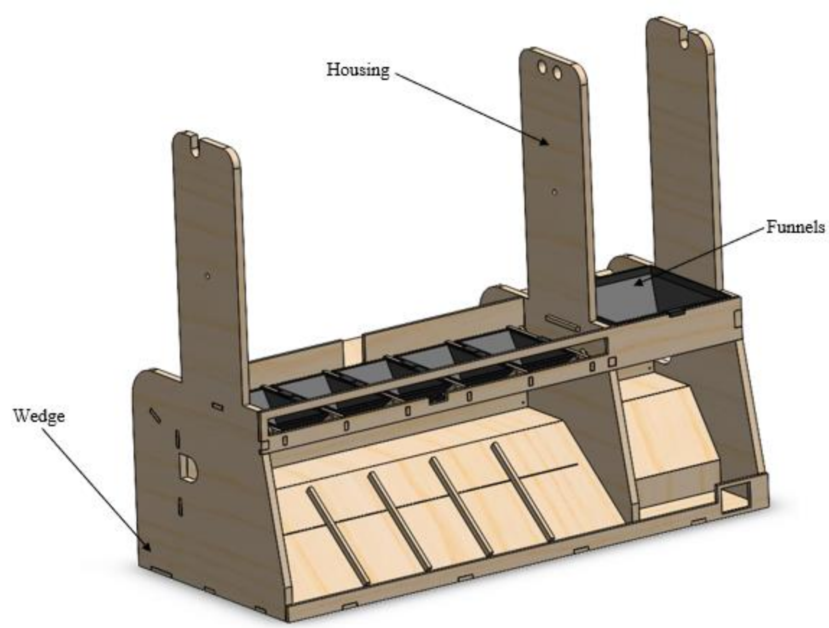


Figure 39. Housing

Step 1: Began by creating a consolidated CAD drawing file with the dimensions from Appendix P for the front, back, bottom, and side pieces of the housing using SOLIDWORKS.

Step 2: Submitted the .DXF files of each part of the housing to lab technicians at Mustang 60 to cut pieces with waterjet.

Step 3: 3D printed the funnels out of PLA from the funnel design in Appendix P.

Step 4: Holes were drilled 0.7" from the bottom and 2.25" from the edges of the sorting crossbeams using a drill with a M6 tap drill bit. Refer to Appendix P for exact positions of holes. After drilling the holes in, the sorter wheels were screwed into the crossbeams.

Step 5: Attached the heat sealer to back panel of housing by following Section 6.6 before continuing further with the housing.

Step 6: Inserted side panels of housing to the bottom panel using the tabs and inserts built into the panels. Refer to Appendix P for connections.

Step 7: Attached tabs needed for sorting templates and template crossbeams into housing, as well as the grommets needed for the mirror frame assembly as shown in Appendix P

Step 8: Sanded down the grab ramp panel using the Belt Sander before attaching to housing with wood glue.

Figure 40. Manufacturing Process – Belt Sander

Step 9: Placed funnel into housing by attaching its hooks onto sorter crossbeams.

Step 10: Inserted front panels using tabs and inserts as shown in Appendix P to complete housing.

One of the challenges with this system was the tabs breaking off. We had to be very careful when removing the tabs from the inserts when taking apart the housing because it was easy to break them off on accident if too much force was exerted. Additionally, it was a little difficult to get the ramp correct when sanding because we wanted to make sure it fit against the rest of the housing exactly so that it was flat.

6.3 Sorting Items

This system will help sort different sized items and drop them into funnels for individual bagging. It includes the two sorting templates, a nut and bolt, sorter handle assembly, mirror, a dowel, two grommets, and wood.

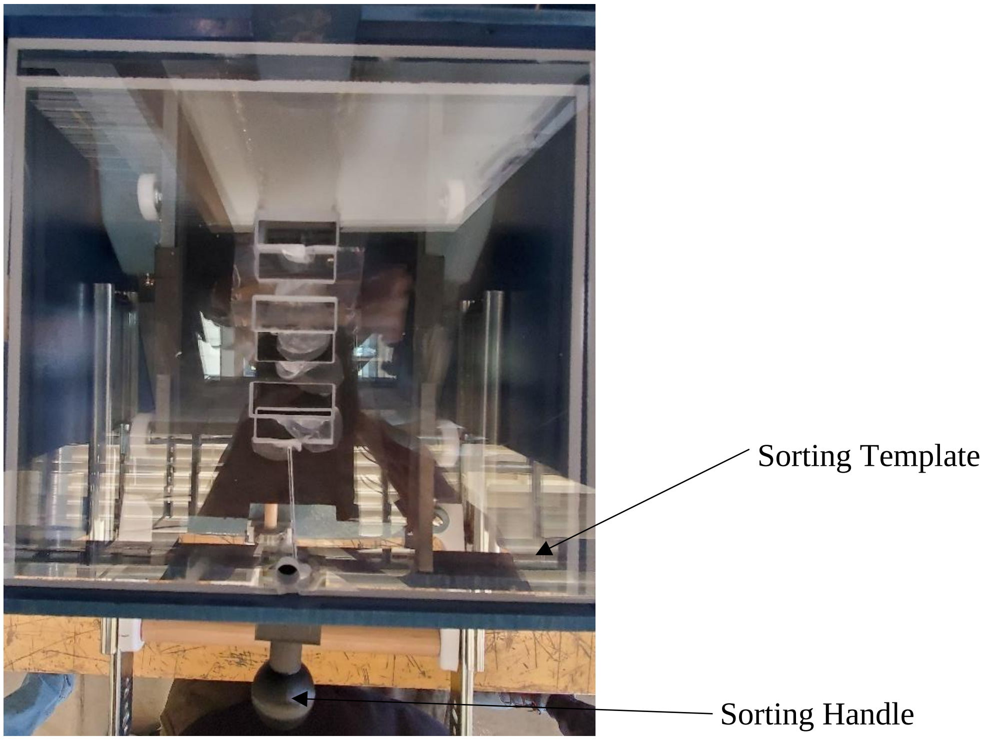


Figure 41. Sorting System

Step 1: Began by creating CAD file with the dimensions as shown in Appendix P for the sorting templates.

Step 2: Submitted drawings to lab technician to cut acrylic plates with waterjet.

Step 3: 3D printed sorter handle with design shown in Appendix P.

Step 4: Lined up the sorter handle and attached it to the bottom sorting template screw hole that is located 0.25” from the edge with a hex bolt and nut.

Step 5: Placed bottom sorting plate into housing front panel cutout.

Step 6: Placed top sorting plate into top of housing.

Step 7: To begin the mirror frame assembly, we cut out four pieces of wood with the table saw. Two were 8” x 1” x 1” and the other two were 6.5” x 1” x 1”.

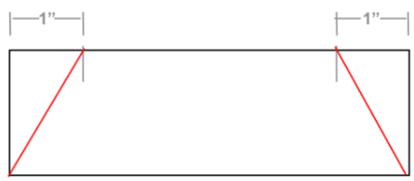


Figure 42. Step 8 Frame Cuts

Step 8: On the top of each piece, we marked 1” indented from either side as shown in Figure 42. We then drew lines connecting the indented markings to the ends to indicate where we would cut the pieces with a Vertical Band Saw.

Step 9: We cut all four pieces with the Vertical Band Saw so that all the edges were slanted like triangle edges.

Figure 43. Manufacturing Process – Vertical Bandsaw

Step 10: We then used the Table Saw to cut the inserts into the top face of each of the frame pieces. To do this, we lowered the Table Saw so that only 0.5” of the blade stuck out and ran the blade twice through our part to create a .1875” cut in the center to serve as the insert that the mirror would be placed into. Refer to Appendix P for further dimensions.

Step 11: We then cut the 3/16” dowel with the Vertical Band Saw so that we had two individual pieces that were both 0.75” long.

Step 12: On the two 6.5” frame pieces, we used a 3/16” drill bit to drill a hole into their side faces. Refer to Appendix P for location of holes.

Step 13: We placed the frame pieces onto the mirror as it was a tight fit. We then put the mirror assembly into the center of the top of the housing and slid the cut dowels onto either side by pushing them through the grommets and tightly fitting them into the two frame holes. This successfully attached the mirror assembly to the housing.

The primary challenge with this system was doing the inserts for the mirror frame assembly. It was tricky to run our workpiece over the saw and still get a tight fit. It was easy to mess up that cut, so we ended up redoing this part a few times. It was also difficult fitting the dowel for the assembly through the grommets because it was such a tight fit.

6.4 Bag Holding System

This system will hold the bags in place and allow users to crank a handle to output the bags that are required in the kitting process. This system includes a steel shaft, PVC pipe, hex bolt, drive socket set, and drive ratchet.

We built the system at Bonderson, and the required equipment included a 3D-printer, spray paint, and epoxy.

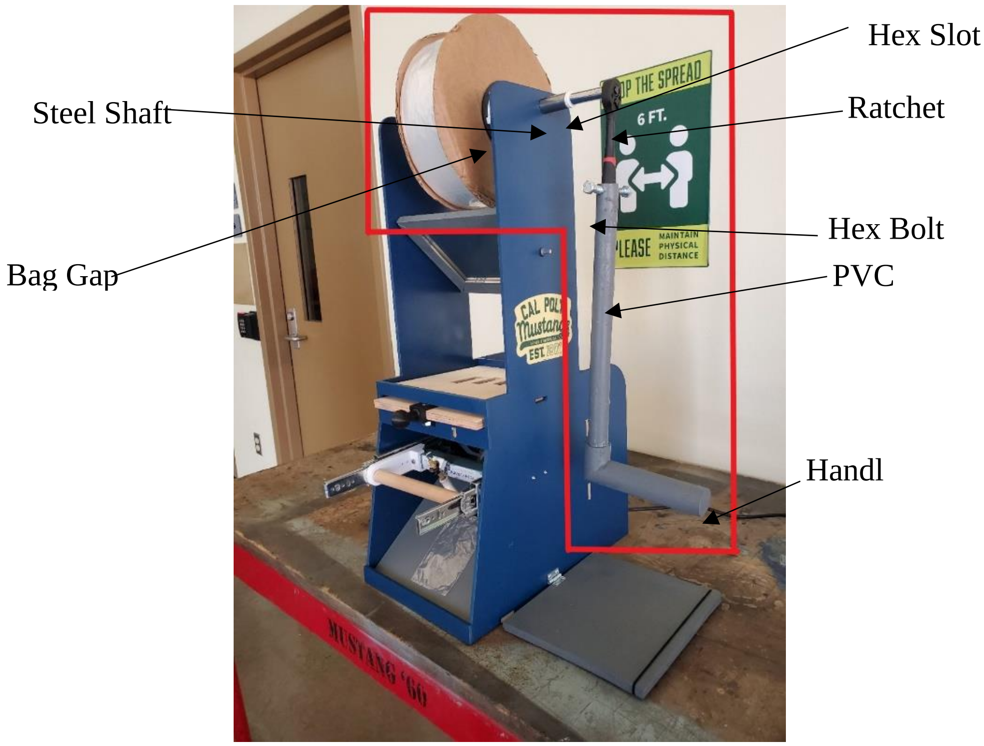


Figure 44. Bag Holding System

Step 1: A foot long hollow steel shaft with an outer diameter of 0.75” and inner diameter of 0.56 in. was procured from McMaster-Carr.

Step 2: Procured a 2-foot-long PVC pipe, two hex 3/8” hex bolt, a 0.25” drive socket set, and a 0.25” drive ratchet from any hardware store.

Step 3: 3D-printed the bag gap, hex slot, and handle, which are available and shown in the SOLIDWORKS drawing in Appendix P.

Step 4: Placed the 3D-printed bag gaps on the side slots of the bag gaps. Inserted the steel shaft through the holes and made it approximately equal in length on both sides.

Step 5: Placed the hex slot on the right side, from the front view, of the shaft. Placed the ratchet socket on the hex slot and connect the ratchet socket with the ratchet.

Step 6: Spray painted the PVC pipe and handle. After the paint was dry, we applied epoxy the handle to the PVC pipe. It will settle and harden within 5-10 minutes.

Step 7: Drilled a hole into the PVC pipes on opposite sides. One in the front and one in the back, from the front view perspective.

Step 8: Inserted the PVC pipes into the ratchet that was attached in Step 5. Inserted the hex bolts on the drilled holes and tightened it so that it was attached to the ratchet.

The primary challenge of this system was getting the tolerance of the bag gap and hex slot to tightly fit to the steel shaft.

6.5 Bag Opening System

This is the system that will open the bags to allow items to fall into them. The bags will be opened with an L-shaped hook attached to a handle. The handle and collar rest were 3D-printed using the designs found in Appendix P. Before reading the steps below, understand that any epoxy applications require 5-10 minutes to dry.

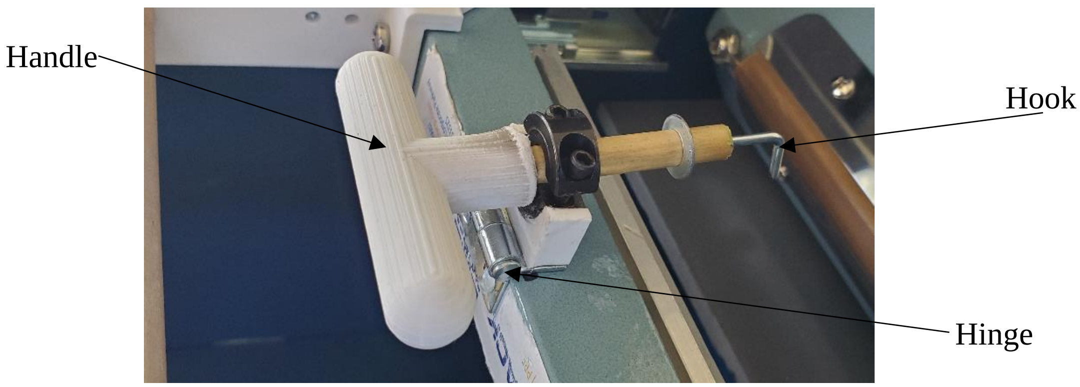


Figure 45. Bag Opening System

Step 1: The end of the hook that will be going into the bag opening was sanded down to create a thinner edge of about 0.05” thickness. A thinner edge allows users to insert the hook into the bag opening.

Step 2: A Hack Saw was used to cut the wooden dowel to a length of 2”.

Step 3: A 5/64” drill was used to drill a hole about 0.5” deep into one end of the dowel.

Step 4: The hook was screwed into the hole on the end of the dowel.

Step 5: The other end of the dowel is then inserted into the hole on the 3D-printed handle. To obtain a strong connection between the dowel and handle, epoxy was applied onto the end of the dowel before inserting it into the handle hole.

Step 6: Using epoxy, one side of the hinge was glued onto the middle of top side of the heat-sealing handle as seen in Figure 45. The collar rest was glued onto the other side of the hinge as seen in Figure 45.

Step 7: The bottom portion of the clamp collar was glued onto the collar rest as seen in Figure 45.

Step 8: The dowel was rested on top of the bottom portion of the clamp collar. Then, the top portion of the collar was screwed onto the bottom to keep the dowel inside the collar. Make sure to not screw on too tight. Allow space for movement for the dowel.

After completing this step-by-step process for the bag opening system, a challenge that stuck out to us was connecting the hinge to the collar. After receiving all the materials, we attempted to epoxy the hinge to the collar, but it was unsuccessful due to the lack of surface area in contact between the two parts. So, we learned our lesson and bought a larger hinge. Along with that, we created a 3D-printed collar rest to increase the surface area being glued between the collar and hinge.

6.6 Heat Sealing System

This is the system that will heat seal the bags once the items are inside the bags. This system includes 3D-printed parts, a 4” impulse heat sealer, and 6” drawer slides. The handle brackets connecting the handle to the drawer slides was 3D-printed, along with the push-rod assembly within the main body of the heat sealer that pushes the button within the heat sealer to activate the heat sealing. The designs for these 3D-printed parts can be found in Appendix P.

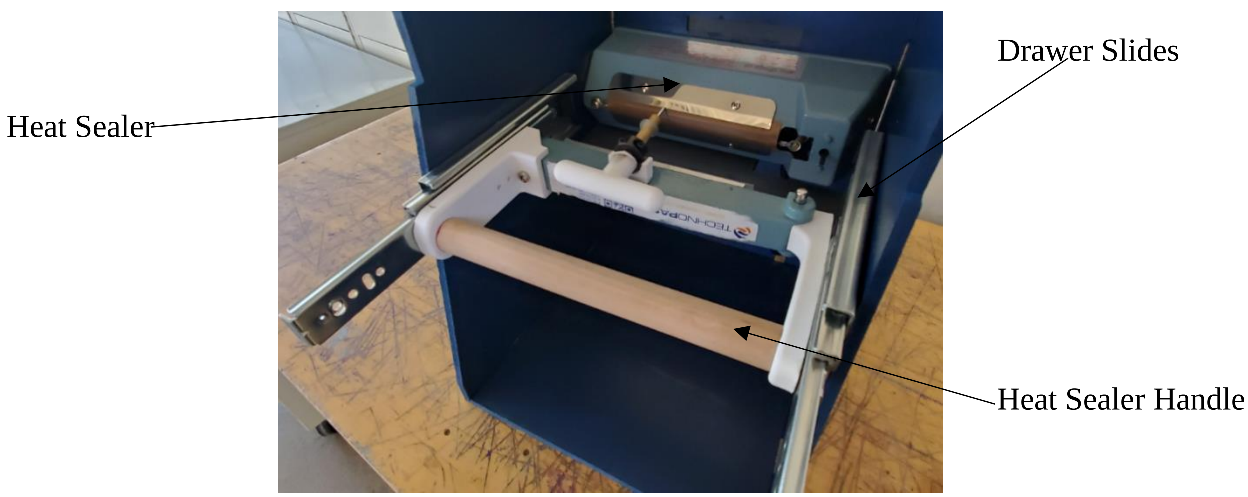
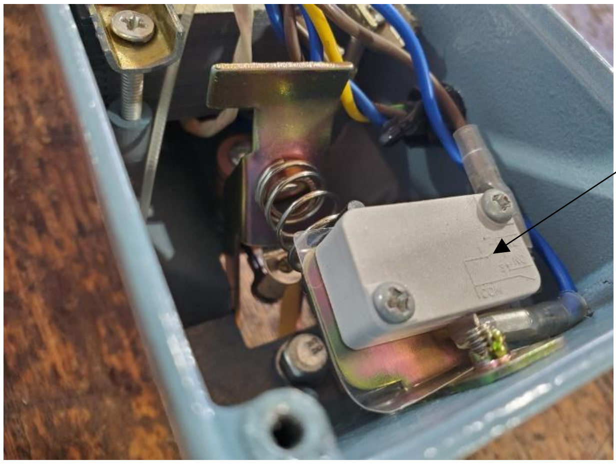


Figure 46. Heat Sealing System



Button that heats the heating element when handle is pushed in.

Figure 47. Inside Heat Sealer

Step 1: Detached the 4” heat sealer handle from the main body of the heat sealer.

a.) First, the bottom of the heat sealer was unscrewed to access the inside.

b.) The L-bracket holding onto the button system was unscrewed to gain access to the spring, push lever, and hex bolt.

c.) The spring was removed first, then the push lever, and finally the hex bolt. These parts are shown in Figure 47.

d.) The L-bracket was screwed back into its original position.

Step 2: Bent the L-bracket located inside the heat sealer to straighten the bracket. Made sure to align the button with the hole originally occupied by the hex bolt.

a.) First, the heat sealer was placed on a vise. This allowed us to bend the L-bracket without the moving the heat sealer.

b.) Then, bend the L-bracket to straighten it. Make sure to straighten it enough for the button to somewhat align with the hole as best as possible.

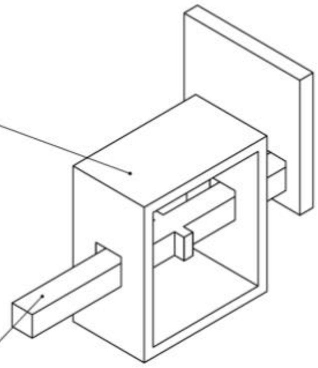


Figure 48. Push Rod Assembly

Step 3: Installed the 3D-printed push-rod assembly inside the heat sealer.

a.) Placed the rod through the spring.

b.) Placed the push rod on one half of the casing. Made sure the rod is positioned as shown in Figure 48 in relation to the casing. The spring should be inside the casing walls. This allows both halves of the casing to successfully combine.

c.) Using epoxy, we connected the second half of the casing onto its other half to complete the casing.

d.) The top end of the push rod is inserted through the hole in which the removed hex bolt was originally located.

e.) The casing is connected to the top inner surface of the heat sealer using epoxy. This allows the casing to be fixed.

f.) Once push rod assembly is complete, close the heat sealer back up.

Step 4: Installed the 3D-printed handle brackets on the heat-sealing handle.

a.) First, we removed the screw on the left side of the heat sealer handle, assuming the same positioning as Figure 46. Then, we removed the metal rod on the right side of the heat sealer handle.

b.) The heat sealer handle was connected to the left handle bracket as shown in Figure 46, and the screw was inserted to maintain that connection.

c.) The right handle bracket and heat sealer handle were connected as shown in Figure 46, and the metal rod was inserted into the concentric holes of the handle bracket and heat sealer handle to maintain that connection.

Step 5: Installed the wooden, cylindrical handle onto the 3D-printed handle brackets. There are holes with counterbores on the brackets to guide the user on where to position the screw and wooden handle.

Step 6: Installed the portion of the drawer railings that combine with the handle brackets.

a.) There are pre-made holes on each handle bracket to guide the user in this process. Make sure it resembles the assembly in Figure 46.

Step 7: Finally, the other portions of the drawer railings that mate with the drawer railings attached to the handle brackets are combined.

When going through this manufacturing process, one challenge that stuck out was the whole push-rod assembly process. Originally, we were unaware of the button that activated the heat sealer. After purchasing and observing the heat sealer, we figured out that we needed some sort of mechanism that activated the heat sealer once the heat sealer handle was pushed onto the heat sealer. This challenge taught us that there will be last minute changes throughout the design process as you learn more about your purchased material. Some part details are not known until after they are purchased and examined by the team.

6.7 Paper Folding System

This is the system that will fold the paper instructions and prepare it for the final bag. This system includes an elastic cord, hinge, and wooden board.

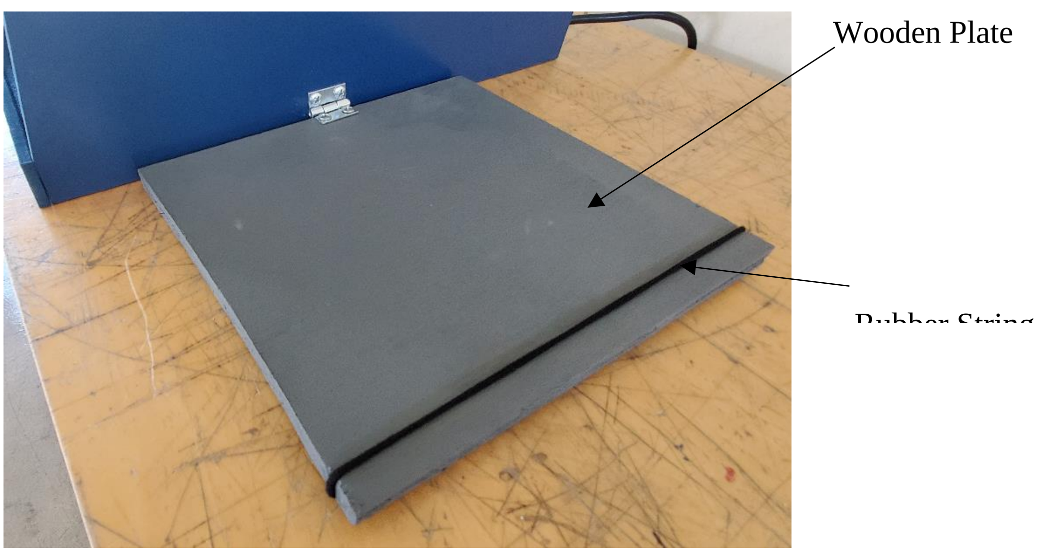


Figure 49. Paper Folding System

Step 1: Using a round file, slots were created about 0.5" from the end of the wooden board. These slots kept the elastic cord from moving around.

Step 2: About 12" of elastic cord was cut from the spool of elastic cord. This cord was placed around the board while remaining on the slots.

Step 3: The elastic cord was tied into a loop and given enough stiffness to allow your fist to get through.

Step 4: One end of the hinge was screwed onto the board, while the other end was screwed onto the right side of the housing.

6.8 UI System Manufacturing Plan

This is the system that will weigh the final bag and track the productivity of the user. This will be Arduino powered and will interface with the user via a touch screen. It is important to note that due to time and budget constraints, this system was not manufactured because we considered it unnecessary to testing the functionality of the design. Instead, we have listed the plans for manufacturing the UI system below.

Step 1: Connected 5kg load cell, HX711 load cell amplifier, Arduino Uno and the touch screen by soldering the jumper cables using the circuit diagram shown below.

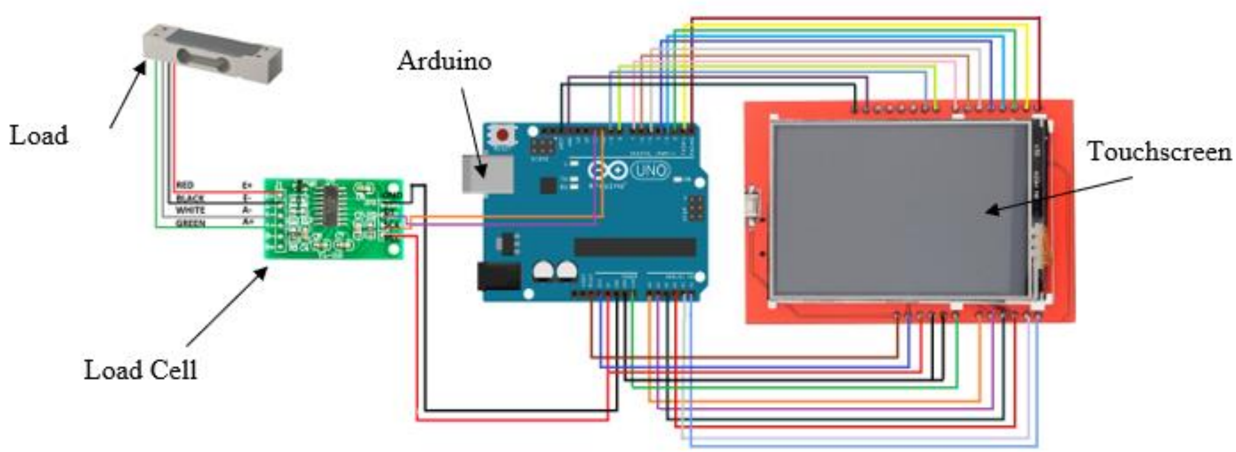


Figure 50. UI System Wiring Diagram

Step 2: Connected a 9V power supply to the HX711 load cell amplifier and used a 7805 IC voltage regulator to reduce to supplied voltage into the Arduino. Figure 50 illustrates the wiring diagram.

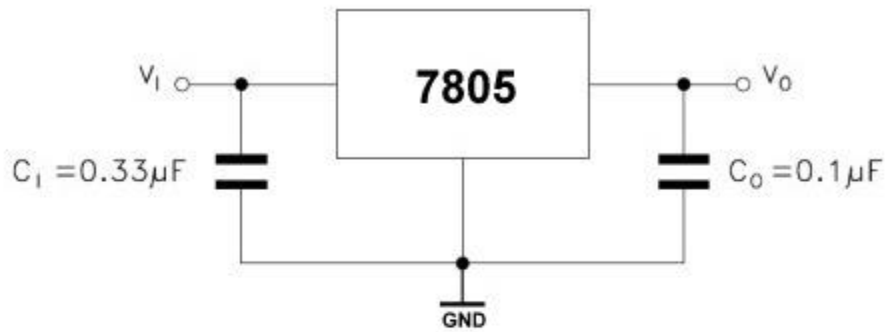


Figure 51. 7805 IC Wiring Diagram.

Step 3: Attached the load cell to the base using M5 screws and a 7.5" x 3"x .25" piece of wood to the top of the load call using M4 screws. This will be the weigh-scale platform.

Step 4: Generated and load the code onto the Arduino.

Step 5: Calibrated scale and touchscreen using masses of known weights. Using the preprogrammed calibration code.

6.9 Prototype Assembly

For this device to work, all the previous subsystems need to be built and attached together in the housing for the workstation to be complete. The list below details our assembly process which was completed in the Bonderson high bay.

Step 1: Removed the back plate of the heat sealer base and attached the heat sealer back plate to the back wall of the housing system using .25" wood screws that came with the drawer rails.

Step 2: Reattached the heat sealer to the back plate by screwing in the four M3 screws at the base of the heat sealer via the screw ports in the back wall of the housing.

Step 3: Attached the drawer rails to the side walls of the housing by screwing each side into the premade holes towards the middle of each wooden piece. These screws were the same ones that were provided with the drawer rails.

Step 4: Assembled the rest of the housing using the instructions listed in section 6.2.

Step 5: Reattached the drawer rails to the rail bases attached to each of the side walls.

Step 5: Used two excess wood screws from the drawer rails to attach the hinge of the paper folding system to the right wall of the housing. We used a drill to drive the screws, as we did not create premade holes when the housing was cut using the waterjet.

Step 6: We fit the dowels of the mirror assembly into the grommets on each side wall of the housing. Then, the mirror and frame were set in between the two walls, and the dowels were pushed inwards until it connected to the mirror frame.

Step 7: Placed the bag holding system at the top of the housing in the premade slots in the side walls.

Step 8: Dropped the funnel into the housing by using its premade tabs to support itself on the template sorter crossbeams.

Step 9: Place the two sorting templates into the top of the workstation by sliding in the lower template (with attached handle) into the lower slot and dropping in the other template into the upper slot.

The completed assembly is shown in Figure 52.

Figure 52. Completed Verification Prototype.

6.10 Future Manufacturing Recommendations

After completing manufacturing of our prototype, we have gained some insight into the shortcomings and difficulties of constructing our design and would like to offer some recommendations to anyone wanting to build the workstation themselves. To begin, the ¼” particleboard we cut the housing walls from are too thin for the two load-bearing side walls. We recommend cutting those two pieces out of ½” wood to support the weight of the bag rolls without buckling. For the sorting system, there seemed to be issues with binding when the lower plate rolled over the wheels. To remedy this, we recommend adding additional vertical tolerance (+.25”) to the slot cut in the housing which would promote a more fluid movement for the template and the handle. For the bag opening system, we chose a clamp collar to facilitate the inwards, sliding motion of the hook. Unfortunately, clamp collars are meant to clamp onto a part and hold it in place which is the opposite of what we intended for this piece. For future iterations, we recommend using a linear bushing instead which should help facilitate motion better. Our final recommendation would be to paint the pieces of the workstation. This step was not a part of our original design, but after receiving the water cut parts back, we saw that it resulted in stains and a dusty finish to the particle board. The paint not only improves the overall aesthetic of the workstation, but it creates a smooth surface finish and creates additional layers of protection for high-wear parts like the handles, bag ramp, and paper folding plate.

7. Design Verification Plan

To verify that our design meets the specifications listed in Section 3.3, we developed seven tests which assess our prototype in regards to safety, feasibility, reliability, and efficiency. These include a hooking test, durability test, tipping test, sorting test, efficiency test, comparative dexterity analysis test, and heat-sealing time test. Our team conducted these tests between April 27, 2021 and May 27, 2021 in the Cal Poly Bonderson facility using our fully developed prototype. The results are listed in the following chapter. (Note: Due to the COVID-19 pandemic, we chose to restrict our testing to only our team members).

7.1 Test 1: Hooking Test

The bag opening system is one of the key subsystems of this design. and the hooking process within this system was tested to check for its functionality. The hooking test was designed for us to obtain the ideal position of the bag for the most effective bag opening functionality. To achieve a successful run, the hook must open the bag enough for the item to fall properly inside the bag. For a visual of this test, see Figure 53 below. In the figure, the user is holding the handle of the hooking system to operate the hook.

Figure 53. Hooking Test

The hooking process was repeated for multiple bag locations between 5.625” and 7.625” (.125” intervals) from the bottom edge of the grab ramp plate to the bottom of the bag. The results are tabulated in Table 9 below. Based on the results, we concluded that the ideal location for the bag is about 6.375” from the end of the ramp, which was later indicated with a line drawn on the grab ramp below the heat sealer.

Table 9. Hooking Test Results

Trial	Line Location [in.]	Pass/Fail	Bag Rip (Y/N)
1	7.625	Fail	N
2	7.375	Fail	N
3	7.125	Fail	N
4	6.875	Fail	N
5	6.625	Pass	N
6	6.375	Pass	N
7	6.125	Pass	N
8	5.875	Fail	N
9	5.625	Fail	N

This test provided us with an acceptable range of bag positions for which our hooking system would reliably function for. From the data, we determined that aligning the lower edge of the 4" long poly bag anywhere between 6.6125" and 6.625" from the bottom edge of the grab ramp would allow for reliable hooking of the bags. Initially, we planned on just placing a single line marker on the grab ramp to indicate a single acceptable hooking location, but based on this data, we could revise this to indicate a .25" "zone" on the grab ramp to assist the user in hooking the bags effectively.

7.2 Test 2: Durability Test

The durability test was designed to show us whether the wooden supports of the housing will withstand the weight of the polybag spools, as well as any potential force being applied on the supports (i.e., push force from the sides, pull force from below, etc.). To conduct this test, we inserted various weights into a plastic bag and hung the plastic bag on the bag holding shaft. To achieve a successful run, the supports must stay firm and not break after each weight is inserted into the plastic bag. For a visual of the durability test, see Figure 54 below.

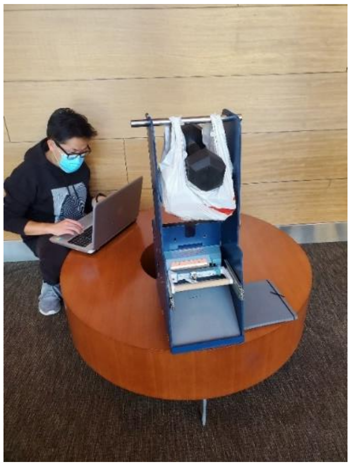


Figure 54. Durability Test

The results of our durability test are tabulated in Table 10 below. Based on the results, we concluded that the supports could withstand the weight of the poly bag spools. For the overall design, the workstation would have to withstand 40lbs of poly bag spools. After testing the prototype, we noticed that even the two supports alone would withstand 40lbs.

Table 10. Durability Test Results

Weight (lbs)	Pass/Fail
15	Pass
25	Pass
40	Pass

During the durability test, we also observed the supports when given a push from the sides. We noticed that the 0.25" thick supports were very fragile and wobbly when given a slight push. This was more than enough for us to conclude that the support beam thicknesses should be increased to about 0.50" to counteract any push force from the sides.

7.3 Test 3: Tipping Test

The tipping test was designed to show us the maximum force that can be applied on the crank for the bag holding system and the handle for the heat-sealing system before the workstation slides/tips. For the equipment, we used a baggage weigher to observe the actual force being applied. To resemble the force that a user would apply on the crank of the bag holding system, we hooked the baggage weigher onto the shaft of the bag holding system. As for the handle of the heat-sealing system, the baggage weigher was hooked to the handle and was pulled towards the user as opposed to the actual motion where the user is pushing the handle away from their body. To get a visual of the test, see Figure 55 below.

Figure 55. Tipping Test

The results for both sections of the test are tabulated in Table 11 below. Before discussing the results, it is important to note that the final design will be much heavier than the prototype. Therefore, the maximum forces found from the tests done on the prototype are not the same maximum forces for the final design. For the bag holding shaft, the maximum force that the prototype can withstand before instability occurs is about 5.7 pounds. For the heat sealer handle, the maximum force that the prototype can withstand before instability occurs is about 7 pounds.

Table 11. Tipping Test Results (Top is for Bag Hold Shaft, Bottom is for Heat Sealer Handle)

Trial	**Desired Force (lb_f)**	**Actual Force (lb_f)**	**Pass/Fail**
1	1	1.5	Pass
2		1.2	Pass
3		1.3	Pass
1	3	3.2	Pass
2		2.9	Pass
3		3.0	Pass
1	5	4.6	Fail
2		4.9	Pass
3		4.8	Pass
1	7	5.7	Fail
2		-	Fail
3		-	Fail

Trial	**Desired Force (lb_f)**	**Actual Force (lb_f)**	**Pass/Fail**
1	4	4.2	Pass
2		4.0	Pass
3		4.3	Pass
1	6	5.9	Pass
2		5.8	Pass
3		5.9	Pass
1	8	7.4	Fail
2		7.0	Fail
3		7.2	Fail
1	10	-	Fail
2		-	Fail
3		-	Fail

Based on this test, we determined that our device is extremely prone to slipping and tipping, especially when pushed at the bag roll shaft. We found that only 5.7 pounds of force needs to be applied at the shaft or 7.0 pounds of force needs to be applied at the heat sealer handle to cause instability of our workstation. These values are far from our target criteria of 29 lbf which was set by OSHA as the maximum seated horizontal pushing force. While our prototype is not an accurate representation of the entire workstation, we expect similar results if this test were implemented on the full design primarily due to the additional mass added at the bag shaft when 5 other poly bag rolls are added at that location. To address this design flaw, we could implement some sort of attachment device (like bolts, suction cups, magnets, etc.) to affix the workstation to the table and alleviate some of the instability concerns.

7.4 Test 4: Sorting Test

The sorting test was designed to show us whether the prototype's sorting system works properly. A successful run occurs when the sorting templates can properly align and allow the item to smoothly fall into the polybag. The sorting templates on the prototype have 3 holes. So, we tested each hole to see how smooth the items can fall into the bags from each hole. For a visual of this test, see Figure 56 below.

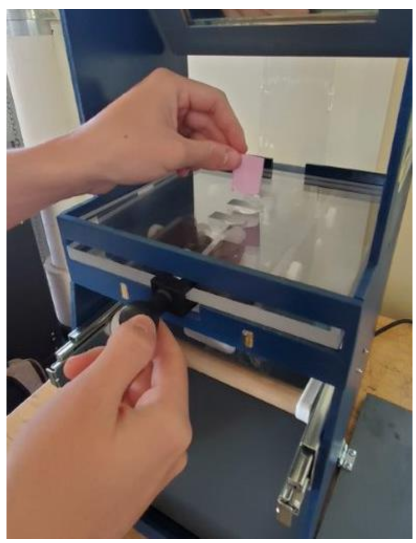


Figure 56. Sorting Test

The results of the sorting test are tabulated in Table 12 below. We had five trials for each hole position on the sorting templates. If the item fell through the templates smoothly, it was considered a pass. If it did not fall through smoothly, the trial was considered a failed attempt. Based on the results, we concluded that the sorting system on the prototype was not very effective.

Table 12. Sorting Test Results

Hole Position	Trial	Pass/Fail
1	1	Pass
	2	Fail
	3	Fail
	4	Pass
	5	Pass
2	1	Fail
	2	Pass
	3	Pass
	4	Pass
	5	Fail
3	1	Fail
	2	Fail
	3	Fail
	4	Fail
	5	Fail

This test highlighted the shortcomings of our sorting system and funnel design. For starters, hole position 3 failed all attempts at dropping the Post-it notes into the polybags. This is because the Post-it notes were inserted vertically into the hole and had a height that we did not consider in our design. When the two sorting templates aligned, the Post-it note dropped down and rested on the surface of the funnel instead of dropping down through the bags. This is a huge flaw in our design but could be addressed by revising the funnel design (making the slopes steeper) or revising the template hole pattern (condensing the holes to be closer to the center of the funnel). We recommend trying to revise the funnel design first as condensing the template holes causes the sorting system to become crowded and more difficult to navigate for the user.

Additionally, hole positions 1 and 2 each had two failures during their testing. We determined the primary cause of these to be misalignment between the two plates. In our current design, we left 0.1” of clearance between the template plates and the housing walls. In implementation, this clearance proved to be too much and left the template plates with enough lateral freedom to readily become misaligned. We could address this by changing the fit of the template plates to 0.025” of clearance between the plates and the housing. This would be possible due to the precision of the waterjet cutter for both the housing and the acrylic plates.

7.5 Test 5: Efficiency Test

The efficiency test was designed to compare between the full kitting time when using the workstation versus the kitting time it takes when doing it manually. Each of our group members had three trials to use the workstation and to create the kit manually.

The results of the efficiency test are tabulated in Table 13 below. The results show that manually kitting the item was far more efficient than the use of our prototype. However, it is important to note that the prototype only allows for one bagging operation as opposed to the five simultaneous bagging operations provided in our main design.

Table 13. Efficiency Test Results

		Workstation		Manual		
Tester	**Trial**	**Kit Time [s]**	**Avg Kit Time [s]**	**Kit Time [s]**	**Avg Kit Time [s]**	**% Change**
Kyle Chuang	1	60	42.33	10.8	9.73	335.05
	2	30		8.3		
	3	37		10.1		
Ashley Humpal	1	41	45.00	11.5	10.63	323.33
	2	60		10.8		
	3	34		9.6		
Keanau Robin	1	32	40.67	8.6	9.57	324.97
	2	40		9.9		
	3	50		10.2		
Christopher Tan	1	40	41.50	9.6	9.63	330.94
	2	-		10.9		
	3	43		8.4		

Based on the results of the efficiency test, our design fails in all aspects. For each person, using our prototype to assemble a single kit increased their average kitting time by over 300%. This is an unacceptable figure and demonstrates that our design is not only inefficient, but actively hinders the performance of the user.

It is important to note that this test is flawed and does not provide an accurate assessment of our design. We must take into account that our prototype demonstrates only a single bagging operation and thus does not model the main benefit of our workstation design (consolidating similar processes like bag opening and sealing for five operations simultaneously). To improve this test, we could manually kit five items and see how that kitting time compares to the kitting time when using the workstation prototype. We must also include an extra 5-10 seconds to account for the time it would take to place the five items into each sorting template. Still, we can reasonably assume that an efficiency test of the full workstation would still see similar test results simply due to the fundamental design of our workstation.

7.6 Test 6: Comparative Dexterity Analysis

The comparative dexterity analysis was designed to time how long it would take for someone to complete a kit using the workstation when given certain impairments. The tested impairments include wearing gloves, using only one arm, and using only one eye. Each team member had three trials for each impairment. For a visual on each tested impairment, see Figure 57, Figure 58, and Figure 59 below.

Figure 57. Gloves Impairment

Figure 58. One Arm Impairment

Figure 59. One Eye Impairment

The results of the comparative dexterity test are tabulated in Table 14 below. Unfortunately, the data does not allow us to draw any conclusions about the effects of different impairments on the efficiency of our workstation. The results show that the average time was decreasing starting from gloves up until the one eye test. However, we believe this is due to our increasing comfortability in using the workstation as we went through our trials.

Table 14. Comparative Dexterity Analysis Test Results

			Workstation		
Tester	**Test**	**Trial**	**Kit Time [s]**	**Average Kit Time [s]**	**Successful [Y/N]**
Kyle Chuang	No Impairments	1	60	42.3	Y
		2	30		N
		3	37		Y
	Gloves	1	23	48.7	Y
		2	52		Y
		3	71		Y
	One Arm	1	28	32.7	N
		2	40		Y
		3	30		Y
	One Eye	1	28	26.3	Y
		2	33		Y
		3	18		Y

Table 14 (continued). Comparative Dexterity Analysis Test Results

Tester	Test	Trial	Workstation Kit Time [s]	Workstation Average Kit Time [s]	Workstation Successful [Y/N]
Ashley Humpal	No Impairments	1	41	45.0	Y
		2	60		N
		3	34		Y
	Gloves	1	46	53.7	Y
		2	64		Y
		3	51		Y
	One Arm	1	35	29.0	Y
		2	23		N
		3	29		Y
	One Eye	1	55	35	Y
		2	30		Y
		3	20		Y
Keanau Robin	No Impairments	1	32	40.7	Y
		2	40		N
		3	50		N
	Gloves	1	41	54	Y
		2	72		N
		3	49		Y
	One Arm	1	86	54.3	N
		2	46		Y
		3	31		Y
	One Eye	1	35	44	Y
		2	36		Y
		3	61		Y
Christopher Tan	No Impairments	1	40	41.5	Y
		2	-		N
		3	43		Y
	Gloves	1	36	35.7	Y
		2	39		Y
		3	32		Y
	One Arm	1	33	31.0	Y
		2	29		Y
		3	31		Y
	One Eye	1	52	43.6	N
		2	48		Y
		3	31		N

This test primarily served to provide us with qualitative information about our prototype because we may not be able to rely on the kitting time data. We conducted the tests in the order of No

Impairments, Gloves, One Arm, and One Eye. By the time we reached the One Eye test, for example, we each had done at least 9 trials with the workstation to learn the kinks and special tricks to make it work more efficiently. This learning curve is most likely why our time data contradicts our initial theory that any impairment would increase the average kit time for the user. It would also account for why the average kitting times seem to decrease going from the Gloves to the One Eye test for each tester. The exception is Christopher, who had a noticeably higher time for the One Eye test. This could be accounted for by the fact the Christopher wears glasses which is why being forced to use one eye had a significant impact on his performance.

Although we may not be able to draw conclusions from the numerical data of this test, we still learned valuable information about our design. For example, due to the sliding instability of the workstation, the One Arm test showed how our workstation would consistently slide away from the user when trying to push the heat sealer handle in. Additionally, Keanau is left-handed and used that arm during the test. This led to him almost completely ignoring the ratchet crank handle that was installed on the right side of the workstation. Instead, he would simply reach into the workstation and pull the bag directly. Since we have ratchet cranks on both sides of our full design, this problem will always occur (probably to a greater extend because the workstation is over 30 inches wide) for a person with only one hand available to operate the workstation.

Another example is during the One Eye test, we noticed that each of us had to bend down and get extremely close to the workstation while hooking the bags due to the limited visibility of that working area. One solution that could help may be implementing LED lights to illuminate the area and provide better visibility, however, the more effective solution would be to increase the vertical working space at the heat sealer/hooking area to improve ergonomics and give the user more room to operate.

The Gloves test did not offer a ton of insight. For this test, we used thick cloth gloves from Home Depot. While they were clunky and hard to manage, it did not affect our performance or experience with the workstation. Perhaps it would have an affect picking up small items like paper clips, but for this test we used a medium sized Post-it note to create the kit. The addition of the gloves simply slowed our operations down, which is the best simulation of dexterity impairments we could achieve. With that being said, we must address that while these tests were meant to test dexterity impairments, they do not fully simulate the experience of people with disabilities. We were not able to find people with dexterity-related disabilities to test our prototype due to the COVID-19 pandemic, so these tests will only be useful to a certain extent. For those looking to develop this design further, we highly recommend finding users with disabilities to test the design to receive the most useful user feedback.

7.7 Test 7: Heat Sealing Test

The heat sealing test was designed to show us the ideal heat-sealing knob setting for the most effective sealing. The heat sealer has nine different knob settings. Knob setting 1 has the lowest heat input, while Knob setting 9 has the highest heat input. The purpose of the test is to figure out which setting is most ideal. For a visual of the test, see Figure 60 below.

Figure 60. Heat Sealing Test

The results of the heat sealing test are tabulated in Table 15 below. There were five trials for each knob angle. We also made sure to observe the quality of the seal (i.e., whether it is airtight and whether the bag sticks to the heat sealer or not). From the results, we learned that all knob settings would effectively seal the bag. However, we did notice that knob angles 5 and above result in smoking and melting of the plastic. Therefore, we concluded that knob angles 1-4 are ideal knob settings for the heat sealer. One more thing to note is that all knob settings result in the bag sticking onto the heat sealer after being sealed, which is not desired.

Table 15. Heat Sealing Test Results

Knob Angle #	Trial #	Seal Time [s]	Avg. Seal Time [s]	Airtight? [Y/N]	Bag Sticks? [Y/N]
1	1	0.42	0.46	Y	N
	2	0.57		Y	Y
	3	0.46		Y	Y
	4	0.38		Y	Y
	5	0.47		Y	Y

Table 15 (cont.). Heat Sealing Test Results

Knob Angle #	**Trial #**	**Seal Time [s]**	**Avg. Seal Time [s]**	**Airtight? [Y/N]**	**Bag Sticks? [Y/N]**
2	1	0.65	0.662	Y	Y
	2	0.58		Y	Y
	3	0.72		Y	Y
	4	0.54		Y	N
	5	0.82		Y	Y
3	1	0.80	0.764	Y	Y
	2	0.75		Y	Y
	3	0.78		Y	Y
	4	0.74		Y	Y
	5	0.75		Y	Y
4	1	0.99	0.944	Y	Y
	2	0.95		Y	Y
	3	0.92		Y	Y
	4	0.91		Y	Y
	5	0.95		Y	Y
5	1	1.12	1.09	Y	Y
	2	0.99		Y	Y
	3	1.13		Y	Y
	4	1.12		Y	Y
	5	1.09		Y	Y
6	1	1.33	1.304	Y	Y
	2	1.34		Y	Y
	3	1.30		Y	Y
	4	1.25		Y	Y
	5	1.30		Y	Y
7	1	1.57	1.512	Y	Y
	2	1.50		Y	Y
	3	1.55		Y	Y
	4	1.47		Y	Y
	5	1.47		Y	Y
8	1	1.75	1.744	Y	Y
	2	1.72		Y	Y
	3	1.75		Y	Y
	4	1.75		Y	Y
	5	1.75		Y	Y

From the heat seal time test, we found that all knob angle settings of the heat sealer would effectively seal the bag and that the seal time approximately increases linearly according to the equation T = 0.1786*θ + 0.2562, where T is the seal time and θ is the knob angle. This relationship was displayed in the plot in Figure 61. Additionally, we calculated a timing uncertainty of ±0.28 seconds for our data which accounts for human reaction time, system sensitivity, stopwatch precision, and repeatability.

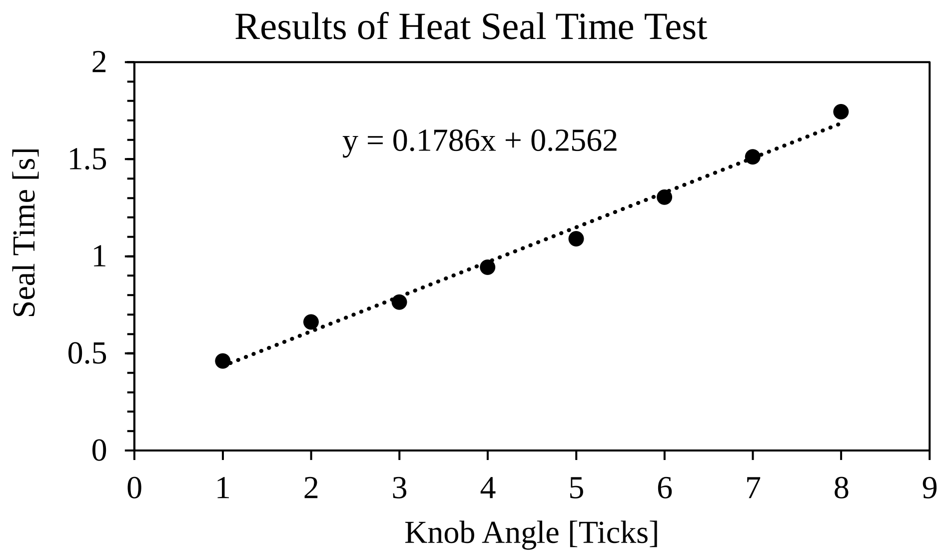


Figure 61. Plotted relationship of seal time vs. knob angle.

At knob angles 5 and above, however, the bag began to smoke during sealing and would cause the plastic to melt. If the user attempted to tear the bag while the plastic was still malleable, the bag would tear at the seal, instead of the perforations. For that reason, we recommend operating the workstation between knob angles 1-4.

We also found that all heat sealer settings caused the poly bag to stick to the Teflon surface of the heat sealer. This is detrimental to our design because the user would have to reach into the workstation and manually peel the bag off of the heating element to continue operation, which slows down production time. We conducted additional research on this and found that it is an unavoidable feature of heat-sealing plastic bags. To address this, a mechanism could be developed which would automate unsticking and tearing the bags after it is sealed. This would eliminate the user's need to put their hands near the heat sealer.

7.8 Missing Tests and Unmet Specifications

After conducting testing, we found that many of our systems did not completely meet their specifications. Most of our specifications from Table 3 of Section 3.3 were not met or we were unable to test for them as they referred to our final design. We were unable to test for specifications 1- 4 and 6 (bag count, label check, item counter, hold paper, heat sealed bag) due to the fact that we were unable to do 100 tests with our prototype, so we could not calculate whether our design would meet our pass rate and therefore meet our specification.

We were also unable to test with users who had disabilities due to Covid so we could not test specification 5. For the durability test, we realized that our specification was irrelevant as we would be unable to observe our prototype for 3 years. Instead, when conducting our durability test, we tested for durability from load rather than wear.

As for specification 8, we were unable to test the 50% increased efficiency because our prototype does not encompass the entirety of our final design. Therefore, we were unable to make any conclusions on the efficiency of our final design. Furthermore, regarding specification 9, our design failed to meet that specification. We realized that cost of $250 was a premature estimate that did not encompass all components needed for the design. Our overall cost for the final design ended up being around $800.

Table 16. Specification Summary Table

Spec. #	Specifications	Final Results	Pass/Fail
1	Bag Count	n/a	n/a
2	Label Check	n/a	n/a
3	Item Counter	n/a	n/a
4	Hold Paper? (Y/N)	n/a	n/a
5	User Survey	n/a	n/a
6	Heat Sealed Bags? (Y/N)	n/a	n/a
7	Durability test	n/a	n/a
8	Efficiency test	n/a	n/a
9	Cost	~$800	Fail
10	Time to Complete Task	n/a	n/a
11	Construction Survey	n/a	n/a
12	Weight	n/a	n/a

In terms of specification 10, we were unable to test the 5 minutes/task target because, as mentioned above, our prototype does not encompass the full process of our final design. When creating that target spec, we were referring to the performance of the final design that includes five packaging stations and one final packaging station. As for specification 11, we did not conduct a test to figure out the full construction time because, as mentioned above, the prototype is not a full representation of our final design. Specification 11 was created for the final design set-up time, so it was not possible for us to test this target time. Finally, for specification 12, the 50lbf was referring to the target weight of the final design. For our prototype, the weight was at approximately 8-12lbf. Although we cannot confirm that the final design will be 50lbf, due to the prototype being roughly a fifth of the final design, there would be a possibility that the weight of the final design would surpass the 50lbf target. For a summary of the specifications mentioned above, see Table 16.

7.9 Challenges and Lessons Learned

In terms of evaluating our design and conducting testing, the biggest challenge we encountered was figuring out what would be considered acceptable criteria. We had to really think about what the user would find acceptable which made us stricter with our passing criteria. For example, in the sorting test we initially had it so that if the user could get the item past the sorting templates it would be considered a pass, however after thinking more about ease of use for our user we made it so if the user can get the item past the templates and to drop in the bag without requiring extra motion (such as pushing templates more than once in case an item is partially stuck) then it would be considered a pass.

During this process we also learned a few lessons. We learned that all data, even data showing bad performance, is good data. When we saw fails occurring in many of our tests, we felt a little discouraged and disappointed. However, we realized that through this data we were able to find design flaws and now have the potential to correct them and make our design even better. Additionally, we learned to look at the purpose of a test closer to ensure that it is testing something that we need to find out more about. When beginning this process, we had a long list of tests but realized many of them were pointless as they were not testing an important specification. Furthermore, we realized that many of our early specifications were not well designed as they were premature and untestable with our current resources.

7.10 Future Testing Recommendations

For future testing work, we would redo the efficiency test but with the whole design. It is hard for us to estimate how much time it would take to do 5 individual kits and 1 consolidated kit and compare that to the time it takes to do manual kitting without actually having the final design built. In addition, we want to actually test with users who have actual motor or dexterity issues to get a more accurate representation of how our design would do, and then conduct a user survey afterward.

8. Project Management

The overall process of design consisted of several parts. We initially began with researching the process of kitting. We were given very broad project parameters and arranged an interview with our sponsor to get more project details. After that, we were able to refine our problem statement and begin our research. To start the research off, we decided to explore the previous designs that were related to the competition. We also researched patents, standards, regulations, and any other technical reports essential for the creation of our design.

Once we went through all the initial research, we began the ideation process. We came up with hundreds of ideas through multiple sessions of brainstorming, brainwriting, and many other ideation processes we felt would be useful. The completion of our ideation sessions helped us transition to the design process. The design process included multiple concept models that gave us a general understanding of which ideas would be feasible or not. Then, we moved on to concept prototypes that demonstrated the functionality of each critical function of the overall system. The concept prototypes led to the creation of the final concept design that we created in SolidWorks.

We ordered parts for the construction of our structural prototype design. The focus of this structural prototype was to observe the feasibility of our housing and heat sealer positioning. Essentially, the structural prototype served as a fit test. Once the fit test was completed, we planned out the building process of our verification prototype that included all our key subsystems. Once all parts were successfully procured, we began the building process. For a full step-by-step of each building process, see Chapter 6 Manufacturing Plan above. After building the verification prototype, we moved on to testing the prototype to test the functionality of each of our subsystem designs. For a full description of each test, see Chapter 7 Design Verification Plan above.

After completing this whole process of ideating, building, and testing, we can confirm that this process works. Multiple ideation sessions allowed us to figure out our desired design, which gave us a clear path to follow for the building process. Once the building was complete, we were able to conduct tests to observe the functionality of our design. With these tests, we generated multiple revision ideas that we could theoretically implement if given more time with this senior project.

Table 17. Project Timeline

Deliverable	Description	Due Date
Scope of Work	Paper outlining project research conducted	10/13/20
Preliminary Design Review	Report/Presentation on project’s current progress and protypes	11/12/20
Critical Design Review	Report on current prototype idea all information needed to build	2/4/21
Manufacturing and Test Review	Updated test schedule and plan	3/2/21
Final Design Review	Final Prototype and Report	5/24/21
Expo	Expo poster and showcase	5/28/21

If we were to do anything differently, we would go back and change the design specifications that we created earlier in the year. Back then, we were unsure of what we really wanted out of the testing of our design. Now that we have completed the testing, we realized how impractical our engineering specifications were. With that said, we still felt that the overall design process led us to great results and a satisfactory design given the time constraints.

Table 17 contains all key deliverables as well as the timeline corresponding to each deliverable. For a more detailed description of what we did, please see Appendix L containing our Gantt Chart.

9. Conclusion

The Final Design Review documents and provides justification for our final design direction. It compiles all the information, diagrams, and tables used in the project up to this point. The key results gathered from the first half of this report is the shift of our disability focus to motor function, specifically the hands because that is the biggest issue involved with disabilities found in kitting since there is no current existing assistive product. After conducting ideation, preliminary design, and conceptual prototyping of the product we decided on a design direction that incorporates a top-down system to maximize efficiency. Then, we went through an iterative design revision process until finalizing a design that incorporated all the key systems such as the template sorter, pre-opened bags, heat sealer, and the user interface system with the optimal dimensions.

We used this final design to create physical prototype of our workstation. Due to time and budget constraints, we chose to create a prototype that would be representative of our final design by including only one "column" of the workstation that included all the key subsystems. These include the bag holding, sorting, bag opening, heat sealing, and paper folding systems. Our first attempt was a structural prototype which was a rough mock-up of the prototype to get an overall feel for scaling and fitting our key components. This included the bag holding, sorting, and heat sealing systems. This build provided us with reassurance that our design could be implemented physically. From there, we constructed a verification prototype which was a better representation of our system. We then ran multiple verification tests that evaluated the workstation's efficiency, feasibility, repeatability, and safety. From these tests, we received crucial insight into all issues with our design ranging from minor dimensioning errors to fundamental design flaws. Ultimately, we found that our workstation design does not significantly simplify complicated movements for people with dexterity-related disabilities. Additionally, it did not increase the kitting efficiency of the user while in operation and rather increased the kitting time by 300%. Thus, our design failed to meet the primary goals of this project and we cannot recommend our current design as a solution to this problem.

9.1 Recommendations

We have several design recommendations which we believe would improve our design to hopefully make it a viable option for workers with dexterity impairments. The bag holding system could see significant improvements. During our testing, we found that we often tried to manually pull the bags down to move them into the correct hooking position instead of using the ratchet crank. We see this problem being even worse for the full design, as it is located at each of the 34" wide workstation. For that reason, we recommend a change to this design. The design could be simplified to eliminate the ratchet cranks and simply rely on the user pulling the bags down into the correct position. As another option, this operation could be automated by attaching motors to drive the bag rolls instead of manually doing it. This change would increase efficiency, but it would also increase the cost of the project.

Next, we found that the sorting system often encountered alignment issues when trying to drop the items into the bags. This was because of the required clearance tolerance for the template plates to fit in the workstation. This allowed for horizontal movement which affected the alignment of the template holes. We recommend limiting these degrees of freedom by adding limits to how far the plate can travel in and out of the workstation and by adding spacers to the sides of the lower template. Additionally, the lower template's holes could be increased slightly to allow for more reliable item passage. As a quality of life improvement, the lower plate could also be designed to be spring loaded to return to the neutral position without having to worry about correct alignment.

We noticed that visibility was limited in the lower bagging area. This made it difficult to see the hooking process or line up the bags to the correct orientation for hooking and would often cause the user to have to bend down to see what is going on. We recommend increasing this access area by shortening (or removing) the lower grab ramps. This would allow for more space and freedom for the user to operate in during the current bag opening and heat-sealing design. This may not be necessary if a new bag opening design is implemented. Additionally, the implementation of LEDs to the inside of the would provide excellent lighting to help improve visibility in that section.

From our testing, we found that the bag opening process was very inconsistent and inefficient as it was very difficult to consistently open one bag. Our overall design included five hooks opening five bags simultaneously which we cannot foresee working reliably if implemented. We recommend completely redesigning the bag opening process to make it much more reliable and functional. From our research, we found that most automated bagging machines use compressed air to blow open the bags which could be a great replacement for the current hooks that would also greatly increase efficiency.

9.2 Next Steps

As of now, our workstation design has never been implemented in its entirety. Thus, the next step would be to construct a full version of our workstation design so we can get a sense of the functionality and feasibility of the complete design. Though we are not optimistic based on the results from the testing of our verification prototype, conducting testing on a full workstation may provide different results as the highlight of our design is consolidating repeated tasks for each bag such as opening and heat sealing. Additionally, testing this workstation design on people with dexterity impairments would be pivotal to improving the design. Due to the COVID-19 pandemic, we were not able to test our design on people with disabilities (or anyone outside of our team for that matter). Getting end user feedback would give us insight into facets of their experiences that we, as designers, would have no idea of. Thus, this step would be crucial for any readers who plan to pursue this project further.

9.3 Project Reflection

As we conclude this project, our team would like to reflect on our experience throughout this entire process. While we did not create the optimum design that would benefit workers with disabilities, we created a device that taught us about the important elements of the engineering design process. Learning about the different brainstorming technique and decision matrices was a fun and interesting experience as we don't get many opportunities to actively practice creativity. Beyond the initial ideation phase, we really appreciated the prototyping and building aspects of this project. Being able to practice hands-on work and tinkering with our design to make ends meet is always a challenging and fun process. Finally, our workstation design placed third in the SourceAmerica design competition against many other colleges nationwide. That is definitely something that we are proud of, looking back on this experience.

Unfortunately, however, we are still greatly disappointed that our design did not function as we initially hoped. It just reiterated the importance of the design process and creating the necessary engineering justification for a design prior to implementation. If we had to do it again, we would take the initial design process more seriously to hopefully come up with a better initial design. Including more input from people with disabilities would have aided us in this process, as they are the ones who would be using this device and would be most knowledgeable in this field. Perhaps the outcome of this project would be different if we were able to meet in person to ideate and meet with people with disabilities to obtain user feedback. Still, we are extremely appreciative of this opportunity to learn these lessons prior to entering the professional engineering profession.

As a final remark, we would just like to thank Dr. Peter Schuster and the rest of the Cal Poly mechanical engineering senior project coaches for creating a fun, interesting experience, and educating us about the engineering design process. It gave us an opportunity to not only refine our skills as engineers but to create lifelong friendships with our teammates which would not have been possible without this project.

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11. Appendices

A. QFD House of Quality
B. Ideation Concepts
C. Concept Models
D. Pugh Matrices
E. Morphological Matrix
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G. CAD Model V2
H. CAD Model V3
I. CAD Model V4
J. CAD Model V5
K. Final CAD Design
L. Gantt Chart
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N. Final Project Budget
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P. Drawing Package
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S. Risk Assessment
T. User Manual
U. Test Procedures
V. Design Verification Plan and Report

Appendix A: QFD House of Quality

Correlations	
Positive	+
Negative	−
No Correlation	

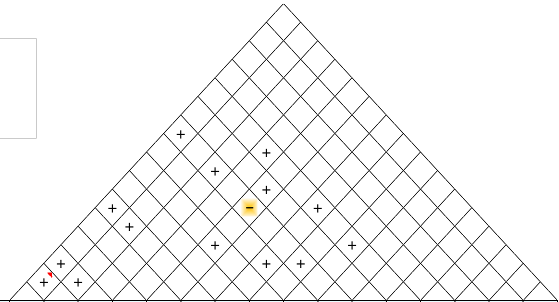
Relationships	
Strong	●
Moderate	○
Weak	▽

Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼

QFD House of Quality

Project: SourceAmerica Kitting and Packaging

Revision Date: 10/07/20

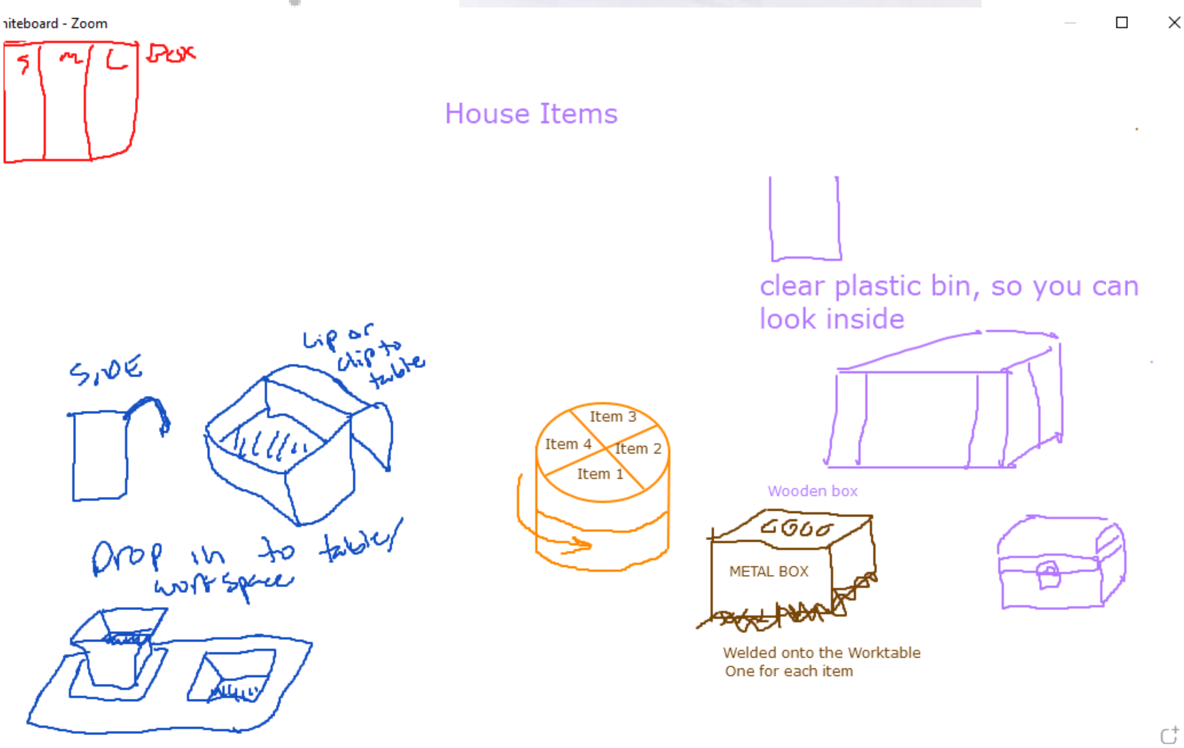


			WHO: Customers					Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	NOW: Curr. Products					
								Direction of Improvement	▼	▼	◇	◇	◇	◇	▲	▼	▼	▼	◇	▼										
Row #	Weight Chart	Relative Weight	Workers w/ Motor Functionality Issues	Workers w/o Disabilities	Company	Manufacturer	Maximum Relationship	HOW: Engineering Specifications (Tests) / WHAT: Customer Requirements (Needs/Wants)	Bag Count Test	Label Check	Item Counter	Hold Paper? (Y/N)	User Survey	Heat Sealed Bags? (Y/N)	Durability Test	Comparative Dexterity Analysis	Cost	Time to complete task	Construction Survey	Weight					Automated Cart Company	Sort A Screw	Weaver Industries ProPak	The Coffee Cube		Row #
1		8%	8	8	8	8	9	Consolodate bags	●	○								○							0	0	0	0		1
2		7%	7	7	9	7	9	Labels on each bag and larger bag	○	●								○							0	0	0	0		2
3		7%	7	7	9	7	9	Hold 2 kinds of 5 small items			●							○							0	4	0	0		3
4		7%	7	7	9	7	9	Hold 2 kinds of 3 medium items			●							○							0	4	0	0		4
5		7%	7	7	9	7	9	Hold 1 kind of 1 large item			●							○							0	4	0	0		5
6		7%	9	9	6	5	9	Hold paper instructions				●													0	3	3	0		6
7		9%	10	10	6	8	9	Ease of Use					●	○		●		▽							3	3	5	5		7
8		5%	5	5	5	6	9	Aesthetics					●							▽					3	2	2	4		8
9		6%	6	6	8	3	9	Heat Sealed Bags						●				▽							0	0	0	0		9
10		7%	6	6	8	7	9	Robust					○		●				○	○					3	2	4	3		10
11		6%	10	6	4	4	9	Can be used ambidextrously or one handed					○			●		○							5	4	5	3		11
12		5%	1	1	8	10	9	Cheap									●								2	1	2	5		12
13		9%	10	8	10	8	9	Increase productivity					○			▽		●		▽					4	3	5	5		13
14		4%	1	1	3	10	9	Easy to construct											●	○					3	3	2	3		14
15		5%	3	3	8	7	9	Lightweight							○					●					4	3	1	4		15
16		0%																												16

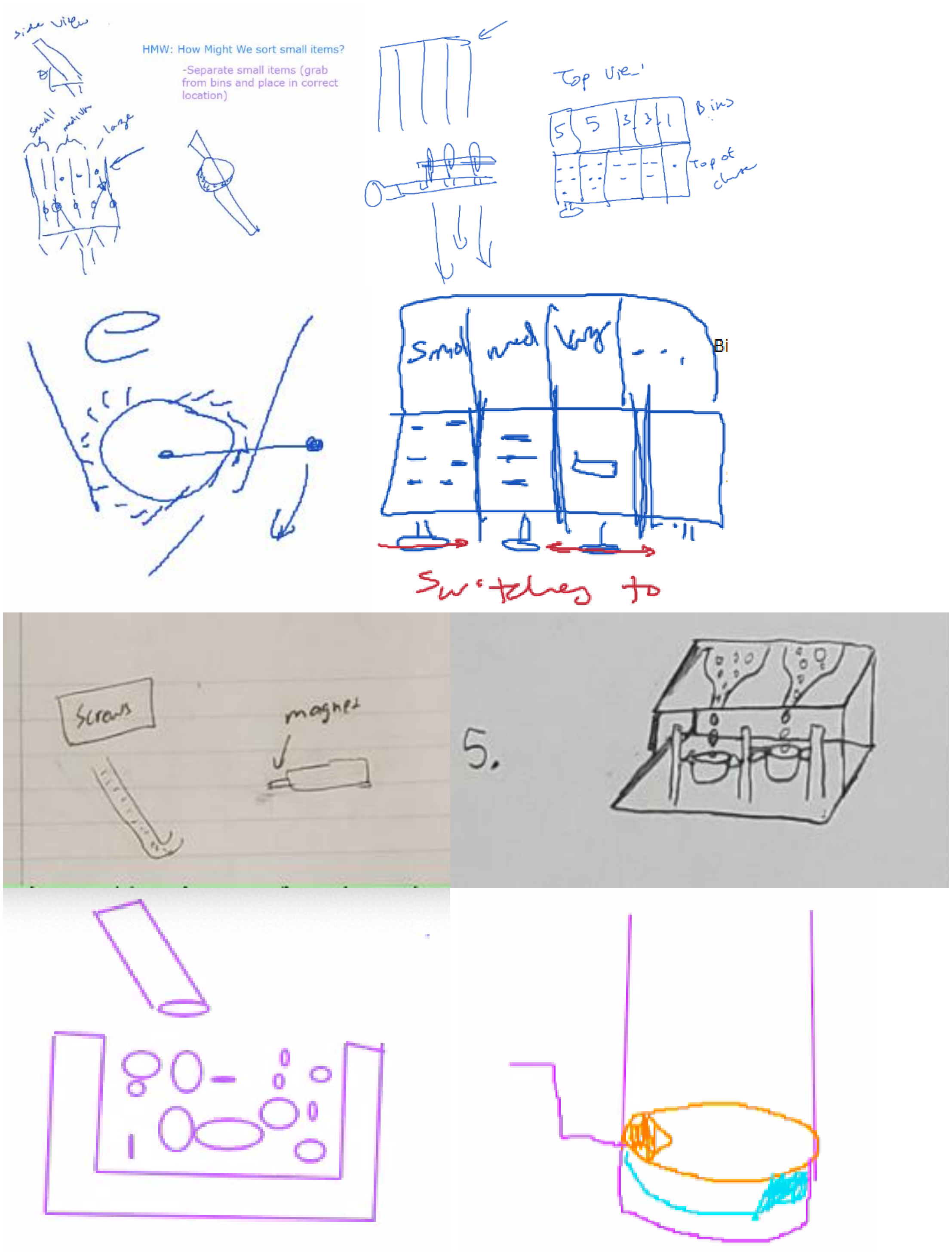
HOW MUCH: Target Values	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Target Values	4 Bags Max	1 excluded bag label out of 100 bags	1 excluded bag out of 100 bags	1 excluded paper instruction out of 100 bags	75% Positive Reviews	1 non-heat-sealed bag out of 100 bags	3 year life span	50% Efficiency increase	$250	5 minutes/task	Constructable in a few hours with all equipments available	50 lbs				
Max Relationship	9	9	9	9	9	9	9	9	9	9	9	9				
Technical Importance Rating	94.37	91.1	201.3	66.22	190	77.44	75.56	141.3	42.79	226.8	52.65	91.04	0	0	0	0
Relative Weight	7%	7%	15%	5%	14%	6%	6%	10%	3%	17%	4%	7%	0%	0%	0%	0%
Curr. Products: Automated Cart Company	0	0	5	4	4	0	3	2	1	3	3	5				
Curr. Products: The Coffee Cube	0	3	5	0	4	2	4	3	5	5	5	5				
Curr. Products: Sort A Screw	0	0	5	0	4	0	3	5	5	5	4	5				
Curr. Products: Weaver Industries ProPak	0	3	3	2	5	0	4	4	3	0	2	1				
Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Appendix B: Ideation Concepts

House Items:

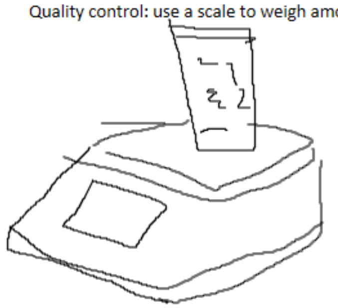


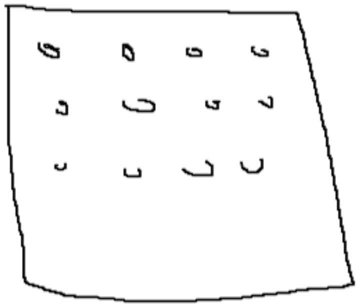
Sort items:

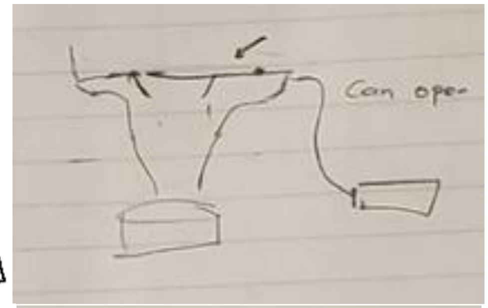

side view
HMW: How Might We sort small items?
-Separate small items (grab from bins and place in correct location)
small
medium
large
Top View
Bins
Top of chute
Small
med
large
Bi
Switches to
Screws
magnet
5.

Count Items:

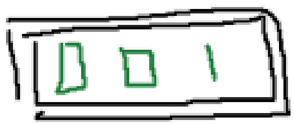
Quality control: use a scale to weigh amounts.

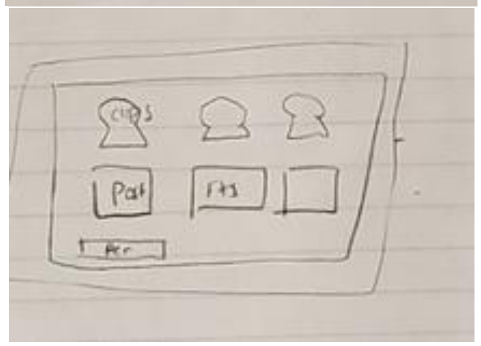


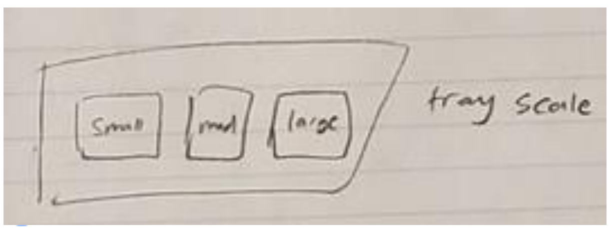




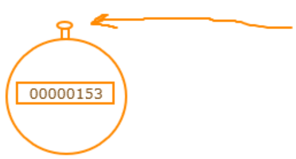
Digital Counter







Count Items



Maybe take into account the dexterity issue by making the button less sensitive than normal tally counter buttons.

Have a tally counter accessible for each counting station. Maybe have it attached to a rope that is attached to the worktable/counting station. That way it won't get lost.

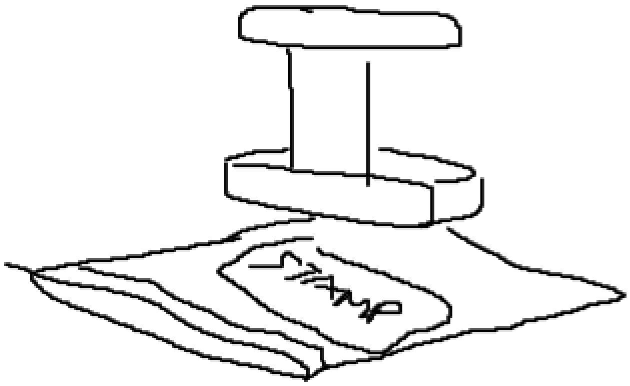
counter with flap that when pushed against (by object) adds to counter

Scale and attached data sheet with approximate weights/Kit. Can be used to approximate total number of kits + quality control

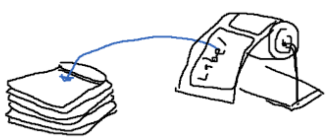
Item counter with a camera and software

label barcode scanner. each bag have specific barcode that specifies small, med, large

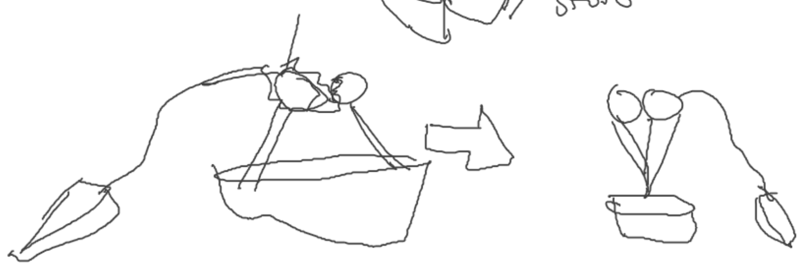
Consolidate Bags:



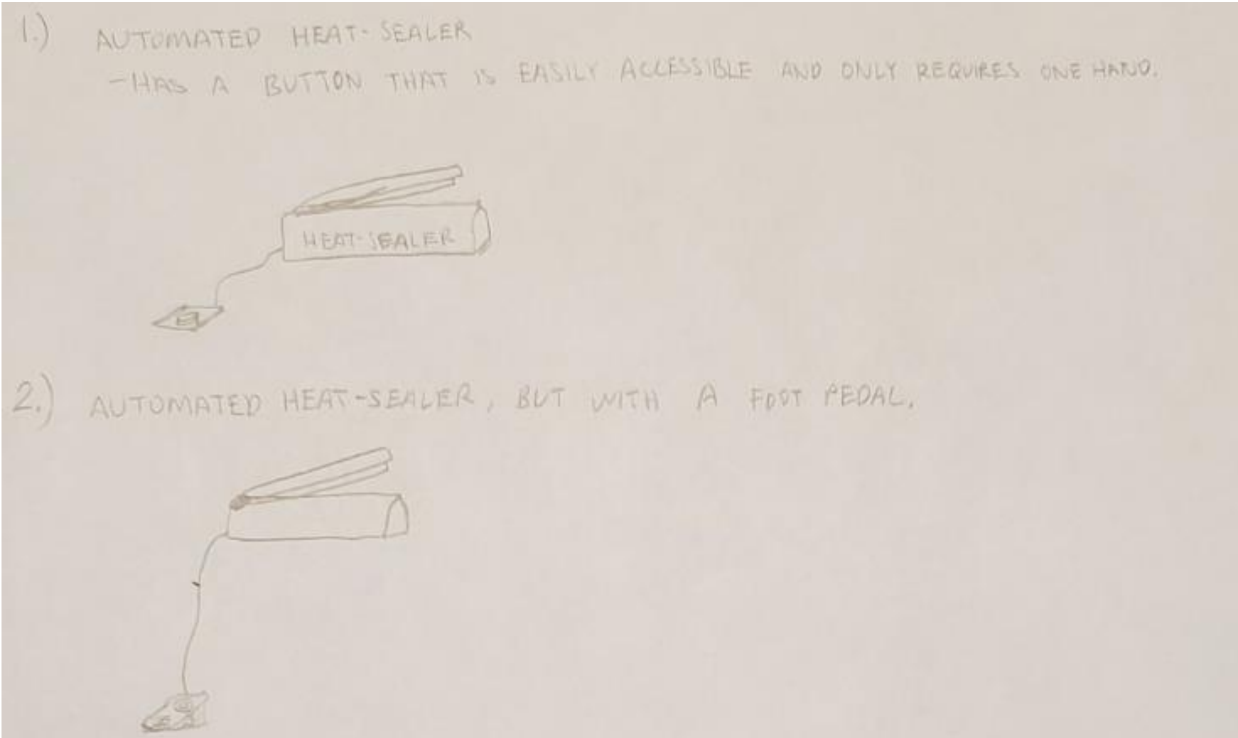
Roll of Sticker labels put on bags

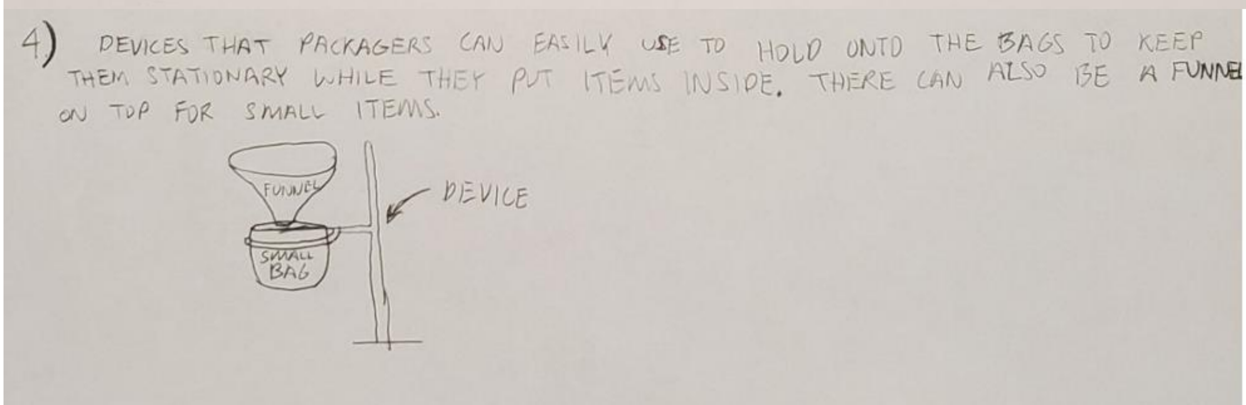


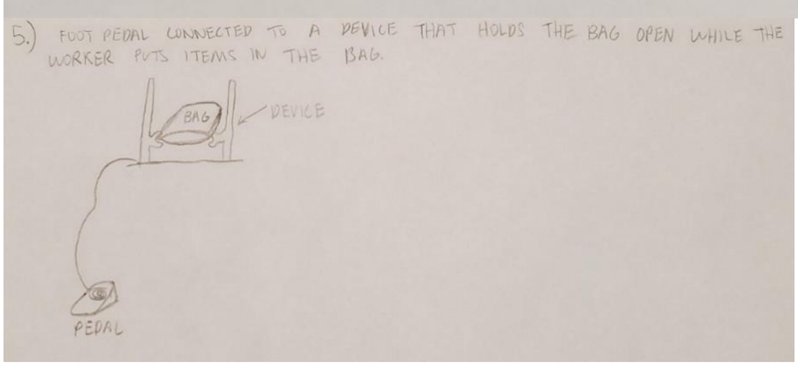
Print labels directly onto bags

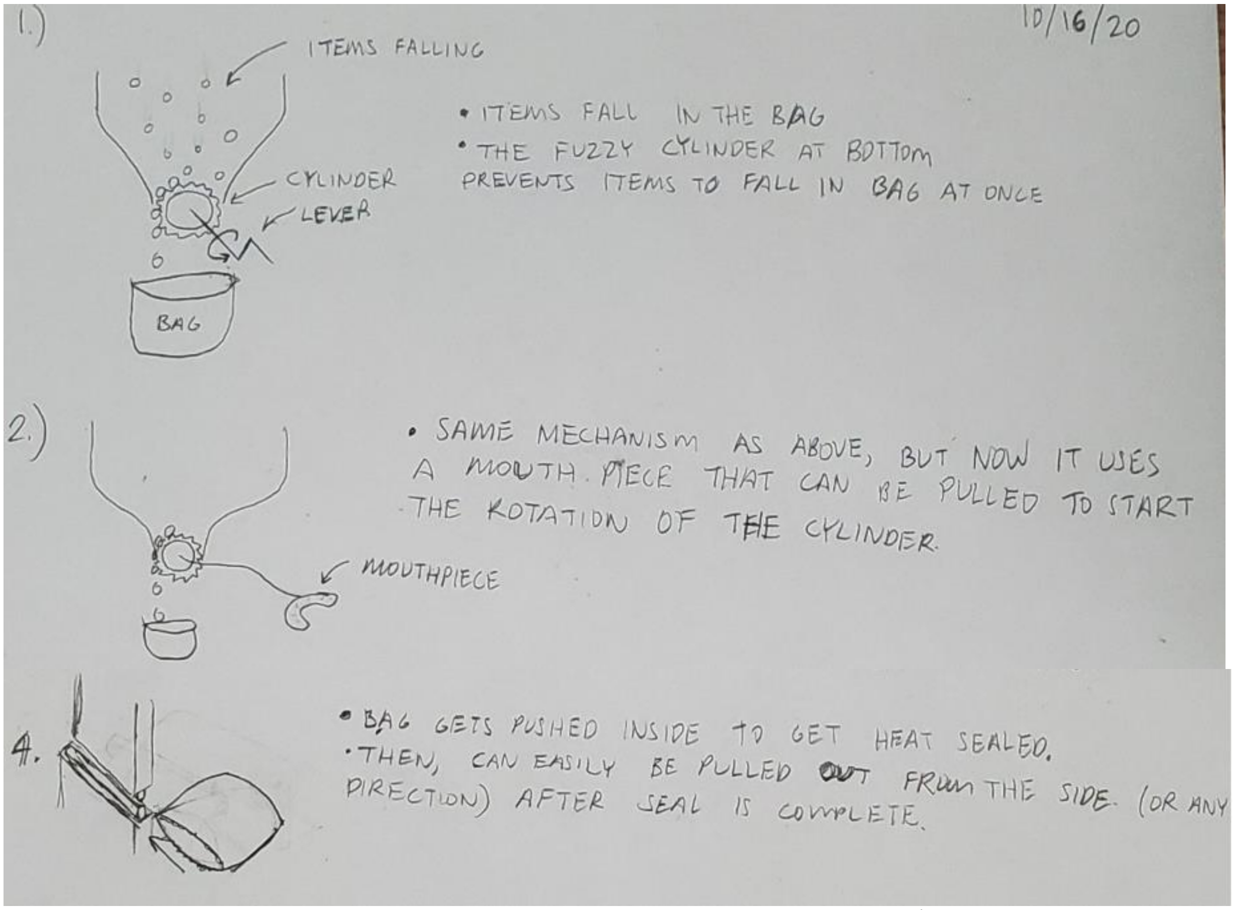


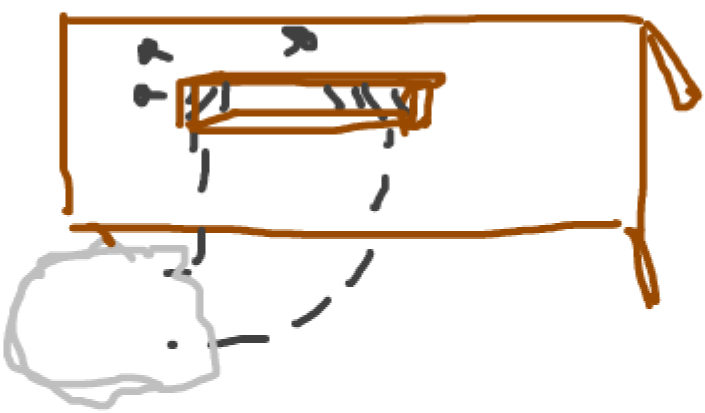
Seal Bags:


1.) AUTOMATED HEAT-SEALER
-HAS A BUTTON THAT IS EASILY ACCESSIBLE AND ONLY REQUIRES ONE HAND.
HEAT-SEALER
2.) AUTOMATED HEAT-SEALER, BUT WITH A FOOT PEDAL.

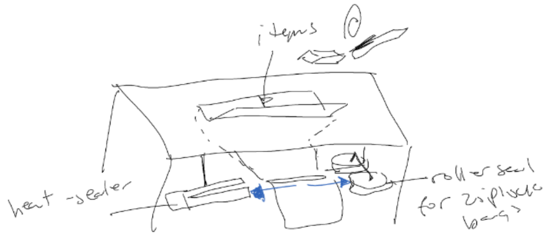

4) DEVICES THAT PACKAGERS CAN EASILY USE TO HOLD ONTO THE BAGS TO KEEP THEM STATIONARY WHILE THEY PUT ITEMS INSIDE. THERE CAN ALSO BE A FUNNEL ON TOP FOR SMALL ITEMS.
FUNNEL
DEVICE
SMALL BAG

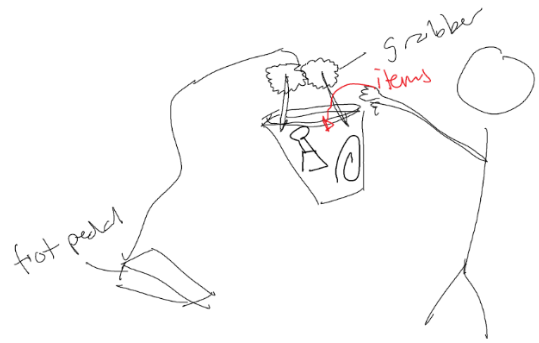

5.) FOOT PEDAL CONNECTED TO A DEVICE THAT HOLDS THE BAG OPEN WHILE THE WORKER PUTS ITEMS IN THE BAG.
BAG
DEVICE
PEDAL

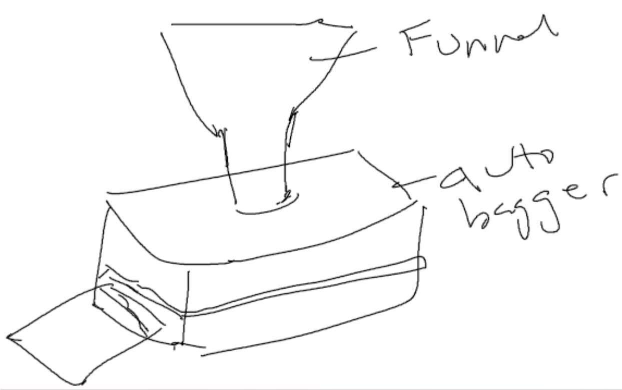

1.)
10/16/20
ITEMS FALLING
CYLINDER
LEVER
BAG
• ITEMS FALL IN THE BAG
• THE FUZZY CYLINDER AT BOTTOM PREVENTS ITEMS TO FALL IN BAG AT ONCE
2.)
• SAME MECHANISM AS ABOVE, BUT NOW IT USES A MOUTH PIECE THAT CAN BE PULLED TO START THE ROTATION OF THE CYLINDER.
MOUTHPIECE
4.
• BAG GETS PUSHED INSIDE TO GET HEAT SEALED.
• THEN, CAN EASILY BE PULLED OUT FROM THE SIDE. (OR ANY DIRECTION) AFTER SEAL IS COMPLETE.

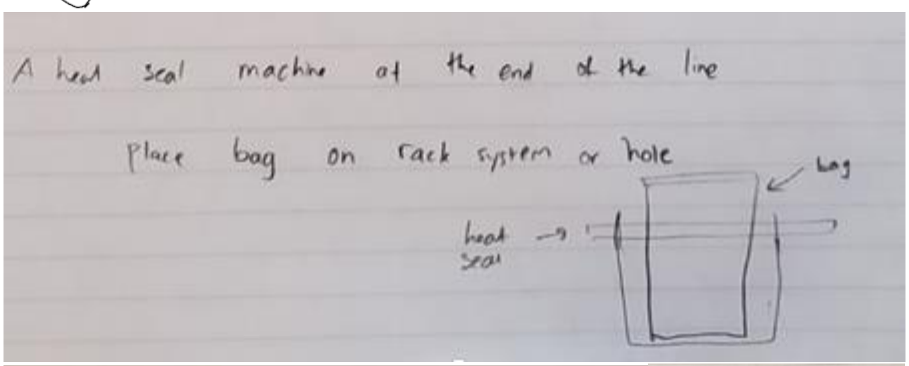


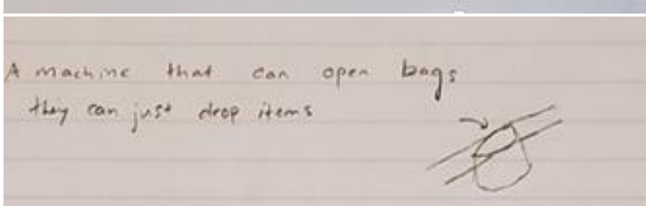

Funnel
heat sealer
foot pedal

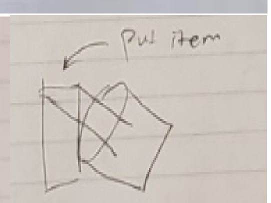

items
heat-sealer
roller seal for ziplock bags

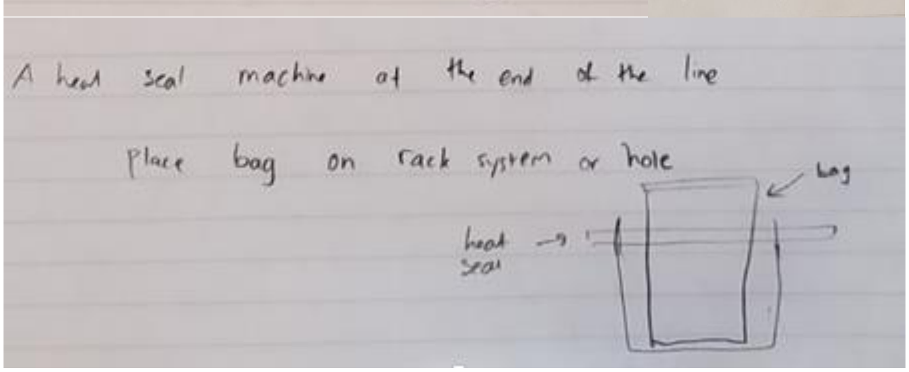

grabber
items
foot pedal


Funnel
auto bagger

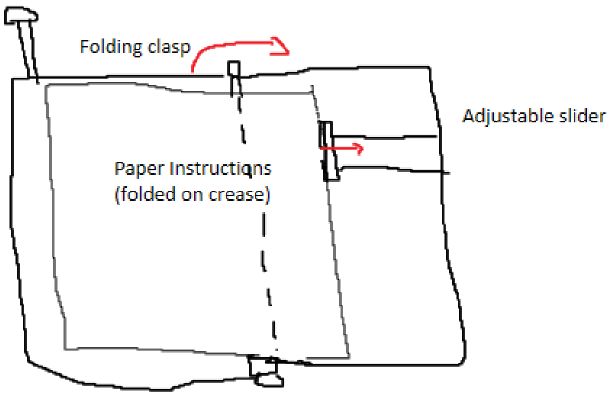

A heat seal machine at the end of the line
Place bag on rack system or hole
bag
heat seal

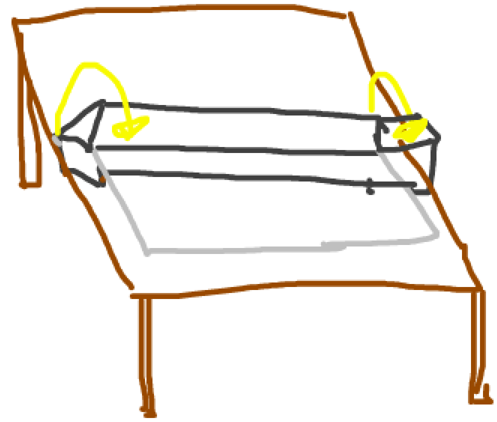

A machine that can open bags
they can just drop items

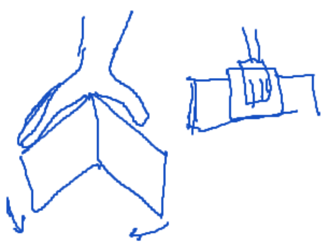

put item

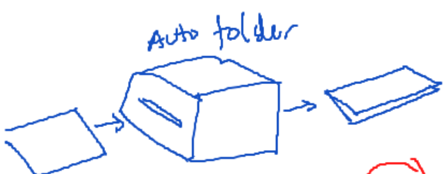

A heat seal machine at the end of the line
Place bag on rack system or hole
bag
heat seal

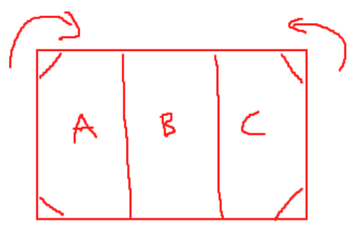
Fold Paper:

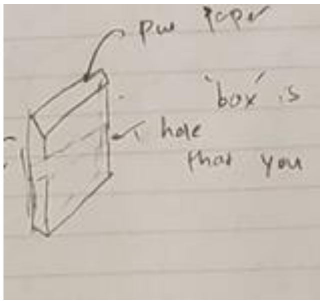

Folding clasp
Adjustable slider
Paper Instructions
(folded on crease)

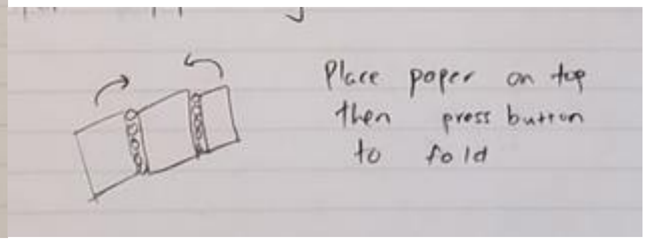


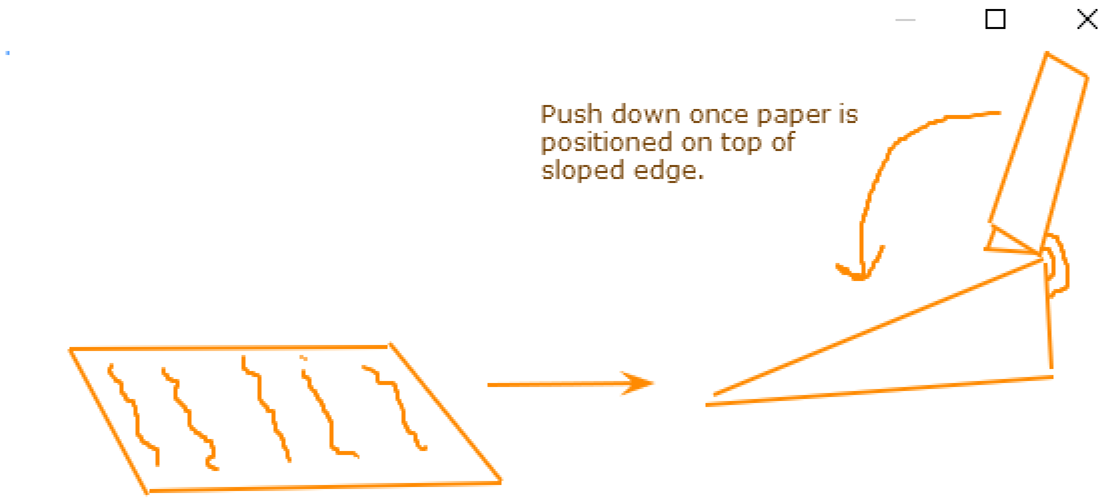



Auto folder

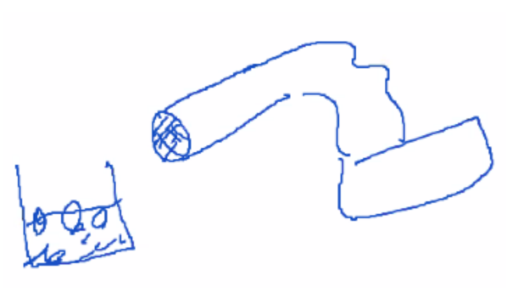

A
B
C

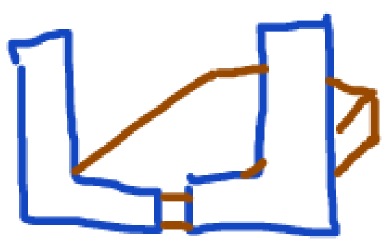


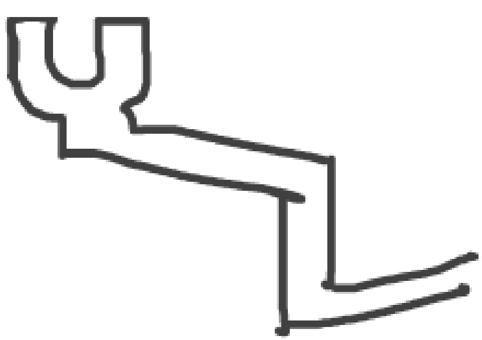


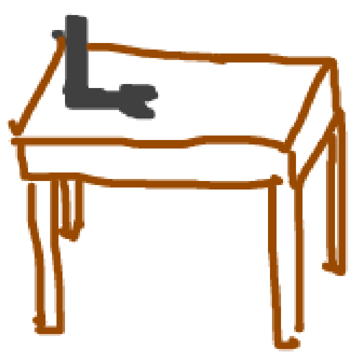


Minimized Required Dexterity:

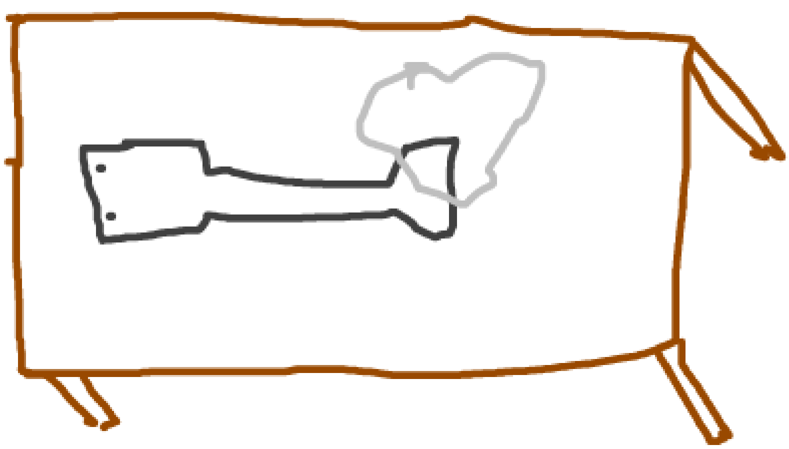


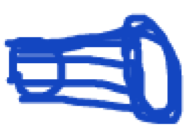


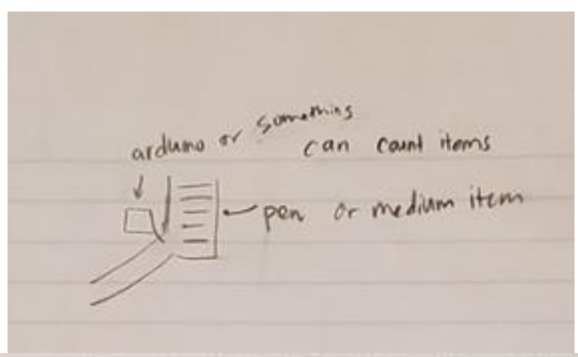


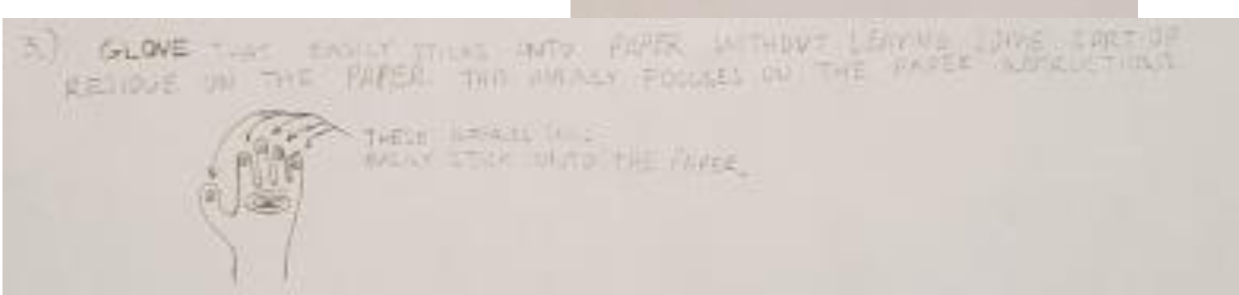


Creating Open Sour



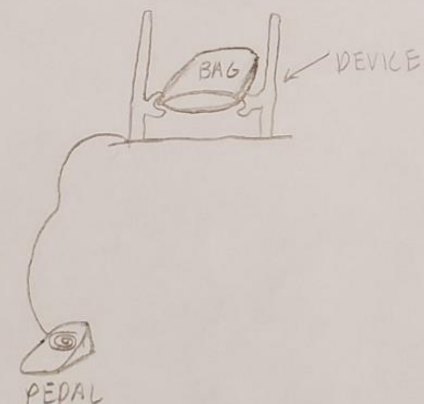




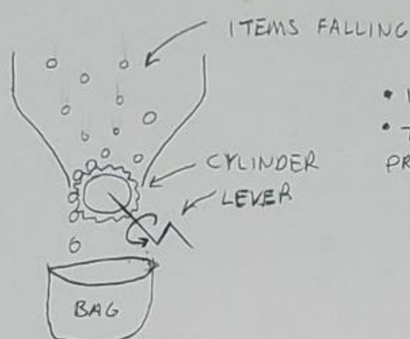


4) DEVICES THAT PACKAGERS CAN EASILY USE TO HOLD ONTO THE BAGS TO KEEP THEM STATIONARY WHILE THEY PUT ITEMS INSIDE. THERE CAN ALSO BE A FUNNEL ON TOP FOR SMALL ITEMS.

5.) FOOT PEDAL CONNECTED TO A DEVICE THAT HOLDS THE BAG OPEN WHILE THE WORKER PUTS ITEMS IN THE BAG.

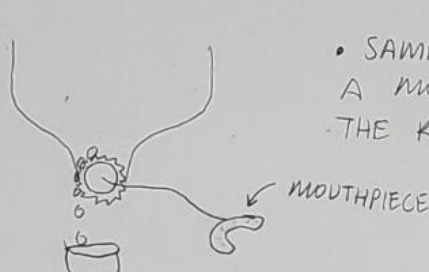


1.) 10/16/20

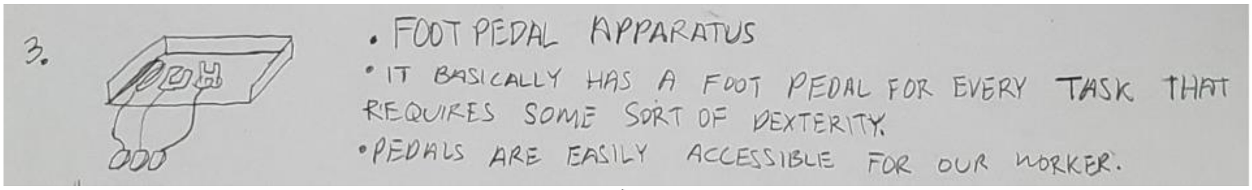


- ITEMS FALL IN THE BAG
- THE FUZZY CYLINDER AT BOTTOM PREVENTS ITEMS TO FALL IN BAG AT ONCE

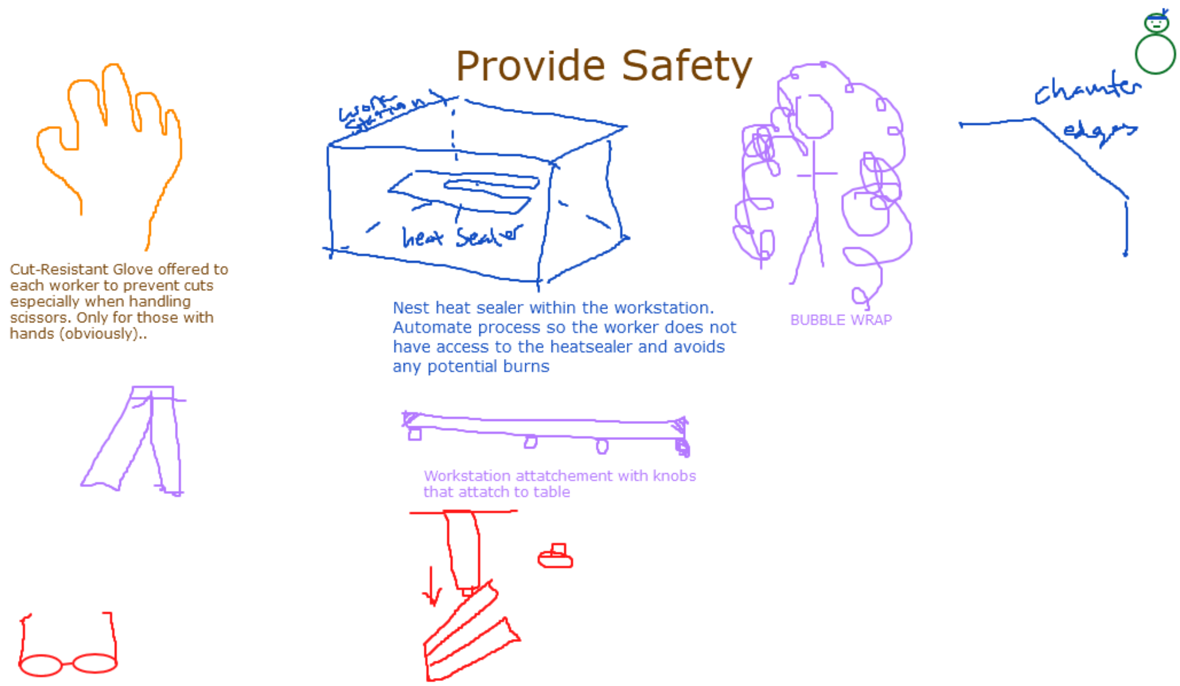
2.)



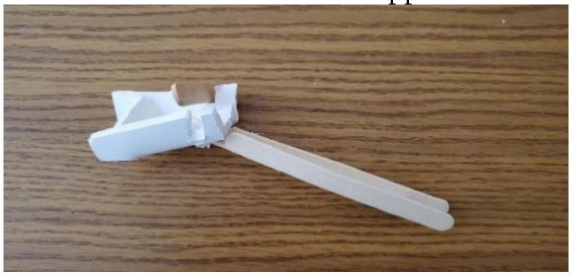
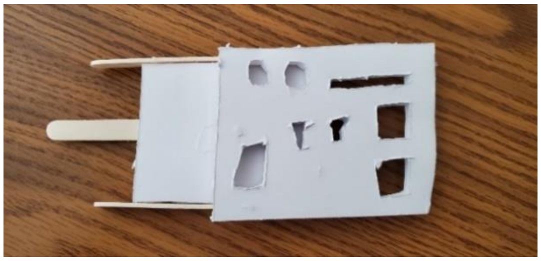
- SAME MECHANISM AS ABOVE, BUT NOW IT USES A MOUTH PIECE THAT CAN BE PULLED TO START THE ROTATION OF THE CYLINDER.

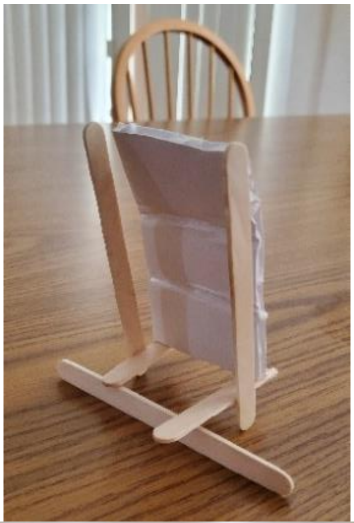


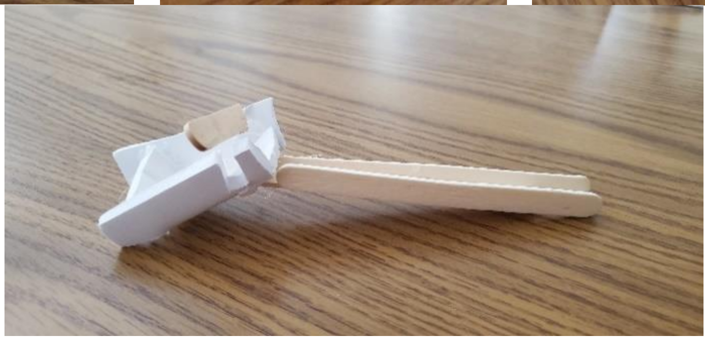
Provide Safety:

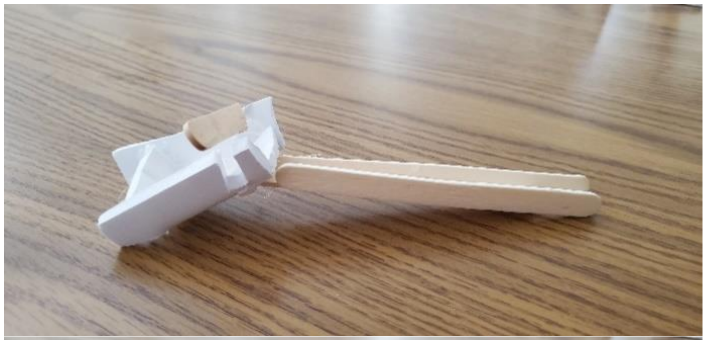


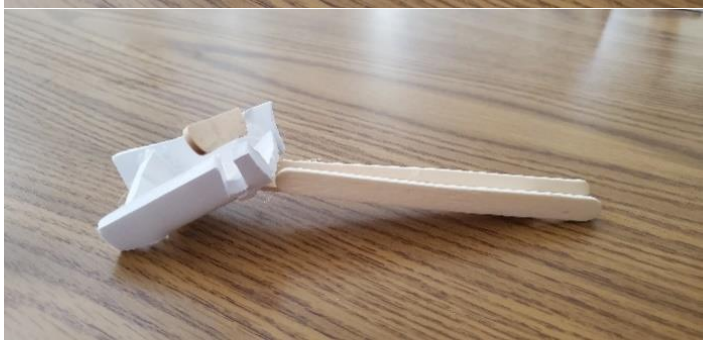
Appendix C: Concept Models

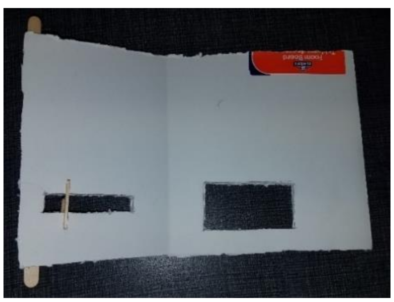



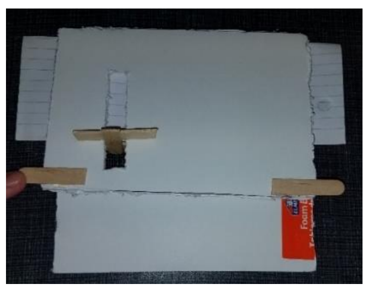




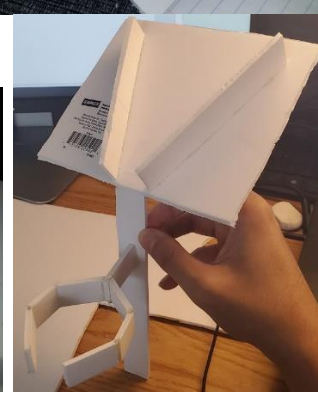


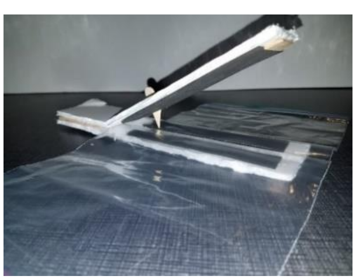




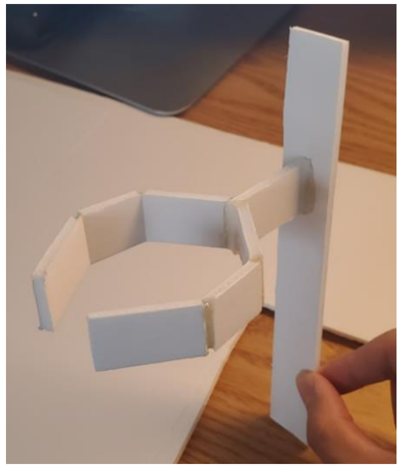


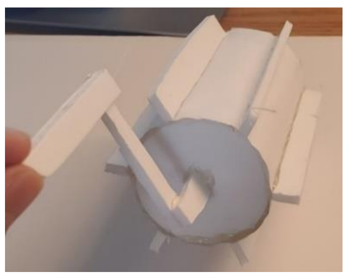

ALESIS





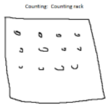
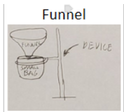
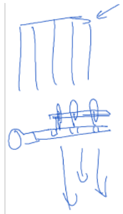
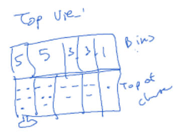
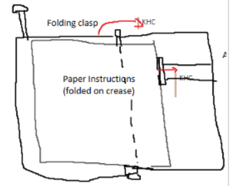
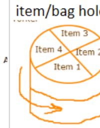

HEAT SEALER

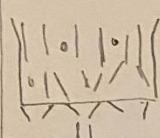
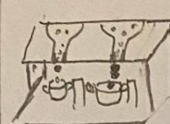
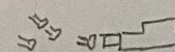



Appendix D: Pugh Matrices

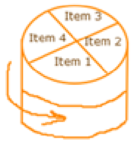
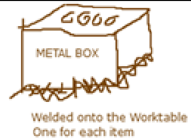
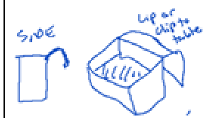
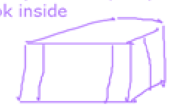
Increase Efficiency:

Criteria	Manual		Funnel 				Foot pedal bagger and sealer 	Fold paper 	Rotatable item/bag holder 
Accuracy	D	+	+	+	+	+	+	+	+
Manufacturability	A	-	-	-	-	-	-	-	-
Budget		-	-	-	-	-	-	-	-
Ease of use		+	+	+	+	+	+	+	+
Robust	T	+	+	+	+	+	+	+	+
Can be operated one handedly		+	+	+	+	+	+	-	+
Increase Productivity	U	+	+	+	+	+	+	+	+
Lightweight	M	-	-	-	-	-	-	+	-
Total		2	2	2	2	2	2	1	2

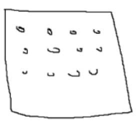
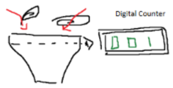
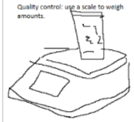
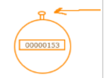
Sort Items:

Sort Items CRITERIA		Roller sorter 	Pinball sorter 	2 Shelf sorter 	Moving Sorting Plates 	Magnetic Sorter 
Hold 2 kinds of 5 small items	D	S	+	+	S	—
Hold 2 kinds of 3 medium items	A	S	+	+	S	—
Hold 1 kind of 1 Large item	T	+	S	S	S	S
Ease of Use	U	S	—	S	S	S
Aesthetics	M	—	S	S	S	S
Robust		—	+	+	—	S
Can be used left or Right handed		+	+	+	S	S
Cheap		+	—	S	S	+
Increase productivity		S	+	+	S	S
Easy to construct		S	—	—	S	S
Lightweight		S	—	—	+	+
Total		1	1	3	0	0

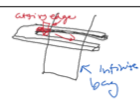
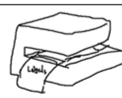
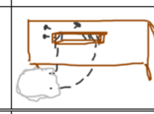
House Items:

Function: House Items						
	Rotating Item Holder	Drop-In Holder	Hooked Bin	Welded Metal Box	Hook-On Bag	Transparent Bin
Stakeholder Needs/Wants			Bin that can hook bags so items can be dropped in 			clear plastic bin, so you can look inside 
Ease of Use	Datum	+	-	+	+	+
Robust		S	+	+	S	+
Aesthetic		S	-	-	-	-
Cheap		S	+	-	+	+
Increase Productivity		-	-	-	S	-
Lightweight		+	S	-	S	S
Easy to Construct		S	+	S	+	+
Can be operated ambidextrously/ One handed		-	-	+	S	-

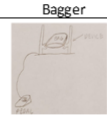
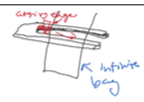
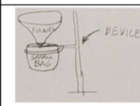
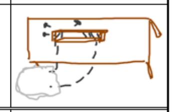
Count Items:

Criteria	Manual count	Counting Rack	Digital Counter	Kit Scale	Camera item counter	Barcode/label scanner	Counter with flap	Package scale	Tally counter
		Counting: Counting rack 	Digital Counter 	Quality control: use a scale to weigh amounts. 	 Item counter with a camera and software	 label barcode scanner. each bag have specific barcode that specifies small, med, large	 counter with flap that when pushed against (by object) adds to counter		
Accuracy	D	+	+	+	+	+	+	+	+
Manufacturability		-	-	-	-	-	-	-	-
Budget	A	-	-	-	-	-	-	-	-
Ease of use		+	+	-	+	+	+	-	-
Robust	T	+	-	+	-	-	-	+	-
Cam be operated one handedly		+	+	S	+	+	+	S	+
Lightweight	U	+	+	-	-	-	-	-	+
Increase Productivity	M	+	+	+	+	+	+	+	+
Total		4	2	-1	1	0	0	-1	0

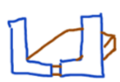
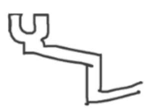
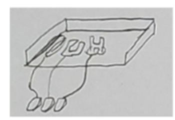
Consolidate Bags:

Function: Bagging Items							
	Manual Bagging	Foot-Pedal Operated Bagger	Heat Sealer w/ Cutter	Automated Bagger	Ziplock Rollers	Funneling Device	Workstation Chute
Stakeholder Needs and Wants							
Consolodate bags	Datum	S	S	S	S	S	S
Labels on each bag		S	S	+	S	S	S
Holds required Items		S	S	S	S	S	S
Increase productivity		+	+	+	+	+	+
Ease of Use		+	-	+	+	+	+
Aesthetics		+	+	+	+	+	+
Heat Sealed Bags		S	+	+	S	S	S
Robust		-	-	-	-	-	-
Can be operated ambidextrously/ One handed		+	-	+	+	+	+
Cheap		-	-	-	-	-	-
Easy to construct		-	-	-	-	-	-
Lightweight		-	-	-	-	-	-

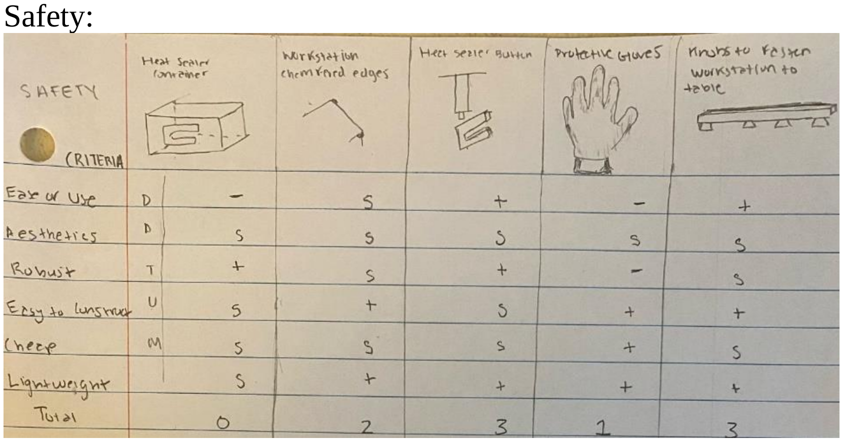
Fold Paper:

Function: Bagging Items							
	Manual Bagging	Foot-Pedal Operated Bagger	Heat Sealer w/ Cutter	Automated Bagger	Ziplock Rollers	Funneling Device	Workstation Chute
Stakeholder Needs and Wants							
Consolodate bags	Datum	S	S	S	S	S	S
Labels on each bag		S	S	+	S	S	S
Holds required Items		S	S	S	S	S	S
Increase productivity		+	+	+	+	+	+
Ease of Use		+	-	+	+	+	+
Aesthetics		+	+	+	+	+	+
Heat Sealed Bags		S	+	+	S	S	S
Robust		-	-	-	-	-	-
Can be operated ambidextrously/ One handed		+	-	+	+	+	+
Cheap		-	-	-	-	-	-
Easy to construct		-	-	-	-	-	-
Lightweight		-	-	-	-	-	-

Minimize Required Dexterity:

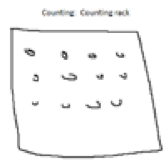
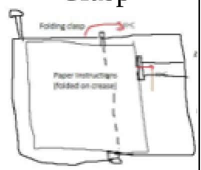
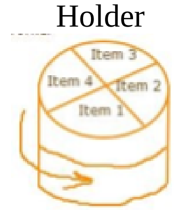
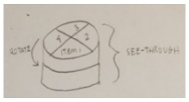
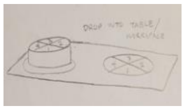
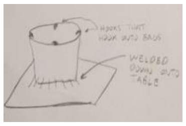
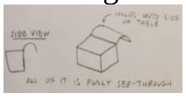
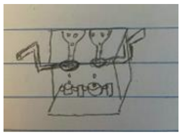
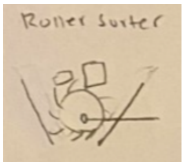
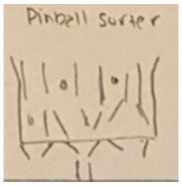
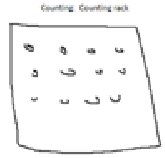
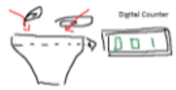
Function: Minimize Required Dexterity							
	Manual Operation	Vacuum Bagger	Elbow Clamp	Mouthpiece Operation	Grabber	Foot Pedals	Funnels
Stakeholder Needs and Wants							
Increase productivity	Datum	+	+	-	-	+	+
Ease of Use		-	-	+	+	+	+
Aesthetics		-	-	-	S	-	S
Robust		-	-	-	-	-	+
Can be operated ambidextrously/ One handed		+	+	+	+	+	+
Cheap		-	-	-	-	-	-
Easy to construct		-	-	-	-	-	-
Lightweight		-	-	-	-	-	-

Safety:

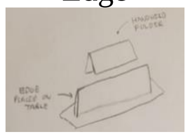
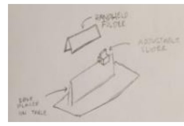
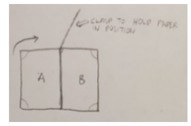
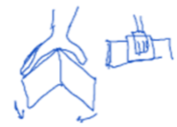
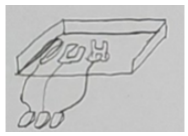
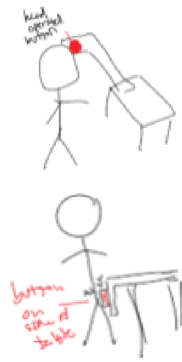
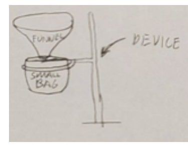
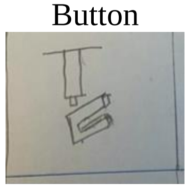
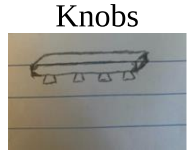


SAFETY CRITERIA		Heat Sealer Container	Workstation chamfered edges	Heat sealer button	Protective Gloves	Knobs to fasten workstation to table
Ease of Use	D	−	S	+	−	+
Aesthetics	D	S	S	S	S	S
Robust	T	+	S	+	−	S
Easy to construct	U	S	+	S	+	+
Cheap	M	S	S	S	+	S
Lightweight		S	+	+	+	+
Total		0	2	3	1	3

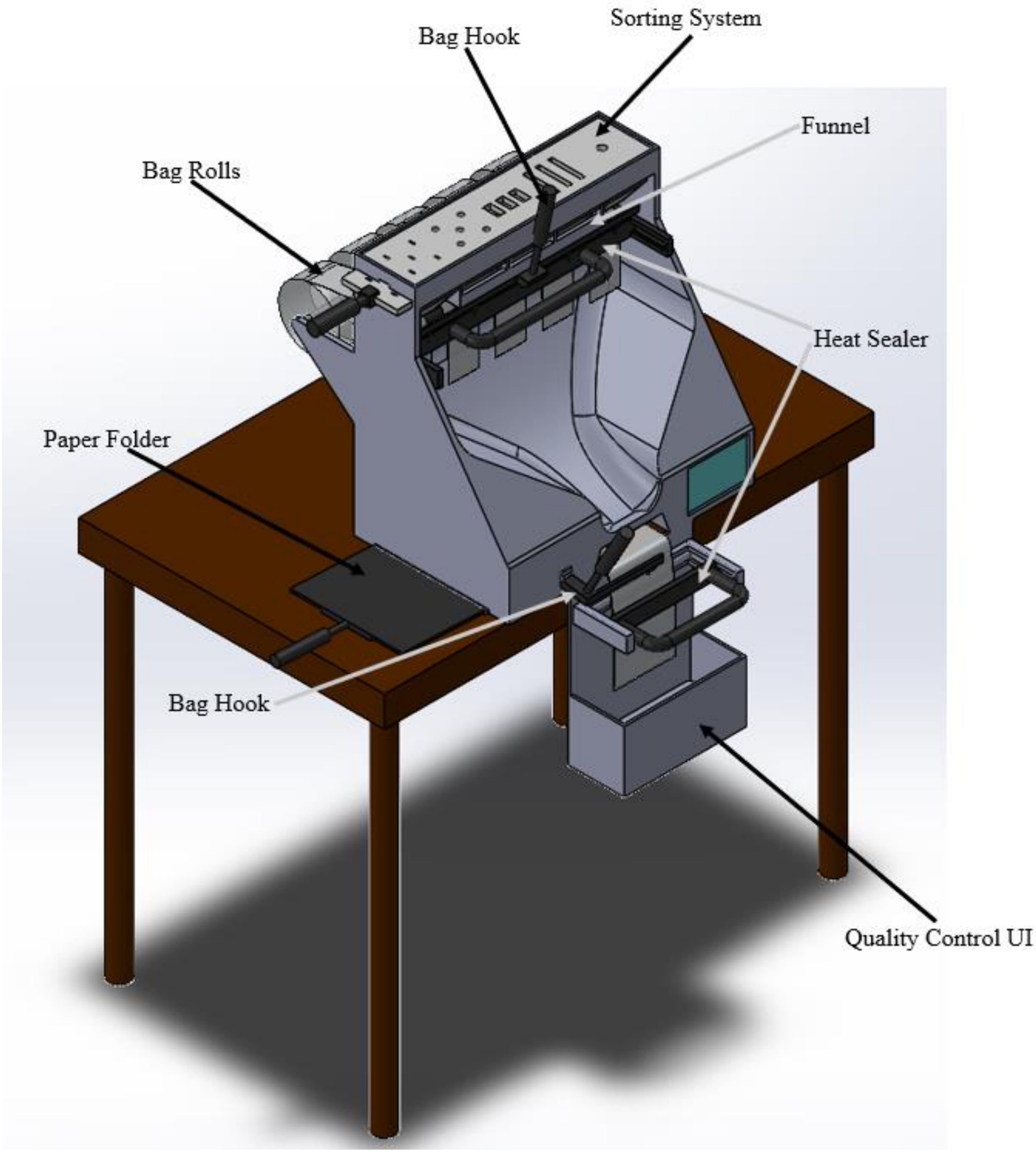
Appendix E: Morphological Matrix

No.	Sub-Function	Concept			
		I	II	III	IV
1	Increase Efficiency	Counting Rack 	Foot Pedal Sealer 	Fold Paper Clasp 	Rotatable Item/Bag Holder 
2	House Items	Transparent Rotating Item Holder 	Drop-In Rotating Item Holder 	Welded Hooked Bin 	Transparent Hook-On Bag 
3	Sort Items	2 Shelf Sorter with Slider 	Roller Sorter 	Pinball Sorter 	
4	Count Items	Counting Rack 	Digital Counter 		
5	Consolidate Bags	Foot pedal sealing 	Modular sealer 	Foot pedal grabber 	Automated bagger 

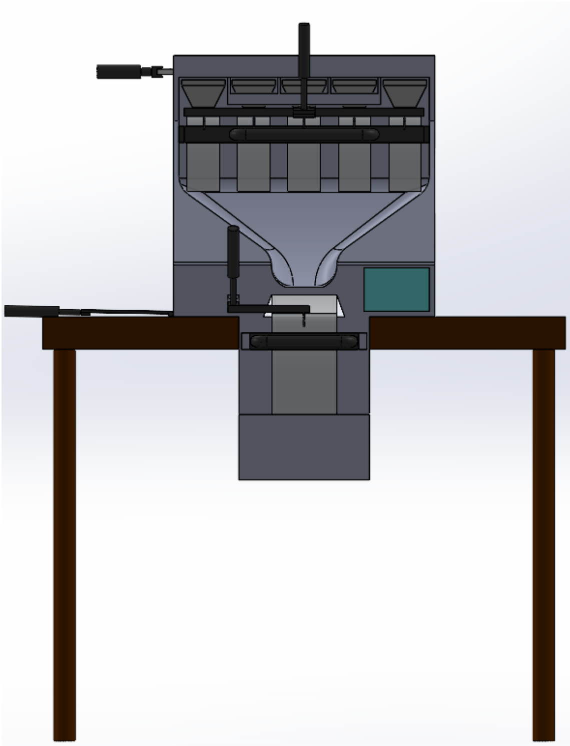
Appendix E: Morphological Matrix

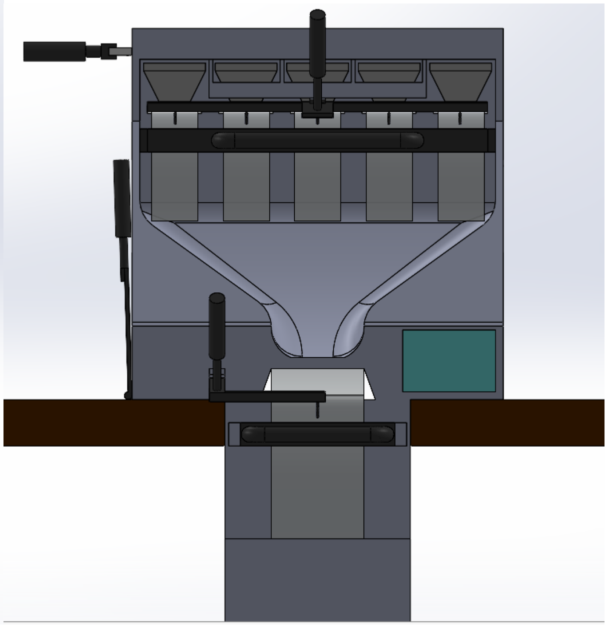
No.	Sub-Function	Concept			
		I	II	III	IV
6	Fold Paper	Handheld Folder on Edge 	Handheld Folder on Edge w/ slider 	Bi-Folder 	Handheld Folder 
7	Minimize Required Dexterity	Foot Pedals 	Body Operated Buttons 	Funnels 	Precision Grabber 
8	Provide Safety	Heat Sealer Button 	Chamfered Edges and Attachable Knobs 		

Appendix F: CAD Model V1

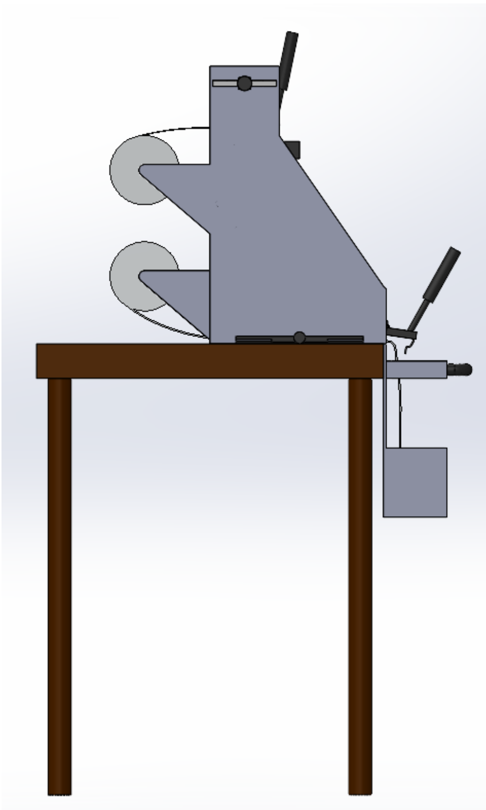


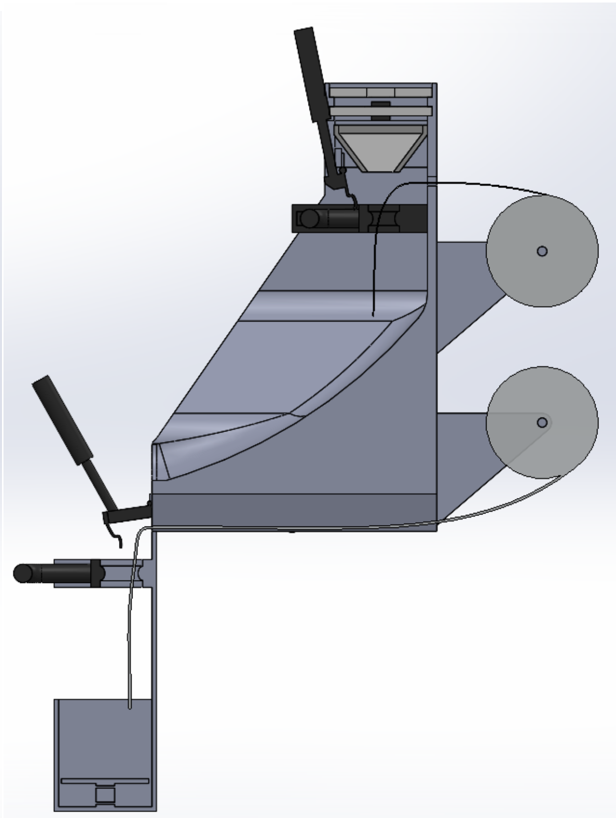
Front View:



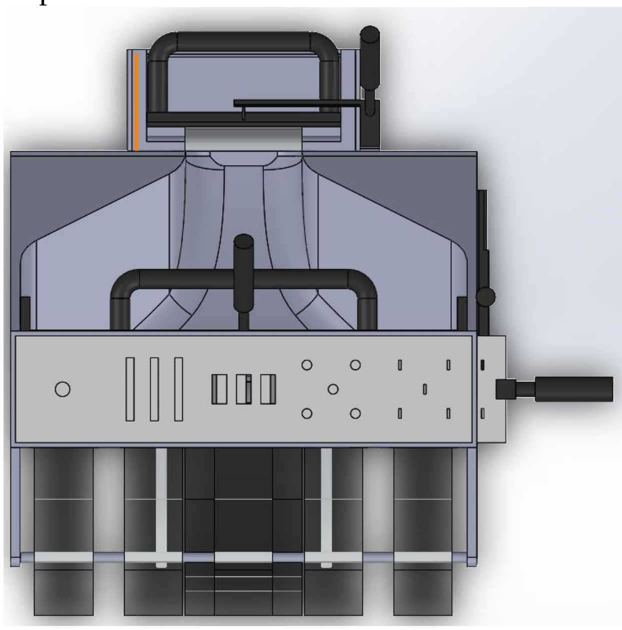


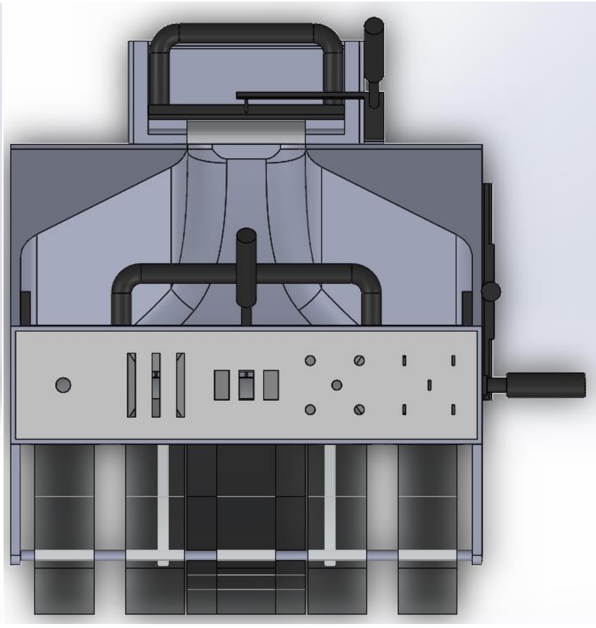
Side and Cross-Sectional View:



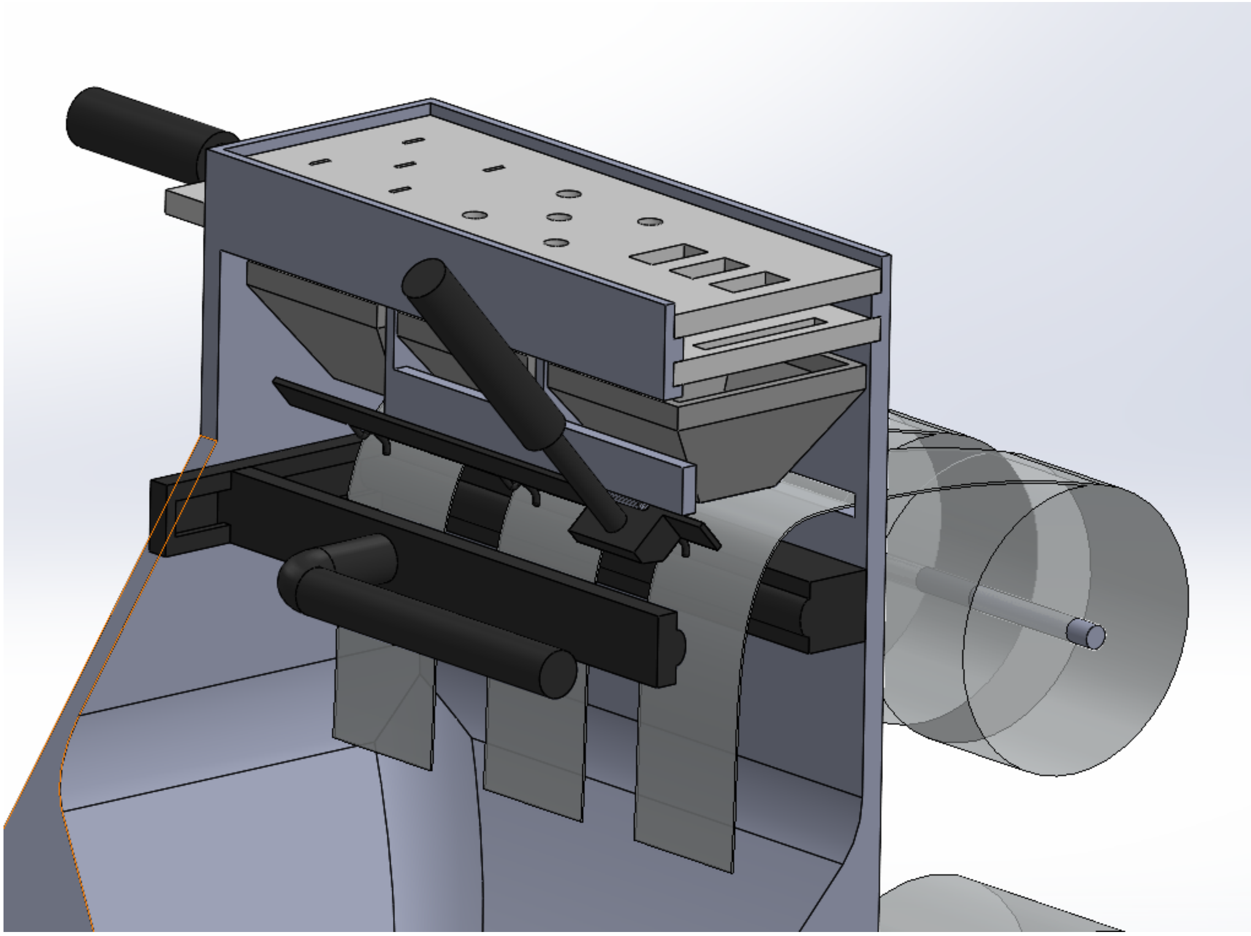


Top View:



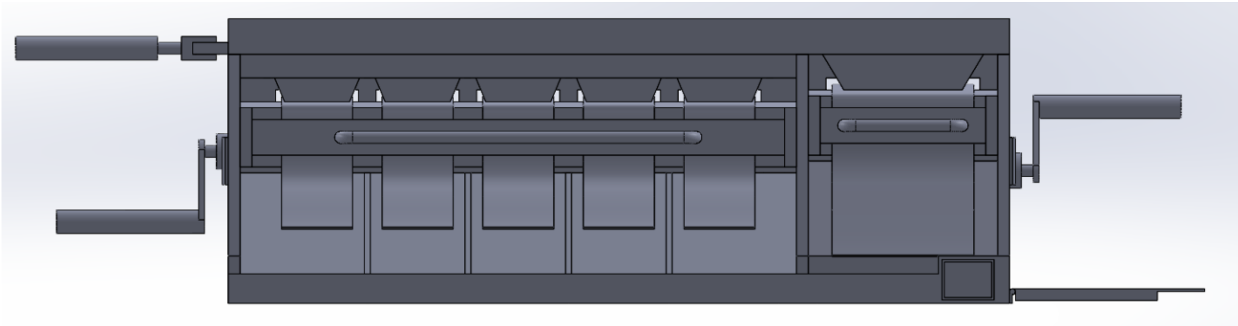


Detailed Picture of the Top Sorting/Bagging Apparatus:

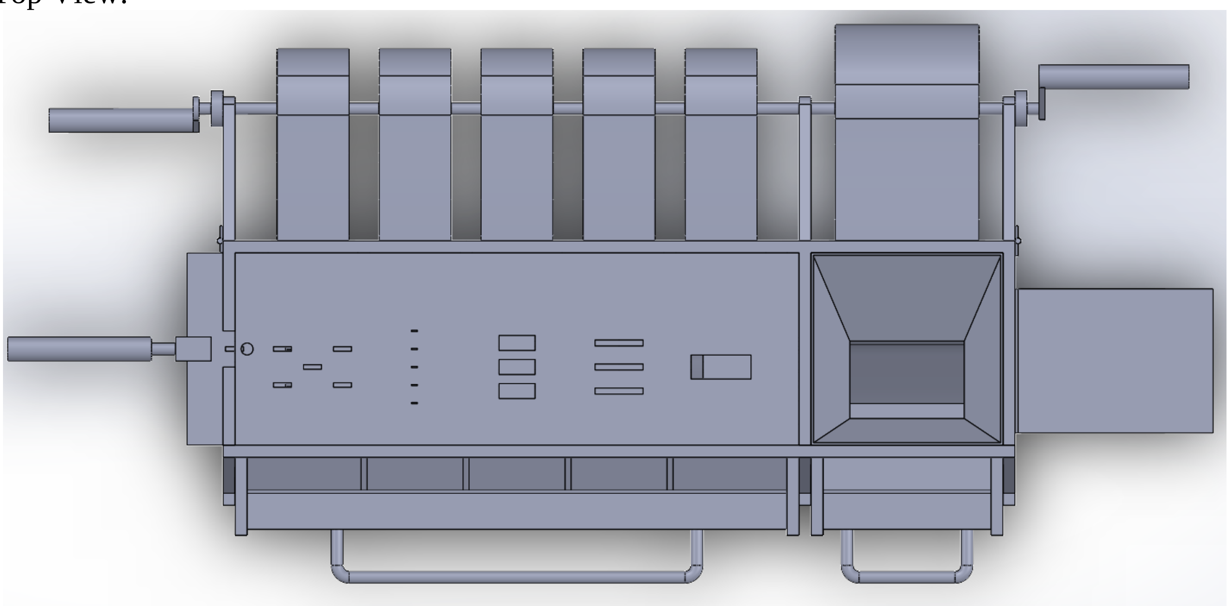


Appendix G: CAD Model V2

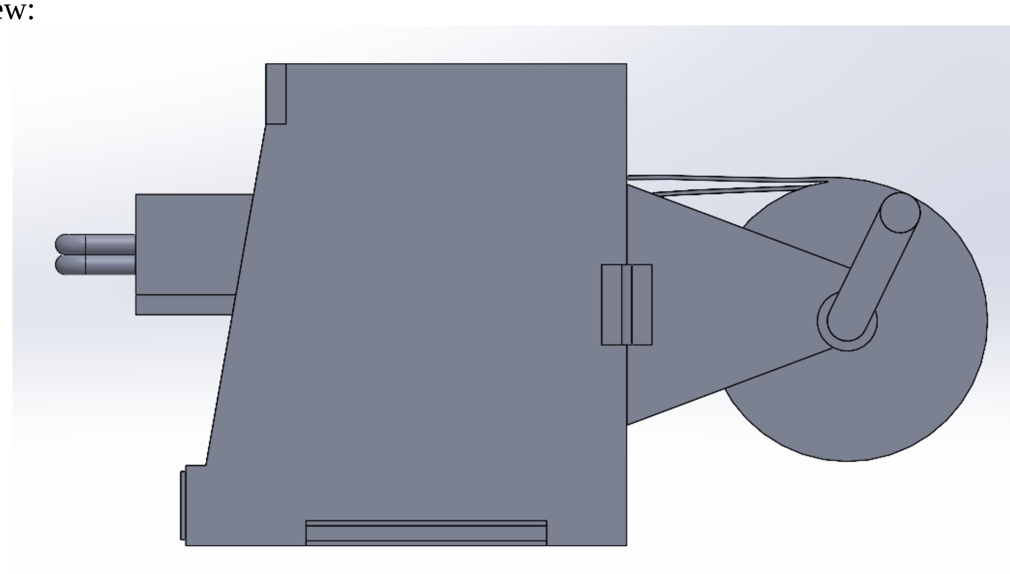
Front View:



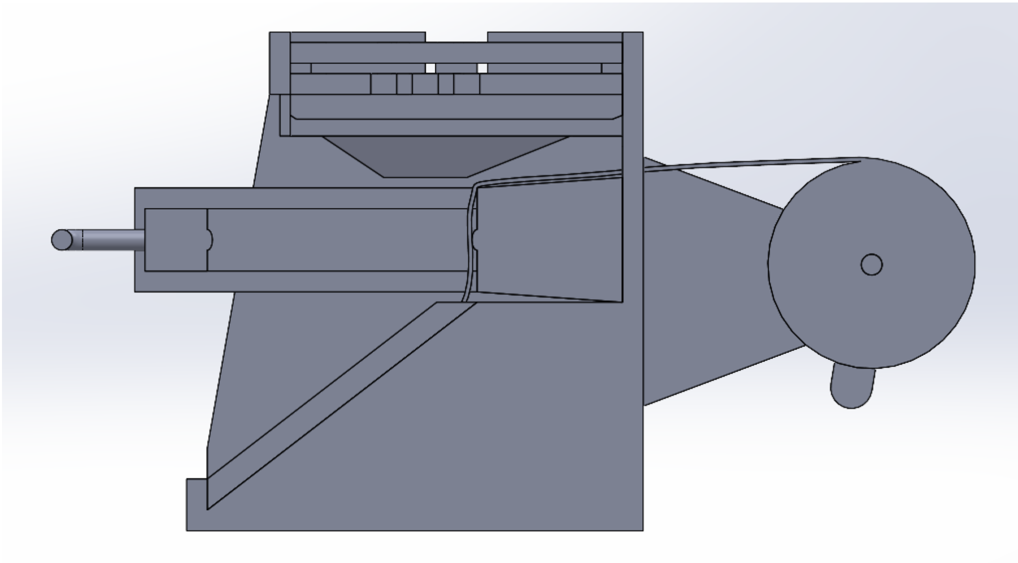
Top View:



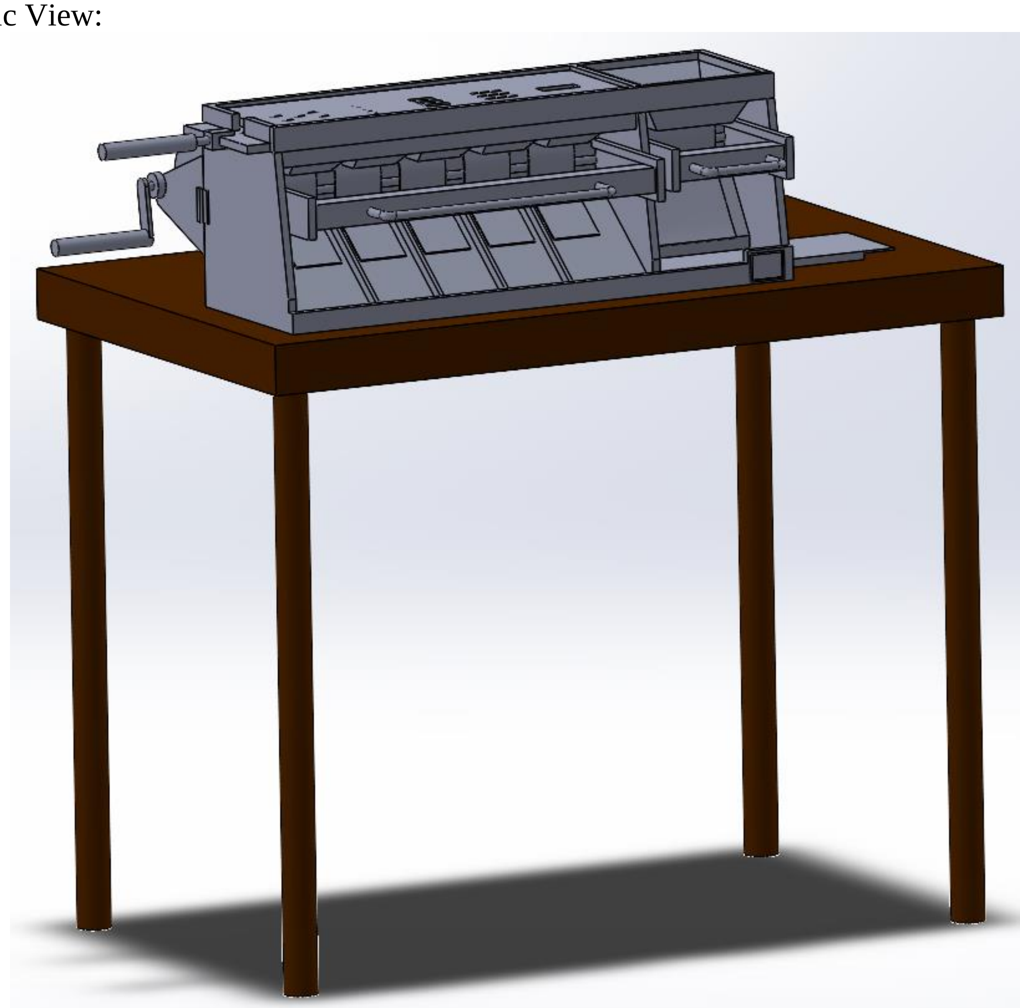
Side View:



Cross Section View:

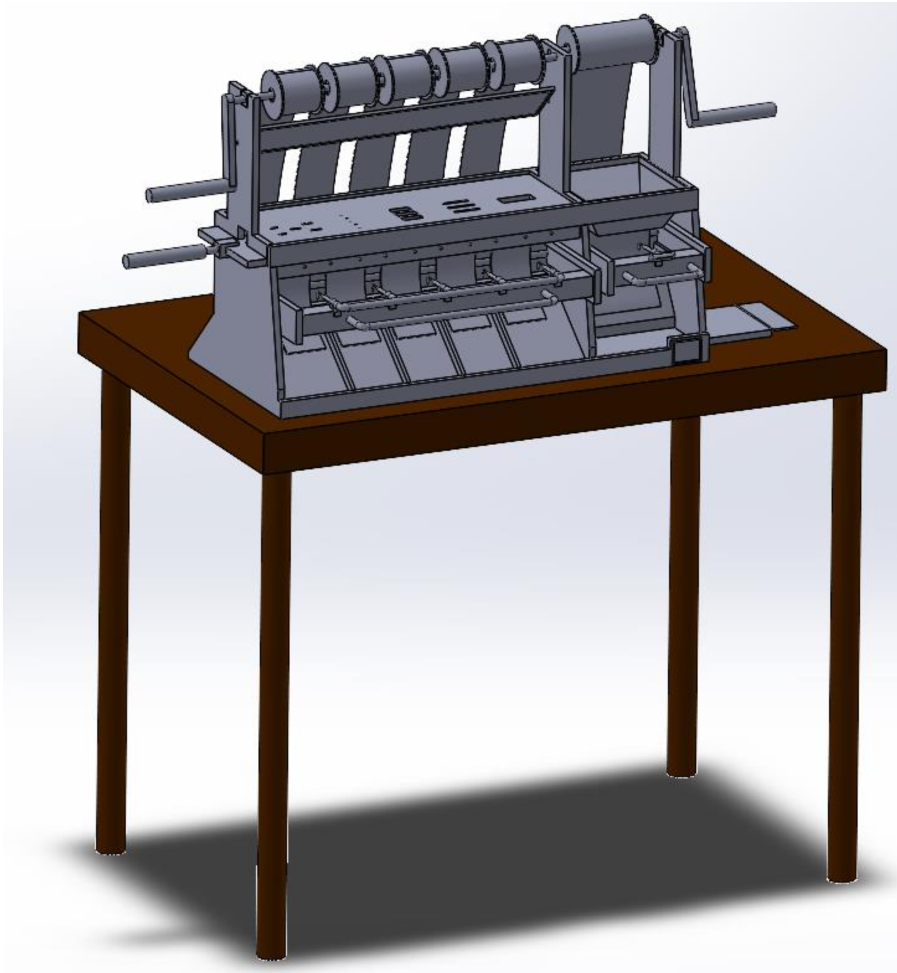


Isometric View:

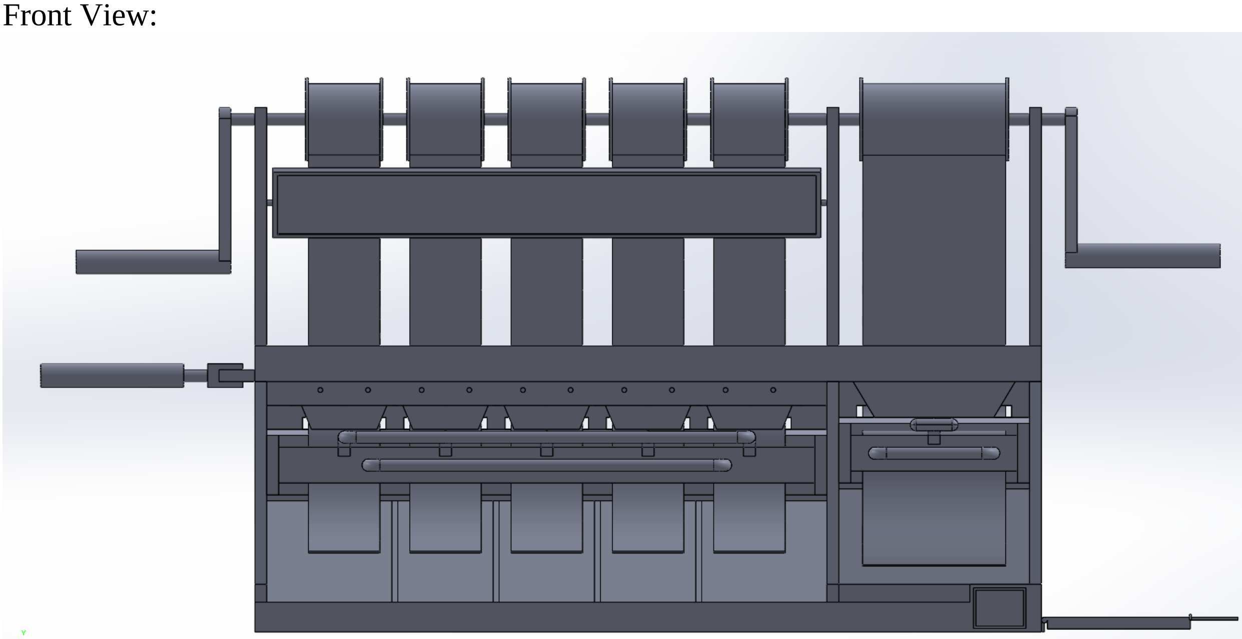


Appendix H: CAD Model V3

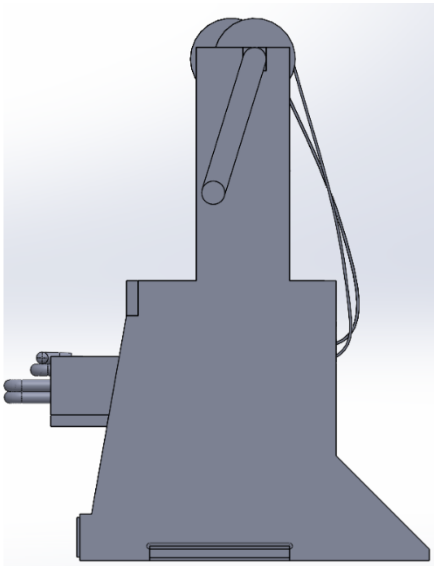
Isometric View:

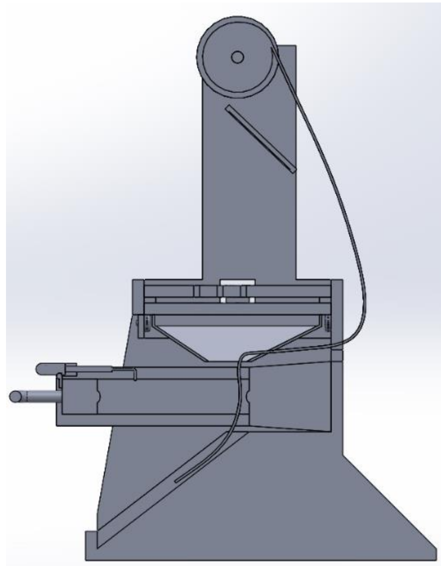


Front View:

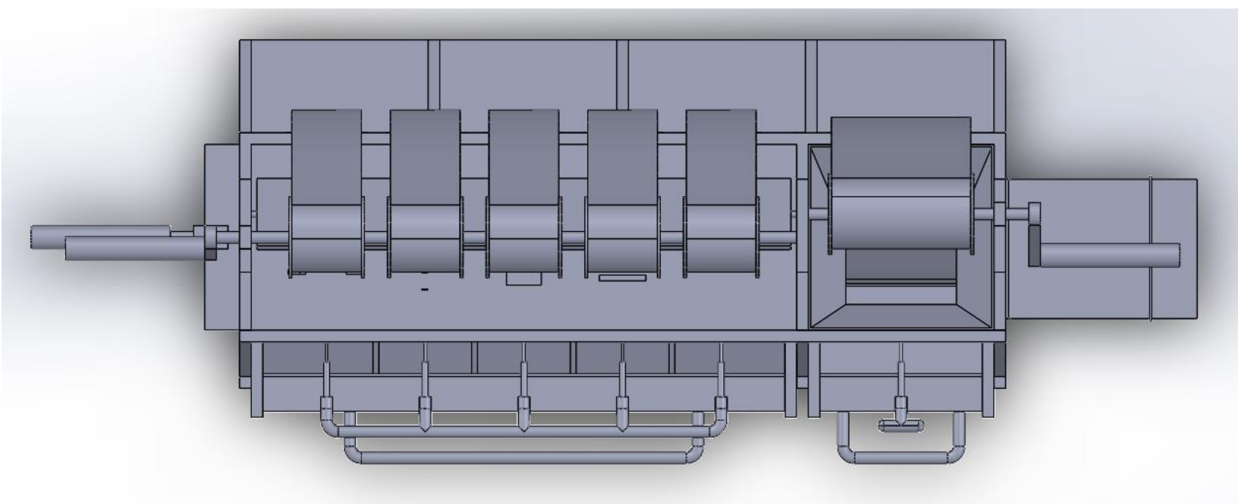


Side View and Section View:



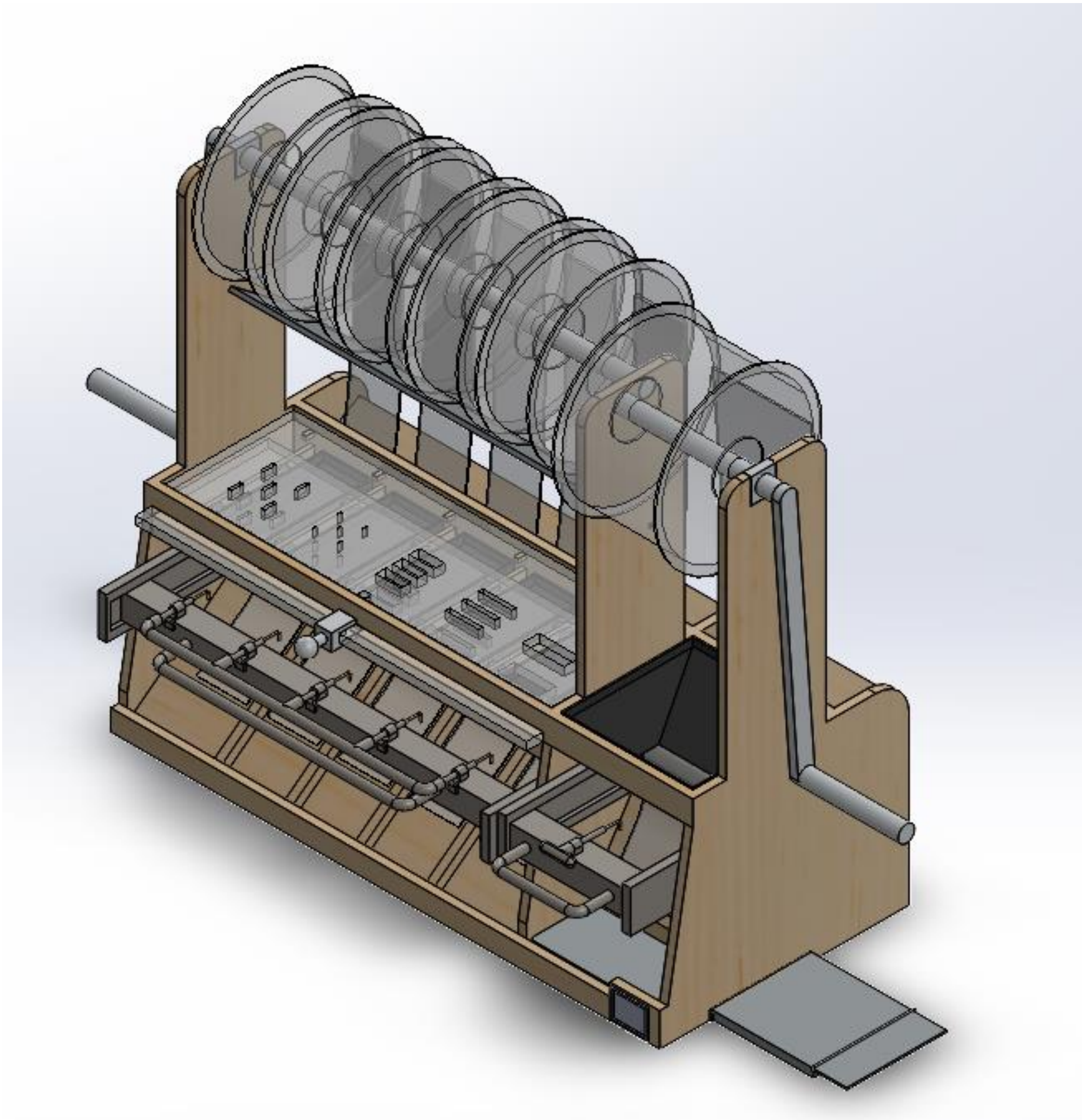


Top View:

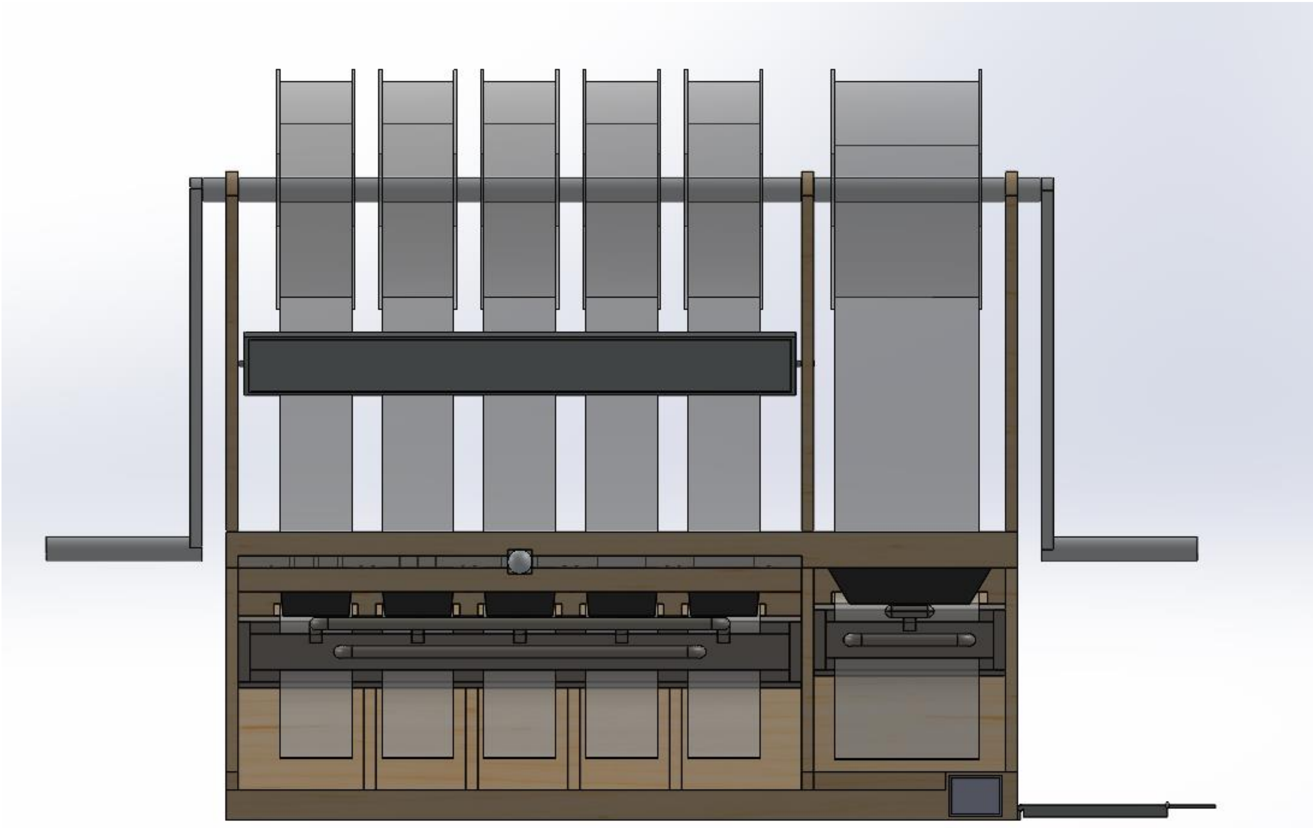


Appendix I: CAD Model V4

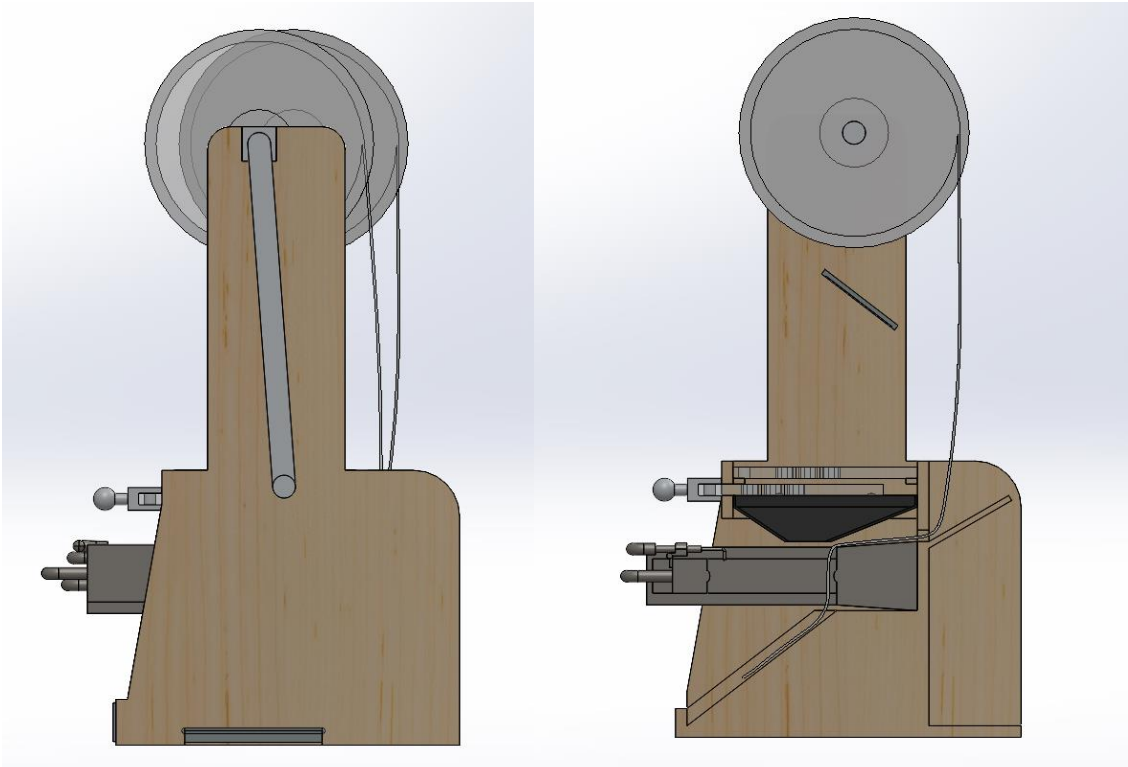
Isometric View:



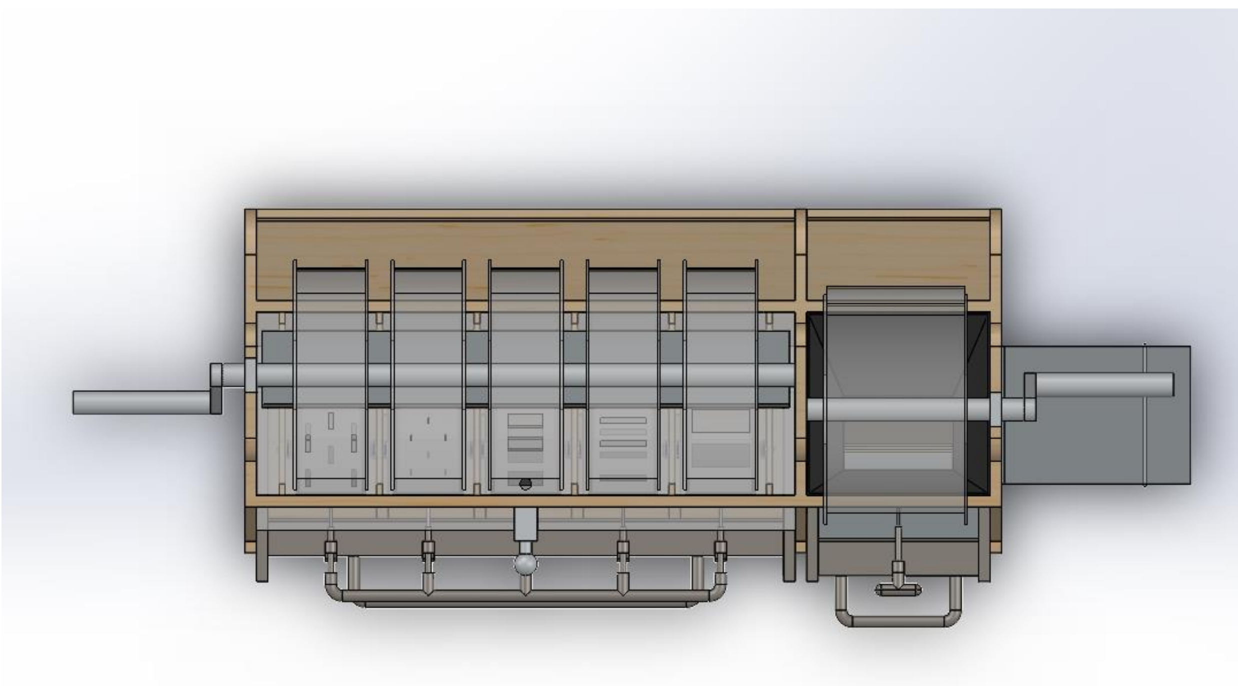
Front View:



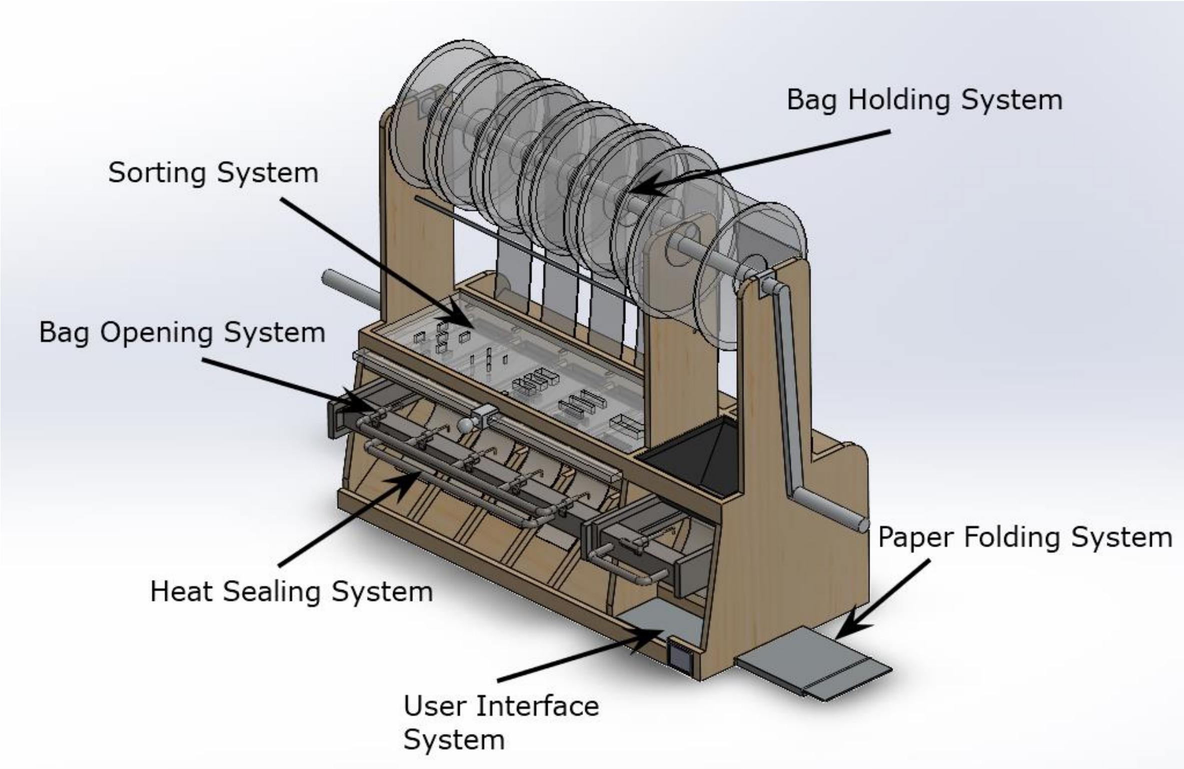
Side View and Section View:



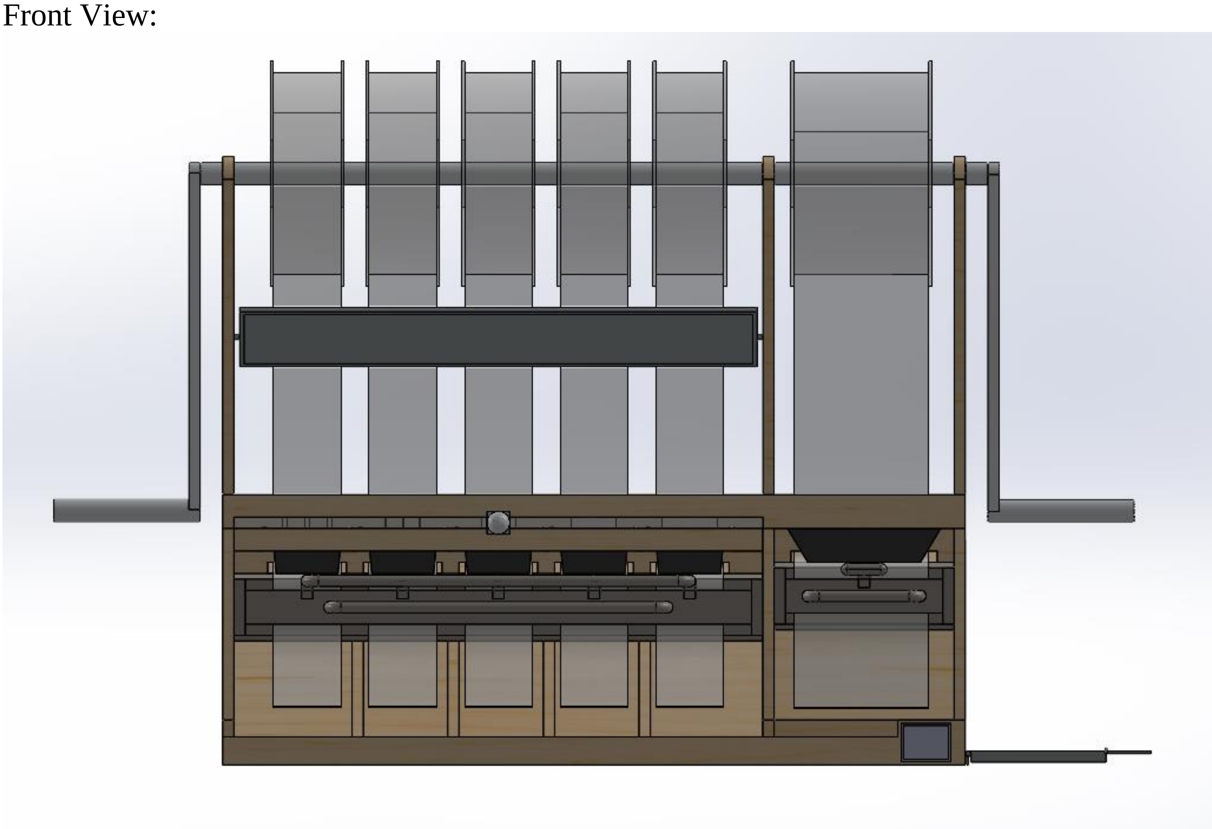
Top View:



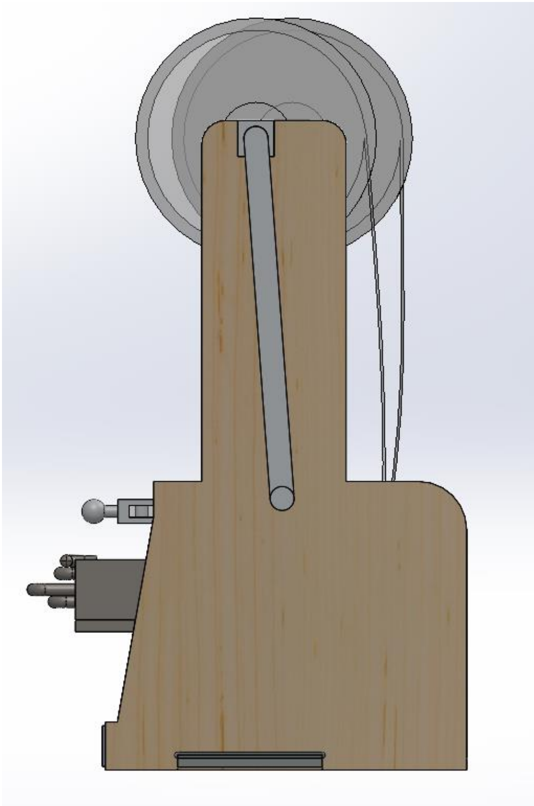
Appendix J: CAD Model V5

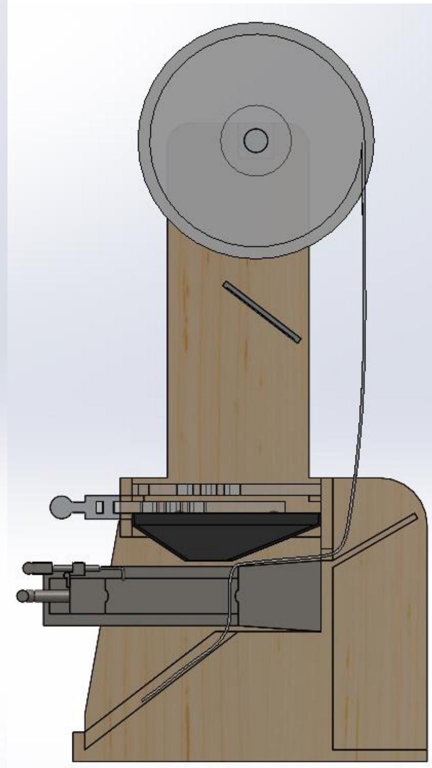


Front View:

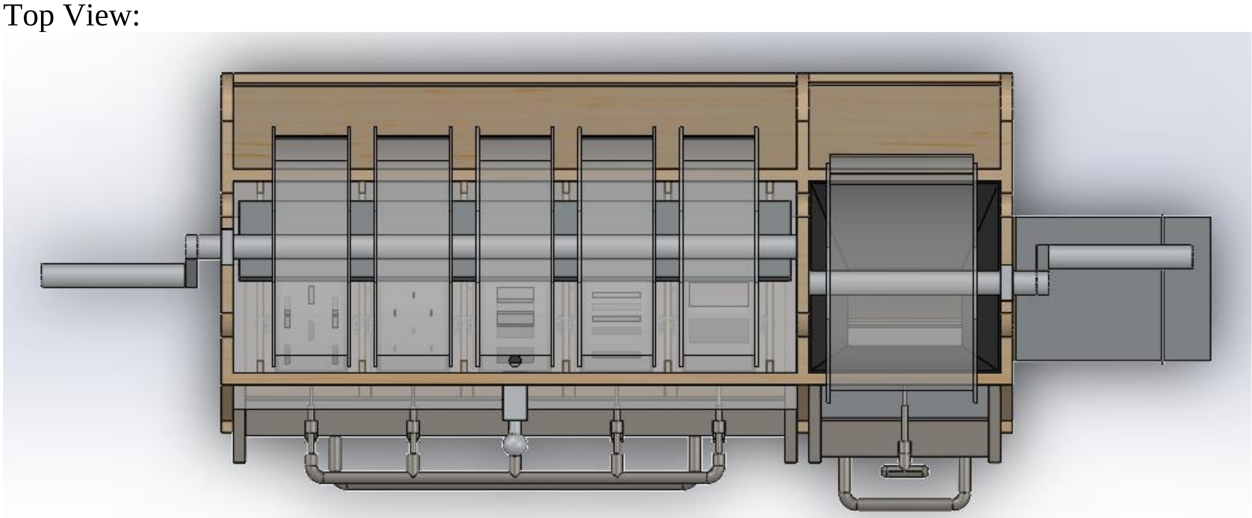


Side and Cross-Sectional View:

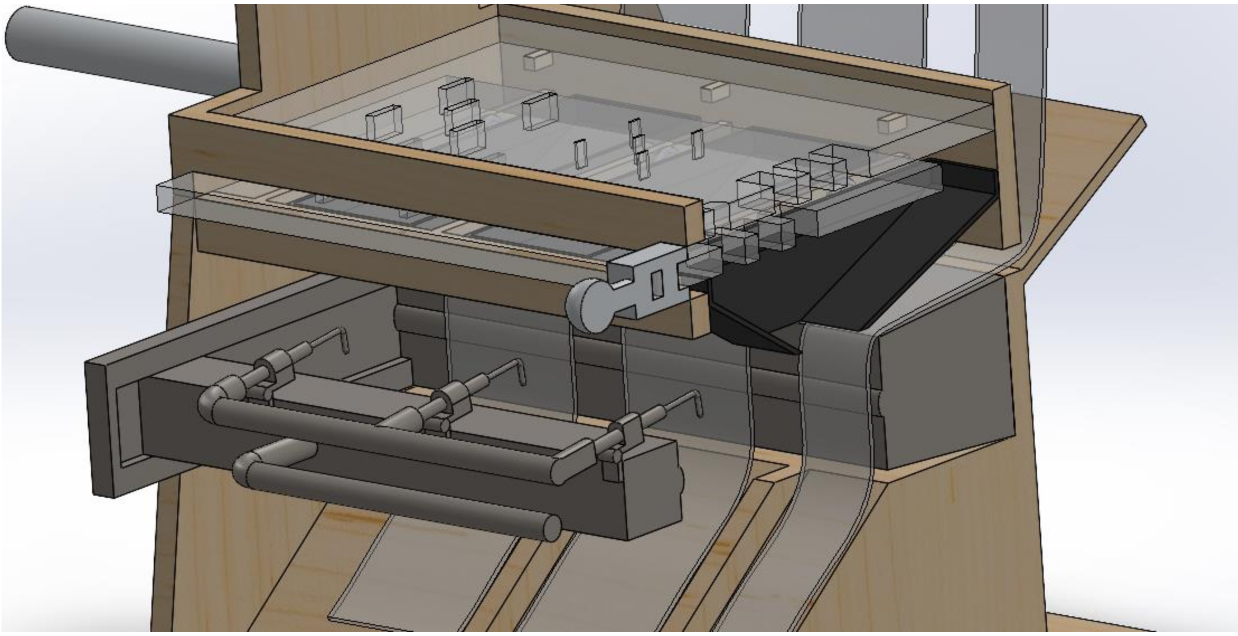




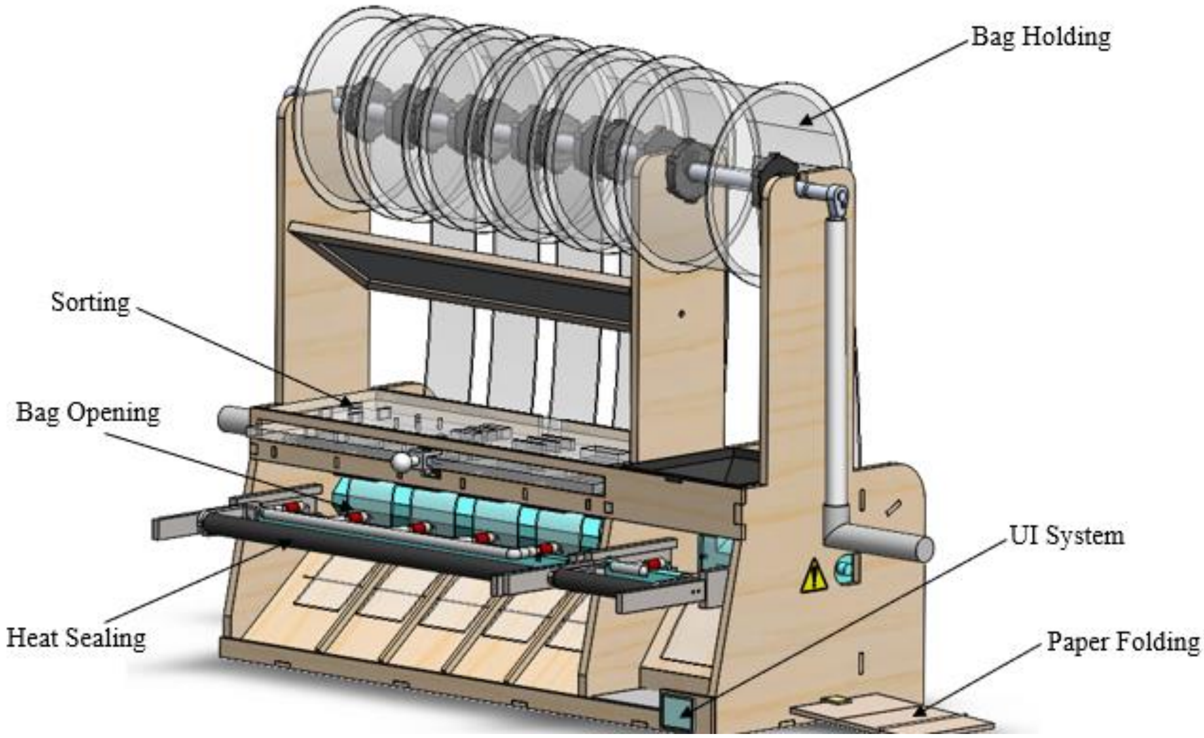
Top View:



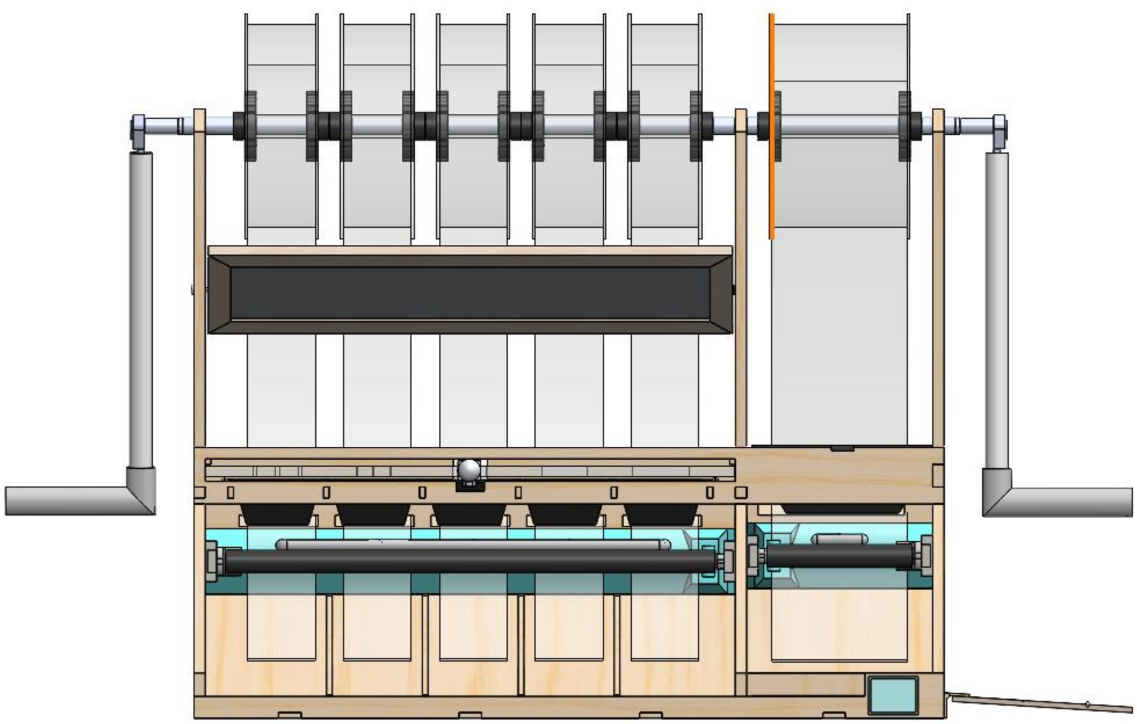
Detailed Picture of the Top Sorting/Bagging Apparatus:



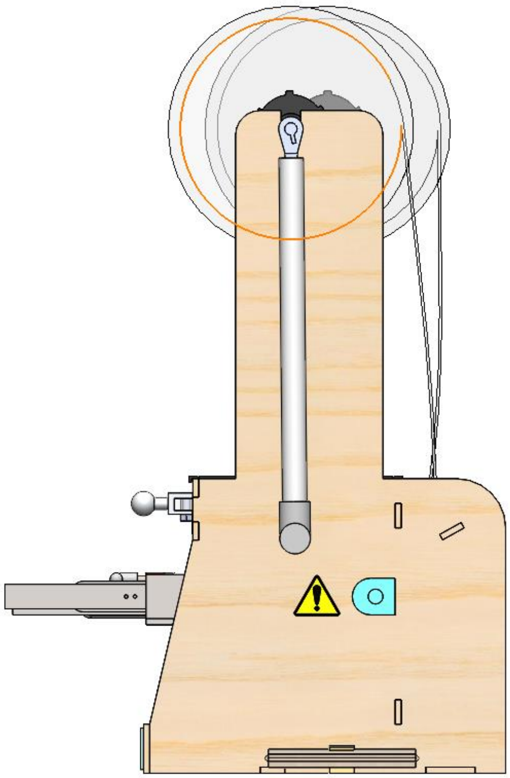
Appendix K: Final CAD Design

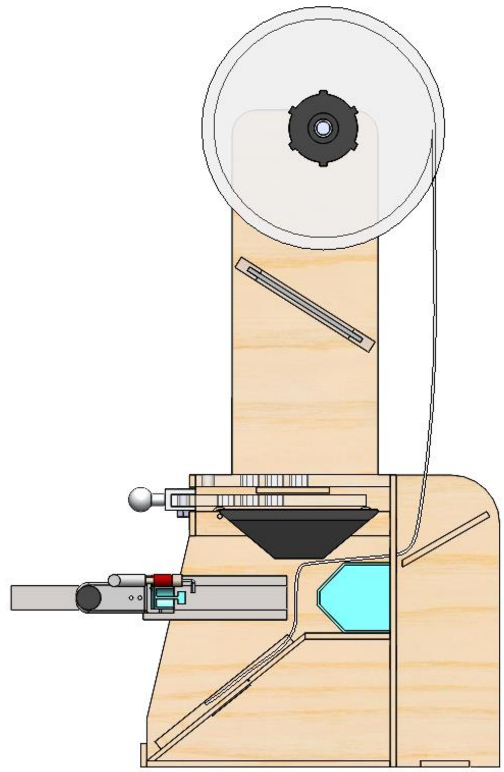


Front View:

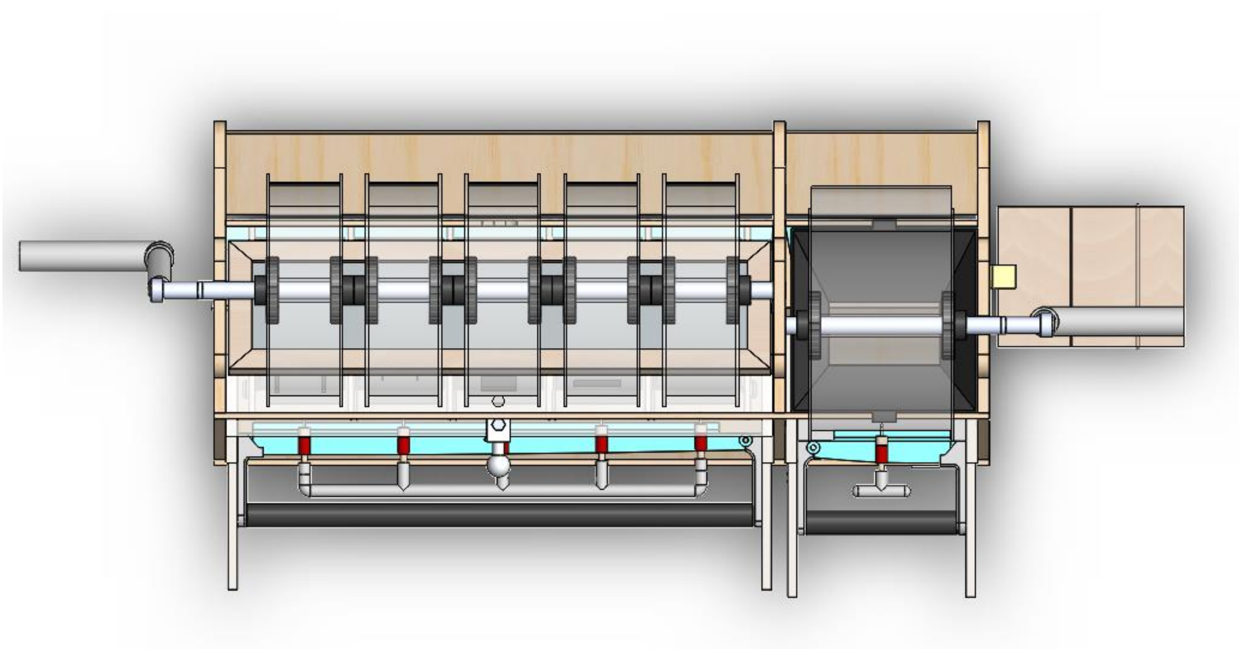


Side and Cross-Sectional View:

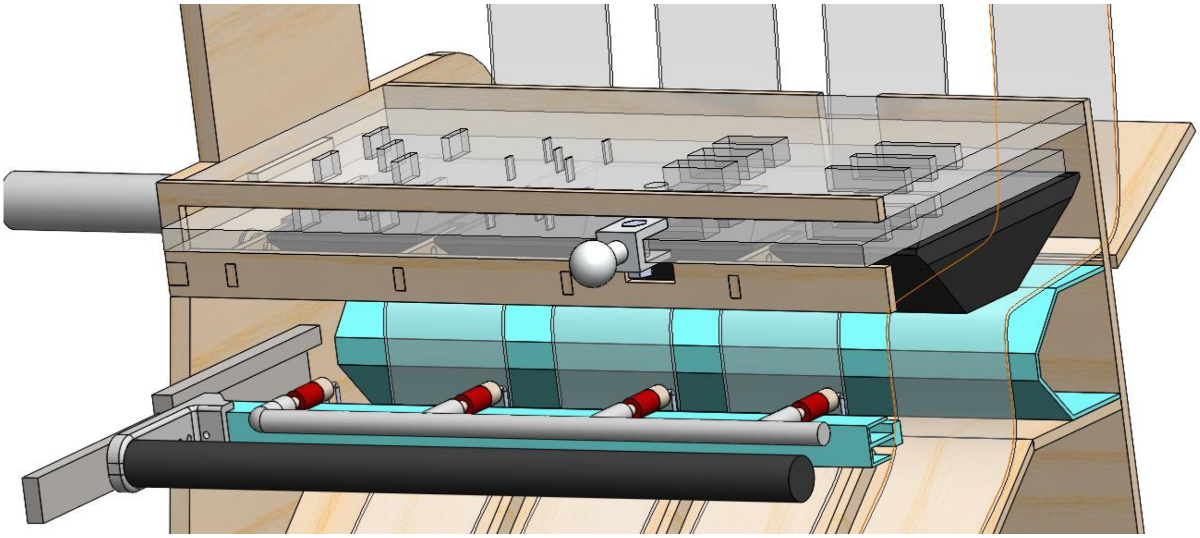




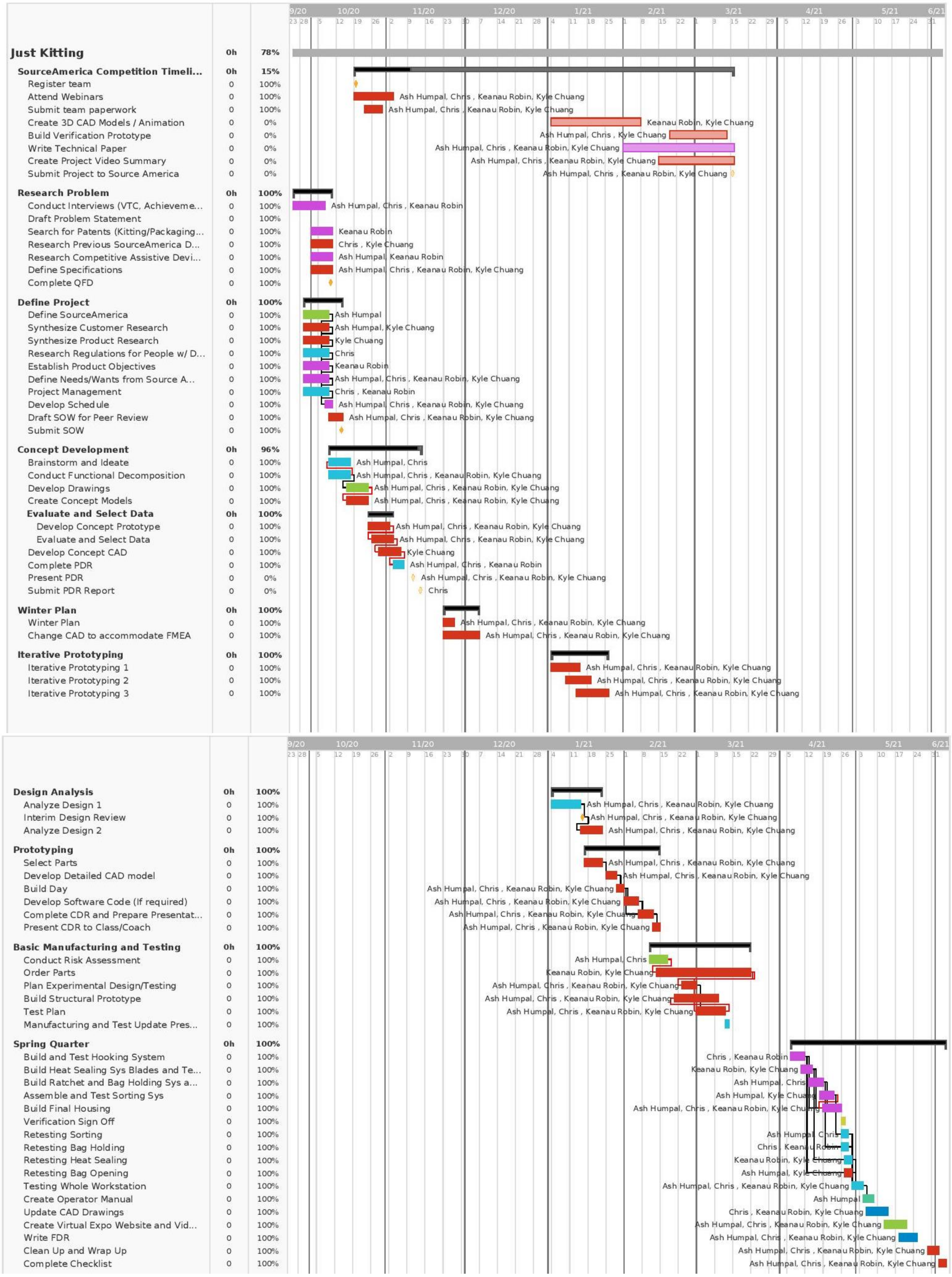
Top View:



Detailed Picture of the Top Sorting/Bagging Apparatus:



Appendix L: Gantt Chart



Appendix M: Indented Bill of Materials

F16

Kitting Workstation

Indented Bill of Material (iBOM)

Assembly Level	Part Number	Description	Mtl	Qty	Cost	Ttl Cost	Source	More Info
		Lvl0 Lvl1 Lvl2 Lvl3 Lvl4						
0	100000	**Packaging Workspace Assembly**						
1	110000	**Housing**						
2	111000	Walls	Wood	4	22.62	90.48	Home Depot	
2	112000	Funnels	PLA	1	22.99	22.99	Amazon	
1	120000	**Sorting System**						
2	121000	Template	Acrylic	1	26.28	26.28	Delvies Plastic	Thin acrylic option hyperlinked; current dimensions 12x 24x .5
2	122000	Handle	PLA	1				Using PLA purchased for funnels which is why no new cost associated
2	123000	Wheels	Plastic	20	9.24	27.72	Amazon	
2	124000	Mirror	Glass	1	39.78	39.78	Fab Glass	23.5" x 5" dimensions
1	130000	**Bag Holding System**						
2	131000	Poly Bag Rolls 3x4		5	30.59	152.95	US Poly Pack	
2	132000	Poly Bag Rolls 6x6		1	48.58	48.58	US Poly Pack	
2	133000	Handle	Wood Dowel	2	1.85	3.70	Home Depot	Machined from one dowel
2	134000	Shaft	Low-Carbon Round Steel Hollow	1	10.30	10.30	Metals Depot	24" long and 1" diameter
2	135000	Slot	Wood	1				Use residual wood from housing.
1	140000	**Bag Opening System**						
2	141000	Collar	Oxide Coated Mild Steel	6	4.91	29.46	Home Depot	
2	142000	Hinge	Zinc-Plated	6	2.18	13.08	Home Depot	
2	143000	Hook Mount	Aluminum	1	11.98	11.98	Home Depot	We will cut this metal tube into multiple tubes of our desired lengths
2	144000	20" 3D-Printed Handle	PLA	1	22.99	22.99		
2	145000	3" 3D-Printed Handle	PLA	1				Using PLA purchased for handle which is why no new cost associated
2	146000	L-shaped Hook	Stainless Steel	3	6.88	20.64	Amazon	They come in packs of 2. Will need to weld, solder, or create a slit within the metal cylinder to attach the L Hook onto the Cylinder.
1	150000	**Heat Sealing System**						Also, will need to bend the hook to create the complete L shape.
2	151000	20" Heat Sealer	Metal	1	94.99	94.99	Amazon	For both heat sealers, they will need to be dismantled to separate the handle from the main body
2	152000	4" Heat Sealer	Metal	1	34.99	34.99	Amazon	
2	153000	6" Drawer Railings	Metal	2	18.92	37.84	Amazon	
2	154000	Casings on ends of Handle	PLA	4				Using PLA purchased for handle which is why no new cost associated
1	160000	**Paper Folding System**						
2	161000	Folding Plate	Wood	1	26.99	26.99	Amazon	Will need to carve on it to display markings for specific paper sizes. Also need to carve the tip of it to leave spacefor the user's hand.
2	162000	Hinge	Stainless Steel	1	2.18	2.18	Home Depot	
2	163000	String	Macrame Cotton	1	3.19	3.19	Amazon	Tied up to create a loop that will go around the plate.
1	170000	**UI System**						
2	171000	Load cell & HX711		1	12.99	12.99	Degraw	
2	172000	Arduino Uno		1	23.00	23.00	Arduino	
2	173000	Touchscreen		1	27.50	27.50	Adafruit	
2	174000	7805 IC		1	1.54	1.54	Mouser	
2	175000	0.33 uF Electrolytic Capacitor		1	0.11	0.11	Mouser	
2	176000	0.1uF Ceramic Capacitor		2	0.36	0.72	Mouser	
2	177000	Platform	PLA					Use same spool of PLA.
1	180000	Screws		50	2.50	2.50	Home Depot	
1	190000	Nuts		2	0.50	1.00	Home Depot	
						Cost		
	Total Parts			**122**		**790.47**		

Total Cost excludes the labor cost

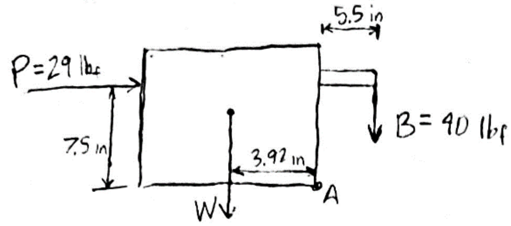
Appendix N. Final Project Budget

Vendor (name, website, phone, or fax)	Product Name (paste the exact product title, include all text)	Part Number	Product Hyper Link	Qty	Price/Ea	Shipping	Tax	Total
US Poly Pack	Clear Pre Opened AutoBags on Roll 3 x 4 x 1.5 Mil Roll:4000	USPP-2762	https://www.uspolypack.com/Clear-Pre-Opened-AutoBags-on-Roll-3-x-4-x-15-Mil-Roll4000_p_1708.html	1	$ 30.59	$ 9.72	$ -	$ 40.31
Home Depot	Plywood + screws + glue		n/a	n/a	$ 43.48	$ -	$ 3.34	$ 46.82
Amazon	C3832-6 Accuride 3832C Full Extension Slide 6"	C3832-6	https://www.amazon.com/C3832-6-Accuride-3832C-Extension-Slide/dp/B004W4OM40	1	$ 18.50	$ -	$ 1.43	$ 19.93
Technopack Corporation	JORESTECH 4"/100mm Manual Impulse Bag Sealer Heavy Duty Housing and Copper Transformer with Repair Kit 110 Volt (MMS-100)	MMS-100	https://www.amazon.com/Impulse-Manual-Sealer-Heat-Closer/dp/B00A4GI0ZM/ref=sr_1_4?crid=1Y6DR2WIO338E&dchild=1&keywords=4+inch+heat+sealer&qid=1610919221&sprefix=heat+sealer+4+in%2Caps%2C250&sr=8-4	1	$ 34.99	$ -	$ 2.54	$ 37.53
Home Depot	Madison Mill 0.25-in dia x 48-in L Round Poplar Dowel	N/A	https://www.homedepot.com/p/6404U-1-4-in-x-1-4-in-x-48-in-Raw-Round-Dowel-10001800/203334060	1	$ 0.84	$ -	$ 0.07	$ 0.91
Amazon	Hillman Hardware Essentials 320498 (0.080-Inch x 1-Inch) 100 Pack Square Bend Hook, 0.080 Inch x 1 Inch, Zinc-Plated, 100 Pieces	320498	https://www.amazon.com/Hardware-Essentials-Square-Bend-0-106/dp/B00FN6KGBY/ref=sr_1_18?dchild=1&keywords=1%2Bhook%2B0.08%22%2Bdiameter&qid=1613668596&sr=8-18&th=1	1	$ 12.97	$ -	$ 1.50	$ 14.47
Amazon	Double Split Shaft Collars 1/4 Inch Bore OD 11/16" Black Oxide Set Screw Style 4 Pcs	DBCS-1/4	https://www.amazon.com/Inches-Double-Split-Shaft-Collars/dp/B07FMZZMYB?th=1	1	$ 8.49	$ -	$ 0.62	$ 9.11
Amazon	RZDEAL 50 PCS Mini Brass Hinges Hardware 180 Degree Rotation for Dollhouse Miniature Furniture Cabinet Closet(DIY) (Silver Tone)	N/A	https://www.amazon.com/RZDEAL-Hardware-Dollhouse-Miniature-Furniture/dp/B07L18MXZJ/ref=sr_1_10?dchild=1&keywords=mini+hinges&qid=1613700216&sr=8-10	1	$ 7.79	$ -	$ -	$ 7.79
McMaster-Carr	Low-Carbon Steel Round Tubes, Outer Diameter of 3/4 Inches and Inner Diameter of 0.56 Inches, 1 ft length	7767T38	https://www.mcmaster.com/hollow-rods/low-carbon-steel-round-tubes/od~3-4/id~0-56/	1	$ 3.12	$ -	$ -	$ 3.12
Harbor Freight	Pittsburgh 1/4 In. Drive SAE High Visibility Deep Socket, 10 Pc.	61333	https://www.harborfreight.com/14-in-drive-sae-high-visibility-deep-socket-10-pc-61333.html	1	$ 9.99	$ -	$ 0.42	$ 10.41
Home Depot	Everbilt 3/8 in.-16 x 1 in. Zinc Plated Hex Bolt (25-Pack)	n/a	https://www.homedepot.com/p/Everbilt-3-8-in-16-x-1-in-Zinc-Plated-Hex-Bolt-25-Pack-800820/204281551	1	$ 5.40	$ -	$ 0.41	$ 5.81
Home Depot	Everbilt 5/16 in.-18 tpi x 1 in. Zinc-Plated Hex Bolt	n/a	https://www.homedepot.com/p/Everbilt-5-16-in-18-Zinc-Plated-Hex-Nut-25-Pack-802354/204274092	1	$ 0.21	$ -	$ 0.02	$ 0.23
Home Depot	Everbilt 5/16 in.-18 Zinc Plated Hex Nut (25 pack)	n/a	https://www.homedepot.com/p/Everbilt-5-16-in-18-Zinc-Plated-Hex-Nut-25-Pack-802354/204274092 Purchase Request Form(hex).xlsx . Excel . Reading View . one worksheet . Current worksheet is Sheet1 . Press Alt Shift A for accessibility help . ■ ▯	1	$ 3.08	$ -	$ 0.24	$ 3.32
Home Depot	3/16 in. x 48 in. Raw Wood Round Dowel	n/a	https://www.homedepot.com/p/3-16-in-x-48-in-Raw-Wood-Round-Dowel-HDDH31648/204354369?MERCH=REC-_-pipsem-_-204354371-_-204354369-_-N	1	$ 0.74	$ -	$ 0.06	$ 0.80
Amazon	Elastic Cord for Masks, 1/8 Inch Black Elastic Bands for Knit Sewing Crafts DIY Ear Band Loop, 10 Yard	n/a	https://www.amazon.com/Elastic-Masks-Black-Sewing-Crafts/dp/B08938G52T/ref=sr_1_6?dchild=1&keywords=elastic+cord&qid=1614665275&refinements=p_36%3A2638326011&rnid=2638325011&s=arts-crafts&sr=1-6	1	$ 3.99	$ -	$ 0.26	$ 4.25
Amazon	HATCHBOX PLA 3D Printer Filament, Dimensional Accuracy +/- 0.03 mm, 1 kg Spool, 1.75 mm, Black, Pack of 1	n/a	https://www.amazon.com/HATCHBOX-3D-Filament-Dimensional-Accuracy/dp/B00J0ECR5I/ref=sr_1_3?dchild=1&keywords=pla&qid=1614703509&sr=8-3	1	$ 22.99	$ -	$ 1.70	$ 24.69
Amazon	25 Rubber Grommets 3/16" Bore Diameter 7/16" O.D.K	n/a	https://www.amazon.com/Rubber-Grommets-Bore-Diameter-D/dp/B0040CZ27K	1	$ 9.99	$ -	$ 0.72	$ 10.71
Fab Glass and Mirror	Length (L): 7" X Width (W): 5 1/2" Inch Mirror Rectangle Shaped 3/16" Thick Standard Mirror Flat Polished Edges	n/a	https://www.fabglassandmirror.com/custo mcut#select-edging	1	$ 34.36	$ -	$ -	$ 34.36
YUANQIAN	8Pcs Bearing Nylon Small Pulley Drawer Plastic Pulley Iron Sheet Cabinet Pulley Positioning Roller File Cabinet Pulley (19mm)	B073NMQCFY	https://www.amazon.com/Bearing-Pulley-Plastic-Cabinet-Positioning/dp/B073NMQCFY/ref=sr_1_6?dchild=1&keywords=Drawer+Rollers&qid=1611106900&sr=8-6	1	$ 8.99	$ -	$ -	$ 8.99
Delvies Plastic	Crystal Clear Cell Cast Plexiglass Sheet	N/A	https://www.delviesplastics.com/p/clear_acrylic_sheet.html	1	$ 26.25	$ 11.02	$ -	$ 37.27
Ace Miner's	Spray Paint and PVC	N/A		1	$ 10.00	$ -	$ -	$ 10.00
Harbor Freight	Ratchet	N/A		1	$ 14.00	$ -	$ -	$ 14.00
CALPOLY Store	Calpoly Sticker	N/A		1	$ 5.31	$ -	$ -	$ 5.31
				TOTAL				$320.83

Original Budget:	$ 500.00
Total Spent:	$320.83
Amount Remaining:	$ 179.17

Appendix O: Hand Calcs and FEA

(OLDER VERSION)
TIPPING HAND CALCS



GIVEN:

- APPLIED FORCE, P = 29 lbf
- BAG WEIGHT, B = 40 lbf

FIND:

- DESIGN WEIGHT, W

SOLUTION:

$$\Sigma M_A = 0$$

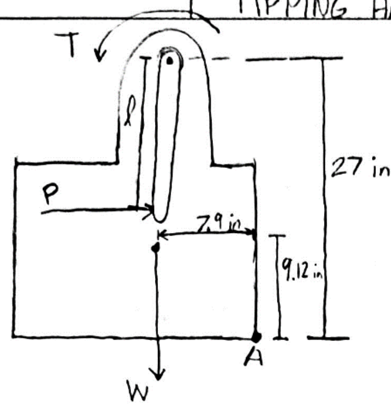
$$W(3.92 \text{ in}) - B(5.5 \text{ in}) - P(7.5 \text{ in}) = 0$$

$$W(3.92 \text{ in}) = (40 \text{ lbf})(5.5 \text{ in}) + (29 \text{ lbf})(7.5 \text{ in})$$

$$\boxed{W = 111.607 \text{ lbf}}$$

TOO HIGH

UPDATED
TIPPING HAND CALC



GIVEN:
$P = 29\ lb_f$
$\ell = 15\ in$

FIND: • DESIGN WEIGHT, W

SOLUTION:

$$\sum M_A = 0$$

$$W(7.9\ in) + \underbrace{P\ell}_{T} - P(27\ in) = 0$$

$$W = \frac{(29\ lb_f)(27\ in) - (29\ lb_f)(15\ in)}{7.9\ in}$$

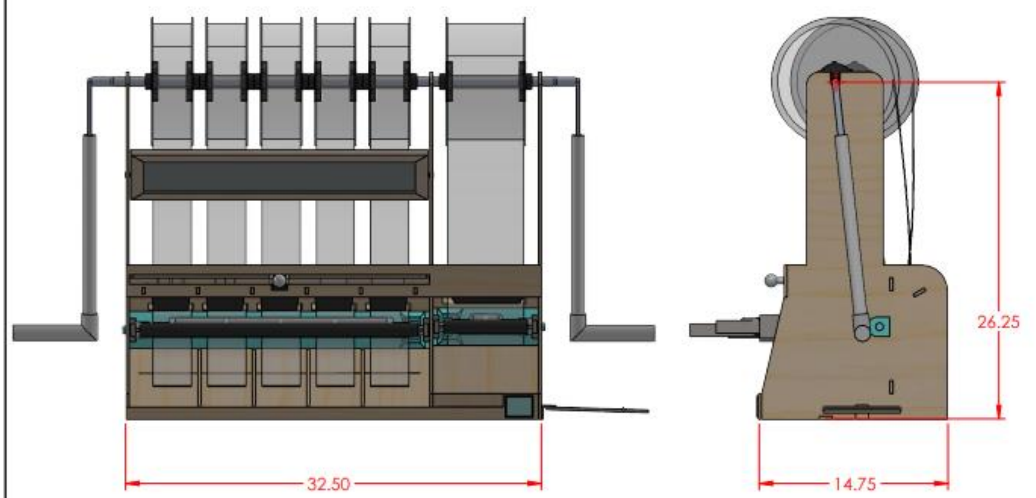
$$\boxed{W = 44.05\ lb_f}$$

BASED ON ROUGH ESTIMATION OF CENTER OF MASS OF OUR CAD MODEL.

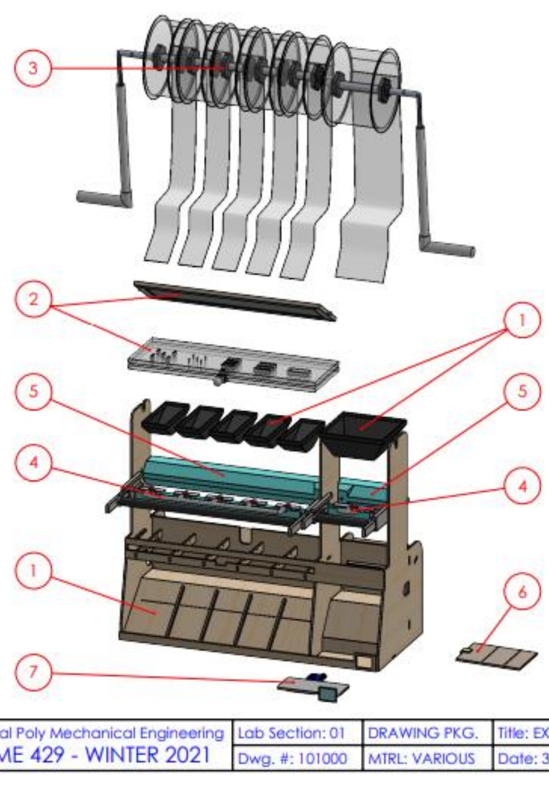
Appendix P: Drawing Package

Drawing Package Contents:

132000 – Poly Bag Rolls 6x6
133000 – Long Shaft
134000 – Short Shaft
135000 – Bag Driver and Gap
136000 – Hex Slot
137000 – Ratchet and Socket
137100 – 1/4 in. Drive Ratchet
137200 – 1/4 in. Drive and 3/8 in. Size Socket
138000 – Ratchet Extender
139000 – Ratchet Extender Handle
140000 – Bag Opening System
141000 – Bushing
142000 – Hinge
143000 – Wooden Dowel
144000 – 20” 3D-Printed Handle
145000 – 2.5” 3D-Printed Handle
146000 – L-Shaped Hook
150000 – Heat Sealing System
151000 – 20” Heat Sealer
152000 – 4” Heat Sealer
153000 – 6” Drawer Railings
154000 – Push Rod Sub-assembly
154100 – Push-Rod Spring
154200 – Push-Rod Casing
154300 – Push Rod
160000 – UI System
160000A – UI System Wiring Diagram
161000 – Load Cell & HX711
162000 – Arduino Uno
163000 – Touchscreen
164000 – 7805 IC
165000 – 0.33 uF Electrolytic Capacitor
166000 – 0.1 uF Ceramic Capacitor
167000 – Platform
170000 – Paper Folding System
171000 – Folding Plate
172000 – Elastic Cord

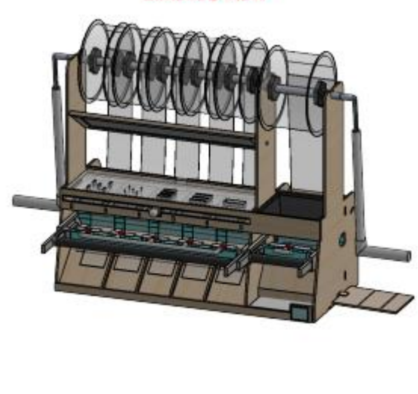


Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: WORKSTATION ASSEMBLY		Drwn. By: KYLE CHUANG
ME 429 - WINTER 2021	Dwg. #: 100000	MTRL: VARIOUS	Date: 3/7/21	Scale: 1:10	Chkd. By: ASHLEY HUMPAL

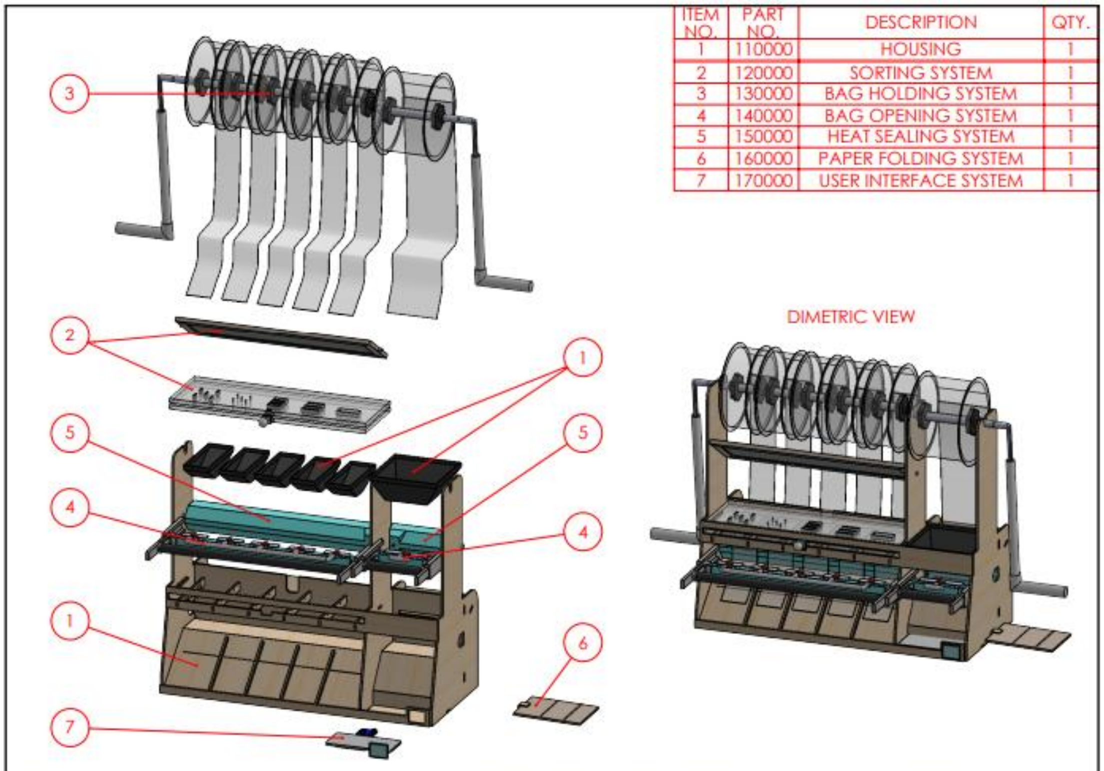


ITEM NO.	PART NO.	DESCRIPTION	QTY.
1	110000	HOUSING	1
2	120000	SORTING SYSTEM	1
3	130000	BAG HOLDING SYSTEM	1
4	140000	BAG OPENING SYSTEM	1
5	150000	HEAT SEALING SYSTEM	1
6	160000	PAPER FOLDING SYSTEM	1
7	170000	USER INTERFACE SYSTEM	1

DIMETRIC VIEW

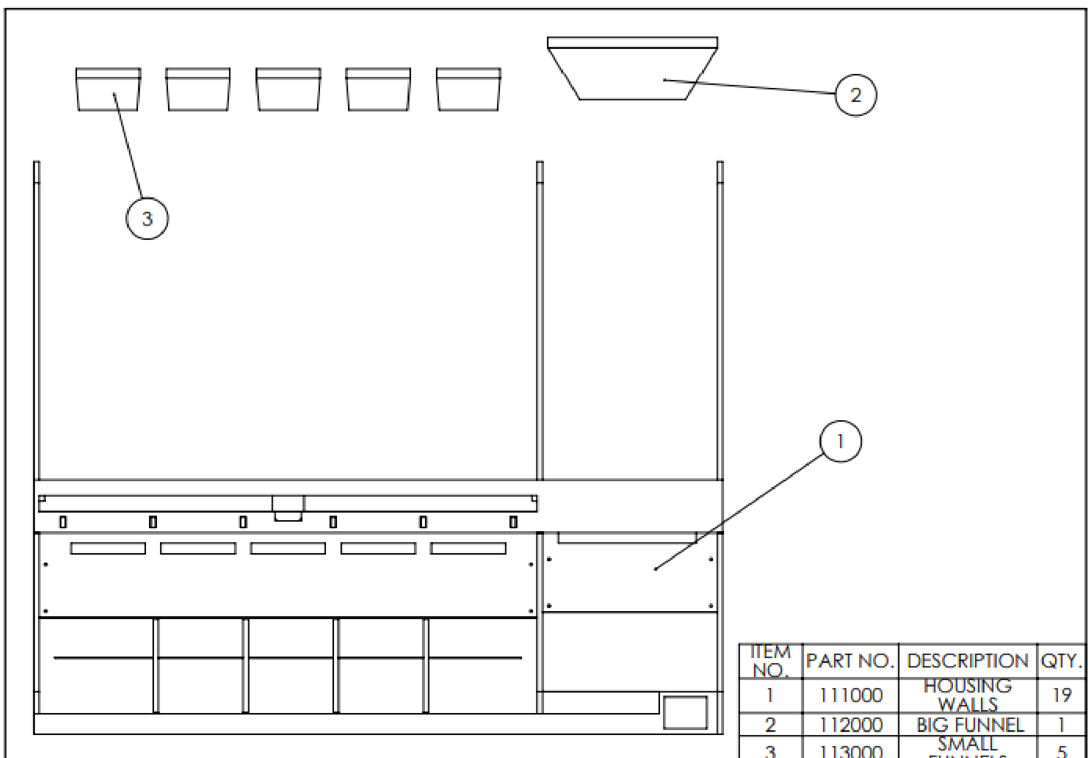


Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: EXPLODED ASSEMBLY		Drwn. By: KYLE CHUANG
ME 429 - WINTER 2021	Dwg. #: 101000	MTRL: VARIOUS	Date: 3/7/21	Scale: 1:12	Chkd. By: ASHLEY HUMPAL



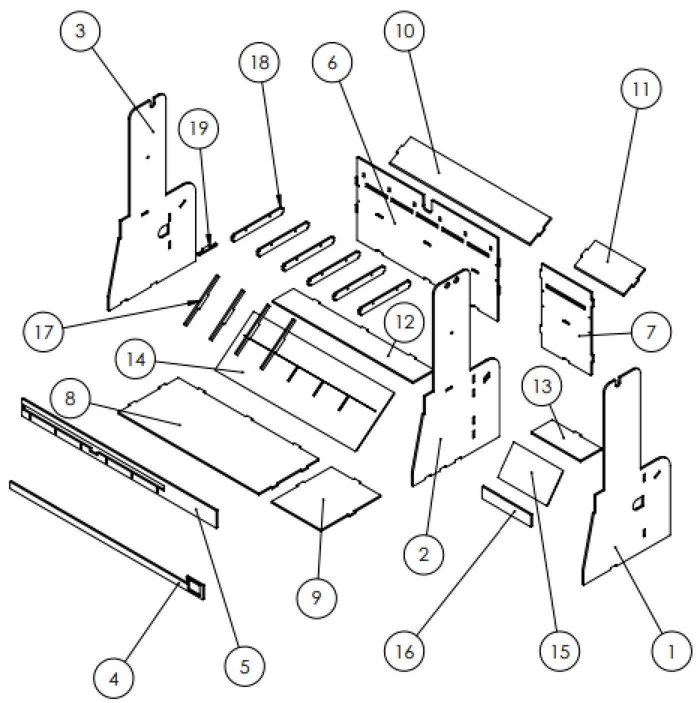
ITEM NO.	PART NO.	DESCRIPTION	QTY.
1	110000	HOUSING	1
2	120000	SORTING SYSTEM	1
3	130000	BAG HOLDING SYSTEM	1
4	140000	BAG OPENING SYSTEM	1
5	150000	HEAT SEALING SYSTEM	1
6	160000	PAPER FOLDING SYSTEM	1
7	170000	USER INTERFACE SYSTEM	1

Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: EXPLODED ASSEMBLY		Drwn. By: KYLE CHUANG
ME 429 - WINTER 2021	Dwg. #: 101000	MTRL: VARIOUS	Date: 3/7/21	Scale: 1:12	Chkd. By: ASHLEY HUMPAL



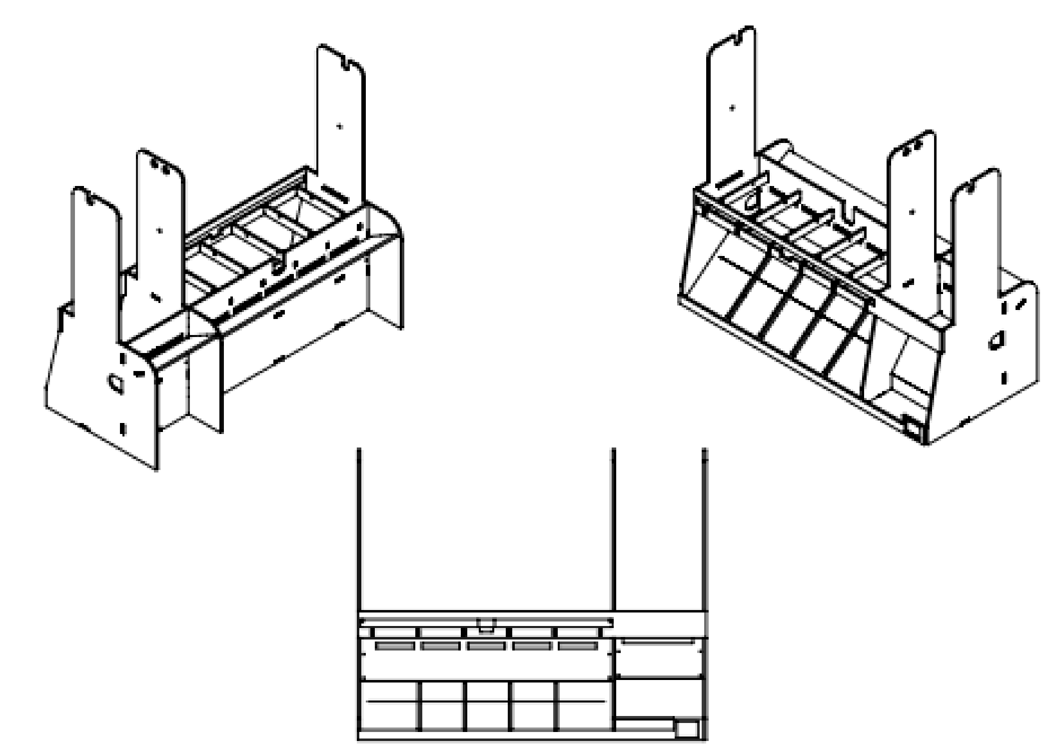
ITEM NO.	PART NO.	DESCRIPTION	QTY.
1	111000	HOUSING WALLS	19
2	112000	BIG FUNNEL	1
3	113000	SMALL FUNNELS	5

Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: HOUSING		Drwn. By: CHRISTOPHER TAN
ME 429 - WINTER 2021	Dwg. #: 110000	MTRL: VARIOUS	Date: 3/9/21	Scale: 1:5	Chkd. By: ASHLEY HUMPAL

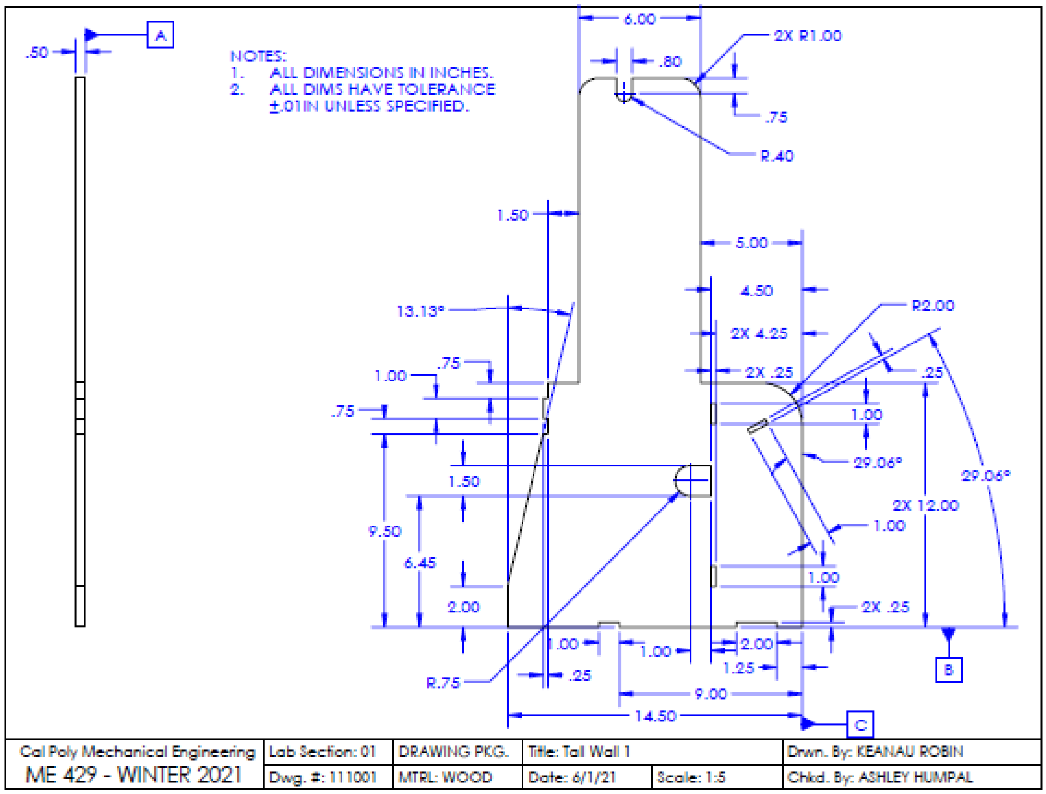


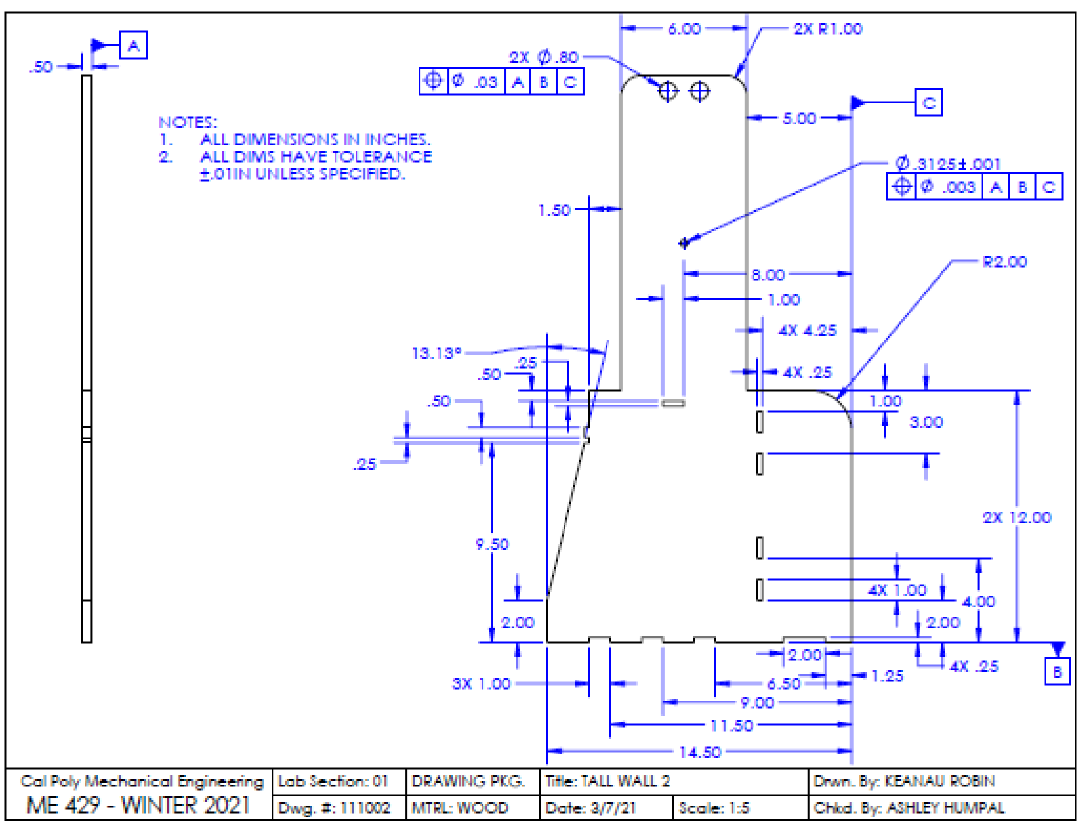
ITEM NO.	PART NO.	DESCRIPTION	QTY.
1	111001	TALL WALL 1	1
2	111002	TALL WALL 2	1
3	111003	TALL WALL 3	1
4	111004	FRONT WALL 1	1
5	111005	FRONT WALL 2	1
6	111006	BACK WALL 1	1
7	111007	BACK WALL 2	1
8	111008	BOTTOM 1	1
9	111009	BOTTOM 2	1
10	111010	BAG RAMP 1	1
11	111011	BAG RAMP 2	1
12	111012	HEAT SEALER WALL 1	1
13	111013	HEAT SEALER WALL 2	1
14	111014	BAG GRAB RAMP 1	1
15	111015	BAG GRAB RAMP 2	1
16	111016	BAG GRAB RAMP 3	1
17	111017	BAG GRAB RAMP DIVIDERS	4
18	111018	TEMPLATE CROSS BEAMS	6
19	111019	SORTER TABS	2

Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: EXPLODED HOUSING WALLS		Drwn. By: CHRISTOPHER TAN
ME 429 - WINTER 2021	Dwg. #: 111000A	MTRL: WOOD	Date: 3/9/21	Scale: 1:12	Chkd. By: ASHLEY HUMPAL



Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: HOUSING WALLS		Drwn. By: CHRISTOPHER TAN
ME 429 - WINTER 2021	Dwg. #: 111000B	MTRL: WOOD	Date: 3/9/21	Scale: 1:10	Chkd. By: ASHLEY HUMPAL


NOTES:
1. ALL DIMENSIONS IN INCHES.
2. ALL DIMS HAVE TOLERANCE ±.01IN UNLESS SPECIFIED.
A
B
C
.50
6.00
2X R1.00
.80
.75
R.40
1.50
5.00
4.50
2X 4.25
2X .25
R2.00
.25
13.13°
1.00
.75
.75
1.00
29.06°
29.06°
1.50
2X 12.00
9.50
1.00
6.45
1.00
2.00
2X .25
1.00
1.00
2.00
1.25
.25
R.75
9.00
14.50
Cal Poly Mechanical Engineering
ME 429 - WINTER 2021
Lab Section: 01
Dwg. #: 111001
DRAWING PKG.
MTRL: WOOD
Title: Tall Wall 1
Date: 6/1/21
Scale: 1:5
Drwn. By: KEANAU ROBIN
Chkd. By: ASHLEY HUMPAL


NOTES:
1. ALL DIMENSIONS IN INCHES.
2. ALL DIMS HAVE TOLERANCE ±.01IN UNLESS SPECIFIED.
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B
C
.50
6.00
2X R1.00
2X Ø.80
Ø .03 A B C
5.00
Ø.3125±.001
Ø .003 A B C
1.50
8.00
1.00
R2.00
4X 4.25
13.13°
.25
.50
4X .25
.50
1.00
3.00
.25
2X 12.00
9.50
4X 1.00
4.00
2.00
2.00
2.00
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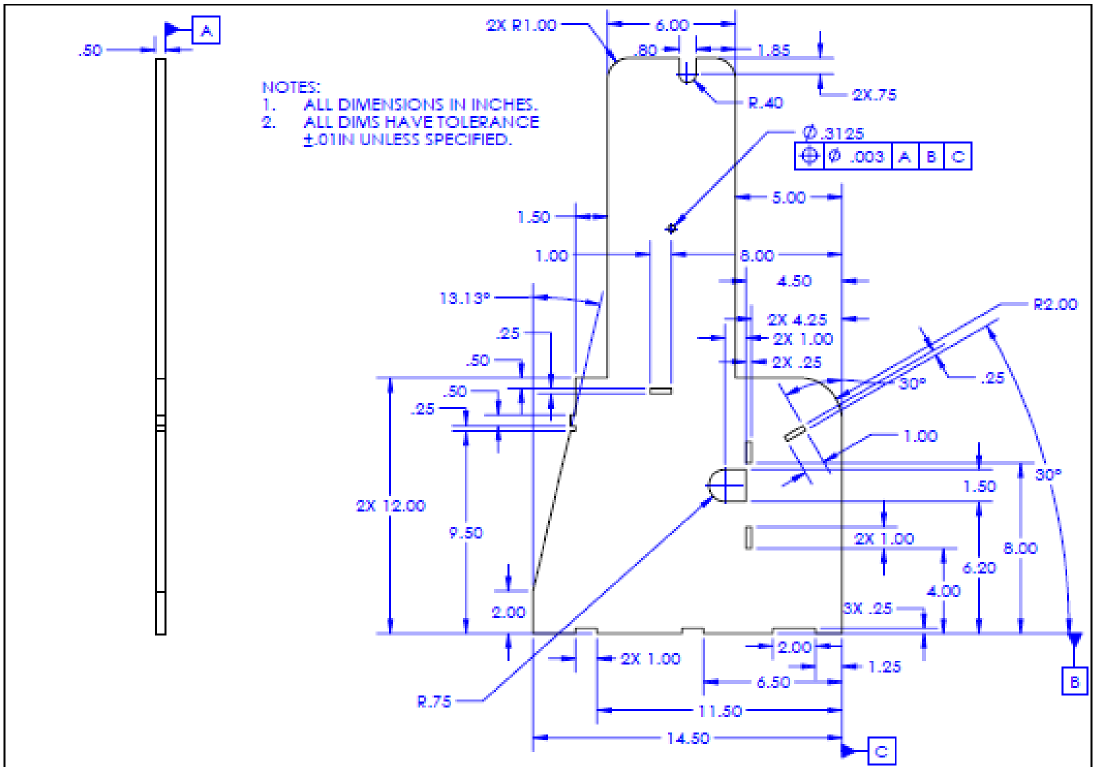
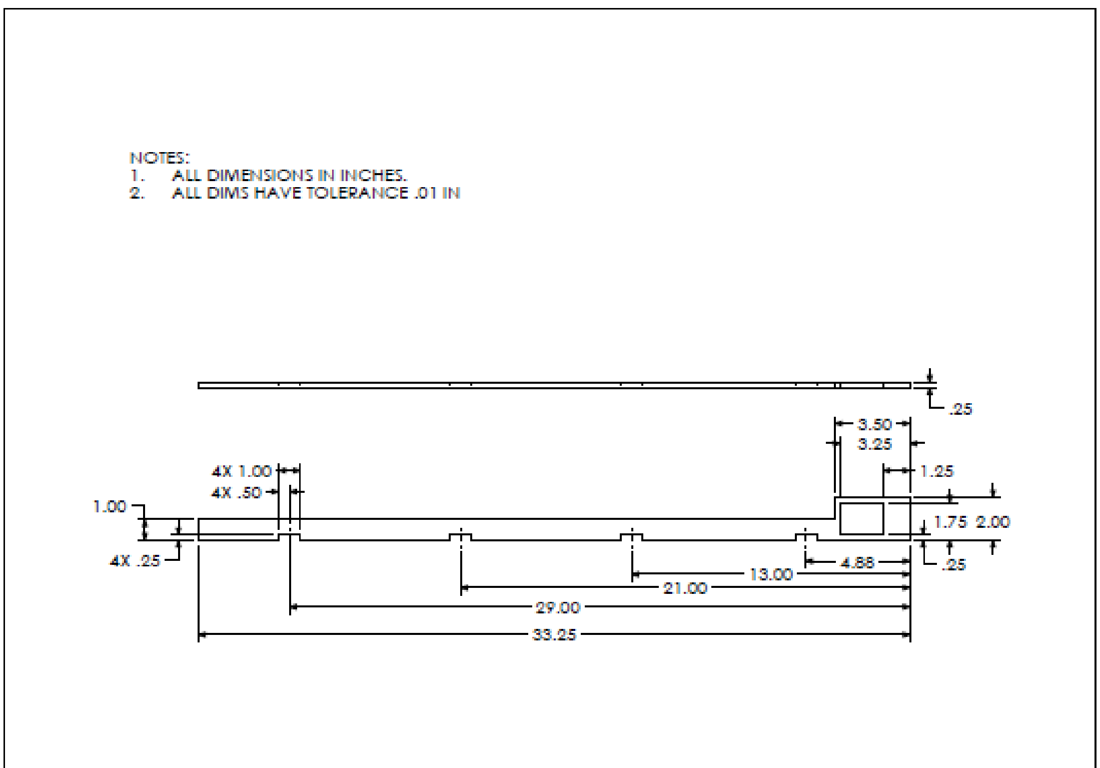
3X 1.00
6.50
1.25
9.00
11.50
14.50
Cal Poly Mechanical Engineering
ME 429 - WINTER 2021
Lab Section: 01
Dwg. #: 111002
DRAWING PKG.
MTRL: WOOD
Title: TALL WALL 2
Date: 3/7/21
Scale: 1:5
Drwn. By: KEANAU ROBIN
Chkd. By: ASHLEY HUMPAL

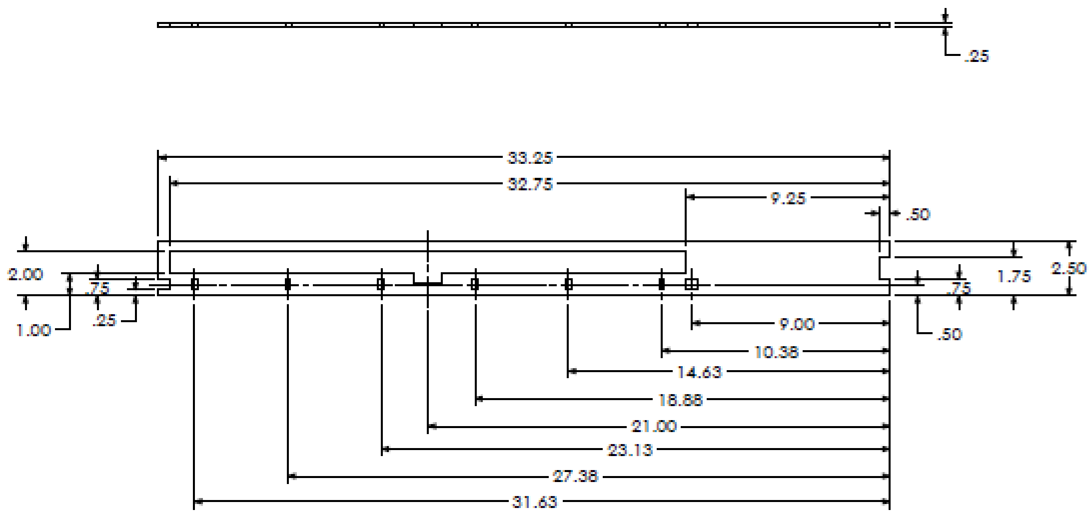


Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: Tall Wall 3		Drwn. By: KEANAU ROBIN
ME 429 - WINTER 2021	Dwg. #: 111003	MTRL: WOOD	Date: 6/1/21	Scale: 1:5	Chkd. By: ASHLEY HUMPAL



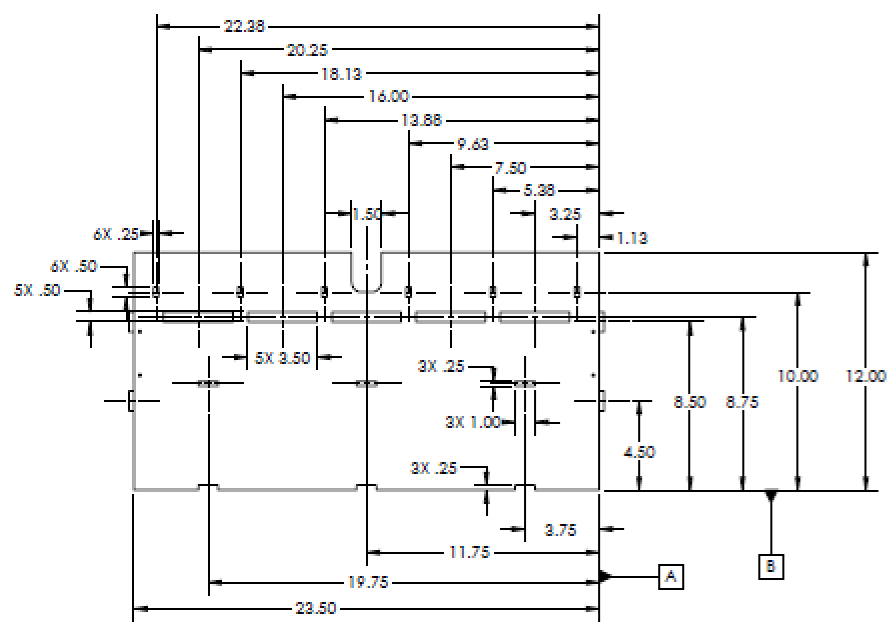
Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: FRONT WALL 1		Drwn. By: KYLE CHUANG
ME 429 - WINTER 2021	Dwg. #: 111004	MTRL: WOOD	Date: 6/2/21	Scale: 1:5	Chkd. By: ASHLEY HUMPAL

NOTES:
1. ALL DIMENSIONS IN INCHES.
2. ALL DIMS HAVE TOLERANCE ±.01 IN

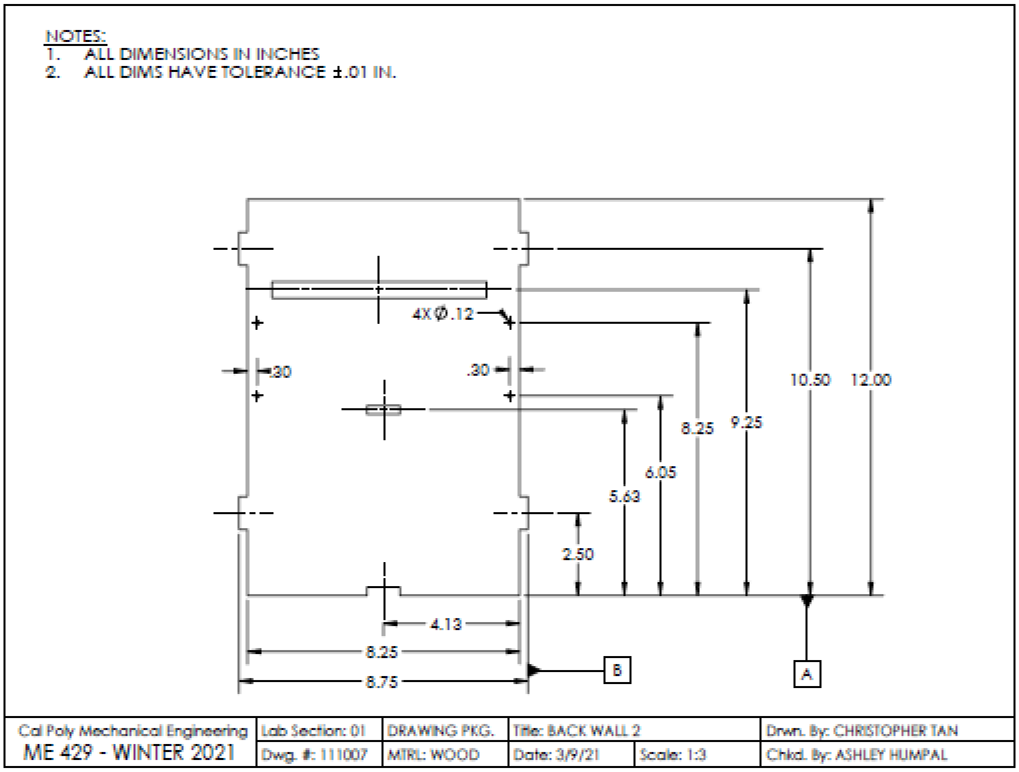


Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: FRONT WALL 2		Drwn. By: KYLE CHUANG
ME 429 - WINTER 2021	Dwg. #: 111005	MTRL: WOOD	Date: 6/2/21	Scale: 1:5	Chkd. By: ASHLEY HUMPAL

NOTES:
1. ALL DIMENSIONS IN INCHES
2. ALL DIMS HAVE TOLERANCE ±.01 IN.



Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: BACK WALL 1		Drwn. By: CHRISTOPHER TAN
ME 429 - WINTER 2021	Dwg. #: 111006	MTRL: WOOD	Date: 3/9/21	Scale: 1:5	Chkd. By: ASHLEY HUMPAL


NOTES:
1. ALL DIMENSIONS IN INCHES
2. ALL DIMS HAVE TOLERANCE ±.01 IN.
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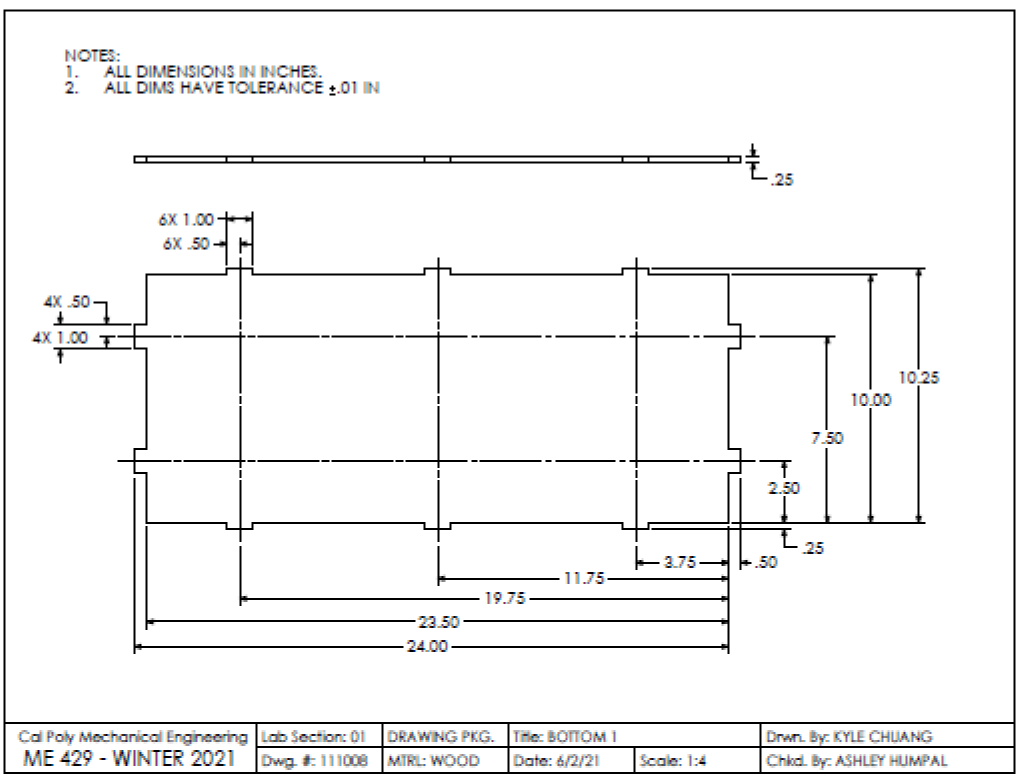
.30
.30
10.50
12.00
8.25
9.25
6.05
5.63
2.50
4.13
8.25
8.75
B
A
Cal Poly Mechanical Engineering
ME 429 - WINTER 2021
Lab Section: 01
Dwg. #: 111007
DRAWING PKG.
MTRL: WOOD
Title: BACK WALL 2
Date: 3/9/21
Scale: 1:3
Drwn. By: CHRISTOPHER TAN
Chkd. By: ASHLEY HUMPAL


NOTES:
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2. ALL DIMS HAVE TOLERANCE ±.01 IN
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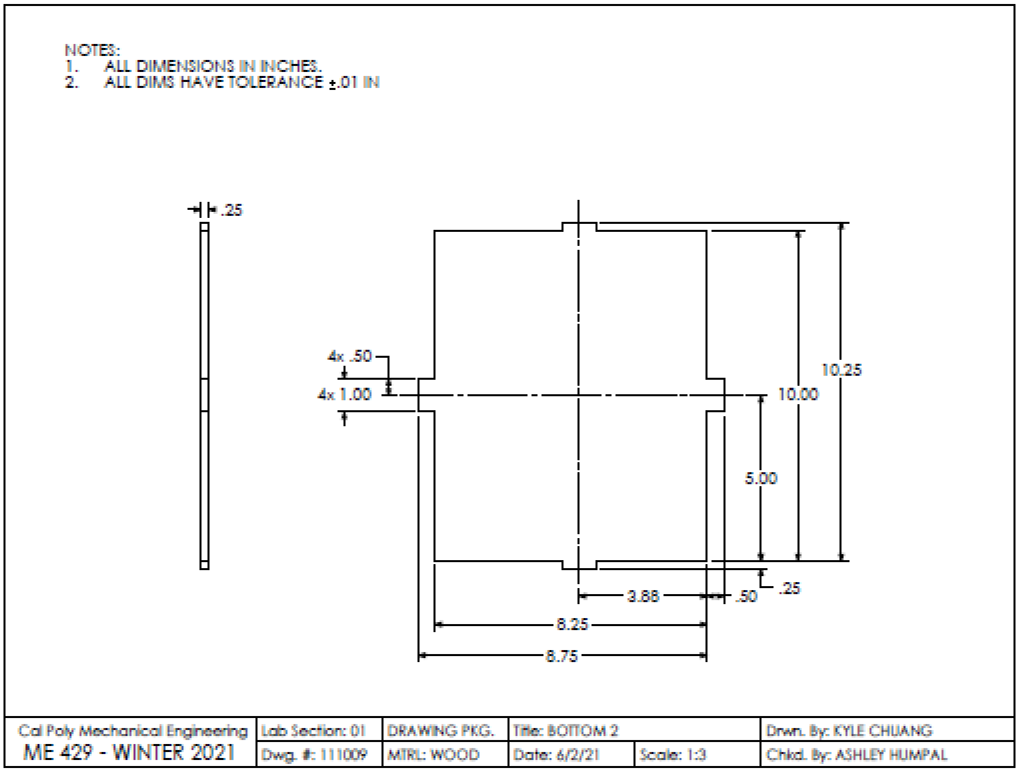
6X 1.00
6X .50
4X .50
4X 1.00
10.25
10.00
7.50
2.50
.25
3.75
.50
11.75
19.75
23.50
24.00
Cal Poly Mechanical Engineering
ME 429 - WINTER 2021
Lab Section: 01
Dwg. #: 111008
DRAWING PKG.
MTRL: WOOD
Title: BOTTOM 1
Date: 6/2/21
Scale: 1:4
Drwn. By: KYLE CHUANG
Chkd. By: ASHLEY HUMPAL


NOTES:
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2. ALL DIMS HAVE TOLERANCE ±.01 IN
.25
4x .50
4x 1.00
10.25
10.00
5.00
.25
3.88
.50
8.25
8.75
Cal Poly Mechanical Engineering
ME 429 - WINTER 2021
Lab Section: 01
Dwg. #: 111009
DRAWING PKG.
MTRL: WOOD
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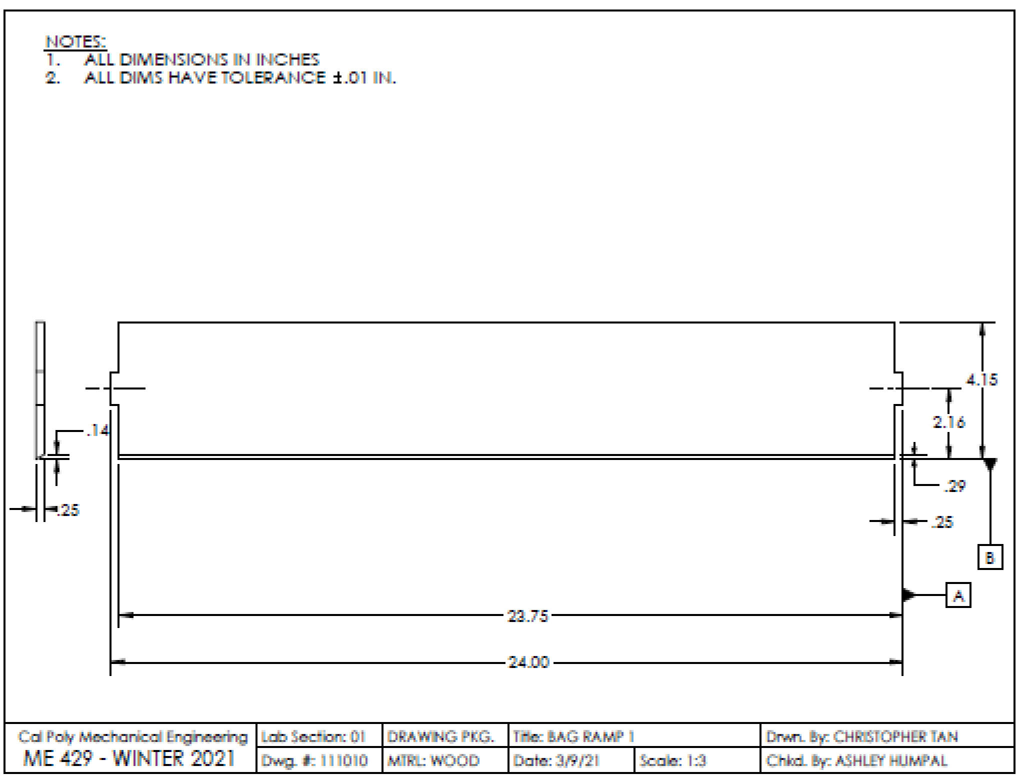
Date: 6/2/21
Scale: 1:3
Drwn. By: KYLE CHUANG
Chkd. By: ASHLEY HUMPAL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1. ALL DIMENSIONS IN INCHES
2. ALL DIMS HAVE TOLERANCE ±.01 IN.
.14
.25
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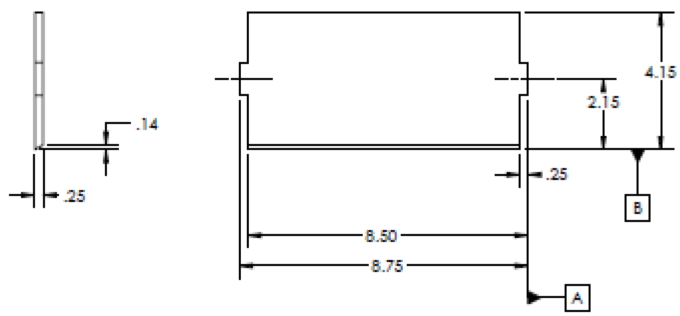
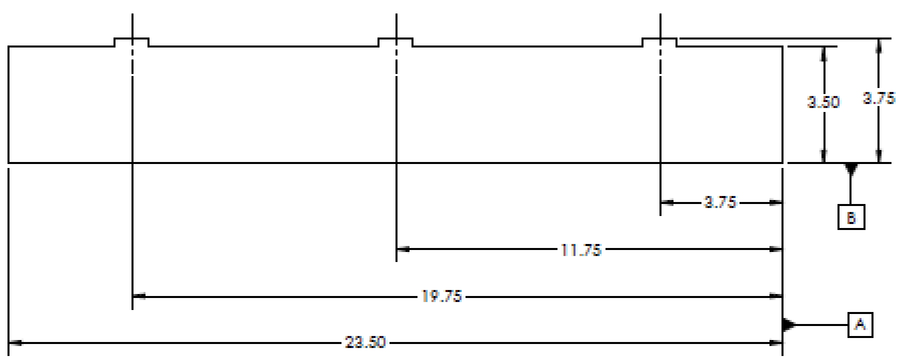
2.16
.29
.25
B
A
23.75
24.00
Cal Poly Mechanical Engineering
ME 429 - WINTER 2021
Lab Section: 01
Dwg. #: 111010
DRAWING PKG.
MTRL: WOOD
Title: BAG RAMP 1
Date: 3/9/21
Scale: 1:3
Drwn. By: CHRISTOPHER TAN
Chkd. By: ASHLEY HUMPAL

NOTES:
1. ALL DIMENSIONS IN INCHES
2. ALL DIMS HAVE TOLERANCE ±.01 IN.



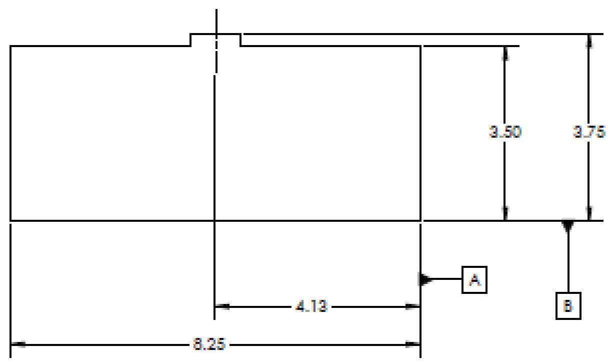
Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: BAG RAMP 2		Drwn. By: CHRISTOPHER TAN
ME 429 - WINTER 2021	Dwg. #: 111011	MTRL: WOOD	Date: 3/9/21	Scale: 1:3	Chkd. By: ASHLEY HUMPAL

NOTES:
1. ALL DIMENSIONS IN INCHES
2. ALL DIMS HAVE TOLERANCE ±.01 IN.



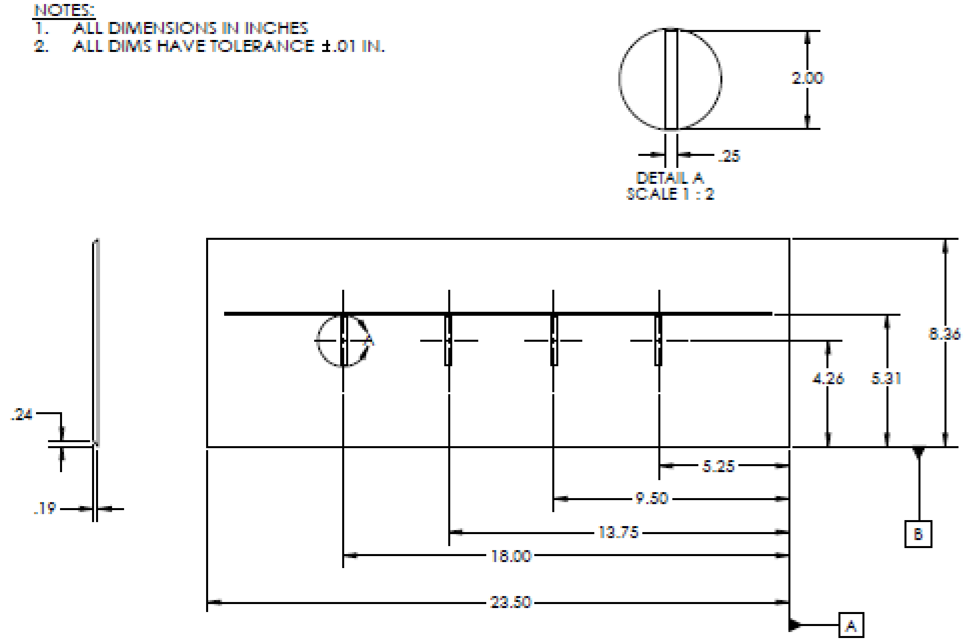
Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: HEAT SEALER WALL 1		Drwn. By: CHRISTOPHER TAN
ME 429 - WINTER 2021	Dwg. #: 111012	MTRL: WOOD	Date: 3/9/21	Scale: 1:3	Chkd. By: ASHLEY HUMPAL

NOTES:
1. ALL DIMENSIONS IN INCHES
2. ALL DIMS HAVE TOLERANCE ±.01 IN.



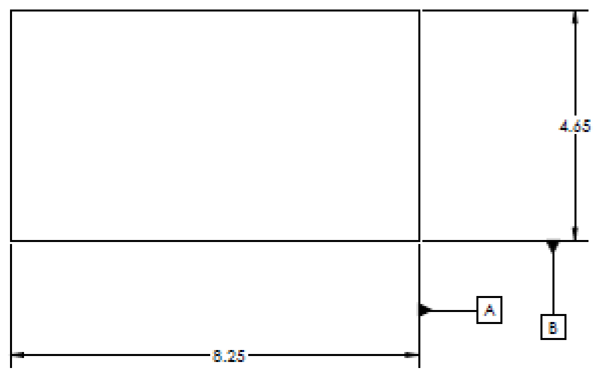
Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: HEAT SEALER WALL 2	Drwn. By: CHRISTOPHER TAN
ME 429 - WINTER 2021	Dwg. #: 111013	MTRL: WOOD	Date: 3/9/21 / Scale: 1:2	Chkd. By: ASHLEY HUMPAL

NOTES:
1. ALL DIMENSIONS IN INCHES
2. ALL DIMS HAVE TOLERANCE ±.01 IN.



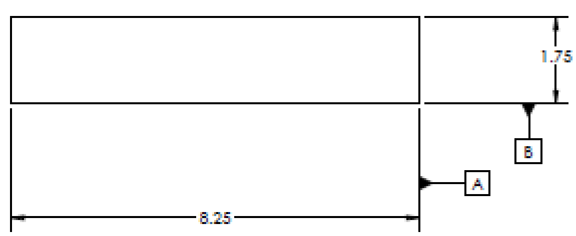
Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: BAG GRAB RAMP 1	Drwn. By: CHRISTOPHER TAN
ME 429 - WINTER 2021	Dwg. #: 111014	MTRL: WOOD	Date: 3/9/21 / Scale: 1:4	Chkd. By: ASHLEY HUMPAL

NOTES:
1. ALL DIMENSIONS IN INCHES
2. ALL DIMS HAVE TOLERANCE ±.01 IN.



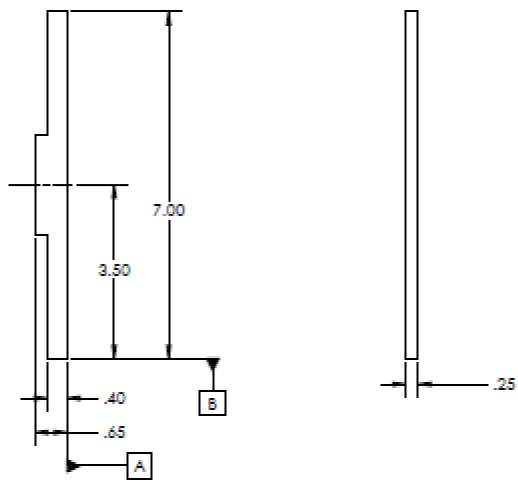
Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: BAG GRAB RAMP 2	Drwn. By: CHRISTOPHER TAN
ME 429 - WINTER 2021	Dwg. #: 111015	MTRL: WOOD	Date: 3/9/21 Scale: 1:2	Chkd. By: ASHLEY HUMPAL

NOTES:
1. ALL DIMENSIONS IN INCHES
2. ALL DIMS HAVE TOLERANCE ±.01 IN.



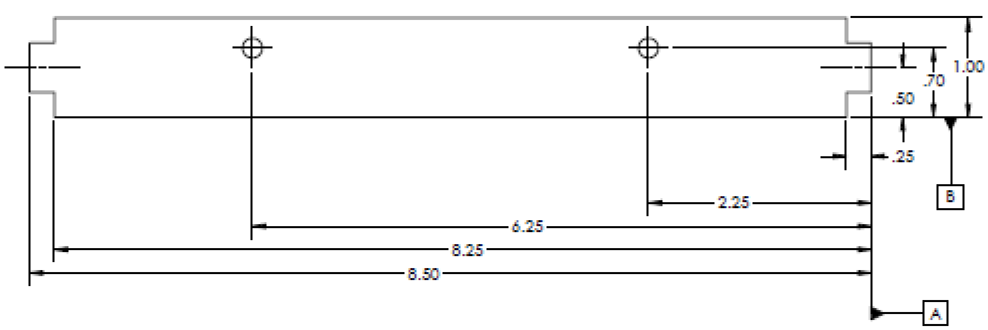
Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: BAG GRAB RAMP 3	Drwn. By: CHRISTOPHER TAN
ME 429 - WINTER 2021	Dwg. #: 111016	MTRL: WOOD	Date: 3/9/21 Scale: 1:2	Chkd. By: ASHLEY HUMPAL

NOTES:
1. ALL DIMENSIONS IN INCHES
2. ALL DIMS HAVE TOLERANCE ±.01 IN.



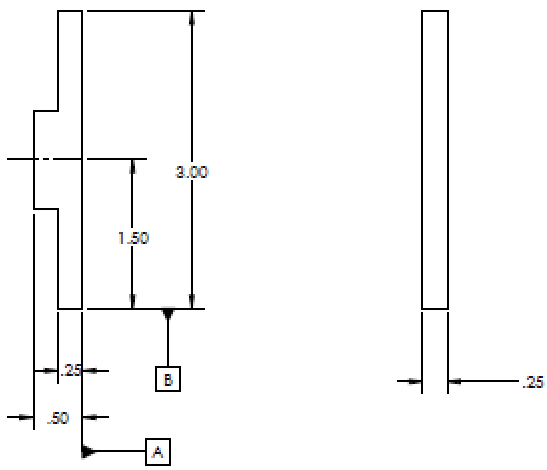
Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: BAG GRAB RAMP DIVIDERS		Drwn. By: CHRISTOPHER TAN
ME 429 - WINTER 2021	Dwg. #: 111017	MTRL: WOOD	Date: 3/9/21	Scale: 1:3	Chkd. By: ASHLEY HUMPAL

NOTES:
1. ALL DIMENSIONS IN INCHES
2. ALL DIMS HAVE TOLERANCE ±.01 IN.



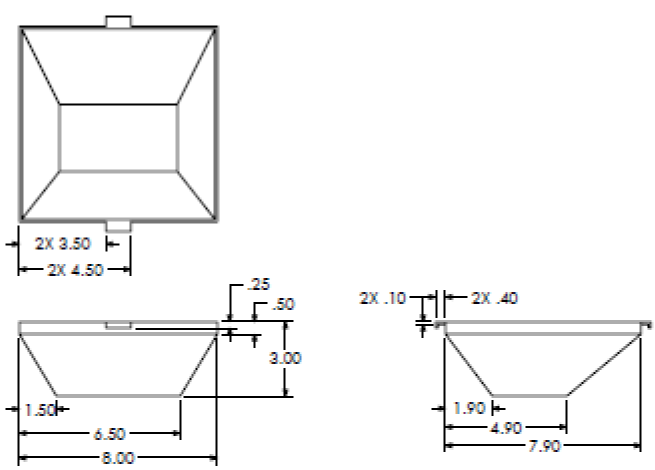
Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: TEMPLATE CROSS BEAMS		Drwn. By: CHRISTOPHER TAN
ME 429 - WINTER 2021	Dwg. #: 111018	MTRL: WOOD	Date: 3/9/21	Scale: 1:1	Chkd. By: ASHLEY HUMPAL

NOTES:
1. ALL DIMENSIONS IN INCHES
2. ALL DIMS HAVE TOLERANCE ±.01 IN.

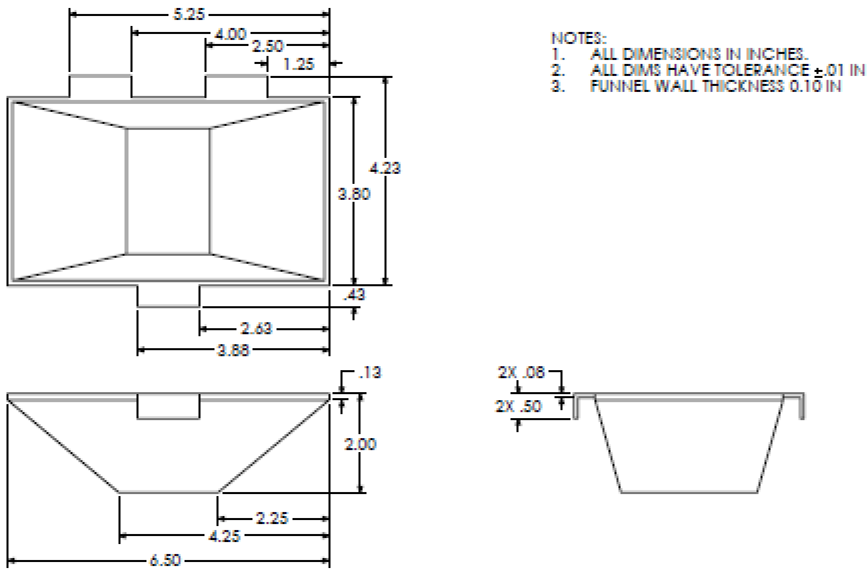


Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: SORTER TABS	Drwn. By: CHRISTOPHER TAN
ME 429 - WINTER 2021	Dwg. #: 111019	MTRL: WOOD	Date: 3/9/21 / Scale: 1:3	Chkd. By: ASHLEY HUMPAL

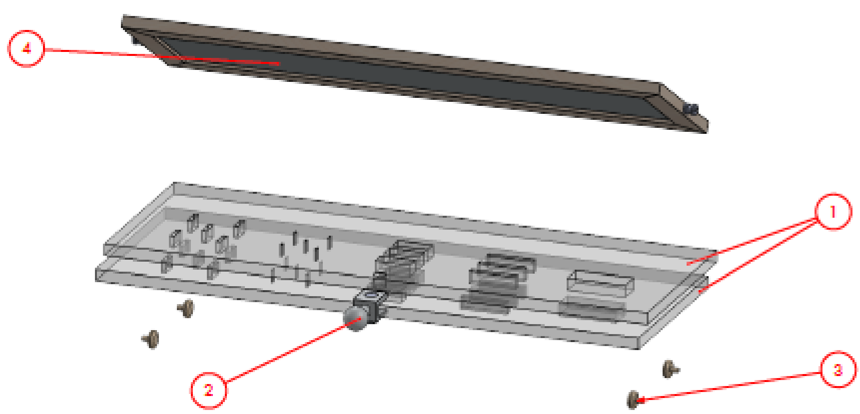
NOTES:
1. ALL DIMENSIONS IN INCHES.
2. ALL DIMS HAVE TOLERANCE ±.01 IN
3. FUNNEL WALL THICKNESS 0.10 IN



Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: BIG FUNNEL	Drwn. By: KYLE CHUANG
ME 429 - WINTER 2021	Dwg. #: 112000	MTRL: WOOD	Date: 6/2/21 / Scale: 1:4	Chkd. By: ASHLEY HUMPAL

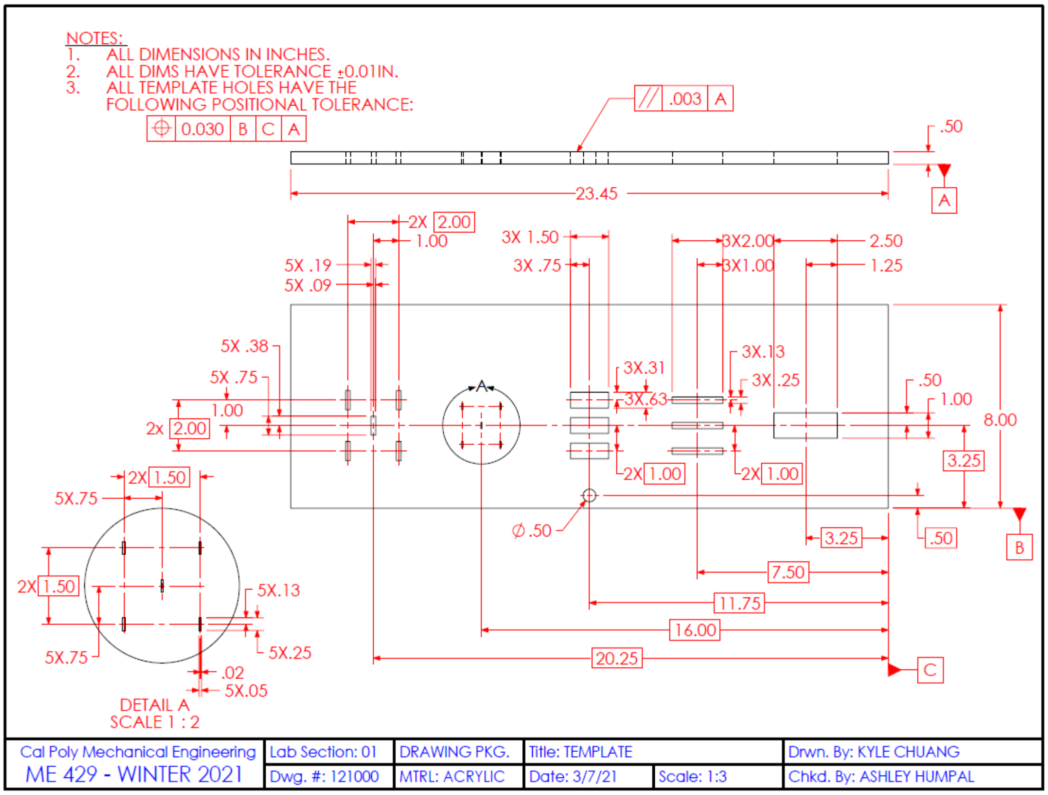


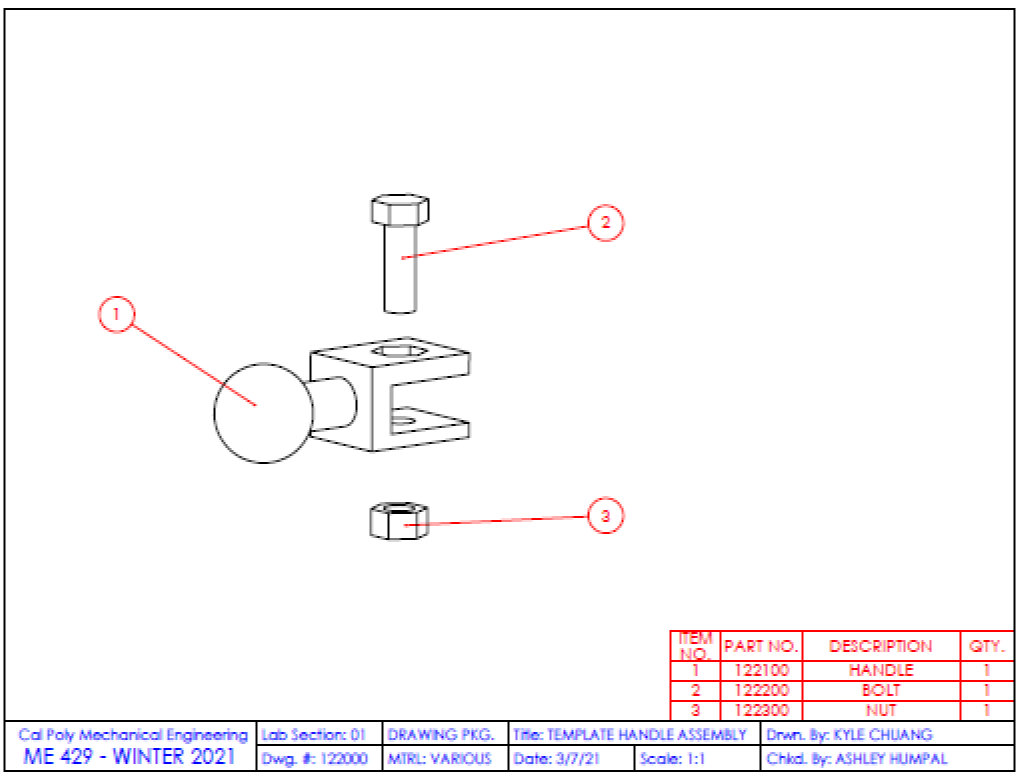
Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: SMALL FUNNEL	Drwn. By: KYLE CHUANG
ME 429 - WINTER 2021	Dwg. #: 113000	MTRL: WOOD	Date: 6/2/21 / Scale: 1:2	Chkd. By: ASHLEY HUMPAL

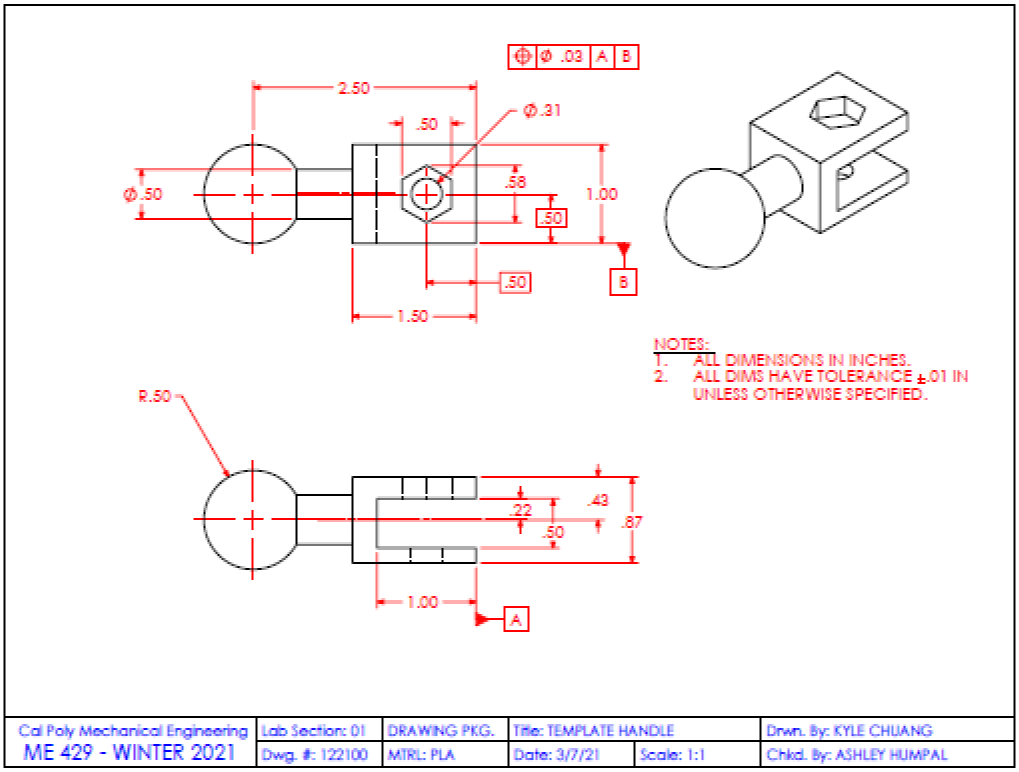


ITEM NO.	PART NO.	DESCRIPTION	QTY.
1	121000	TEMPLATE	2
2	122000	TEMPLATE HANDLE	1
3	123000	CABINET ROLLER	4
4	124000	MIRROR	1

Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: TEMPLATE SORTER SYSTEM	Drwn. By: KYLE CHUANG
ME 429 - WINTER 2021	Dwg. #: 120000	MTRL: VARIOUS	Date: 2/11/21 / Scale: 1:5	Chkd. By: ASHLEY HUMPAL

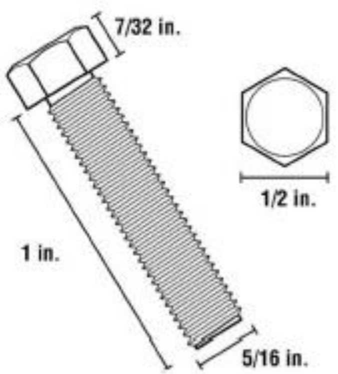

NOTES:
1. ALL DIMENSIONS IN INCHES.
2. ALL DIMS HAVE TOLERANCE ±0.01IN.
3. ALL TEMPLATE HOLES HAVE THE FOLLOWING POSITIONAL TOLERANCE:
0.030 B C A
.003 A
23.45
DETAIL A
SCALE 1 : 2
Cal Poly Mechanical Engineering
ME 429 - WINTER 2021
Lab Section: 01
Dwg. #: 121000
DRAWING PKG.
MTRL: ACRYLIC
Title: TEMPLATE
Date: 3/7/21
Scale: 1:3
Drwn. By: KYLE CHUANG
Chkd. By: ASHLEY HUMPAL


ITEM NO.
PART NO.
DESCRIPTION
QTY.
1 122100 HANDLE 1
2 122200 BOLT 1
3 122300 NUT 1
Cal Poly Mechanical Engineering
ME 429 - WINTER 2021
Lab Section: 01
Dwg. #: 122000
DRAWING PKG.
MTRL: VARIOUS
Title: TEMPLATE HANDLE ASSEMBLY
Date: 3/7/21
Scale: 1:1
Drwn. By: KYLE CHUANG
Chkd. By: ASHLEY HUMPAL



PART 122200: BOLT

5/16 IN. -18TPI X 1 IN. ZINC-PLATED HEX BOLT



- Steel construction
- Zinc-plated
- 5/16 in.-18 tpi
- Buy by the box and save
- California residents see Prop 65 WARNINGS

PART 122300: NUT

5/16 IN.-18 ZINC PLATED HEX NUT

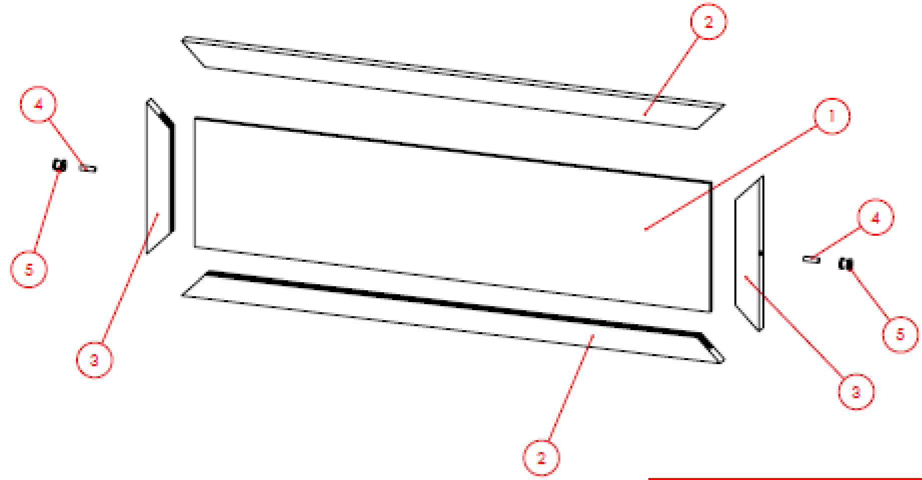
- Used to connect both metal and wood components
- Made from zinc plated steel for durability
- Use a 1/2 in. socket or wrench to tighten
- Includes 1 piece to complete your project

PART 123000: CABINET ROLLER

8PCS BEARING NYLON SMALL PULLEY DRAWER PLASTIC PULLEY IRON SHEET CABINET PULLEY POSITIONING ROLLER FILE CABINET PULLEY (19MM)

Technical Details

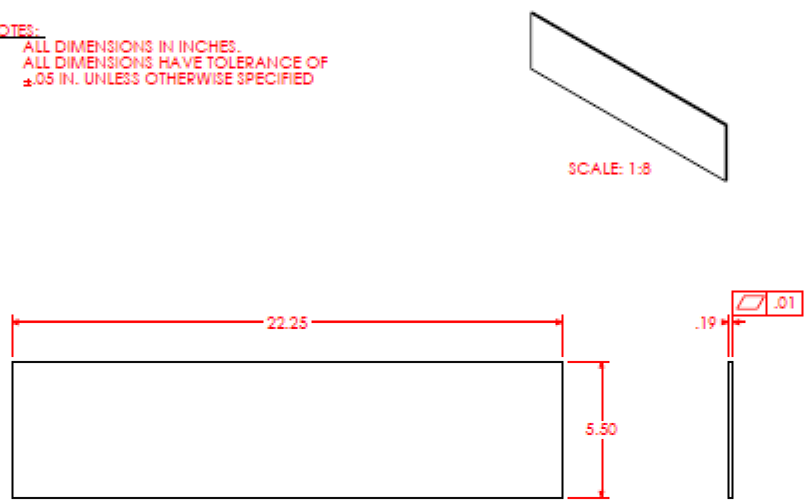
Manufacturer	YUANQIAN
Item Weight	2.11 ounces
Product Dimensions	3.94 x 3.94 x 1.97 inches
Is Discontinued By Manufacturer	No
Color	19mm
Item Package Quantity	8
Batteries Included?	No
Batteries Required?	No



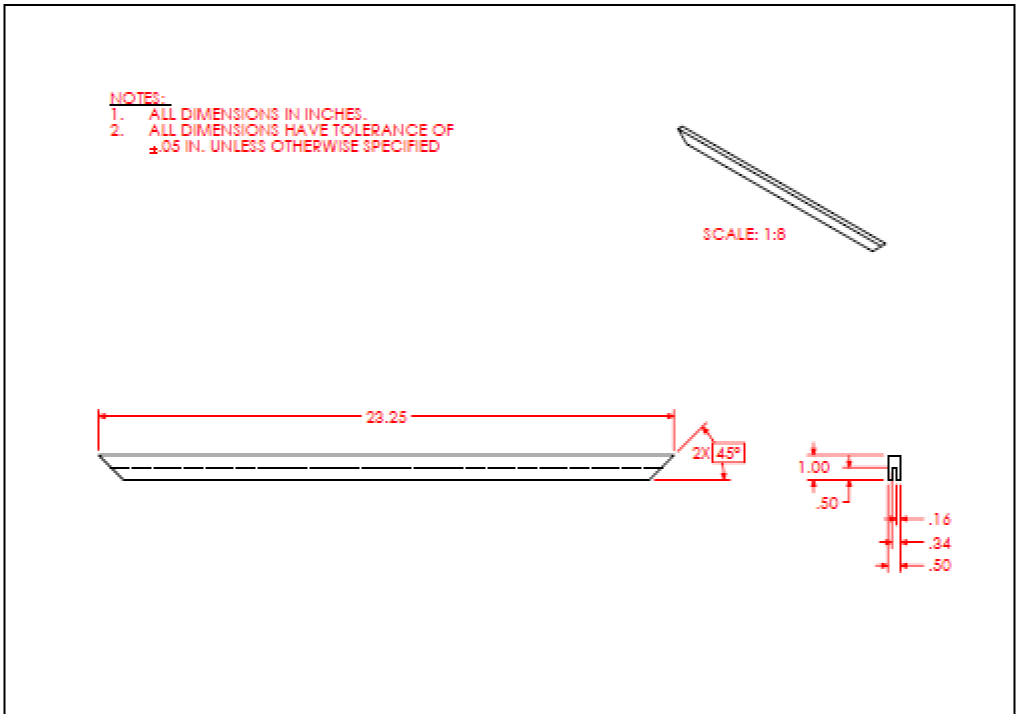
ITEM NO.	PART NO.	DESCRIPTION	QTY.
1	124100	MIRROR	1
2	124200	FRAME L	2
3	124300	FRAME W	2
4	124400	DOWEL	2
5	124500	GROMMET	2

Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: MIRROR ASSEMBLY		Drwn. By: KYLE CHUANG
ME 429 - WINTER 2021	Dwg. #: 124000	MTRL: VARIOUS	Date: 3/7/21	Scale: 1:4	Chkd. By: ASHLEY HUMPAL

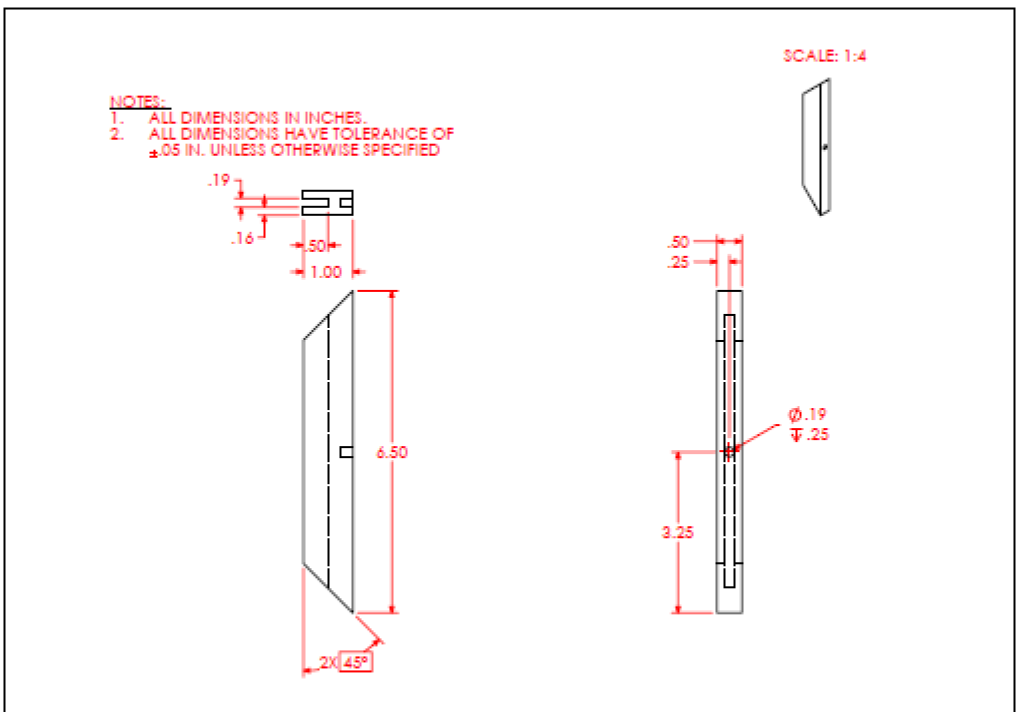
NOTES:
1. ALL DIMENSIONS IN INCHES.
2. ALL DIMENSIONS HAVE TOLERANCE OF ±.05 IN. UNLESS OTHERWISE SPECIFIED



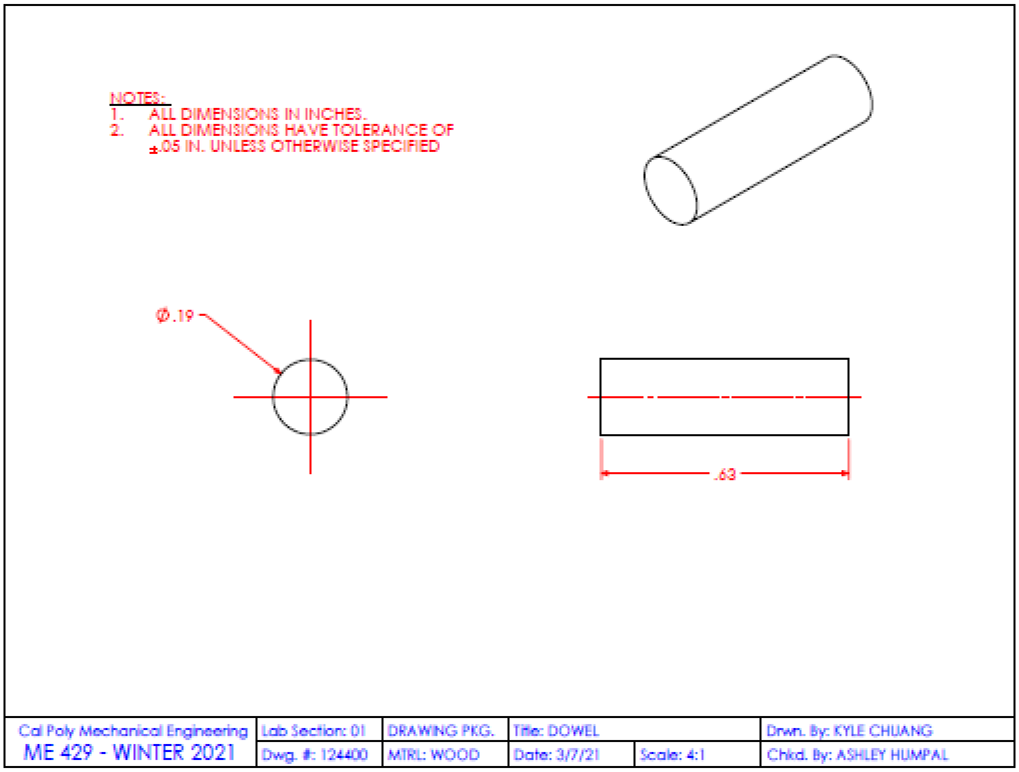
Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: MIRROR		Drwn. By: KYLE CHUANG
ME 429 - WINTER 2021	Dwg. #: 124100	MTRL: ALUMINUM	Date: 3/7/21	Scale: 1:4	Chkd. By: ASHLEY HUMPAL



Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: FRAME L	Drwn. By: KYLE CHUANG
ME 429 - WINTER 2021	Dwg. #: 124200	MTRL: WOOD	Date: 3/7/21 Scale: 1:4	Chkd. By: ASHLEY HUMPAL



Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: FRAME W	Drwn. By: KYLE CHUANG
ME 429 - WINTER 2021	Dwg. #: 124300	MTRL: WOOD	Date: 3/7/21 Scale: 1:2	Chkd. By: ASHLEY HUMPAL



PART 124500: GROMMET

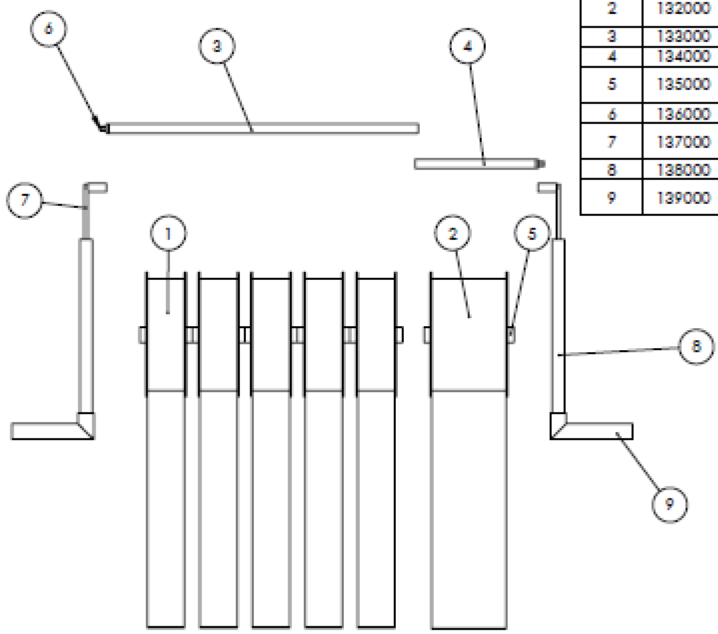
25 RUBBER GROMMETS 3/16" BORE DIAMETER 7/16" O.D.

Product description

- Rubber Grommets
- Durometer hardness 60
- Bore Diameter: 3/16"
- Groove Width: 1/4"
- Groove Diameter: 5/16"
- Outside Diameter: 7/16"
- Overall Thickness: 3/8"
- 25 Per Package

Technical Details

Manufacturer	Clipsandfasteners Inc
Part Number	3230725
Item Weight	0.006 ounces
Package Dimensions	3.27 x 1.93 x 1.54 inches
Material	Rubber
Item Package Quantity	1
Measurement System	English
Batteries Included?	No
Batteries Required?	No



ITEM NO.	PART NO.	DESCRIPTION	QTY.
1	131000	POLY BAG ROLLS 3X4	5
2	132000	POLY BAG ROLLS 6X6	1
3	133000	LONG SHAFT	1
4	134000	SHORT SHAFT	1
5	135000	BAG DRIVER AND GAP	12
6	136000	HEX SLOT	2
7	137000	RATCHET AND SOCKET	2
8	138000	RATCHET EXTENDER	2
9	139000	RATCHET EXTENDER HANDLE	2

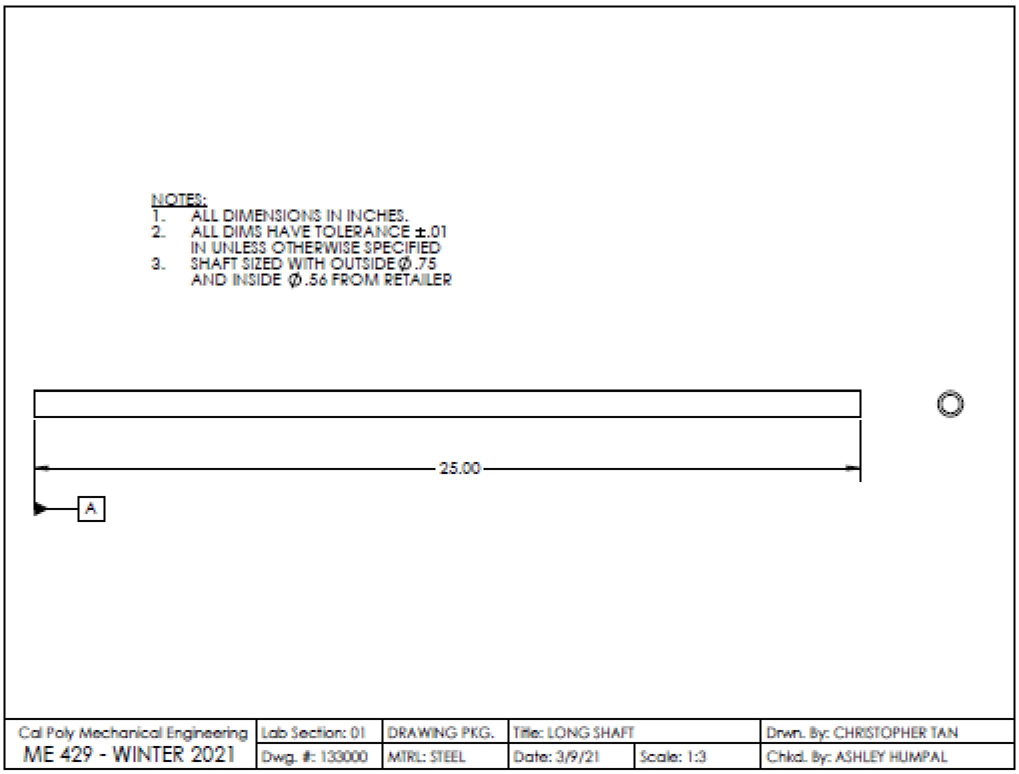
Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: BAG HOLDING SYSTEM		Drwn. By: CHRISTOPHER TAN
ME 429 - WINTER 2021	Dwg. #: 130000	MTRL: VARIOUS	Date: 3/9/21	Scale: 1:8	Chkd. By: ASHLEY HUMPAL

NAME	CLEAR PRE-OPENED AUTOBAGS ON ROLL 3 X 4 X 1.5 MIL
DIAMETER	10 in.
BAG LENGTH	4 in.
BAG WIDTH	4 in.
BAG GAUGE	1.5 MIL
ROLL	4000
QUANTITY	5
RETAILER	US POLY PACK

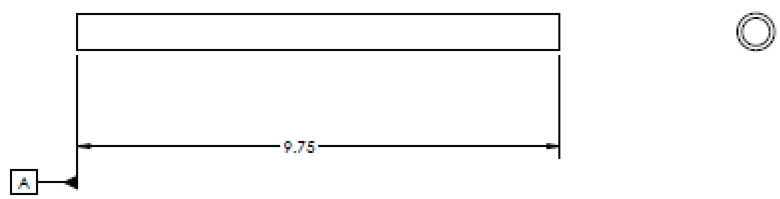
PART #.: 131000

NAME	CLEAR PRE-OPENED AUTOBAGS ON ROLL 6 X 6 X 1.5 MIL
DIAMETER	10 in.
BAG LENGTH	6 in.
BAG WIDTH	6 in.
BAG GAUGE	1.5 MIL
ROLL	2500
QUANTITY	1
RETAILER	US POLY PACK

PART #. : 132000

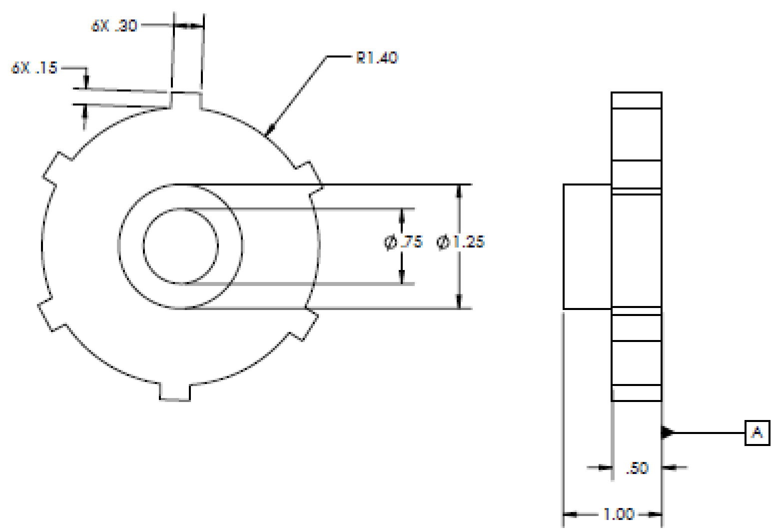


NOTES:
1. ALL DIMENSIONS IN INCHES.
2. ALL DIMS HAVE TOLERANCE ±.01 IN UNLESS OTHERWISE SPECIFIED
3. SHAFT SIZED WITH OUTSIDE Ø.75 AND INSIDE Ø.56 FROM RETAILER



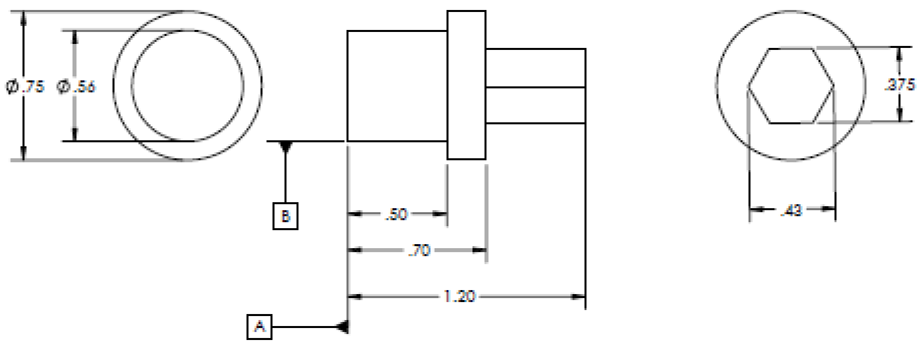
Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: SHORT SHAFT	Drwn. By: CHRISTOPHER TAN
ME 429 - WINTER 2021	Dwg. #: 134000	MTRL: STEEL	Date: 3/9/21 Scale: 1:2	Chkd. By: ASHLEY HUMPAL

NOTES:
1. ALL DIMENSIONS IN INCHES.
2. ALL DIMS HAVE TOLERANCE ±.01 IN UNLESS OTHERWISE SPECIFIED

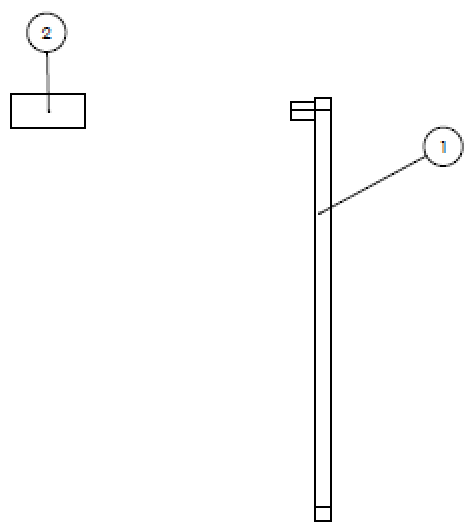


Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: BAG DRIVER AND GAP	Drwn. By: CHRISTOPHER TAN
ME 429 - WINTER 2021	Dwg. #: 135000	MTRL: PLA	Date: 3/9/21 Scale: 1:1	Chkd. By: ASHLEY HUMPAL

NOTES:
1. ALL DIMENSIONS IN INCHES.
2. ALL DIMS HAVE TOLERANCE ±.01 IN UNLESS OTHERWISE SPECIFIED



Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: HEX SLOT	Drwn. By: CHRISTOPHER TAN
ME 429 - WINTER 2021	Dwg. #: 136000	MTRL: PLA	Date: 3/9/21 Scale: 1:1	Chkd. By: ASHLEY HUMPAL



ITEM NO.	PART NO.	DESCRIPTION	QTY
1	137100	1/4 in. DRIVE RATCHET	2
2	137200	1/4 in. DRIVE AND 3/8 in. SIZE SOCKET	2

		DRAWING PKG.	Title: RATCHET AND SOCKET	
		MTRL: STEEL	Date: 3/9/21 Scale: 1:1	

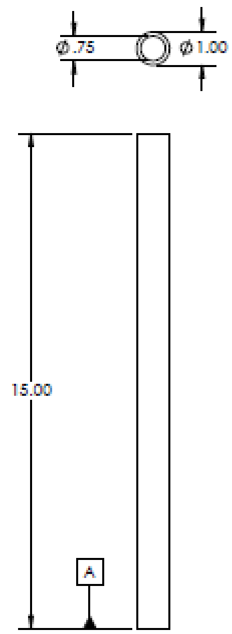
NAME	FLEX HEAD STUBBY RATCHET SET, 3 PC.
SIZE	1/4 in, 3/8 in, 1/2 in. DRIVE
SKU(S)	46742
BRAND	PITTSBURGH
QUANTITY PER PACKAGE	3
PACKAGE	1
MATERIAL	CHROME VANADIUM STEEL
WEIGHT	1.45 lb.
RETAILER	HARBOR FREIGHT

PART #. : 137100

NAME	1/4 in. DRIVE SAE HIGH VISIBILITY DEEP SOCKET, 10 PC.
SKU(S)	61333, 67876
BRAND	PITTSBURGH
DRIVE SIZE	1/4 in.
SIZE	SAE
SIZE(S)	3/16 in., 7/32 in., 1/4 in., 9/32 in., 5/16 in., 11/32 in., 3/8 in., 7/16 in., 1/2 in. and 9/16 in.
CERTIFICATION	ANSI
QUANTITY PER PACKAGE	10
PACKAGE	1
MATERIAL	CHROME VANADIUM STEEL
WEIGHT	1 lb.
RETAILER	HARBOR FREIGHT

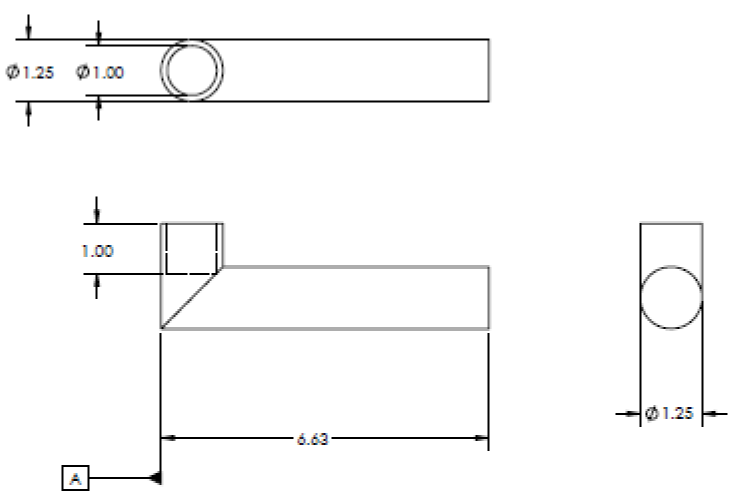
PART #. : 137200

NOTES:
1. ALL DIMS IN INCHES.
2. ALL DIMS HAVE TOLERANCE ±.01 IN.

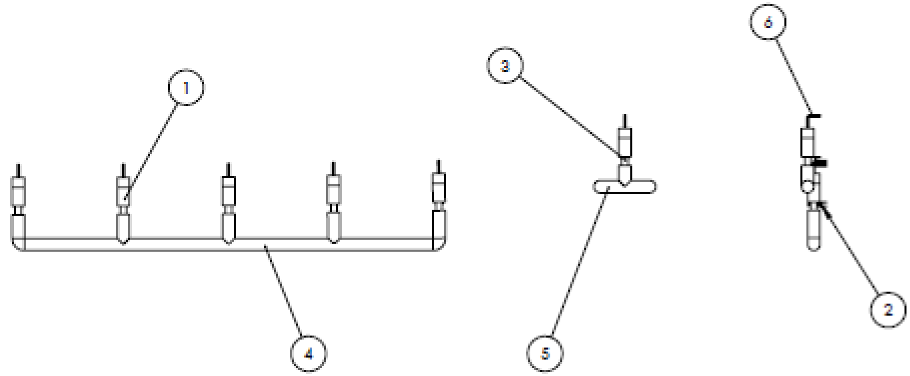


Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: RATCHET EXTENDER		Drwn. By: CHRISTOPHER TAN
ME 429 - WINTER 2021	Dwg. #: 138000	MTRL: PLA	Date: 3/9/21	Scale: 1:3	Chkd. By: ASHLEY HUMPAL

NOTES:
1. ALL DIMS IN INCHES.
2. ALL DIMS HAVE TOLERANCE ±.01 IN.



Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: RATCHET EXTENDER HANDLE		Drwn. By: CHRISTOPHER TAN
ME 429 - WINTER 2021	Dwg. #: 139000	MTRL: PLA	Date: 3/9/21	Scale: 1:2	Chkd. By: ASHLEY HUMPAL



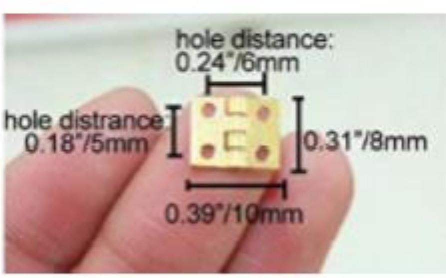
ITEM NO.	PART NO.	DESCRIPTION	QTY.
1	141000	BUSHING	6
2	142000	HINGE	6
3	143000	WOODEN DOWEL	6
4	144000	20" 3D-PRINTED HANDLE	1
5	145000	2.5" 3D-PRINTED HANDLE	1
6	146000	L-SHAPED HOOK	6

Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: BAG OPENING SYSTEM		Drwn. By: KEANAU ROBIN
ME 429 - WINTER 2021	Dwg. #: 140000	MTRL: VARIOUS	Date: 3/7/21	Scale: 1:4	Chkd. By: ASHLEY HUMPAL

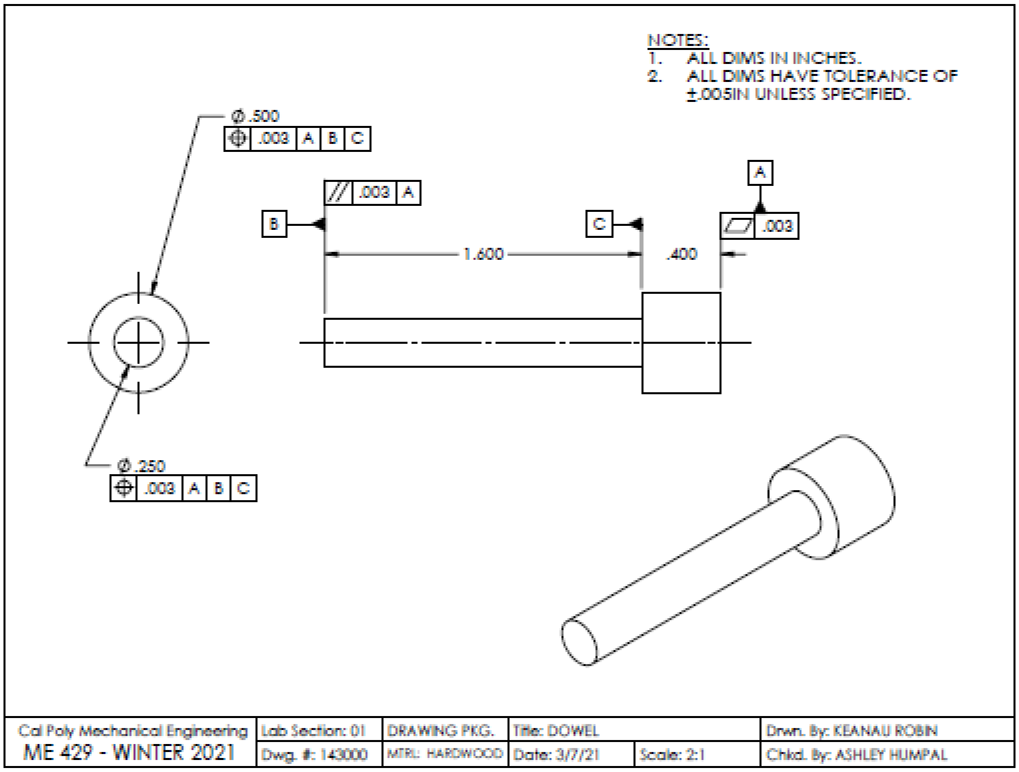
PART 141000: BUSHING

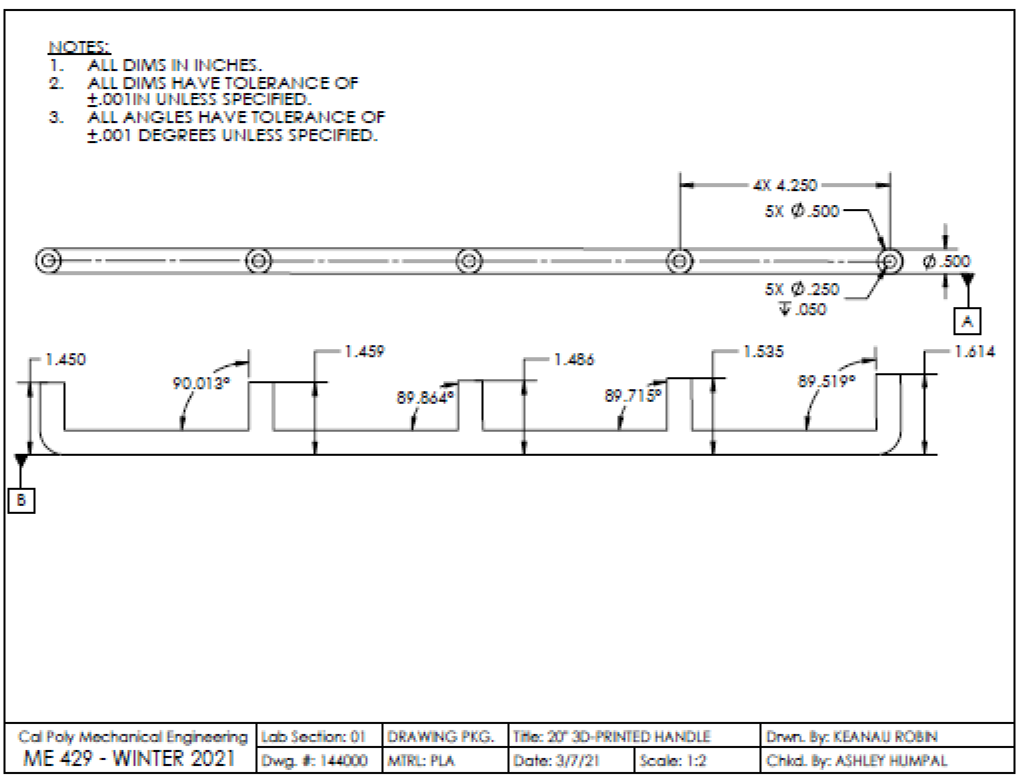
I.D. d (inch)	O.D. D (inch)	Overall Length L (inch)
0.25 in (1/4")	0.50 in (1/2")	0.75 in (3/4")
0.25 in (1/4")	0.50 in (1/2")	0.75 in (3/4")

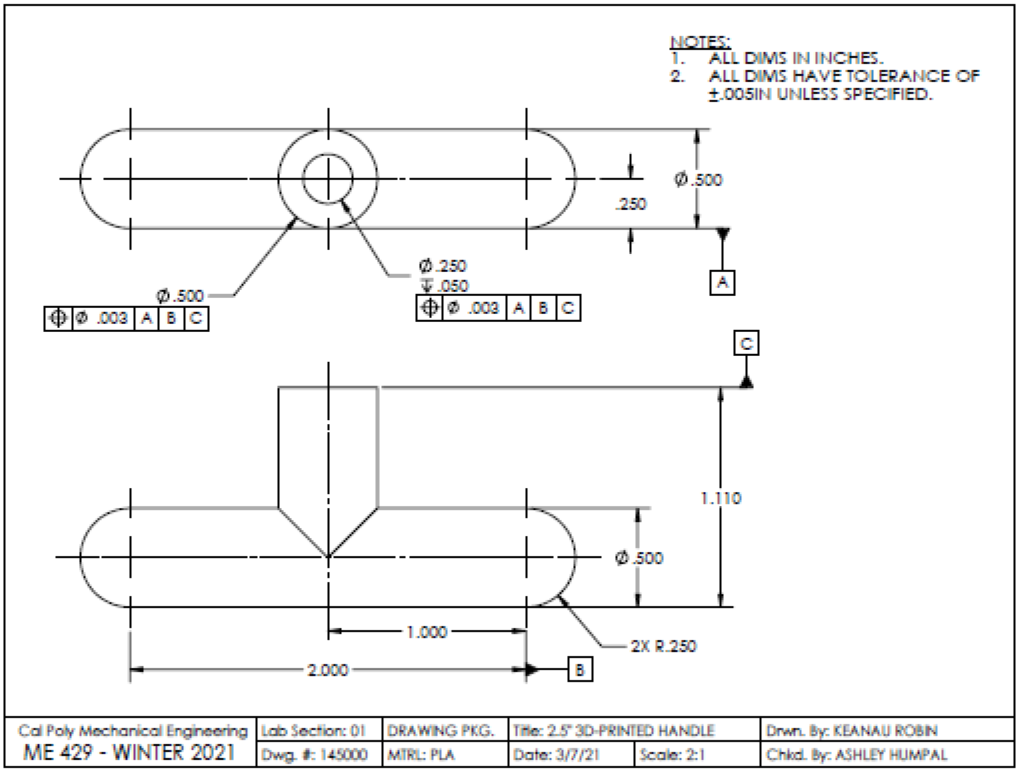
PART 142000: HINGE



NOTE:
THICKNESS = 0.02 IN
WEIGHT = 0.35 g

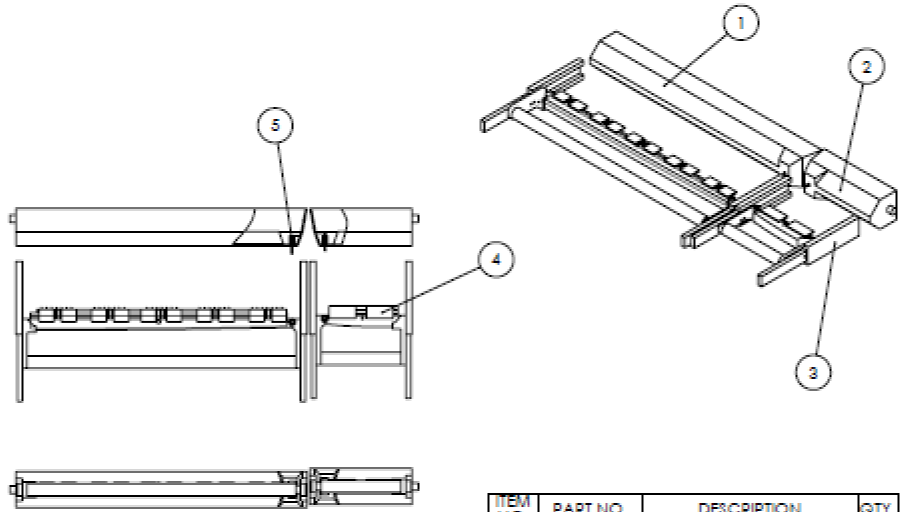

NOTES:
1. ALL DIMS IN INCHES.
2. ALL DIMS HAVE TOLERANCE OF ±.005IN UNLESS SPECIFIED.
Ø .500
.003 A B C
// .003 A
B
C
A
.003
1.600
.400
Ø .250
.003 A B C
Cal Poly Mechanical Engineering
ME 429 - WINTER 2021
Lab Section: 01
Dwg. #: 143000
DRAWING PKG.
MTRL: HARDWOOD
Title: DOWEL
Date: 3/7/21
Scale: 2:1
Drwn. By: KEANAU ROBIN
Chkd. By: ASHLEY HUMPAL


NOTES:
1. ALL DIMS IN INCHES.
2. ALL DIMS HAVE TOLERANCE OF ±.001IN UNLESS SPECIFIED.
3. ALL ANGLES HAVE TOLERANCE OF ±.001 DEGREES UNLESS SPECIFIED.
4X 4.250
5X Ø .500
Ø .500
5X Ø .250
↧ .050
A
1.450
90.013°
1.459
89.864°
1.486
89.715°
1.535
89.519°
1.614
B
Cal Poly Mechanical Engineering
ME 429 - WINTER 2021
Lab Section: 01
Dwg. #: 144000
DRAWING PKG.
MTRL: PLA
Title: 20" 3D-PRINTED HANDLE
Date: 3/7/21
Scale: 1:2
Drwn. By: KEANAU ROBIN
Chkd. By: ASHLEY HUMPAL



PART 146000: L-SHAPED HOOK

HILLMAN HARDWARE L-SHAPED HOOK	
DIAMETER:	0.080IN
LENGTH:	1.0IN



ITEM NO.	PART NO.	DESCRIPTION	QTY.
1	151000	20" HEAT SEALER	1
2	152000	4" HEAT SEALER	1
3	153000	6" DRAWER RAILINGS	2
4	154000	ACRYLIC GUARDS	14
5	155000	PUSH ROD SUBASSEMBLY	2
5	155100	PUSH-ROD SPRING	2
5	155200	PUSH-ROD CASING	2
5	155300	PUSH ROD	2

Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: HEAT SEALING SYSTEM		Drwn. By: KEANAU ROBIN
ME 429 - WINTER 2021	Dwg. #: 150000	MTRL: VARIOUS	Date: 3/7/21	Scale: 1:8	Chkd. By: ASHLEY HUMPAL

PART 151000: 20" HEAT SEALER

Specification:

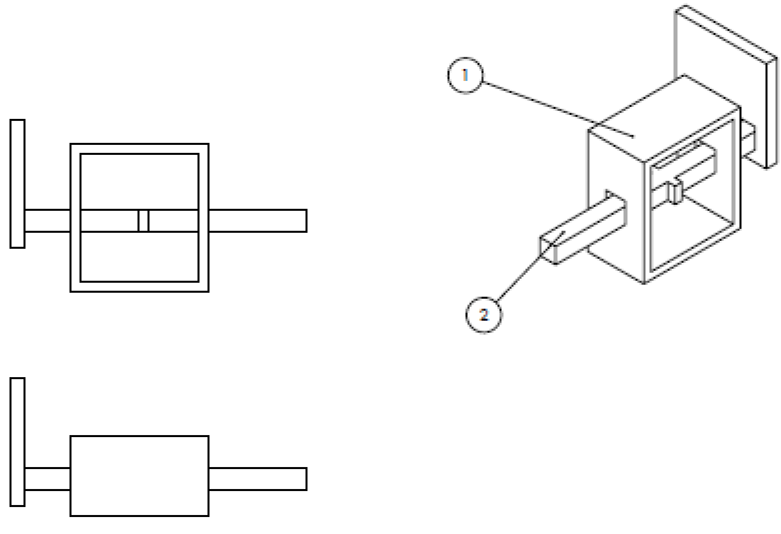
Impulse Power(600W)
Voltage(110V)
Heat Time(0.2 - 2s)
Sealing Length(500mm / 19685mil)
Sealing Width(2mm / 78.7mil)
Max sealing Thickness(0.2mm / 7.9mil)
Dimension(24 1/2"L x 5 1/2"D x 6 1/3"H)
Machine Weight(11.5 lbs)

PART 152000: 4" HEAT SEALER

- 4" (100 mm) sealing length / 1/16" (2 mm) wide sealing
- Includes Full spare parts kit: 2 sealing elements 2 PTFE sheets
- Voltage: 110 V / 60 hz - Impulse power:180 w
- Heat Time: 0-3.5 Sec
- Note: Seals bags made of any thermo sealable material, with the possible exception of thicker metalized lamin ations. Please see below for more information.

PART 153000: 6" DRAWER RAILING

FULL DIMENSION: 6 X 1.8 X 0.5 INCHES
WEIGHT: 14.4 OZ



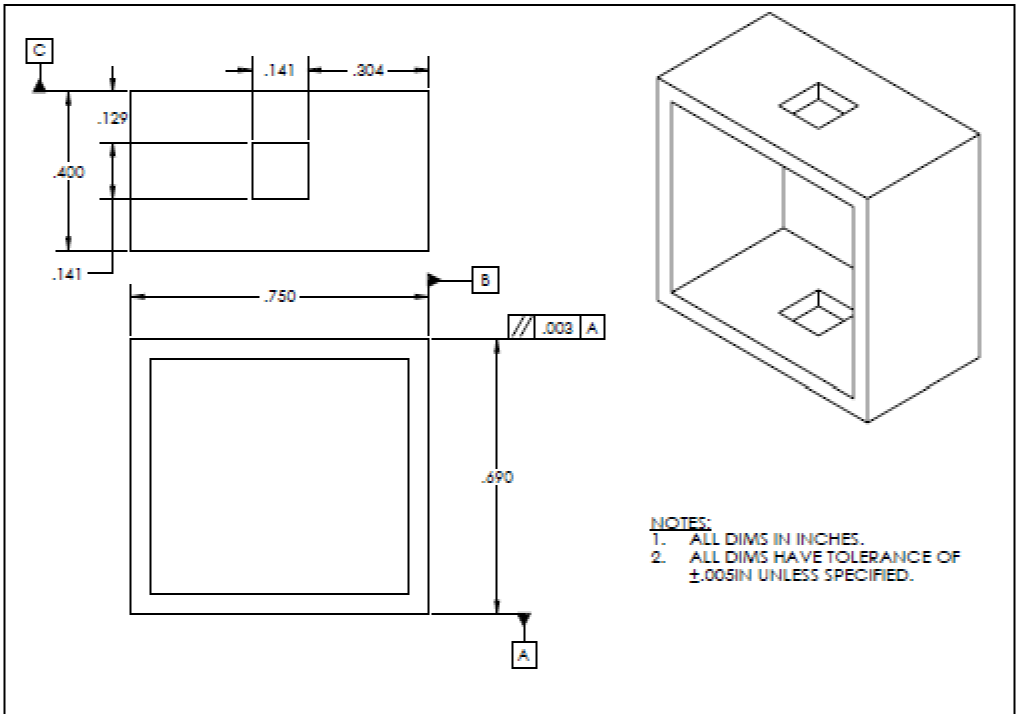
ITEM NO.	PART NO.	DESCRIPTION	QTY.
N/A	154100	PUSH-ROD SPRING	2
1	154200	PUSH-ROD CASING	2
2	154300	PUSH ROD	2

Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: PUSH-ROD SUBASSEMBLY		Drwn. By: KEANAU ROBIN
ME 429 - WINTER 2021	Dwg. #: 154000	MTRL: VARIOUS	Date: 3/7/21	Scale: 2:1	Chkd. By: ASHLEY HUMPAL

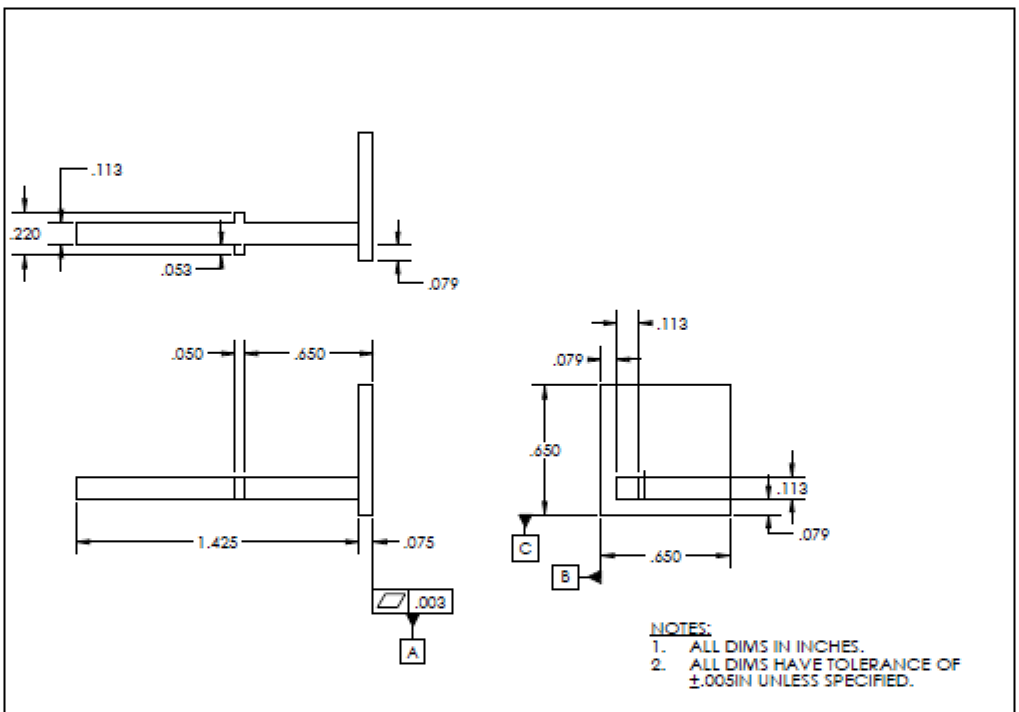
PART 154100: PUSH-ROD SPRING

SPECIFICATIONS:

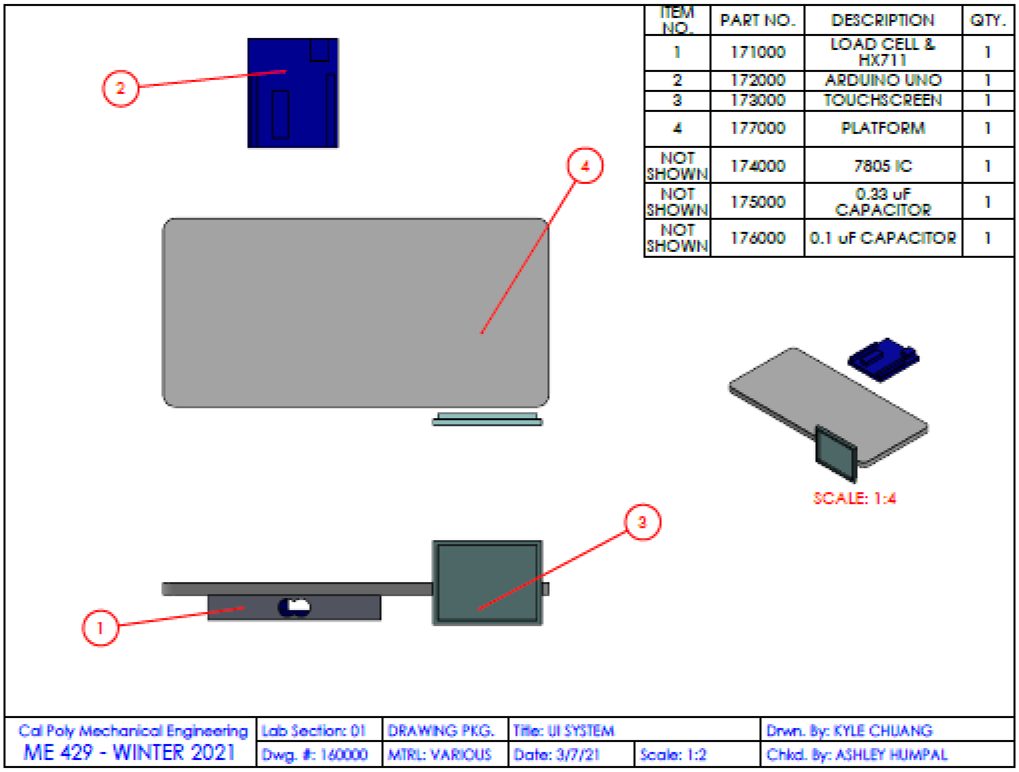
- LENGTH=0.375 IN
- OD=0.3 IN
- ID=0.256 IN
- WIRE DIAMETER=0.022 IN



Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: PUSH-ROD CASING		Drwn. By: KEANAU ROBIN
ME 429 - WINTER 2021	Dwg. #: 154200	MTRL: PLA	Date: 3/7/21	Scale: 4:1	Chkd. By: ASHLEY HUMPAL



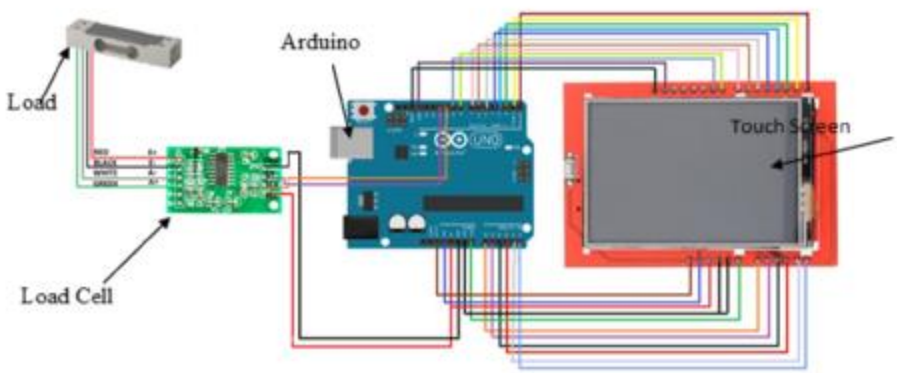
Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: PUSHROD		Drwn. By: KEANAU ROBIN
ME 429 - WINTER 2021	Dwg. #: 154300	MTRL: PLA	Date: 3/7/21	Scale: 2:1	Chkd. By: ASHLEY HUMPAL



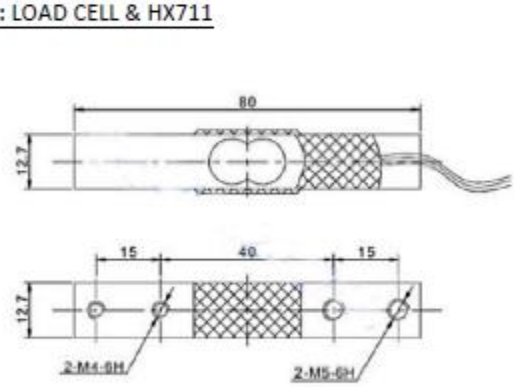
ITEM NO.	PART NO.	DESCRIPTION	QTY.
1	171000	LOAD CELL & HX711	1
2	172000	ARDUINO UNO	1
3	173000	TOUCHSCREEN	1
4	177000	PLATFORM	1
NOT SHOWN	174000	7805 IC	1
NOT SHOWN	175000	0.33 uF CAPACITOR	1
NOT SHOWN	176000	0.1 uF CAPACITOR	1

Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: UI SYSTEM		Drwn. By: KYLE CHUANG
ME 429 - WINTER 2021	Dwg. #: 160000	MTRL: VARIOUS	Date: 3/7/21	Scale: 1:2	Chkd. By: ASHLEY HUMPAL

PART 160000A: UI SYSTEM WIRING DIAGRAM



PART 161000: LOAD CELL & HX711

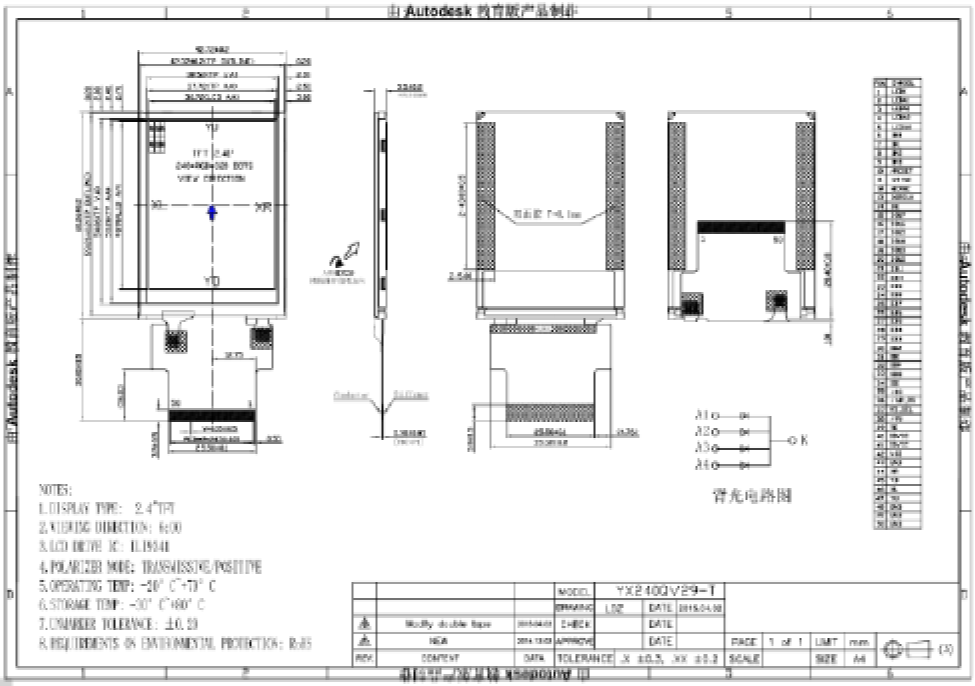


- Load cell specs:
  -Wire leads pre-attached, 22 cm (8.5 in) long
  -Dimensions 12.7 mm high, 12.7 mm wide, 80 mm long (0.5 in x 0.5 in x 3.15 in)
  -4 mounting holes, 15 mm spacing on each side. One side both holes tapped M4 thread, the other side both holes tapped M5 thread.
- HX711 specs:
  -Operation Voltage: 2.7V~5V
  -Operation Current: < 1.5mA
  -Mounted on breakout board
  -Includes breakaway headers for connection, soldering required

PART 162000: ARDUINO UNO

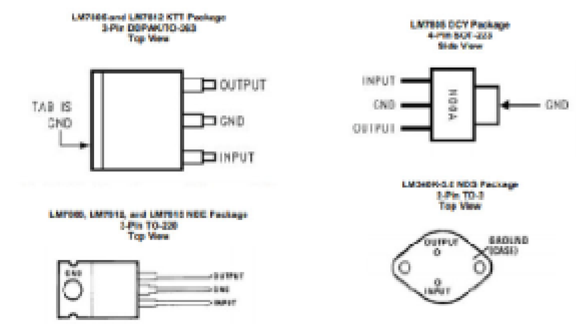
Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328P) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
LED_BUILTIN	13
Length	68.6 mm
Width	53.4 mm
Weight	25 g

PART 163000: TOUCHSCREEN



PART 164000: 7805 IC

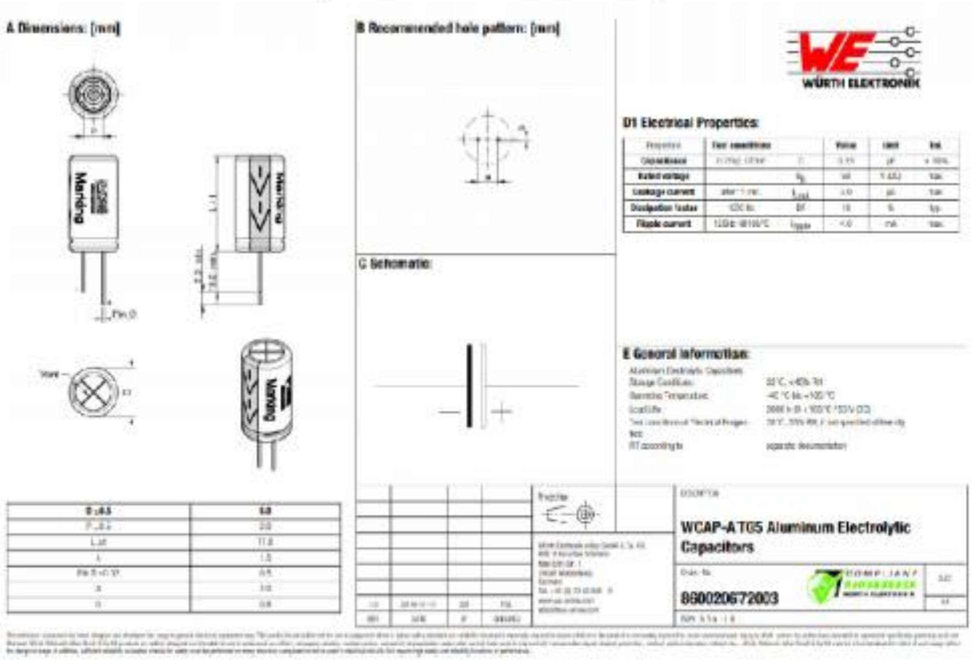
5 Pin Configuration and Functions



Pin Functions

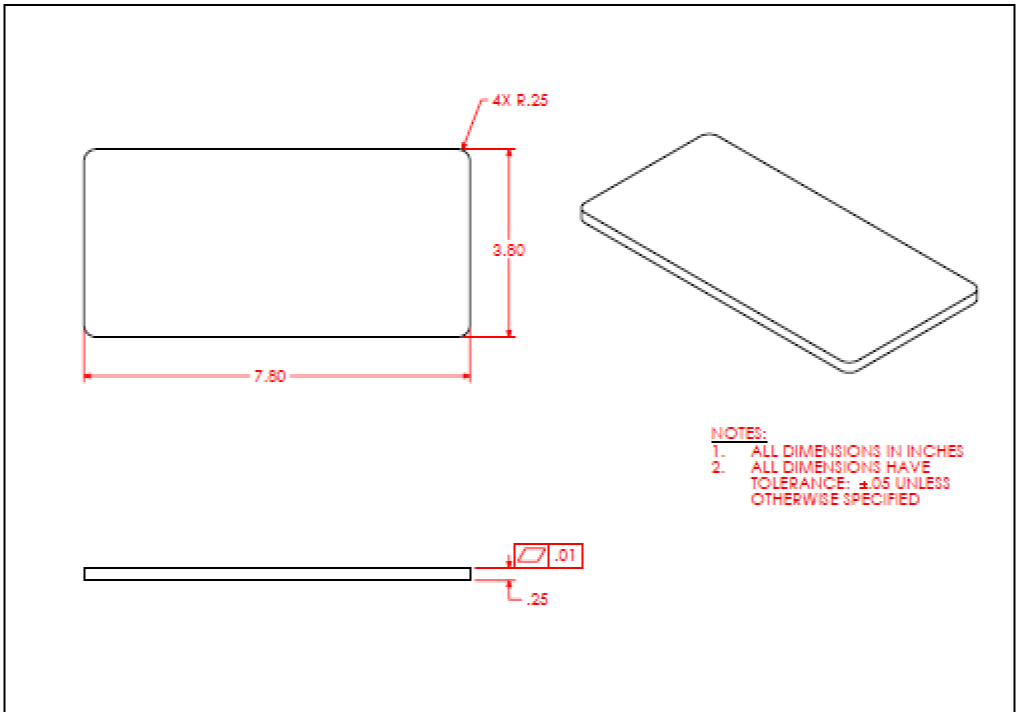
PIN		I/O	DESCRIPTION
NAME	NO.		
INPUT	1	I	Input voltage pin
GND	2	I/O	Ground pin
OUTPUT	3	O	Output voltage pin

PART 165000: 0.33uF CAPACITOR

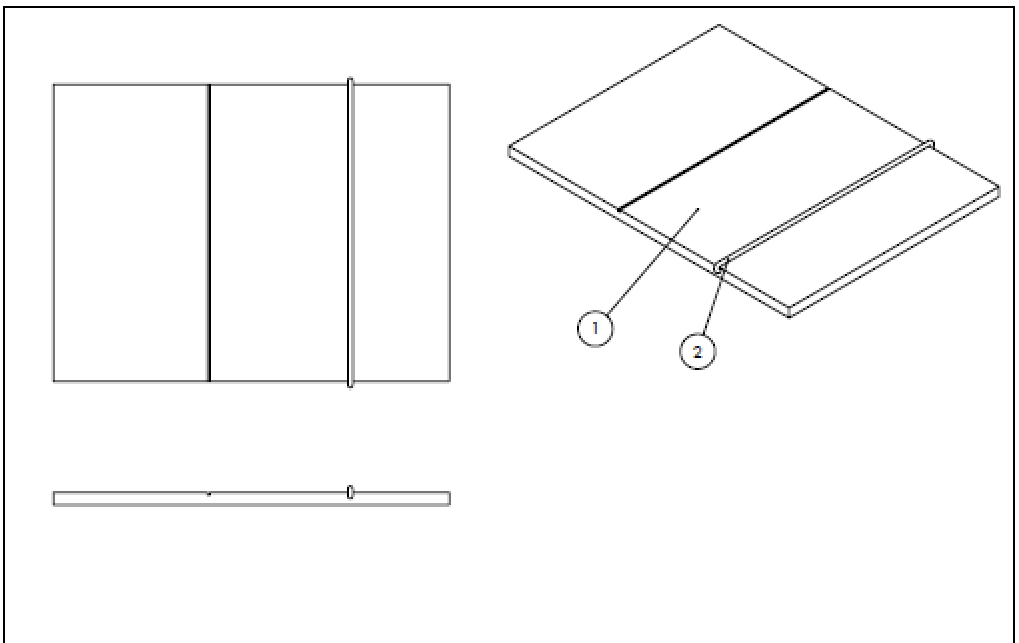


PART 166000: 0.1 uF CAPACITOR

Product Attribute	Attribute Value
Manufacturer:	AVX
Product Category:	Multilayer Ceramic Capacitors MLCC - SMD/SMT
RoHS:	Details
Packaging:	Cut Tape
Packaging:	MouseReel
Packaging:	Reel
Termination:	Standard
Capacitance:	0.1 uF
Voltage Rating DC:	[illegible] VDC
Dielectric:	X7R
Tolerance:	10 %
Case Code - in:	0805
Case Code - mm:	[illegible]
Height:	1.02 mm
Minimum Operating Temperature:	- 55 C
Maximum Operating Temperature:	+ 125 C
Product:	General Type MLCCs
Termination Style:	SMD/SMT
Qualification:	AEC-Q200
Series:	[illegible]
Length:	2 mm
Package / Case:	0805 (2012 metric)
Width:	1.27 mm
Brand:	AVX
Capacitance - nF:	100 nF
Capacitance - pF:	100000 pF
Class:	Class 2
Product Type:	Ceramic Capacitors
Factory Pack Quantity:	4000
Subcategory:	Capacitors
Tradename:	[illegible]
Unit Weight:	[illegible]

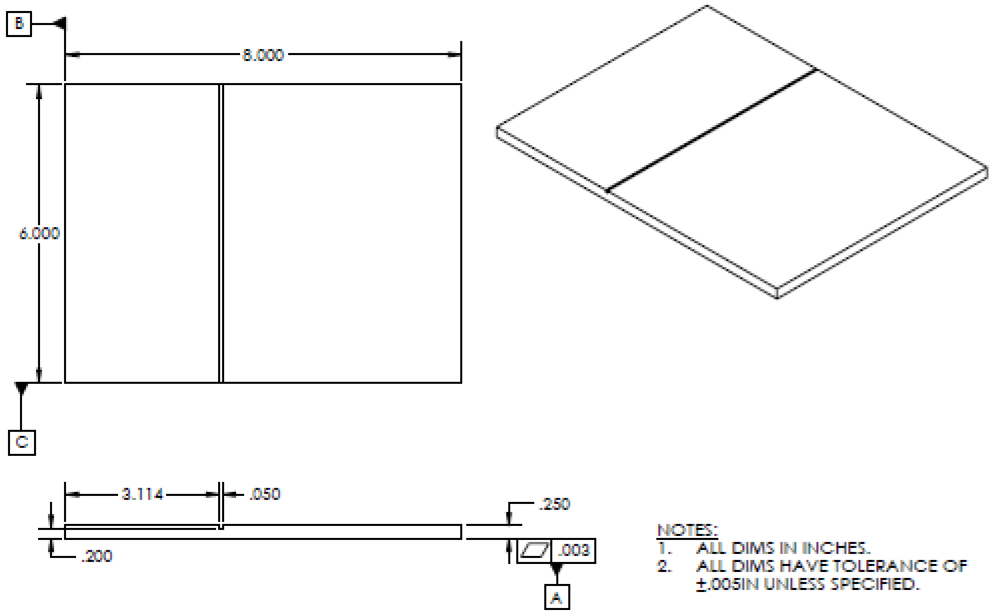


Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: PLATFORM		Drwn. By: KYLE CHUANG
ME 429 - WINTER 2021	Dwg. #: 167000	MTRL: ALUMINUM	Date: 3/7/21	Scale: 1:2	Chkd. By: ASHLEY HUMPAL



ITEM NO.	PART NO.	DESCRIPTION	QTY
1	181000	FOLDING PLATE	1
2	182000	ELASTIC CORD	1

Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: PAPER FOLDING SYSTEM		Drwn. By: KEANAU ROBIN
ME 429 - WINTER 2021	Dwg. #: 170000	MTRL: VARIOUS	Date: 3/7/21	Scale: 1:2	Chkd. By: ASHLEY HUMPAL



NOTES:
1. ALL DIMS IN INCHES.
2. ALL DIMS HAVE TOLERANCE OF ±.005IN UNLESS SPECIFIED.

Cal Poly Mechanical Engineering	Lab Section: 01	DRAWING PKG.	Title: FOLDING PLATE		Drwn. By: KEANAU ROBIN
ME 429 - WINTER 2021	Dwg. #: 171000	MTRL: WOOD	Date: 3/7/21	Scale: 1:2	Chkd. By: ASHLEY HUMPAL

PART 172000: ELASTIC CORD

SPECIFICATIONS:
DIAMETER=0.125 IN
TOTAL LENGTH=30 FT
WEIGHT=0.317 OZ

Appendix Q: Failure Mode Table

Design Failure Mode and Effects Analysis

Product: Just Kitting Workstation

Prepared by: F16 SourceAmerica

Team: F16 SourceAmerica

Date: 11/20/20 (orig)

												Action Results					
System / Function	Potential Failure Mode	Potential Effects of the Failure Mode	Severity	Potential Causes of the Failure Mode	Current Preventative Activities	Occurence	Current Detection Activities	Detection	Priority	Recommended Action(s)	Responsibility & Target Completion Date	Actions Taken	Severity	Occurence	Detection	RPN	* high RPN considered for scores over 50
Sorting System / Sort Items	Items sorted incorrectly	Decrease quality assurance	7	Items placed incorrectly in template holes	Template has unique holes	5	Weigh Final Kit	1	35								
	Items do not drop in bags	Decrease user efficiency	7	Items fall out of funnel/do not drop into bags	Use large funnels	5	Weigh Final Kit	1	35								
Sorting System / Count Items	Item count incorrect	Kits made incorrectly; decrease productivity	7	Items placed incorrectly in template holes	Template Holes	5	Weigh Final Kit	1	35								
Sorting System / Hold Items	Items are not held in holes	Decrease efficiency; Damage items	2	Items fall out of template holes	Template Holes	8	Inspection	1	16								
Sorting System / Increase Efficiency	Sorting system less efficient than hand bagging	Reduces effectiveness of our product	8	Items palced incorrectly into template; Component failure	Template Holes	2	Timed Test	4	64	Flare holes; place funnels into template holes	Ashley-12/4		8	1	1	8	
	Requires too much dexterity to individually place items in holes	Restricts our target user; decrease in productivity	7	Template holes too small/precise to drop	Template holes	4	Timed Test	4	112	Flare holes; place funnels into template holes; Revise Sorting design	Ashley-12/4		7	2	2	28	
Sorting System / Support Items	Slider jam	Slider cannot operate; decrease in productivity	2	Rails damaged/ unclean	Detachable sliders	1	Inspection	1	2								
Bag Holding System / Holds bag	Bag rips	Kit item falls down and get lost; Kit items get jammed in machine;items fall on user	4	Wrong bag rolls placed;bag gets jammed	Purchase thick bags	2	Observation	3	24								
	Shaft breaks or bends	User can't get any bags to put kit items into; user injured; sharp edges exposed	8	Motor gets jammed; motor breaks; shaft can't handle bag weight; something gets caught in shaft making it unable to turn	RPM limit (so shaft doesn't spin too fast)	2	Observation	1	16								
Bag Holding System / Feeds out bag	Motor breaks or malfunctions	User injured; bags stop dispensing	8	item gets stuck in motor; shaft gets stuck	Limit motor speed	3	Obsevation	1	24								
	Shaft gets jammed	Bags stop dispensing	8	Motor jams; too much weight on shaft	Use proper lubricant	3	Observation	1	24								
	Bag rolls get jammed when coming out	Bags stop dispensing; Causes shaft to jam	5	Shaft stops turning; wrong size bags on roll	Limit max bag roll size	3	Inspection	2	30								
	Shaft breaks or bends	Bags stop dispensing	8	Too much weight on shaft: Motor goes to fast (resonance frequency)	Limit kit weight size	2	Observation	1	16								

Design Failure Mode and Effects Analysis

Product: Just Kitting Workstation **Prepared by:** F16 SourceAmerica

Team: F16 SourceAmerica **Date:** 11/20/20 **(orig)**

System / Function	Potential Failure Mode	Potential Effects of the Failure Mode	Severity	Potential Causes of the Failure Mode	Current Preventative Activities	Occurence	Current Detection Activities	Detection	Priority	Recommended Action(s)	Responsibility & Target Completion Date	Action Results: Actions Taken	Action Results: Severity	Action Results: Occurence	Action Results: Detection	Action Results: RPN
Bag Holding System / Supports bag	Shaft flexes too much	User is uncomfortable; Harder for items to get placed in bags	8	Shaft made of weak material; Kit items too heavy	Limit kit weight size	2	Observation	3	48							
Bag Opening System / Keep Bags Open	Items miss bag opening	User forced to stop process; Must pick up loose item	7	Locking mechanism is too hard to lock; Locking Mechanism breaks	Smaller end for the funnels; Bigger bag openings	5	Observation	1	35							
Bag Opening System / Prevent hook obstruction	Locking mechanism failure	User forced to stop process; bags cannot smoothly move to next station	7	Mechanism is too hard to lock; Mechanism is too weak to maintain stationary position	Precisely manufacture mechanism's locking points	4	Observation	1	28							
	Rotary motion is not functioning properly	Bags constantly held by hook	7	Hinges get rusty; Hinges break; Hinges wear out	Use Aluminum or other strong, rust-proof material	4	Observation	2	56	Oil Hinges and inspect material for wear	Keanau -12/4		7	3	1	21
Bag Opening System / Minimize required dexterity	Lever Malfunction	User cannot properly open bag (depending on severity of damage)	7	Lever material wears out; Lever produces rust	Use Aluminum or other strong, rust-proof material	3	Observation	1	21							
Heat Sealing System/ Seal Bag Shut	Heat seal breaks or malfunctions	Cannot heat seal bags; Decrease productivity; Damage bags	6	Heat seal malfunction due to component error or circuit breaks	Heat seal in a protective area and checked once in a while	2	Observation	3	36							
	Rail breaks	Cannot heat seal bags; Decrease productivity	5	Rail wears out or needs to be lubricated	Lubricate once in a while	3	Observation	2	30							
Heat Sealing System/ Detatch Bag from Roll of Bags	Heat seal doesn't cut completely through bag	Cannot heat seal bags; Decrease productivity	3	The user does not push the handle all the way or the rails are worn out	Users judgement	6	Observation	2	36							
	Heat seal breaks or malfunctions	Cannot heat seal bags; Decrease productivity; Damage bags	6	Heat seal malfunction due to component error or circuit breaks	Heat seal in a protective area and checked once in a while	2	Observation	3	36							
UI System/ Count Items	Kit is over/under target weight	Kits assembled incorrectly	5	User error; Inconsistent item weights; Scale malfunctions	Item sorter ensures the correct number of items are placed in the kit	3	Test kit weight	2	30							
UI System/Track Productivity	Over/underestimate worker productivity	User over/under paid based on productivity	4	Timer/counter hardware issues	Verify UI code to ensure hardware works correctly	4	Observation	5	80	Modify counter code to only add to the count when the kit is within tolerance	Kyle C - 2/1		4	2	2	16
UI System/Minimize required dexterity	Unresponsive interface	Final quality assessment unavailable	6	Glitch/errors in electrical circuit;	Ensure quality circuit construction	2	Observation	2	24							

* high RPN considered for scores over 50

Product: Just Kitting Workstation

Design Failure Mode and Effects Analysis

Prepared by: F16 SourceAmerica

Team: F16 SourceAmerica

Date: 11/20/20 **(orig)**

												Action Results				
System / Function	**Potential Failure Mode**	**Potential Effects of the Failure Mode**	**Severity**	**Potential Causes of the Failure Mode**	**Current Preventative Activities**	**Occurence**	**Current Detection Activities**	**Detection**	**Priority**	**Recommended Action(s)**	**Responsibility & Target Completion Date**	**Actions Taken**	**Severity**	**Occurence**	**Detection**	**RPN**
Paper Folding System / Fold Paper	Clamp breaks	User cannot hold paper in place	7	Screws attaching clamp to device comes loose; clamp material is weak	Use Aluminum or other strong, rust-proof material	4	Observation	1	28							
	Hinge breaks	User cannot properly fold paper	8	Hinge material is weak; screws loosen	Use Aluminum or other strong, rust-proof material	4	Observation	1	32							
	Paper slides out	User cannot properly fold paper	7	clamp doesn't hold down on paper	Include a stopping point/edge that the paper rests on to prevent it from sliding off	6	Observation	1	42							
Paper Folding System / Ensure Quality	Inconsistent paper folding	User must re-fold the paper	7	Folding plane and stationary plane are not close enough during folding process	Have both planes as close as possible without obstructing folding plane's rotary motion	6	Observation	1	42							
	User forgets to fold paper	Kit are not able to be sent out as instructions are not available	6	User forgets	User's judgement or a checklist	6	Observation	3	108	Button that says "Paper In" in the user interface	Kyle C - 12/4		6	2	2	24
Paper Folding Device / Minimize Required Dexterity	Hinge breaks or clamp gets stuck or clamp breaks	Papers are not able to be folded or difficult to fold	6	Hinge material is weak; screws loosen; clamp bends	Use Aluminum or other strong, rust-proof material	3	Observation	2	36							
General/ Hold parts together	Joints separate	Parts break and workstation unusable	10	Joints gets worn out over time	Yearly inspection	2	Observation	2	40							
	Joints flex too much	Parts break and workstation unusable	10	Some parts are too heavy or the forces applied to it are to severe	Use lighter material and users judgement	2	Observation	2	40							
General/ Maintain appearance	Surfaces get damaged	Looks used or worn	1	Abration or impact	User judgement	8	Observation	1	8							
General/ Provide user safety	Strong parts reduce risk of injury	Parts break and workstation unusable	5	Parts worn out over long use	User strong reliable materials, machine the workstation well	1	Observation	4	20							

* high RPN considered for scores over 50

Appendix R: Design Hazard Checklist

Y	N	
✓		1. Will any part of the design create hazardous revolving, reciprocating, running, shearing, punching, pressing, squeezing, drawing, cutting, rolling, mixing or similar action, including pinch points and sheer points?
	✓	2. Can any part of the design undergo high accelerations/decelerations?
	✓	3. Will the system have any large moving masses or large forces?
	✓	4. Will the system produce a projectile?
✓		5. Would it be possible for the system to fall under gravity creating injury?
	✓	6. Will a user be exposed to overhanging weights as part of the design?
	✓	7. Will the system have any sharp edges?
	✓	8. Will any part of the electrical systems not be grounded?
✓		9. Will there be any large batteries or electrical voltage in the system above 40 V?
	✓	10. Will there be any stored energy in the system such as batteries, flywheels, hanging weights or pressurized fluids?
	✓	11. Will there be any explosive or flammable liquids, gases, or dust fuel as part of the system?
	✓	12. Will the user of the design be required to exert any abnormal effort or physical posture during the use of the design?
	✓	13. Will there be any materials known to be hazardous to humans involved in either the design or the manufacturing of the design?
	✓	14. Can the system generate high levels of noise?
	✓	15. Will the device/system be exposed to extreme environmental conditions such as fog, humidity, cold, high temperatures, etc?
✓		16. Is it possible for the system to be used in an unsafe manner?
	✓	17. Will there be any other potential hazards not listed above? If yes, please explain on reverse.

Description of Hazard	**Planned Corrective Action**	**Planned Date**	**Actual Date**
The system could be pulled off the table, which could cause injury to the user.	The system's weight is equally distributed throughout the system and the bottom of the housing has a little wedge to make it harder for the station to fall. For permanent installations, the workstation can be bolted down.	11/12/20	4/20/21
The impulse heat sealer has 110V.	The main heat sealer that has the wiring and electric circuit will be placed inside the workstation where it will avoid any water spills or electrical damage and prevent access to the user.	1/28/21	4/13/21
The heat sealer, when handled improperly, may cause burns.	Rather than using a typical heat sealer which is always hot, we instead decided to use an impulse heat sealer because it will only turn on when the handle is closed instead of constantly being on, like the constant heat sealer which can build up heat. This greatly reduces the chance of user injury.	1/28/21	4/1/21

Appendix S: Risk Assessment

designsafe Report

Application:	Packaging Workstation - F16	Analyst Name(s):	Kyle Chuang, Ashley Humpal, Keanau Robin, Christopher Tan
Description:		Company:	Team F16
Product Identifier:		Facility Location:	
Assessment Type:	Detailed		
Limits:			
Sources:			
Risk Scoring System:	ANSI B11.0 (TR3) Two Factor		

Guide sentence: When doing [task], the [user] could be injured by the [hazard] due to the [failure mode].

Item Id	User / Task	Hazard / Failure Mode	Initial Assessment Severity Probability	Risk Level	Risk Reduction Methods /Control System	Final Assessment Severity Probability	Risk Level	Status / Responsible /Comments /Reference
1-1-1	operator normal operation	mechanical : pinch points operating the paper folding system; operating the sorting template	Minor Likely	Low	warning label(s)	Minor Likely	Low	TBD Ashley
1-1-2	operator normal operation	mechanical : equipment instability potential tipping of workstation	Serious Unlikely	Medium	warning label(s); widen the base or bolt down workstation to table	Serious Remote	Low	TBD Kyle
1-1-3	operator normal operation	ergonomics / human factors : excessive reach, poor access / clearance access to sorting template	Minor Likely	Low	implement a mirror for better view of sorting template	Minor Unlikely	Negligible	Complete [1/28/2021] Keanau
1-1-4	operator normal operation	ergonomics / human factors : static posture constantly sitting during operation	Minor Very Likely	Medium	scheduled rest periods	Minor Unlikely	Negligible	TBD Ashley
1-1-5	operator normal operation	ergonomics / human factors : repetition / personnel fatigue repetitive motions	Minor Very Likely	Medium	scheduled rest periods	Minor Unlikely	Negligible	TBD Chris
1-1-6	operator normal operation	slips / trips / falls / egress : falling object / material bag rolls potentially falling off; lack of dexterity results in user dropping items	Moderate Unlikely	Low				
1-1-7	operator normal operation	heat / temperature : burns / scalds heat sealer	Serious Unlikely	Medium	warning label(s)	Serious Remote	Low	TBD Keanau
1-1-8	operator normal operation	heat / temperature : hot material / severe heat individual bags will be hot after heat sealing	Moderate Unlikely	Low	Same as Item 1-1-7	Moderate Remote	Negligible	TBD Ashley
1-1-9	operator normal operation	chemical / toxicity : toxic smell burnt plastic	Moderate Likely	Medium	scheduled rest periods	Moderate Remote	Negligible	TBD Chris
1-1-10	operator normal operation	seismic / natural hazards : moving / overturning equipment earthquake tips over workstation	Serious Unlikely	Medium	Same as Item 1-1-2	Serious Remote	Low	TBD Kyle
1-2-1	operator load / unload materials	mechanical : pinch points pinch in bag roll and sorting plate	Minor Likely	Low	Same as Item 1-1-1	Minor Likely	Low	TBD Keanau
1-2-2	operator load / unload materials	mechanical : crushing / impact bag rolls falling on user	Minor Unlikely	Negligible				
1-3-1	operator sort / inspect parts	mechanical : pinch points finger caught in sorting templates	Minor Likely	Low	Same as Item 1-1-1	Minor Likely	Low	TBD Chris
1-4-1	operator clear jams	heat / temperature : burns / scalds heat sealer	Serious Likely	High	Same as Item 1-1-7	Serious Unlikely	Medium	TBD Keanau
1-5	operator basic troubleshooting	<None>						

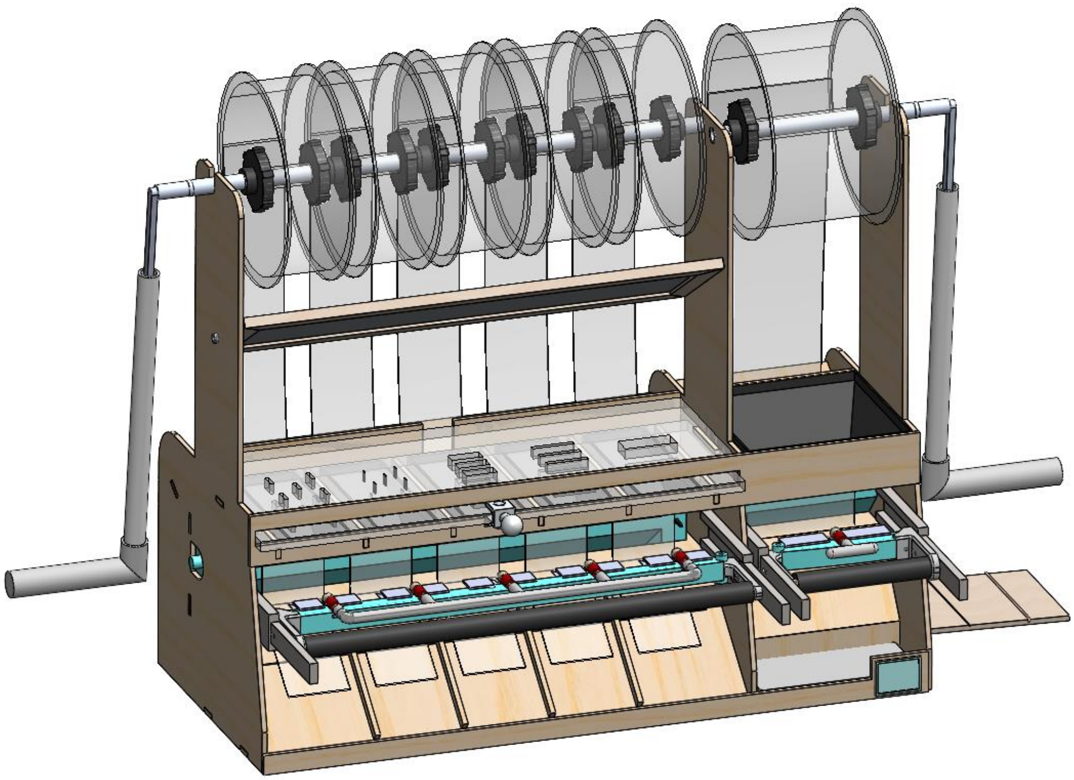
Item Id	User / Task	Hazard / Failure Mode	Initial Assessment Severity Probability	Risk Level	Risk Reduction Methods /Control System	Final Assessment Severity Probability	Risk Level	Status / Responsible /Comments /Reference
1-6	operator shut down	<None>						
1-7-1	operator clean machine	heat / temperature : burns / scalds heat sealer	Serious Remote	Low	Same as Item 1-1-7	Serious Remote	Low	TBD Keanau
1-8-1	operator misuse - (add description)	mechanical : entanglement / drawing in bag rolls overflow	Minor Unlikely	Negligible				
1-8-2	operator misuse - (add description)	mechanical : equipment instability workstation tips over	Serious Unlikely	Medium	Same as Item 1-1-2	Serious Remote	Low	TBD Chris
1-8-3	operator misuse - (add description)	electrical / electronic : software errors wrong code for UI system	Minor Unlikely	Negligible				
1-8-4	operator misuse - (add description)	chemical / toxicity : toxic smell burnt plastic	Moderate Likely	Medium	instruction manuals	Moderate Remote	Negligible	TBD Keanau
2-1-1	machinery mechanic / service technician inspect machinery / equipment	mechanical : head bump on overhead objects head bumps the mirror	Moderate Unlikely	Low				
2-1-2	machinery mechanic / service technician inspect machinery / equipment	mechanical : equipment instability workstation tips over	Serious Unlikely	Medium	Same as Item 1-1-2	Serious Remote	Low	TBD Kyle
2-2-1	machinery mechanic / service technician periodic maintenance	heat / temperature : burns / scalds heat sealer	Serious Remote	Low	Same as Item 1-1-7	Serious Remote	Low	TBD Ashley

Item Id	User / Task	Hazard / Failure Mode	Initial Assessment Severity Probability	Risk Level	Risk Reduction Methods /Control System	Final Assessment Severity Probability	Risk Level	Status / Responsible /Comments /Reference
2-3-1	machinery mechanic / service technician trouble-shooting / problem solving	electrical / electronic : shorts / arcing / sparking re-wiring the UI system	Minor Unlikely	Negligible				
2-3-2	machinery mechanic / service technician trouble-shooting / problem solving	electrical / electronic : software errors UI failure	Minor Unlikely	Negligible				
2-3-3	machinery mechanic / service technician trouble-shooting / problem solving	heat / temperature : burns / scalds heat sealer	Serious Unlikely	Medium	Same as Item 1-1-7	Serious Remote	Low	TBD Ashley
2-4-1	machinery mechanic / service technician decommissioning	mechanical : damage to machine mirror breaking; heat sealer falling	Moderate Unlikely	Low				
2-4-2	machinery mechanic / service technician decommissioning	mechanical : equipment instability workstation tips over	Serious Unlikely	Medium	Same as Item 1-1-2	Serious Remote	Low	TBD Keanau
2-4-3	machinery mechanic / service technician decommissioning	heat / temperature : burns / scalds heat sealer	Serious Remote	Low	Same as Item 1-1-7	Serious Remote	Low	TBD Ashley
3-1-1	engineer adjust software program / controls	electrical / electronic : improper wiring / grounding improper wiring of UI system	Minor Unlikely	Negligible				
3-1-2	engineer adjust software program / controls	electrical / electronic : shorts / arcing / sparking improper wiring of UI system	Minor Unlikely	Negligible				
3-1-3	engineer adjust software program / controls	electrical / electronic : software errors wrong code for UI system	Minor Unlikely	Negligible				

Item Id	User / Task	Hazard / Failure Mode	Initial Assessment Severity Probability	Risk Level	Risk Reduction Methods /Control System	Final Assessment Severity Probability	Risk Level	Status / Responsible /Comments /Reference
3-2-1	engineer conduct tests	mechanical : damage to machine improper assembly of workstation	Minor Unlikely	Negligible	Safety Glasses	Minor Unlikely	Negligible	 Ashley
3-3-1	engineer repair / modify parts / components	electrical / electronic : shorts / arcing / sparking improper wiring of UI system	Minor Unlikely	Negligible				
3-3-2	engineer repair / modify parts / components	electrical / electronic : software errors wrong code for UI system	Minor Unlikely	Negligible				
3-3-3	engineer repair / modify parts / components	heat / temperature : burns / scalds disassemble heat sealer	Serious Remote	Low				
3-4	engineer All operator hazards apply to engineer	<None>						
4-1-1	passer-by / non-user walk near machinery	mechanical : equipment instability workstation tips over	Serious Unlikely	Medium	Same as Item 1-1-2	Serious Remote	Low	TBD Ashley
4-1-2	passer-by / non-user walk near machinery	slips / trips / falls / egress : debris / trip hazards trip over power cords	Minor Unlikely	Negligible				
4-1-3	passer-by / non-user walk near machinery	slips / trips / falls / egress : falling object / material item falling from sorting template	Minor Unlikely	Negligible				
4-2-1	passer-by / non-user work next to / near machinery	mechanical : equipment instability workstation tips over	Serious Unlikely	Medium	Same as Item 1-1-2	Serious Remote	Low	TBD Keanau

Item Id	User / Task	Hazard / Failure Mode	Initial Assessment Severity Probability	Risk Level	Risk Reduction Methods /Control System	Final Assessment Severity Probability	Risk Level	Status / Responsible /Comments /Reference
4-2-2	passer-by / non-user work next to / near machinery	slips / trips / falls / egress : falling object / material item falls from sorting template	Minor Unlikely	Negligible				
4-2-3	passer-by / non-user work next to / near machinery	chemical / toxicity : toxic smell burnt plastic	Moderate Likely	Medium	recommend working in well-ventilated area	Moderate Remote	Negligible	TBD Chris

Appendix T: User Manual

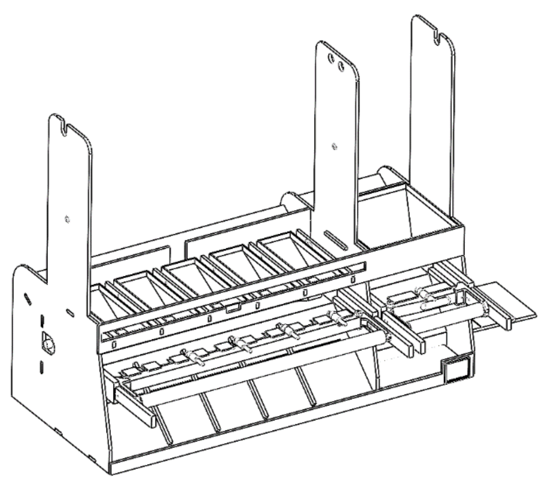


This manual includes instructions for the set-up and operation of the kitting station as well as any parts requiring maintenance. Also included are basic safety instructions.

Included Parts

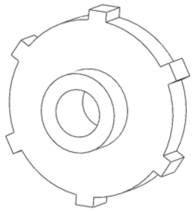
Included within this section are the various parts needed for the workstation. Please refer to the Project Budget in Appendix N for links to replacement parts.

1. **Workstation**
    - Housing
    - Two Heat Sealers
    - Funnels
    - Weigh Scale

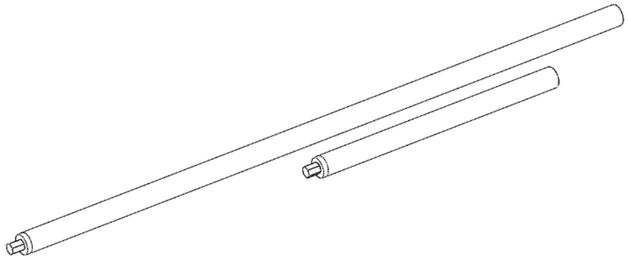


2. **6X PolyBag Rolls**
   - Five 3” x 4” Rolls
   - One 6” x 6” Roll
   - Replacements can be ordered from US PolyPack.

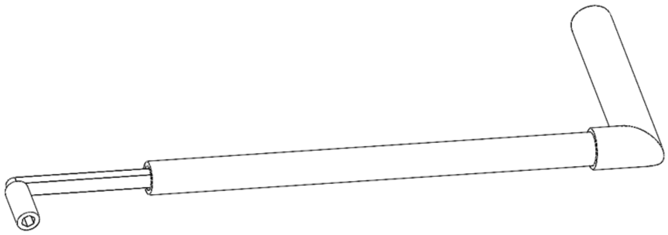
3. **12X Bag Gap**
   - Please contact your supplier for replacement pieces.



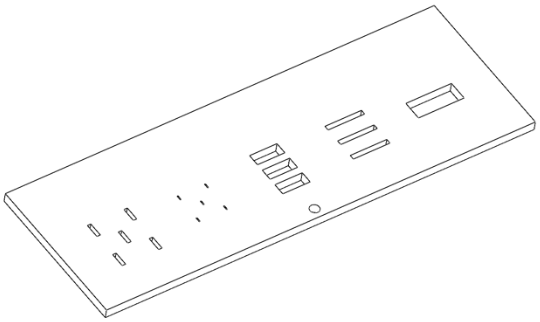
4. **2X Steel Shafts**
   - One 2ft. Shaft
   - One 9” Shaft.
   - Replacements can be ordered from McMasterCarr.



5. **2X Ratchet Handles**
   - Ratchet Wrench
   - 3/8” Hex Socket
   - Two 5/16” Bolts
   - Extended Handle

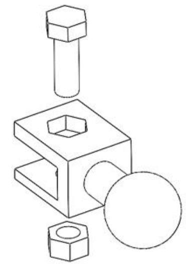


6. **2X Sorter Templates**
   - Please contact your supplier for custom/replacement templates.



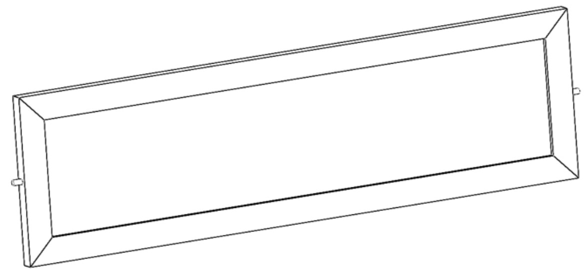
7. Template Handle

- Handle
- 5/16" x 1" Hex Bolt
- 5/16" Hex Nut.
- Replacements can be ordered from any hardware store.



8. Mirror Assembly

- Framed Mirror
- Two 3/16" x 75in. Dowels
- Please contact your supplier for replacement pieces.



Set-up Instructions

Please follow the steps outlined in this section to properly assemble your kitting workstation.

Attaching Mirror Frame Assembly

1. Grab the 2 precut dowels and place 1 into each of the grommets that are located in the housing posts. Place them so that the length of the dowel lies inside the housing.

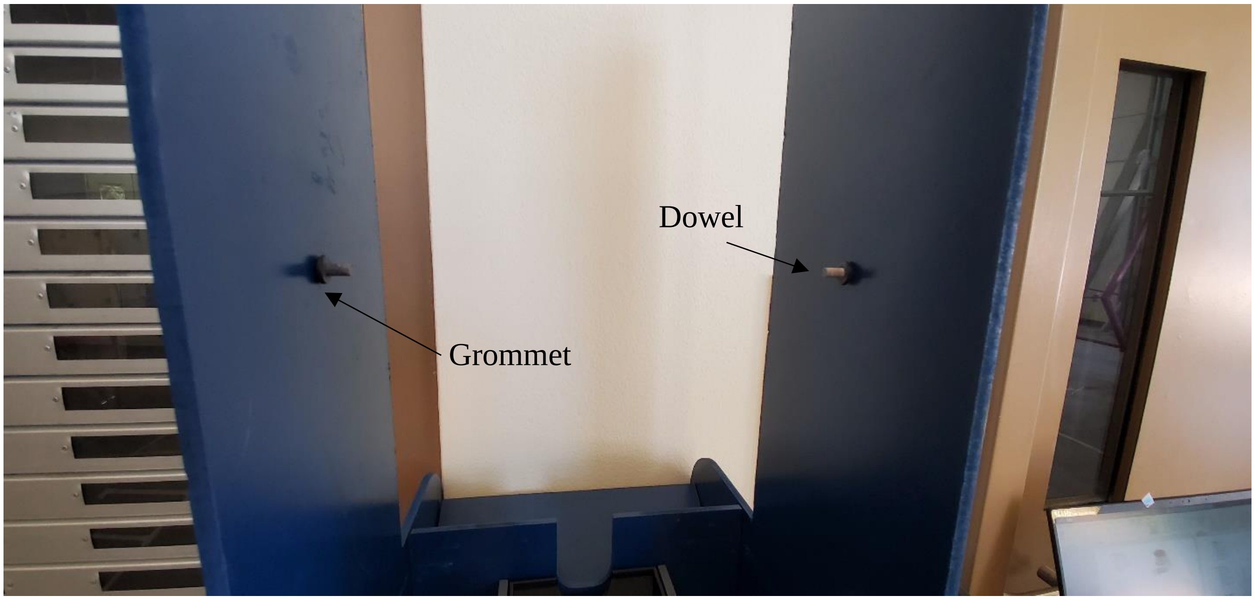


Figure 1. Dowel Placement in Grommets

2. Hold the mirror frame assembly in between the two housing posts so its 2 holes are aligned with the dowels on either side of the mirror frame. CAUTION: The mirror frame assembly will require 2+ people for assembly.

3. Push the dowels into the mirror frame assembly holes. This should be a tight fit that secures the mirror frame assembly to the housing while allowing rotation.

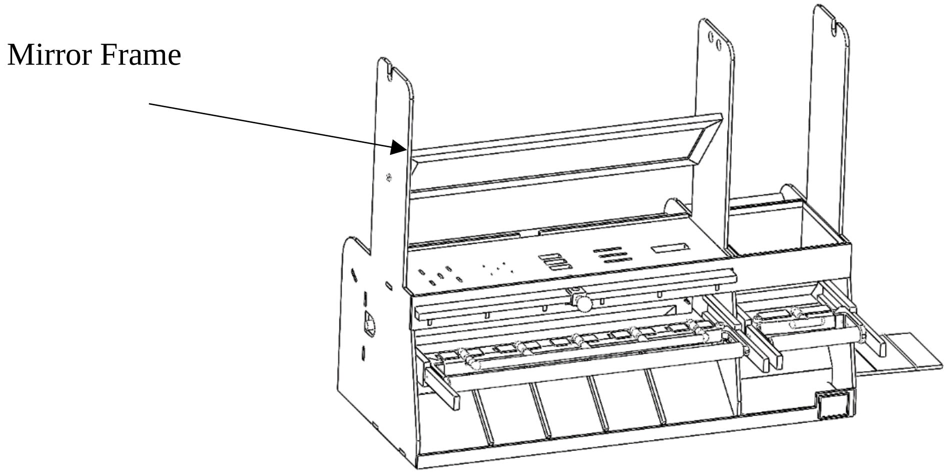


Figure 2. Mirror Frame Assembly in Housing

Attaching Bag Rolls

1. Attach two bag gaps to each of the six Polybag rolls.

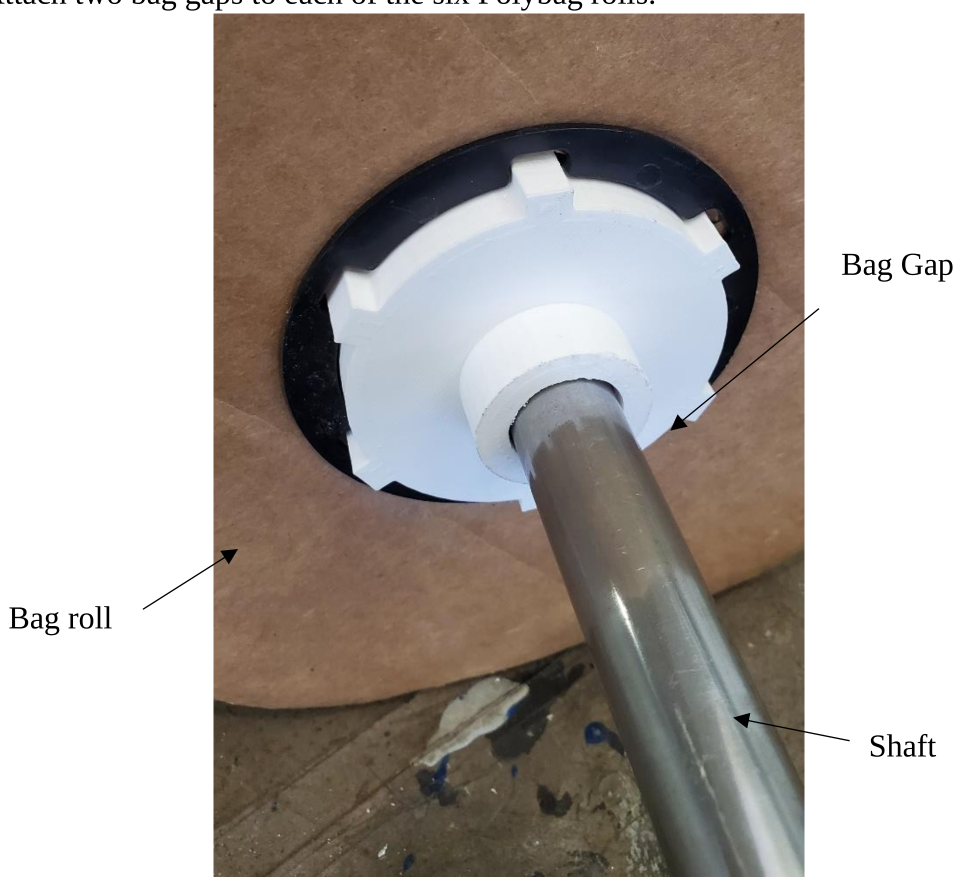


Figure 3. Attaching Bag Gaps

2. On the 2ft shaft, slide the five 3”x4” bag rolls onto the shaft through the holes in the bag gap pieces. This should ensure proper distancing between each roll.

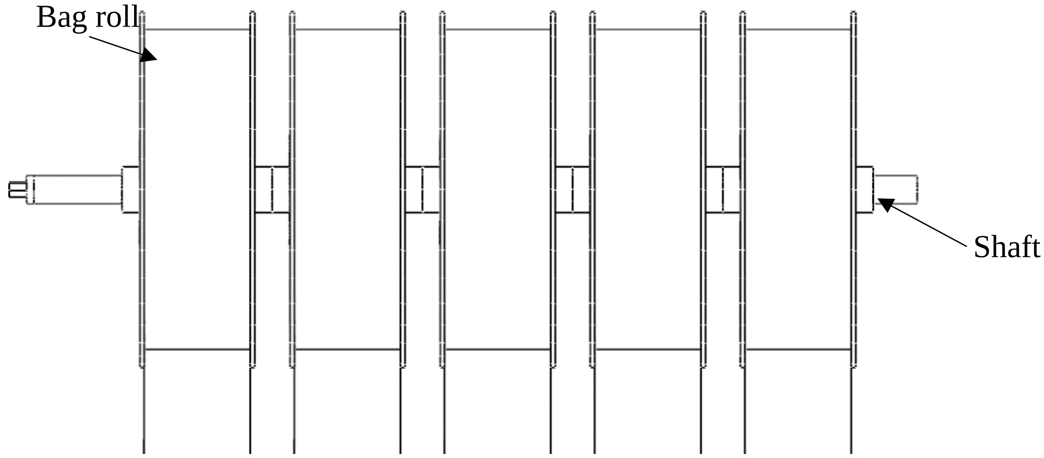


Figure 4. Bag roll on shaft

3. Repeat the same process for the 9in. shaft with the one 6x6 bag roll.
4. Lift the 2ft shaft and place it through the slots at the top of the housing. CAUTION: The shaft will weigh about 40lb. 2+ people may be required to place the shaft to avoid injury.
5. Repeat the last step with the small shaft.
6. Feed each bag roll into the holes in the back of the housing.

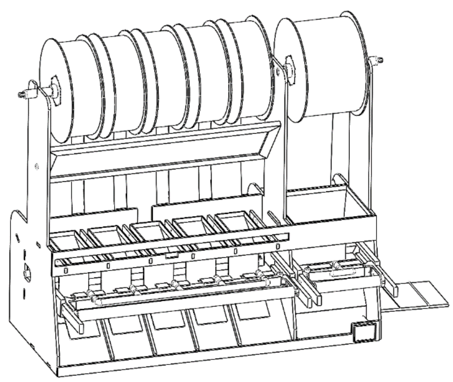


Figure 5. Bag roll on Housing

7. Attach the two ratchet handles to the hex protrusion of each shaft.

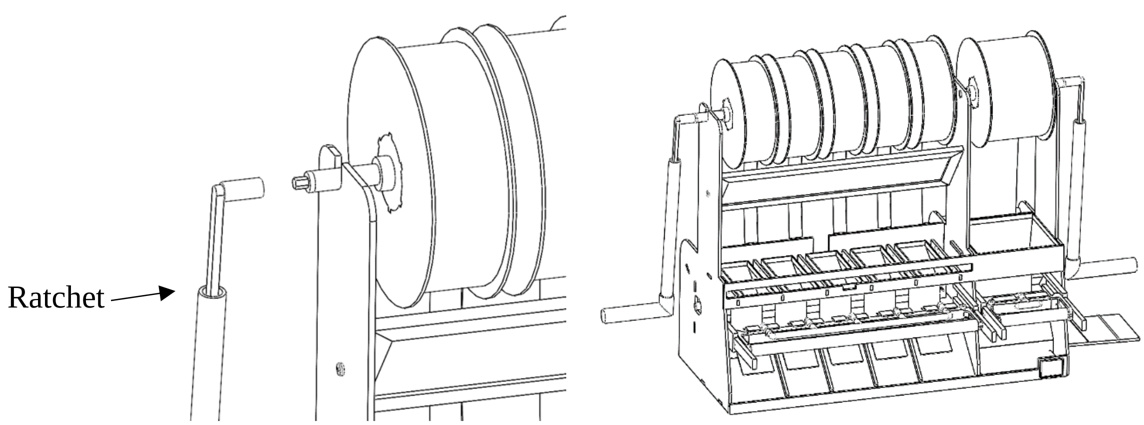


Figure 6. Final Configuration of Ratchet

Attaching Sorting Templates

1. Select either template to be your bottom sorting plate. Both plates should be identical, so the selection doesn't matter.
2. Place the sorting handle onto the bottom template sorter handle and line up the sorting handle hole to the template hole.

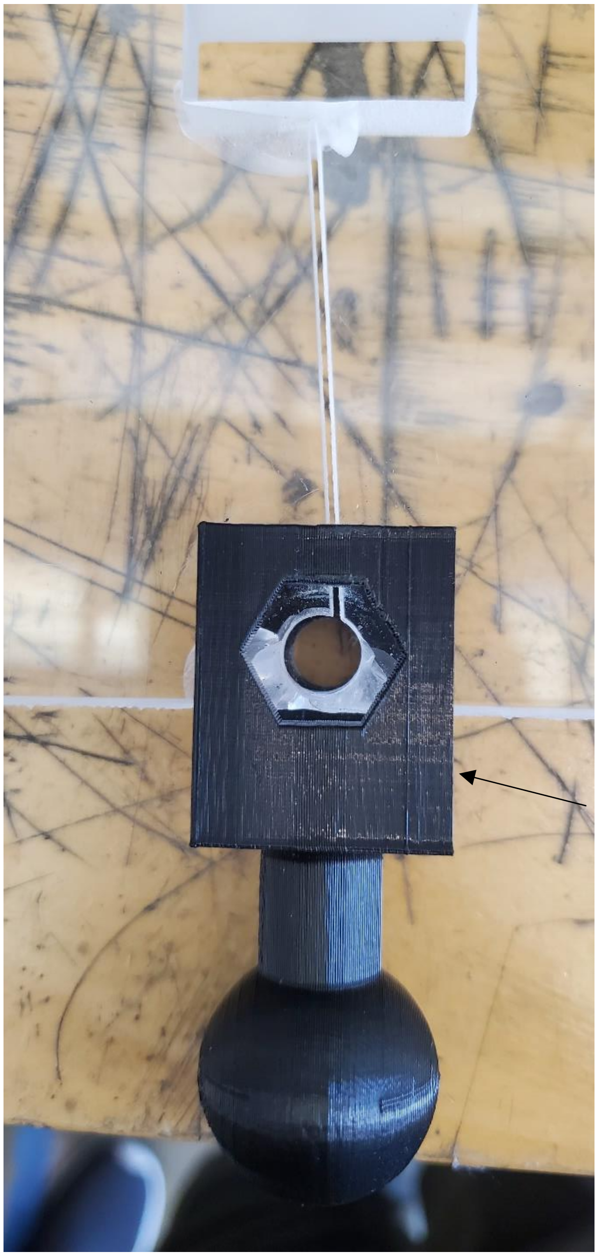


Figure 7. Sorting Handle Alignment

3. Place the hex bolt through both holes and secure the bottom of the bolt with the hex nut.

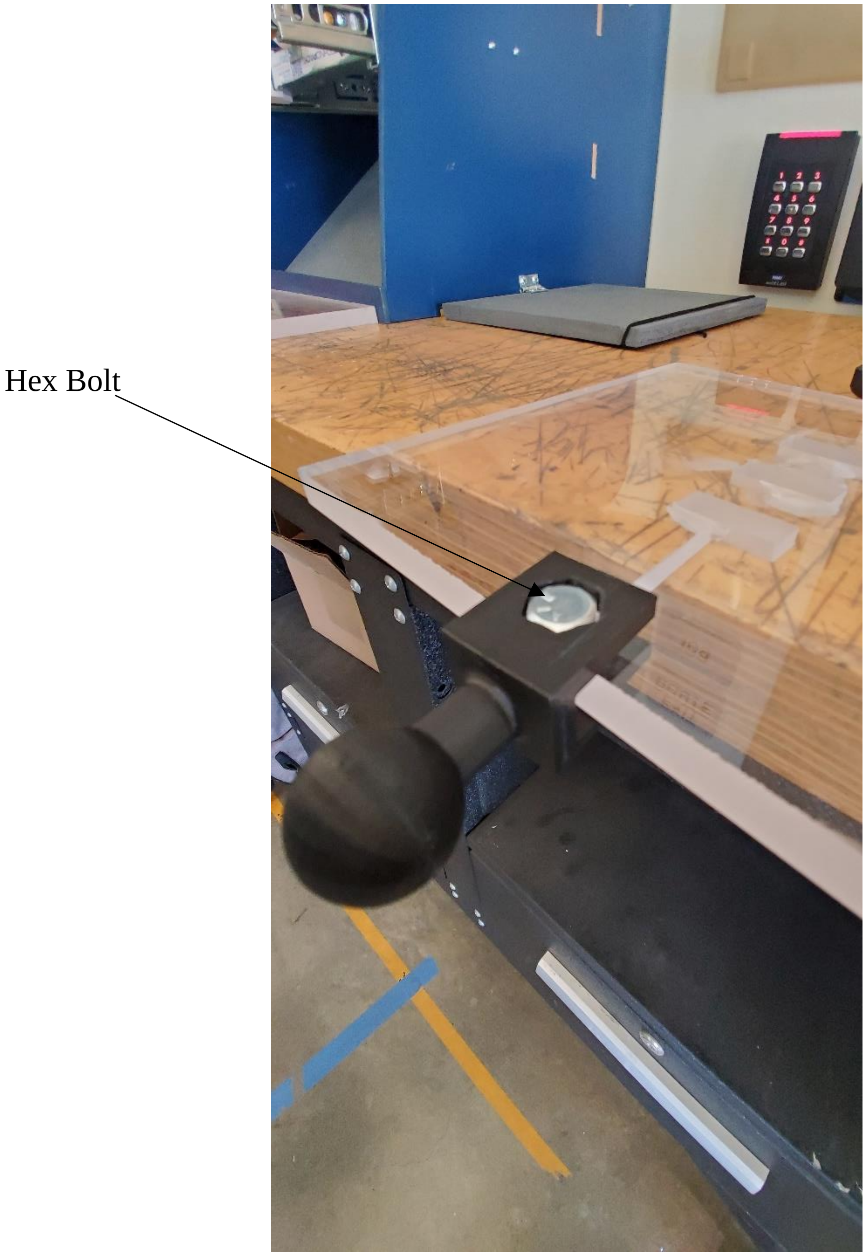


Figure 8. Handle Assembly

4. Slide the bottom template, now with the sorting handle attached, through the front panel cutout in the housing.

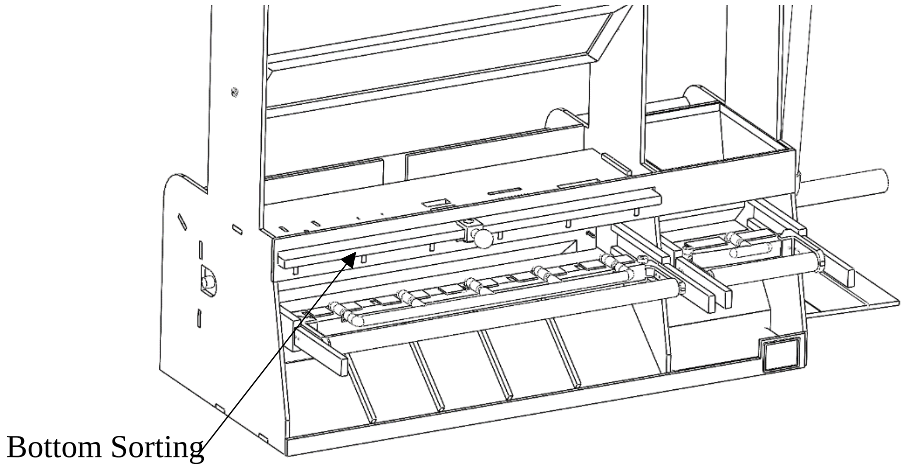


Figure 9. Bottom Sorting Plate Placement

5. Place the top sorting template on top of the bottom template. Top template should be resting on the support tabs.

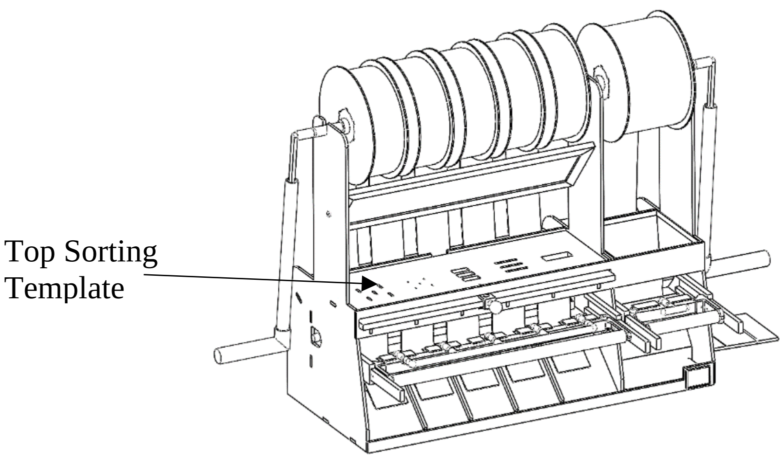


Figure 10. Sorting Plate Configuration

Operation Instructions

Please follow the instructions in this section to operate the workstation properly.

1. Begin by moving the left crank counterclockwise to get a bag to unload into the kitting station. Keep turning the crank until the bottom of the polybag lines up with the marking on the ramp, as seen in Figure 11. This is the ideal position to load items into the bag.

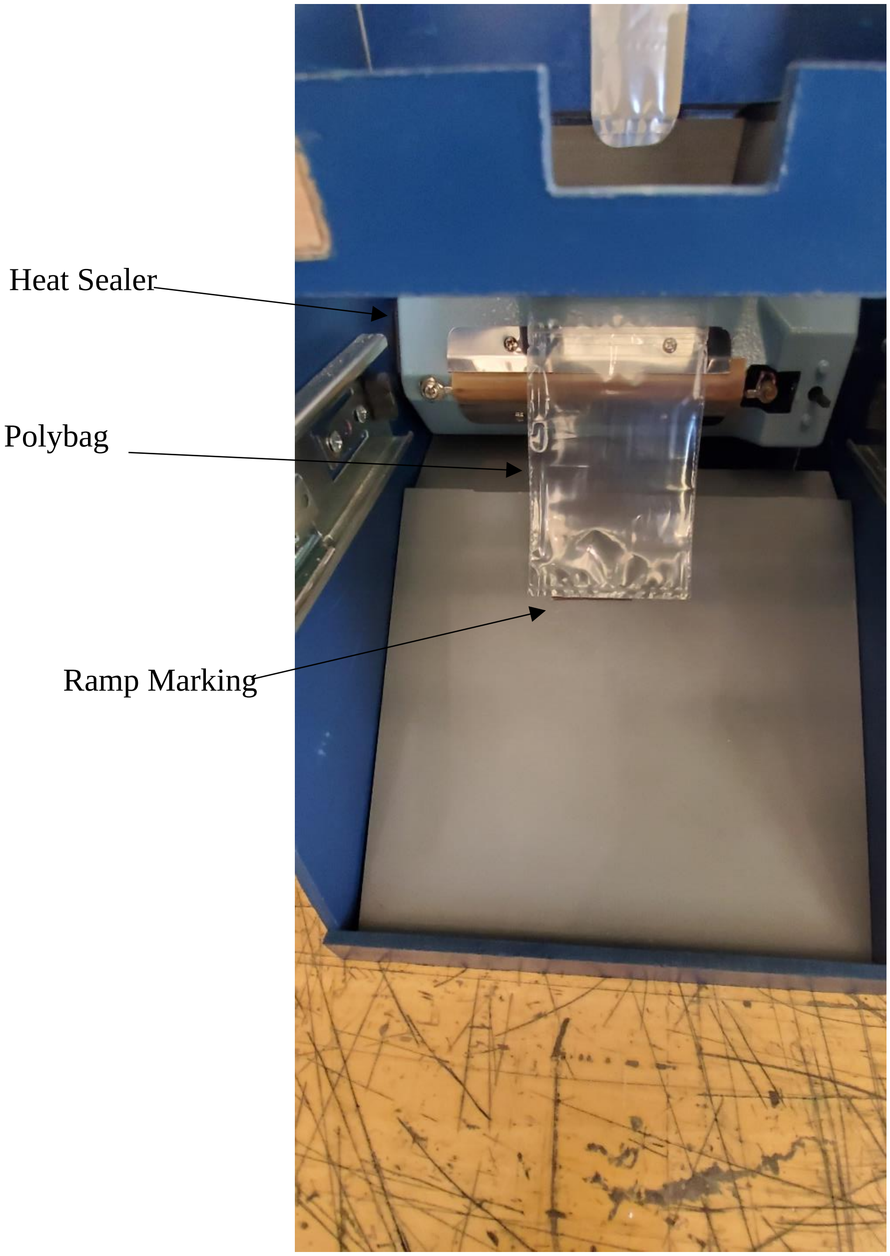


Figure 11. Bottom of Polybag on Ramp Marking

2. Use the sorting handle to pull out the bottom sorting plate a quarter of an inch out of the housing. For a visual on the ideal sorting plate offset, see Figure 12. This ensures that its holes aren't aligned with that of the top template’s to prevent items from falling before sorting has been completed.

Figure 12. Offset Sorting Plates

3. Push in the heat-sealing handle toward the heat sealer. Make sure the handle is close enough to the heat sealer so that the hook on the handle can reach the polybag. Make sure to not push the heat-sealing handle too much or else the heat sealer will activate.
4. Operate the hooking handle to allow the hook to enter the polybag opening.
5. Maneuver the hook so that it opens the polybag. Once the polybag is opened, leave it in that position. For a visual of this hooking position, see Figure 13 below.

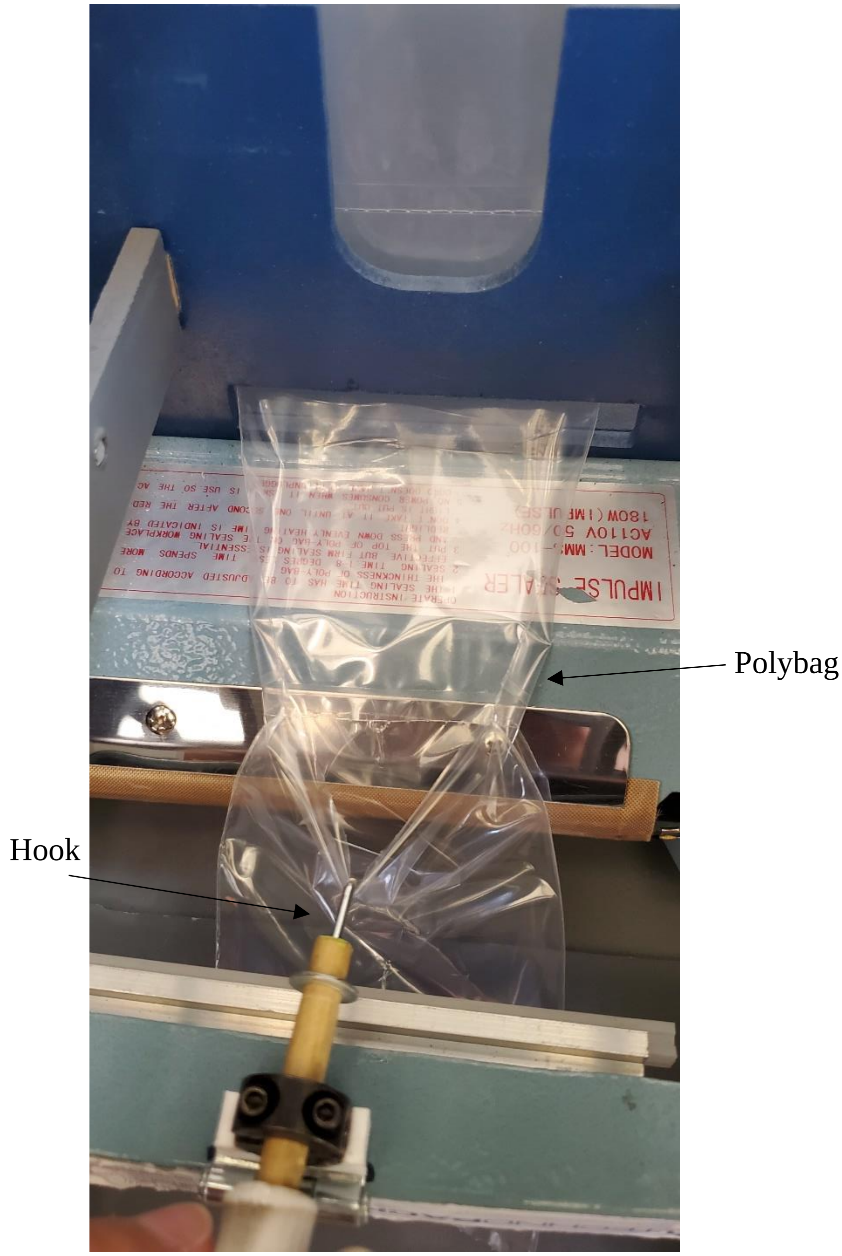


Figure 13. Hook Opening Polybag

6. Place items that are to be kitted into their designated holes in the top sorting plate, as seen in Figure 14 below. After all items have been placed, push the bottom sorting plate back in so that its holes are now aligned with that of the top sorting plate.

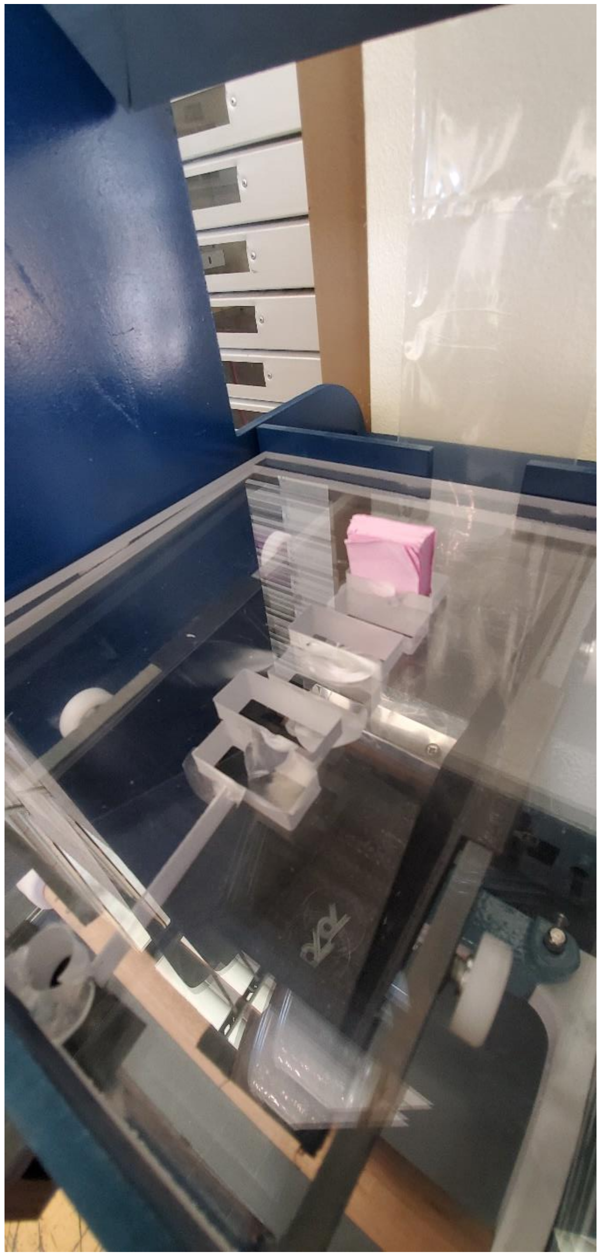


Figure 14. Items in Sorting Plate

7. The items should fall through the funnel into the polybag. Once that occurs lift the hook out of the bag.
8. Once the hook has been taken out of the bag, push the heat sealer in completely. Push it until you hear a clicking sound which is the heat sealer being actuated.
9. Wait until you hear a second clicking sound which signals that the heat sealing is completed.
10. Pull the heat sealer handle back out.
11. Rotate the crank clockwise to lower the heat-sealed bags so they are within arms reach.

12. Push the heat sealer handle in again against the bottom of the next bag. For a visual of the bag positioning, see Figure 15 below. Make sure to not push the heat-sealing handle too much or else the heat sealer will activate.

Figure 15. Configuration of Bag Before Tearing

13. Tear the five heat-sealed bags out but keep them on the front ramp for now.
14. Move the right crank clockwise to get a big bag to unload into the kitting station. Keep turning the crank until the bottom of the polybag lines up with the marking on the ramp. This is the ideal position to load items into the bag.
15. Repeat steps 4-5 to open the final 6x6 bag.
16. Put all five heat-sealed bags on the funnel that leads to the final 6x6 bag.

17. Grab the paper instructions and slide it under the elastic band located on the paper folding system to the right of the workstation. Slide it until the elastic band is half-way along the paper. For a visual of the paper underneath the elastic band, see Figure 16 below.

Figure 16. Paper in Elastic Band

18. Fold the paper over the side that is laying on the wooden panel. For a visual of this fold, see Figure 17 below.

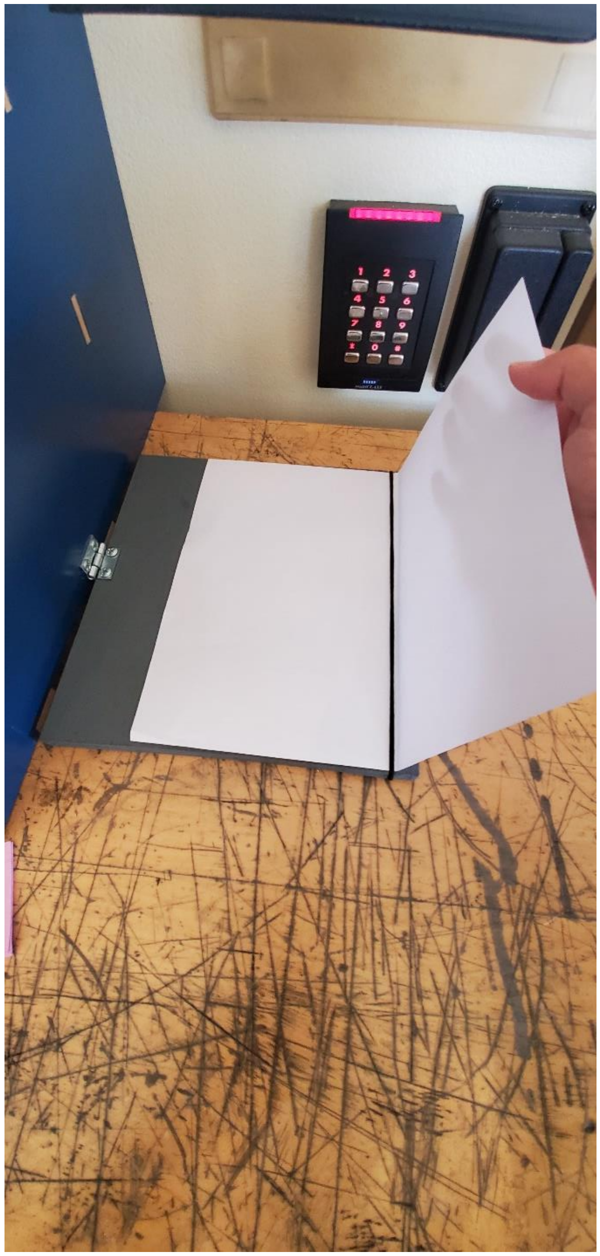


Figure 17. Paper being Folded

19. Remove the paper from the elastic band and place it into the funnel that feeds into the final bag.
20. Once the paper instructions are in the bag, heat seal the final bag.
21. Repeat steps 11-13 to tear off the final bag.
22. Let the final bag drop onto the weighing scale.
23. On the screen at the bottom right, the UI system will tell the user whether the bag is complete or is lacking the correct number of items.
24. Once the screen says the bag is good, you have officially completed the kitting process.

Maintenance

The workstation has been built so that only a minimum number of parts require replacement due to basic wear and tear that occurs through the normal operation cycle. The Polybag rolls require replacement after they have been all used up. These bags all require replacement at the same time as they all have same number of bags. Additionally, the acrylic plates require changing when the items being kitted are changed.

Repair Procedures for Components Subject to Wear

The components subject to wear within the workstation includes the front ramps and elastic band located on the paper folding system.
For the front ramps, polybags filled with different parts/items will frequently slide along the front ramps. After extensive use, the paint on the front ramps and the wood itself will begin to scrape off. To prevent possible splinters or any component failure, the front ramps can simply be detached by having the user put one finger in each slot on top of the front ramps and pulling the ramp out. Then, the user can replace the front ramp with a new one.
For the elastic band, after extensive use, it will lose its elasticity. Loss of elasticity will lead to component failure. To prevent this, the user can simply take off the elastic band from the paper folding system and replace it with a new one.

Safety

No safety PPE (Personal Protective Equipment) are required. Keep hands or fingers out of pinch points which are located at the template sorter and hooking system. The heat sealer will be hot when pressed and in contact with the heating element. Let the heat sealer cool for 5-10 seconds if you plan on touching the heating element.

Troubleshooting Guide

1. Bag Jam
   If there is a bag jam, stop cranking the handle and take hold of the polybag that is located at the top of the workstation. Roll the polybag so that they are fed back up to the polybag spool. If this does not help, hold the spool and tear off the poly bags. Tear off all the polybags that are causing the jam. Re-insert the polybags into the slot and continue operation.

2. Items Stuck in the Template Sorter
   If items are stuck in the template sorter, you can push and pull the template sorter by the handle until the item falls. Otherwise, you may attempt to pull the template sorter all the way out and let the item fall into the funnel.

3. Heat Sealer Not Sealing
   In the case of the heat sealer not sealing, check if the heat sealer is plugged in. Check if you are pressing the heat sealer handle enough so that it contacts the push rod and that you hear a “click” noise and the LED light turns on. If you are pressing the push rod and

you don’t hear any “click” noise, that means that the button has been displaced and the heat sealer must be opened from its backside. Once the heat sealer is opened, the bracket attached to the button must be re-positioned to allow the push rod to make contact with the button.

4. Plastic Melting or Smoke Visible from the Seal
   If the plastic is melting or smoke is visible during or after the seal, that means that the heat sealer gauge is dialed too high. Lower the gauge that is located on the left side of the workstation and lower the gauge. Make sure that the gauge arrow is pointing to 2 or 3.

Appendix U: Test Procedures

Test Procedure #1

Test Name: Hooking Test

Purpose: Test the functionality of the hooking system. To check if the hooks will hook on to the bags and open them.

Scope: This test will show if the hooks can hook on to the bags so that items can be placed inside the bag and be heat sealed and packaged. Without the hooking test to show the hooking system, we will not know whether the bags will open or not.

Equipment: Complete Workstation, heat sealer handle, L hooks assembled on the heat sealer handle with hinges and the shaft collar, and Poly bags.

Hazards: None as we will only test the hooking system to open the bag. The heat sealer will not be on and there will not blades present.

PPE Requirements: Safety Googles

Facility: Mustang 60 or Aero hangar

Procedure:

Hooking

1. Wear Safety goggles
2. Push the heat sealer handle so that it is in the middle of the drawer slides.
3. Use the handle that is attached to the hooks to push the hooks.
4. Push down the hooks into the poly bags to hook it.
5. Pull the handle when hooked so that it opens the bag.

Results: Pass Criteria, Fail Criteria, Number of samples to test
Pass criteria: If bags can be easily hooked when the heat sealer handle is pushed.
Fail Criteria: If it is difficult to hook the bags or not be able to open the bags from the pre-opened side at all.
Number of samples to test: 10

Test	Location	Pass/Fail
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Test Date(s) : TBD
Test Results: TBD
Performed By: Christopher Tan, Keanau Robin

Test Procedure #2

Test Name: Durability Test

Purpose: To determine whether the wooden posts that hold the bag shaft can withstand the bag load without breaking or cracking.

Scope: This will test the durability of the wooden posts and essentially that of the workstation in regards to the load it can carry.

Equipment: Kitting station housing, dowel for shaft, 10, 15, and 25 lb weighted dumbbells, and plastic bag.

Hazards: If wooden posts break possible debris could hit tester (i.e. wooden chips)

PPE Requirements: Safety goggles

Facility: Bonderson

Procedure:

1. Take shaft off housing by sliding it out of the housing slots up top.
2. Pick up plastic bag and slide the handles of the plastic bag onto the shaft until bag is centered.
3. Pick up the shaft (now accompanied by the plastic bag) and place it back onto the housing.
4. Place weighted dumbbells into plastic bag.
5. Observe the wall posts to see if there's any cracking or breaking.
6. Continue to add weights.
7. When finished, take all weights out of bag, remove shaft off housing, take plastic bag off, and place shaft back.

Results: Pass Criteria, Fail Criteria, Number of samples to test
This is a pass / fail test. If at any point the wooden posts break or cracks then test considered a fail.

Test Date(s): TBD
Performed By:
Ashley Humpal, Keanau Robin, Christopher Tan, Kyle Chuang

Test Results:

Weight (lb)	Pass or Fail
25	
30	
35	
40	

Notes:
Extremely flimsy
Is bending but not breaking
If no external force is applied it is fine and not sway
We tried swaying it a couple times and is fine

Test Procedure #3

Test Name: Tipping Test

Purpose: Our purpose is to test whether the workstation will move and/or fully tip over when given a variety of pushing forces on its lever handles. The lever handles are part of the bag holding system. They allow the user to feed the bags into the workstation.

Scope: This test is to observe the workstation's ability to remain stationary during normal operation.

Equipment: Full workstation (includes all systems), poly bags on the bag holding shaft, 40lbs of weights, and one digital luggage scale.

Hazards: Workstation may fall over and potentially crush one of the user's body parts, or a person passing by. If workstation falls, parts might fly off.

PPE Requirements: Safety goggles.

Facility: Bonderson, Mustang 60, or Aero Hanger

Procedure:

1. Put on safety goggles.
2. Install poly bag onto the bag holding shaft.
3. Apply the 40 lbs of extra weight onto the workstation to resemble the weight of the full workstation.
4. Attach the digital luggage scale onto the lever handle.
5. Make sure the lever handle are positioned towards the front (user's side).
6. Pull lever handle from behind the workstation using the digital luggage scale. This pulling motion will be an equivalent force to the pushing force done by the user during normal operation. Aim for a value of 20lbf on the scale throughout the entire motion. Once the motion is complete, maintain the 20lbf for 3 more seconds before letting go. While doing this, **observe the workstation to ensure that it does not move**. Then, re-position the crank handle to its original forward position.
7. Repeat step 6 three more times.
8. Now, aim for a new value of 30lbf on the digital scale while repeating step 6.
9. Aim for a new value of 40lbf on the digital scale while repeating step 6.
10. Aim for a new value of 50lbf on the digital scale while repeating step 6.

Results: Pass Criteria, Fail Criteria, Number of samples to test
This is a pass/fail test. If the workstation moves or comes off of the table, then the test is considered a fail. If the workstation remains stationary while the pulling force is applied onto the lever handle, then the test is considered a pass.
There will be 4 different force values to aim for. Each force will require 3 trials. That will give us a total of 12 samples to test.

Trial Number	Pulling Force (lbf)	Result (Pass/Fail)
1	20	
2		
3		
1	30	
2		
3		
1	40	
2		
3		
1	50	
2		
3		

Test Date(s): TBD
Test Results: TBD
Performed By: Keanau Robin, Christopher Tan, Kyle Chuang, Ashley Humpal

Test Procedure #4

Test Name: Sorting Test

Purpose: Our purpose is to test the functionality of the sorting system to ensure it properly sorts items placed by the user.

Scope: Will test whether items can fall through the top sorting plate and into the bottom plate without having items get stuck, otherwise design will need more modification.

Equipment: Sorting plates (2), and 3 pads of mini post-its.

Hazards: Fingers may get hurt if individual sticks their fingers in when pushing bottom sorting plate.

PPE Requirements: Safety goggles.

Facility: Bonderson

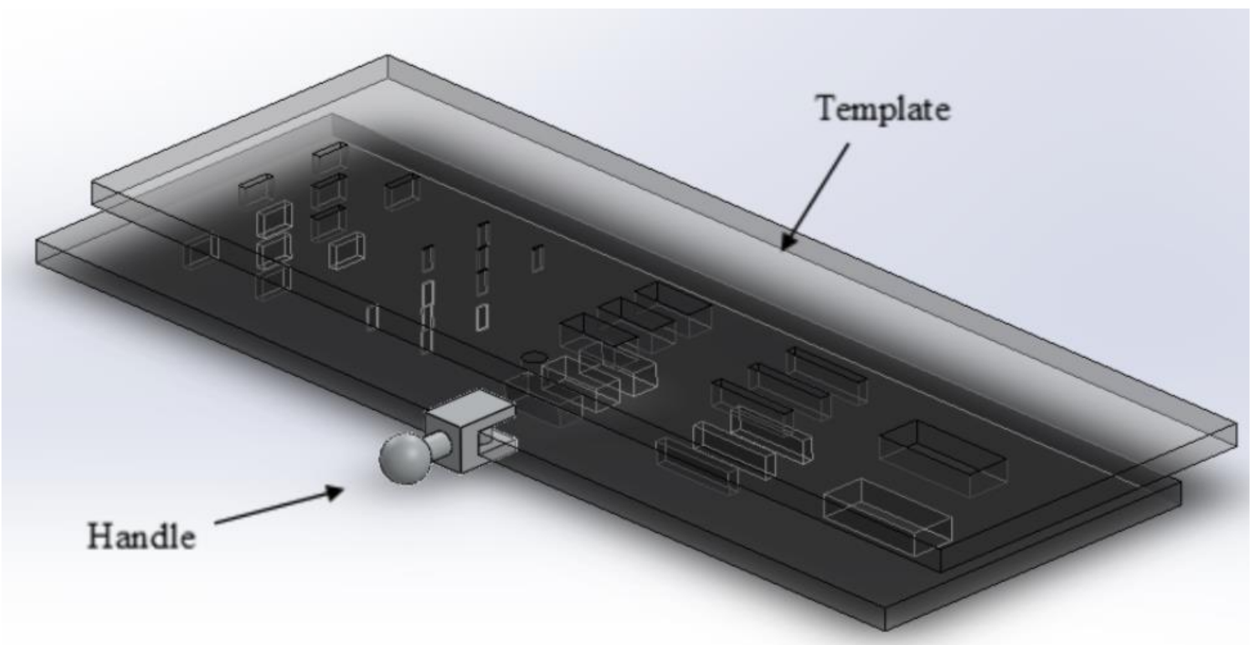


Figure 1. Sorting System

Procedure:

1. Pull out bottom sorting plate a little via its handle so that its holes aren't aligned with those of the top plate.
2. Place each post-it pad into top sorting plate.
3. Push bottom sorting plate in so its holes align with that of the top sorting plate.
4. Once aligned observe whether item in top plate falls into bottom plate and drops into the funnel below it without getting stuck.

Results: Pass Criteria, Fail Criteria, Number of samples to test
This is a pass / fail test. If item gets stuck at any point in the sorting system then test considered a fail. Each item will be tested 5 times to see whether it passes or fails the sorting test. If less than 4/5 tests pass then need for design revision is apparent.

Test Date(s): TBD
Performed By: Ashley Humpal, Keanau Robin, Christopher Tan, Kyle Chuang
Test Results: TBD

Item	Test Number	Pass or Fail
Post-it pad 1	1	
	2	
	3	
	4	
	5	
Post-it pad 2	1	
	2	
	3	
	4	
	5	
Post-it Pad 3	1	
	2	
	3	
	4	
	5	

Test Procedure #5

Test Name: Efficiency Test

Purpose: This test involves recording how long it takes a worker to produce a complete and correct kit. These time values would then be compared the time it takes for a worker manually creating a kit which would simulate the current workflow of the kitting and packaging system. We will record 5 trials for each of our team members and compare the average times from the workstation to the manual bagging results.

Scope: This test will be our primary metric when determining the effectiveness of our design. The lower the time, the greater the efficiency of our system. If our test fails significantly, then we must reconsider the design of our workstation.

Equipment: Complete workstation prototype, stopwatch, and items to be bagged (post it notes).

Hazards: Same hazards as normal use of the workstation (heat sealer and blade hazards)

PPE Requirements: N/A

Facility: Flexible (Bonderson, Mustang 60, Aero Hangar, at home)

Procedure:

1. Configure workstation on top of a desk with the first tester sitting in front of it. Arrange a box for each item to be bagged within arm's reach of the user.
2. Turn on system with pre configured heat sealer settings based on heat sealer time test.
3. At the convenience of the tester, they will start the stopwatch and begin the complete kitting process.
4. When the tester completes a kit, they will stop the stopwatch and record two metrics: the total time taken to create the kit, t_{ws} and whether the kit was made correctly (Y/N).
5. Repeat the test but for the user manually creating the kits. Record the time it took to assemble the kit, t_m and whether the kit was made correctly (Y/N) in the data table.
6. Repeat steps 1-5 five times using the same tester.
7. Repeat steps 1-6 for each of our team members.

Results:

Average t_{ws} and t_m for each tester and each test. Do not include any data where kits were made incorrectly

Pass criteria:

$t_{ws} < t_m$ & Kit made correctly

Fail Criteria:

Kit made incorrectly

$t_{ws} > t_m$

$t_{ws} > 5$ minutes

Test Date(s): TBD
Test Results: TBD
Performed By: Kyle Chuang, Ashley Humpal, Keanau Robin, Christopher Tan

		Workstation		Manual	
Tester	**Trial**	**Kit Time [t_{ws}]**	**Correct [Y/N]**	**Kit Time [t_m]**	**Correct [Y/N]**
Kyle Chuang	1				
	2				
	3				
	4				
	5				
Ashley Humpal	1				
	2				
	3				
	4				
	5				
Keanau Robin	1				
	2				
	3				
	4				
	5				
Christopher Tan	1				
	2				
	3				
	4				
	5				

Test Procedure #6

Test Name: Comparative Dexterity Analysis

Purpose: This test involves recording how long it takes a worker to produce a complete and correct kit using our workstation. These time values would then be compared the time it takes for a worker to create a kit with our workstation with dexterity impairments like wearing gloves, using one hand, or closing one eye, which are meant to simulate dexterity related disabilities. We will record 5 trials for each of our team members for each of the dexterity impairment scenarios and compare the average times to the control data to determine how well our design works for people with dexterity disabilities.

Scope: This test will be our secondary metric when determining the effectiveness of our design besides the efficiency test. This will test by how much dexterity impairments decrease the efficiency of the kitting process. If our test fails significantly, then we must reconsider the design of our workstation.

Equipment: Complete workstation prototype, stopwatch, items to be bagged (post it notes), and gloves.

Hazards: Same hazards as normal use of the workstation (heat sealer and blade hazards)

PPE Requirements: N/A

Facility: Flexible (Bonderson, Mustang 60, Aero Hangar, at home)

Procedure:
1. Configure workstation on top of a desk with the first tester sitting in front of it. Arrange a box for each item to be bagged within arm's reach of the user.
2. Turn on system with pre configured heat sealer settings based on heat sealer time test.
3. At the convenience of the tester, they will start the stopwatch and begin the complete kitting process.
4. When the tester completes a kit, they will stop the stopwatch and record two metrics: the total time taken to create the kit, $t_{control}$ and whether the kit was made correctly (Y/N).
5. Repeat steps 1- five times using the same tester.
6. Repeat steps 1-5 when the tester is wearing gloves.
7. Repeat steps 1-5 when the tester uses only one arm to operate the workstation.
8. Repeat steps 1-5 when the tester closes one eye when operating the workstation.
9. Repeat steps 1-8 for each of our team members.

Results:
Average t_{ws} and t_m for each tester and each test. Do not include any data where kits were made incorrectly
Pass criteria:
Kit time for dexterity impairment tests, t_i does not exceed the control kit time $t_{control}$ by 25%.
Kit made correctly
Fail Criteria:
Kit made incorrectly
$t_i > t_{control}$ by over 25%
$t_{ws} > 5$ minutes

Test Date(s): TBD
Test Results: TBD
Performed By: Kyle Chuang, Ashley Humpal, Keanau Robin, Christopher Tan

			Workstation	
Tester	**Test**	**Trial**	**Kit Time [t]**	**Correct [Y/N]**
Kyle Chuang	No Impairments	1		
		2		
		3		
		4		
		5		
	Gloves	1		
		2		
		3		
		4		
		5		
	One Arm	1		
		2		
		3		
		4		
		5		
	One Eye	1		
		2		
		3		
		4		
		5		
Ashley Humpal	No Impairments	1		
		2		
		3		
		4		
		5		
	Gloves	1		
		2		
		3		
		4		
		5		
	One Arm	1		
		2		
		3		
		4		
		5		
	One Eye	1		
		2		
		3		
		4		
		5		

Keanau Robin	No Impairments	1		
		2		
		3		
		4		
		5		
	Gloves	1		
		2		
		3		
		4		
		5		
	One Arm	1		
		2		
		3		
		4		
		5		
	One Eye	1		
		2		
		3		
		4		
		5		
Christopher Tan	No Impairments	1		
		2		
		3		
		4		
		5		
	Gloves	1		
		2		
		3		
		4		
		5		
	One Arm	1		
		2		
		3		
		4		
		5		
	One Eye	1		
		2		
		3		
		4		
		5		

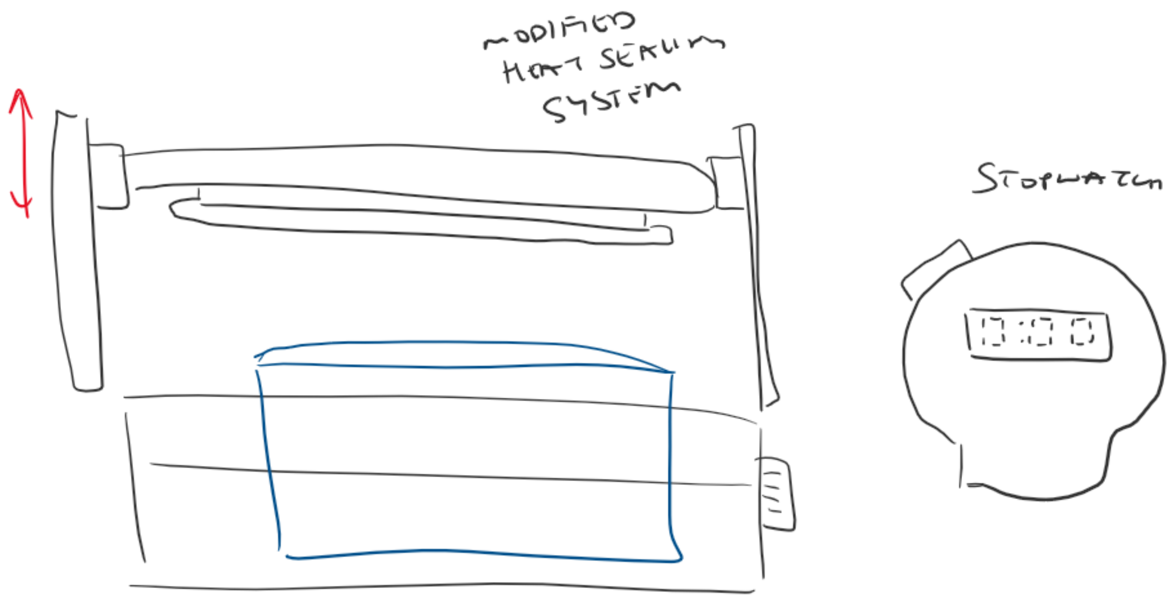
Test Procedure #7

Test Name: Heat Seal Time Test

Purpose: Our desired results are to obtain an operating point (knob position) for an effective (not over or under sealed) heat seal. This entails finding the minimum setting required to achieve a quality bag seal. Measurements to be taken: time to seal (uncertainty analysis explained in next sentence), knob angle (number approximated to +/- 0.5 ticks), visual inspection of bag sealer (over, under, sufficiently sealed). What to include in uncertainty analysis: reaction time (0.25s), system sensitivity (ut), precision of stopwatch (up), repeatability to 95% confidence (use equation ts/sqrt(n). t = 2.571, n = 5, standard deviation TBD).

Scope: This will test the relationship between seal time and knob angle to find the optimal knob setting for our specific bags.

Equipment: Complete Workstation, Heat Sealer System, Preopened Poly Bag roll, and Stopwatch or equivalent timer.



Hazards: Burns and scalds if we place our finger in between the heating element and the heat sealer handle.

PPE Requirements: Safety Goggles

Facility: Mustang 60 or Aero Hangar

Procedure:

1. Zero the timer
2. Start the timer and begin heat sealing the poly bag simultaneously.
3. Once light turns off, stop the timer. Wait 1 second and then lift the heat sealer handle to complete the seal. Observe quality of heat seal and collect time data.
4. Remove poly bag and insert new bag.
5. Repeat steps a-d for a total of 5 times.
6. Move the knob to the next tick.
7. Repeat steps a-d for a total of 5 times on the new knob setting. There will be 8 ticks to change into. Record data for each trial according to the data table below.

Knob Angle #	**Trial #**	**Seal Time [s]**	**Airtight? [Y/N]**	**Bag Sticks to Sealer? [Y/N]**

Results: (Pass Criteria, Fail Criteria, Number of samples to test)
Pass Criteria: The bag must be airtight, and the seal cleanly comes off the heat sealer without sticking onto the heat sealer.
Fail Criteria: The bag is not sealed properly (not airtight), and/or the bag sticks onto the heat sealer due to melted plastic.
Number of samples: 5 samples per tick for a total of 8 ticks (**Total of 40 samples**)
Test Date(s): TBD
Performed By: Christopher Tan, Kyle Chuang, and Ashley Humpal

Test Results: TBD

Knob Angle #	Trial #	Seal Time [s]	Airtight? [Y/N]	Bag Sticks to Sealer? [Y/N]
1				
2				
3				
4				
5				
6				
7				
8				

Performed By: Christopher Tan, Kyle Chuang, and Ashley Humpal

Appendix V: Design Verification Plan and Report

DVP&R - Design Verification Plan (& Report)

Project: F16 Source America | Sponsor: n/a | Edit Date: 5/19/2021

TEST PLAN										TEST RESULTS	
Test #	Specification	Test Description	Measurements	Acceptance Criteria	Required Facilities/	Parts Needed	Responsibility	TIMING: Start date	TIMING: Finish date	Numerical Results	Notes on Testing
1	Hooking Test	Test if hook in bag opening system functions correctly and opens bags enough for item to be placed	Measure clearance of the bag opening	Hook opens back so clearance is a minimum of 2 inches	N/A	Hook assembly; Bag	Keanau	4/27/2021	5/13/2021	The most optimum distance of the bottom of the bag to the bottom of the ramp is at indicator line 6 or 6.375" from the bottom. Acceptable positions were between 6.6125" to 6.625". Refer to Table 1 for full results.	We will likely mark a 0.25" zone on the grab ramp to assist the user in hooking the bag effectively
2	Durability Test	Place heavy load (40lb) onto bag-holding shaft to see if there are any cracks or bends on the wooden supports holding onto the steel shaft	Observe the wooden supports for any cracks/bends	No cracking or bending	Loaded weights	The Workstation	Kyle	4/27/2021	PLANNED (5/27/2021)	TBD	TBD
3	Tipping Test	Place bag rolls onto shaft and push with moderate force (average push force is 29lbf) on the cranks attached to the shaft	Observe whether the workspace tips over towards the backside	Kitting station doesn't fall or tip	N/A	The Workstation; Luggage Weigher	Chris	4/27/2021	5/13/2021	Maximum Pulling Force for Bag Holding Shaft is 5lbf. Maximum Pulling Force for heat sealing handle is 7lbf. Refer to Tables 3 and 4 for full results.	Prone to sliding/tipping from small amounts of force. Will likely refine the design to account for this (i.e. apply bolts, magnets, suction cups, etc.)
4	Sorting Test	Make sure items placed in top sorting plate can fall smoothly through the bottom sorting plate and into the funnels below	Observe how easily items drop	Item can drop through sorter without requiring additional force from user	Items such as mini post-it notes	Sorting System	Ashley	4/27/2021	5/13/2021	Refer to Table 5 for full results.	Hole position 3 (the one closest to the user) failed every test due to a design flaw. The other 2 holes had a mixed pass/fail rate as extra clearance caused plate missalignment.
5	Efficiency Test	Time how long it takes to complete the full bagging process versus manual bagging process.	Time	Workstation improves efficiency and kitting time is less than 5 minutes.	Timer	The Workstation	Chris	4/27/2021	5/13/2021	The workstation increased each person's kitting time by over 300%. Refer to Table 6 for full numerical test results.	Test may not be reflective of the entire system since prototype only models one kitting operation and the full design models 5 concurrent kitting operations.
6	Comparative Dexterity Analysis	Time how long it takes for someone who has dexterity issues (simulated due to covid) to normally package vs with Kitting station	Time	25% efficiency increase with kitting station to pass test	Timer	The Workstation	Ashley	4/27/2021	5/13/2021	Refer to Table 7 for full numerical test results.	Numerical data is skewed by learning curve with machine. Workstation is difficult to operate with one hand. Using one eye highlighted the poor visibility of the hooking system.
7	Heat Sealing Test	Tests the guage setting it takes to achieve a high quality heat seal on the preopened poly bags	Visual inspection of the heat seal to ensure the heat seal is complete without damaging the bag	No melted plastic residue on the heat sealer, poly bag doesn't rip when picked up and airtight.	N/A	Heat Sealer and Poly Bags	Kyle	4/27/2021	5/13/2021	We recommend heeat sealer knob settings of 1-4 for consistent and fast seals. Refer to Table 8 for full results.	When the knob/gauge of the heat sealer is on 5 or more, the seal on the bag will start to smoke and liquify the plastic.

ME 430 DVP&R Sign-Off Scorecard

TEAM: F16 SourceAmerica

Category		Percent Complete	Issues	Recovery Plan
Part Procurement				
	Counting by item on your iBOM, what percentage of parts have been **RECEIVED**? **If less than 100%, fill out Issues and Recovery Plan fields.**	100%		
Manufacturing				
	Reviewing Verification Prototype, what % of it is fully **ASSEMBLED**? **If less than 100%, fill out Issues and Recovery Plan fields.**	100%		
Testing				
	Reviewing your DVP, what % of your tests have been **COMPLETED** (including SP & component tests)? **If less than 100%, fill out Issues and Recovery Plan fields.**	86%	We haven't completed the Durability Test yet.	We plan to complete the Durability Test after creating our EXPO video because this test will likely destroy the prototype. Will have it done Thursday 05/27.
Safety				
	Reviewing your FMEA, Hazard Checklist, & Risk Assessment, what % of your recommended design actions have you **IMPLEMENTED** in your design/build? **If less than 100%, fill out Issues and Recovery Plan fields.**	75%	Warning labels not implemented.	We do not plan on implementing warning labels on our prototype due to time constraints. Additionally, we feel they are unnecessary because our team will be the only people testing the workstation and we understand the risks and dangers of our design.
	Reviewing your FMEA, Hazard Checklist, & Risk Assessment, what % of your user instructions have you **INCLUDED** in your User Manual? **If less than 100%, fill out Issues and Recovery Plan fields.**	100%		
	Based on **timing presented at CDR**, what is your team's status today? **Please use the text box to explain your timing status.**	Highlight status: ON TRACK MODERATELY OFF TRACK GREATLY OFF TRACK		

Hooking Test

Table 1. Hooking Test Table

Test #	Indicator Line Location [in] (from bottom of ramp)	Pass/Fail	Bag Rip (Y/N)
1	7.625	Fail	N
2	7.375	Fail	N
3	7.125	Fail	N
4	6.875	Fail	N
5	6.625	Pass	N
6	6.375	Pass	N
7	6.125	Pass	N
8	5.875	Fail	N
9	5.625	Fail	N

Notes:

- We aligned the bottom of the bag with the indicator line and hooked it. The most optimum spot to have the indicator line is at line 6 or 6.375" from the bottom of the ramp.

Recommendations:

- We created a black line for the users to place the bag accordingly as an indicator and users can align the bottom of the bag at the line.

Figure 1. Hooking Test

Durability Test

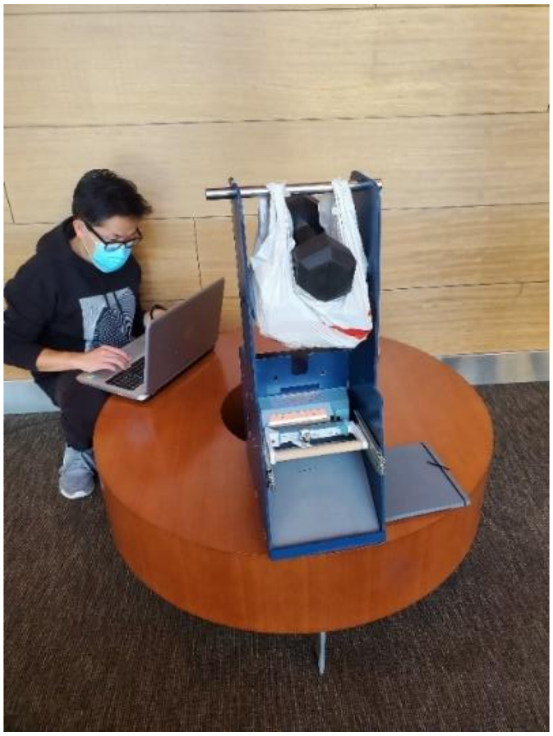


Figure 2. Durability Test

Test Results:

Weight (lb)	Pass or Fail
25	Pass
30	Pass
35	Pass
40	Pass

Notes:
Extremely flimsy
Is bending but not breaking
If no external force is applied it is fine and not sway
We tried swaying it a couple times and is fine

Tipping Test

Table 2. Tipping Test Table (for Bag Holding Shaft)

Trial Number	Desired Pulling Force (lbf)	Actual Pulling Force (lbf)	Result (Pass/Fail)	Notes
1	1	1.5	Pass	
2		1.2	Pass	
3		1.3	Pass	
1	3	3.2	Pass	
2		2.9	Pass	
3		3.0	Pass	
1	5	4.6	Fail	Begins to slip
2		4.9	Pass	
3		4.8	Pass	Barely passes
1	7	5.7	Fail	Too much slipping
2		-	Fail	
3		-	Fail	

Table 3. Tipping Test Table (for Heat Sealer Handle)

Trial Number	Desired Pulling Force (lbf)	Actual Pulling Force (lbf)	Result (Pass/Fail)	Notes
1	4	4.2	Pass	
2		4.0	Pass	
3		4.3	Pass	
1	6	5.9	Pass	
2		5.8	Pass	
3		5.9	Pass	
1	8	7.4	Fail	Begins to slip beyond this trial
2		7.0	Fail	
3		7.2	Fail	
1	10	-	Fail	
2		-	Fail	
3		-	Fail	

Additional Notes:

- Pulling the bag holding shaft with a force greater than 5lbf will cause the workstation to start slipping, therefore the rest of the tests that required 7lbf of pull force were not conducted as at 5.7 lbf the workstation slips too much.
- Pulling the heat sealer handle greater than 7lbf will cause the workstation to start slipping, therefore the rest of the tests of 8lbf and 10lbf pull force were not conducted as at 7 lbf the workstation slips too much.
- These pulling forces were adjusted due to the lower weight of the prototype compared to our final design.

Recommendations:

- Bolting the workstation to the worktable would eliminate any slipping caused by the user's pushing force.

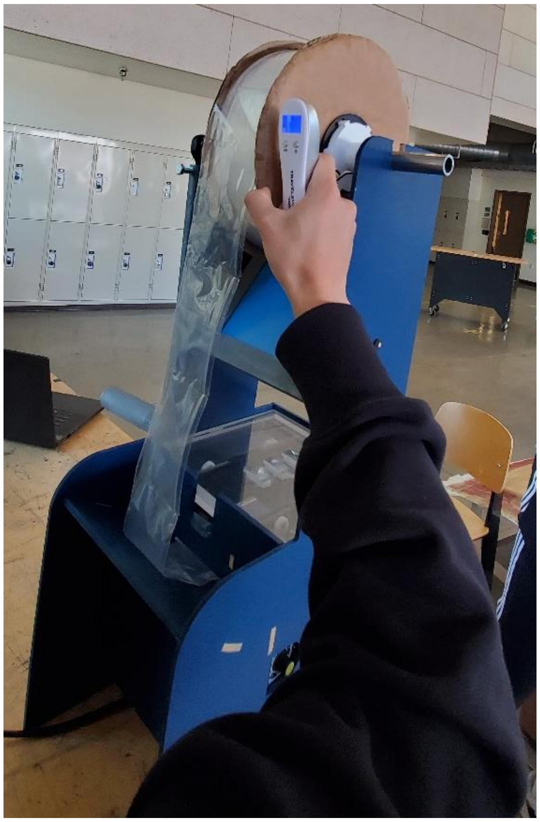


Figure 3. Tipping Test

Sorting Test

Table 4. Sorting Test Table

Item	Test Number	Pass or Fail	Notes
Post-it Pad Position 1 (hole farthest from the user)	1	Pass	
	2	Fail	
	3	Fail	Sorting Templates were misaligned
	4	Pass	Made sure to put more force when pushing, as well as making sure the holes line up
	5	Pass	
Post-it Pad Position 2 (middle hole)	1	Fail	
	2	Pass	
	3	Pass	
	4	Pass	
	5	Fail	
Post-it Pad Position 3 (hole closest to the user)	1	Fail	This hole is misaligned
	2	Fail	
	3	Fail	
	4	Fail	
	5	Fail	

Notes:

- For the taller/longer items, they wouldn't fit through the whole sorting system because they hit the surface of the funnel before completely going through the sorting holes.
- We cut the post its after realizing they were too tall to get past the funnel.

Recommendations:

- Placing the post-it notes in the middle hole would result in the greatest success in dropping the item to the bag.
- A redesign and reprint of the 3D printed funnel is recommended so that the funnel end would align with the bag hole, thus ensuring that placing the post-it notes in any position in the template sorter will allow the item to drop successfully into the bag.
- Use a bigger size poly bag.

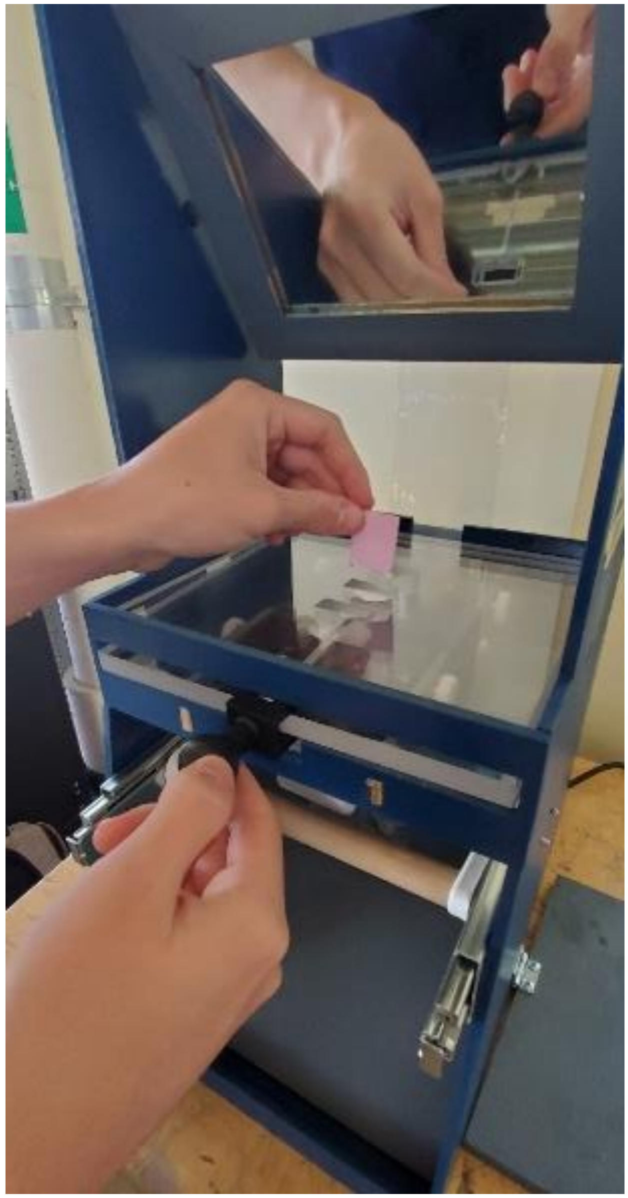


Figure 4. Sorting Test

Efficiency Test

Table 5. Efficiency Test Table

Tester	Trial	Workstation Kit Time, t_{ws} [s]	Workstation Successful [Y/N]	Manual Kit Time, t_m [s]	Manual Successful [Y/N]	Notes
Kyle Chuang	1	60	Y	10.8	Y	
	2	30	N	8.3	Y	Item kept missing the bag opening
	3	37	Y	10.1	Y	Changing the direction of the ratchet reduces efficiency
Ashley Humpal	1	41	Y	11.5	Y	
	2	60	N	10.8	Y	
	3	34	Y	9.6	Y	Bag keeps sticking on heat sealer. Had to pull the bag from the bottom
Keanau Robin	1	32	Y	8.6	Y	
	2	40	N	9.9	Y	Item kept missing the bag opening
	3	50	N	10.2	Y	Item kept missing the bag opening
Christopher Tan	1	40	Y	9.6	Y	Item missed the bag opening. Bag got stuck on heat sealer
	2	-	N	10.9	Y	Item missed the bag opening multiple times. Incomplete
	3	43	Y	8.4	Y	Item missed the bag opening multiple times. Bag got stuck on heat sealer after heat sealing

Notes:

- We updated the funnel and 3D printed the newest version. However, we have now realized that the funnel hole doesn't align with the bag opening once the hook has opened the bag.
- Big issues:

- Items would miss the bag opening after sliding down funnel.
    - Bag would get stuck on heat sealer after heat sealing.
- Manual kitting is significantly faster because the prototype doesn't take into account the fact that the main design will be bagging 5 small bags at once.
    - Also take into account the fact that we do not have dexterity issues.

Recommendations:

- Redesign and reprint the 3D printed funnel so that its funnel end would align with the bag opening, to increase the chance of the item correctly falling into the poly bag.
- Use a bigger size poly bag.

Figure 5. Manual Efficiency Test

Comparative Dexterity Analysis

Table 6. Comparative Dexterity Analysis Test Table

			Workstation		
Tester	**Test**	**Trial**	**Kit Time [t]**	**Successful [Y/N]**	**Notes**
Kyle Chuang	No Impairments	1	60	Y	
		2	30	N	Item kept missing the bag opening
		3	37	Y	Changing the direction of the ratchet reduces efficiency
	Gloves	1	23	Y	
		2	52	Y	Although item was in the bag, it wouldn't slide all the way to the bottom of the bag
		3	71	Y	When rotating the crank, the bags would stick to each other due to static electricity.
	One Arm	1	28	N	When the item was placed at the front hole, it got stuck at the funnel and did not drop to the bag.
		2	40	Y	Back hole is fine
		3	30	Y	
	One Eye	1	28	Y	
		2	33	Y	
		3	18	Y	
Ashley Humpal	No Impairments	1	41	Y	
		2	60	N	
		3	34	Y	Bag keeps sticking on heat sealer. Had to pull it from the bottom
	Gloves	1	46	Y	
		2	64	Y	
		3	51	Y	
	One Arm	1	35	Y	
		2	23	N	Heat sealed wrong bag.
		3	29	Y	
	One Eye	1	55	Y	Cycled too far after bagging. Item stuck at mouth of bag.
		2	30	Y	
		3	20	Y	

Keanau Robin	No Impairments	1	32	Y	
		2	40	N	Item kept missing the bag opening
		3	50	N	Item kept missing the bag opening
	Gloves	1	41	Y	Item stuck at the bag opening.
		2	72	N	Template misalignment. Items missing hole.
		3	49	Y	Keanau now needed two hands to open the bag.
	One Arm	1	86	N	Workstation slid when heat sealed. Ripped two bags. No heat seal.
		2	46	Y	Workstation slid again. Difficult for Keanau (left handed) to operate right crank.
		3	31	Y	Workstation slip. Hooking must be balanced in order to stay
	One Eye	1	35	Y	Bag seal was crooked. Had to get close to see.
		2	36	Y	Nudged item into the template hole.
		3	61	Y	Item missed bag 3 times before working.
Christopher Tan	No Impairments	1	40	Y	Item missed the bag opening. Bag got stuck on heat sealer
		2	-	N	Item missed the bag opening multiple times. Incomplete
		3	43	Y	Item missed the bag opening multiple times. Bag got stuck on heat sealer after heat sealing
	Gloves	1	36	Y	
		2	39	Y	
		3	32	Y	
	One Arm	1	33	Y	Did not use crank handle to cycle bag.
		2	29	Y	Nudged item into template hole.
		3	31	Y	Item stuck at the top of the bag.
	One Eye	1	52	N	Hook pierced item.
		2	48	Y	Item missed bag 2 times.
		3	31	N	Heat sealer handle rotated so no seal was done.

Notes:

- No way to check if bag was sealed correctly before tearing.
- Learning curve may affect the times. Later times might be faster because we are more familiar with the product.

Figure 6. One Arm Test

Figure 7. Gloves Test

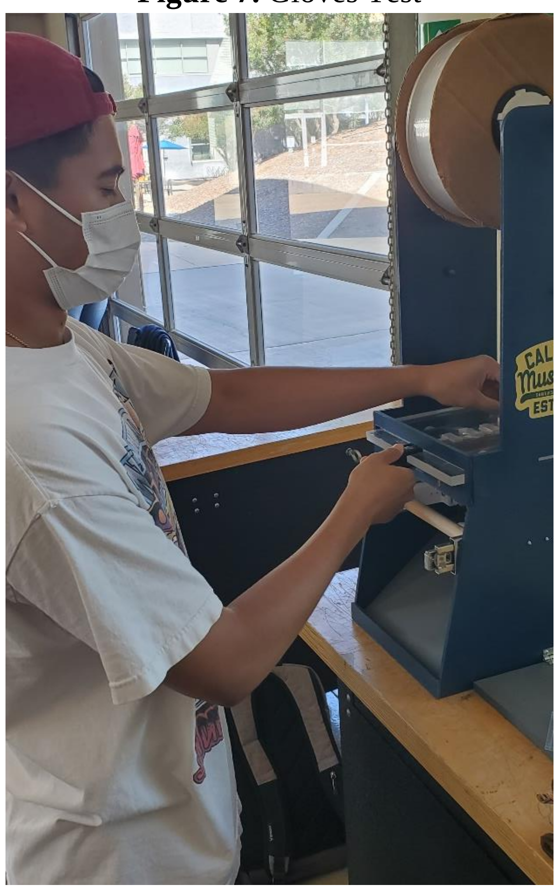


Figure 8. One Eye Test

Heat Sealing Test

Table 7. Heat Sealing Test Table

Knob Angle #	Trial #	Seal Time [s]	Seal Time Avg [s]	Airtight? [Y/N]	Bag Sticks to Sealer? [Y/N]	Notes
1	1	0.42	0.46	Y	N	
	2	0.57		Y	Y	
	3	0.46		Y	Y	
	4	0.38		Y	Y	
	5	0.47		Y	Y	
2	1	0.65	0.662	Y	Y	
	2	0.58		Y	Y	
	3	0.72		Y	Y	
	4	0.54		Y	N	
	5	0.82		Y	Y	
3	1	0.80	0.764	Y	Y	
	2	0.75		Y	Y	
	3	0.78		Y	Y	
	4	0.74		Y	Y	
	5	0.75		Y	Y	
4	1	0.99	0.944	Y	Y	
	2	0.95		Y	Y	
	3	0.92		Y	Y	
	4	0.91		Y	Y	
	5	0.95		Y	Y	
5	1	1.12	1.09	Y	Y	
	2	0.99		Y	Y	Bag begins to smoke
	3	1.13		Y	Y	
	4	1.12		Y	Y	
	5	1.09		Y	Y	
6	1	1.33	1.304	Y	Y	Smoke
	2	1.34		Y	Y	
	3	1.30		Y	Y	
	4	1.25		Y	Y	Wait 3 seconds before peeling off or else bag will tear
	5	1.30		Y	Y	
7	1	1.57	1.512	Y	Y	
	2	1.50		Y	Y	
	3	1.55		Y	Y	3 second wait time is insufficient
	4	1.47		Y	Y	
	5	1.47		Y	Y	Update: 5 seconds is new wait time or else bag will tear
8	1	1.75	1.744	Y	Y	6 seconds was sufficient
	2	1.72		Y	Y	5 seconds causes small tear
	3	1.75		Y	Y	
	4	1.75		Y	Y	
	5	1.75		Y	Y	Update: **6-7 seconds** wait time after sealing is sufficient to prevent tearing

Notes:

- When the gauge or knob of the heat sealer is greater than 5, the heat sealer will cause the plastic to burn greater and cause it to smoke. A longer wait time is also needed after sealing with higher. When the bag is quickly pulled right after sealing, the bag will tear at the seal.

Recommendations:

- If using a 1mil thickness plastic poly bag, keep the gauge or knob at 4 or below. The most optimum gauge is at 1 because the average seal time and average wait time is the shortest and it is airtight similar to the other gauges, and therefore will increase the overall efficiency of packaging the items.

Figure 9. Heat Sealing Time Test