GAYLORD PRODUCE REMOVAL MACHINE
Final Design Review

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Statement of Disclaimer

Abstract

This Final Design Review Report outlines the senior design project that began Winter Quarter of 2021 at California Polytechnic State University. Our team consists of three mechanical engineers and a general engineer, working together to design, build, and test a product for Alameda County Food Bank. The goal of the final product is to relieve volunteers and employees of tedious manual labor and increase efficiency during the removal of produce from large Gaylord containers. This document describes background research, the objectives of the project, chosen concept design, analysis and initial prototyping of said concept, the final design, and verification prototype and testing.

The W25 Gaylord Produce Removal Team would like to sincerely thank Eileen Rossman, Kevin Williams, Nephi Derbidge, the shop technicians at the Aerospace Hangar and Mustang 60, our sponsors Erik Trujillo and Leif Magnuson, and everyone else who made this project possible.

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I. Introduction

Gaylord boxes are used at the Alameda County Foodbank to transport bulk quantities of produce between warehouses and distribution centers. Gaylord boxes are bulk-size corrugated boxes and are often shipped on pallets; an example of those used at the food bank warehouse can be seen in Figure 1. As part of the distribution process, volunteers remove produce from the Gaylords by hand and bag it to be transported in more manageable quantities. This procedure is often strenuous on volunteers and their backs, and it is less efficient than desired. Project sponsors, Marcos Trujillo and Leif Magnuson, seek to find a solution to this problem to help both the volunteers and the efficiency of the Foodbank's operations. Our team: Carissa Kamm, Marcus Lee, Mark Loera, and Jacob Perlman is tasked with developing and building a product to remove produce from Gaylords and transfer it into bags and boxes in a more efficient and safe way. This report will communicate our team's understanding of the problem we are tasked with solving, our plan to achieve an optimal solution for all parties involved, a presented design decision, and a completed verification prototype with testing. The Background section will cover information gained from research and insights into the problem at hand. The Objectives section will include the problem statement, customer needs and wants, and engineering specifications for our project. The Concept Design section of the report covers our team's design process and decided design concept and direction for this project. The Final Design section contains a detailed description of the final design, with the following Manufacturing section detailing the exact methods in which the prototype has been fabricated. Next, the Design Verification section contains the tests and verification methods for the design, as well as the details and results of said tests. The Project Management section will describe our process in completing the project and meeting specifications and requirements. Finally, the Conclusion section includes recommendations in improvements to the design and recommended steps to take in the future.

Figure 1. Gaylord Box

II. Background

Our background research has been focused on research in three main areas: customer needs, existing solutions, and technical research. Our customer research focuses on the experiences, needs, and wants of our sponsors and others involved with the Alameda County food bank. Research into existing solutions centered around finding products that addressed those needs and wants, while our technical research focused on patents and papers relevant to the project's problems and possible solutions.

2.1 Customer Research

We interviewed our sponsors to gain a better understanding of the parameters of this project and its wants, needs, and restrictions. Our team's summary of requirements for this project are listed below:

- Works with Gaylords box (42"x48"x28") and the pallets they are on (42"x48") (Figure 1)
- Smaller sizes preferred to leave maneuverability in warehouse
- Work with Gaylords boxes that can weigh upwards of 700lbs
- Safe for volunteers & employees to operate, as well as children to be around
- Reduce strain on volunteers/employees
- Increased speed and efficiency when compared to unassisted manual labor
- Prevent or minimize damage to Gaylords boxes for reusability
- Relatively low cost and difficulty of production for easier reproduction in more locations
- Cannot be bolted down into the floor
- Easily and quickly operable
- High durability, low risk in case of catastrophic failure
- Must be able to remove produce into mesh bags or boxes

2.2 Existing Solutions

Our research on existing solutions centered around finding systems and mechanisms applicable to the requirements for our project for inspiration and comparison.

Our product research was jumpstarted by an example from our sponsors – container tilting tables such as the model from TP Supply Co. pictured in Figure 2. The table tilts the container, lessening the amount of bending over a volunteer would need to remove the produce inside. This product can support high loads, has adjustable heights, and are portable. The tilting table serves as a strong benchmark for many of our specifications – our project aims to provide a solution that performs at similar or higher levels in the specifications that the tilting table satisfies, at a lower cost of production. The designs for any possible tilting and mobility would be based on tilting tables and convertible handcarts (Figure 3).

Figure 2. Portable Container Tilter (Material Flow)

Figure 3. Convertible Handcart (Mutual Hardware)

Our sponsors had also mentioned prior use of a conveyor belt system with a team of volunteers at the warehouse. A conveyor belt, such as the type seen in Figure 4, would improve the efficiency and speed of produce removal by automating movement of produce and freeing up volunteers to focus on other steps of the removal process.

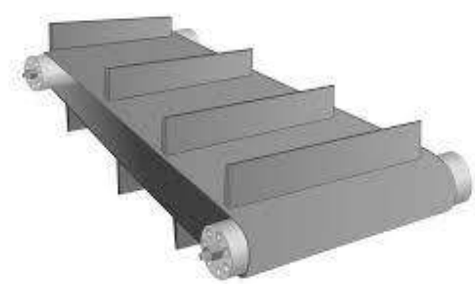

Figure 4. Conveyor Belt (VectorStock)

Another product that we considered was the vacuum system such as this variation used in apple farms. These vacuum systems, such as the one pictured in Figure 5, suck produce through tubes and deposit them at their destination. The vacuum system addresses the accessibility, efficiency, and ease of use desired in our design by making produce more easily accessible.

Figure 5. Vacuum System (Milkovich)

Products such as the ATCOPACK Net Packaging Machine (Figure 6) specialize in taking produce and bagging them efficiently. This system bags produce in mesh bags, as is done in most cases at the Alameda County food bank.

Figure 6. ATCOPACK Net Packaging Machine (ATCO Business Solutions)

A system that combines many of the products' functions is the Conair Gaylord Tilters 299 and 120 Series (Figure 7). These tilters are easy to load - the Gaylord and pallet can be loaded directly onto the system with a handcart, as the tilting platform is flat to the floor. As the vacuum feed tube sucks to contents away to their destination, the Gaylord is tilted to ensure a constant feed rate into the vacuum tube.

Figure 7. Conair Gaylord Tilters 299 and 120 Series (CONAIR)

2.3 Technical Research

With the design ideation process still ahead of us, our technical research can broadly be split into three sections so far: worker safety and health, product safety, and design mechanisms.

2.3.1 Worker Safety and Health

The following section contains papers and regulations regarding the health and safety of any operators of the system, as well as people nearby.

The damage caused by spending long periods of time in a low, bent posture that many volunteers of the Alameda County food bank find themselves in when working on produce removal is well documented in papers such as "Low back pain related to bowing posture of greenhouse farmers" (Maeda, 1980). Medical papers such as these, as well as the *OSHA Pocket Guide for Warehousing Worker Safety Issues* document methods to prevent ergonomic harm to those working with our system. The OSHA guide also has sections on powered instruments and the lifting and handling of items, which will become more relevant as our ideation process begins. While our project is mainly geared towards handling the Gaylords boxes themselves, alternate solutions such as those found in "Assessment of an active industrial exoskeleton to aid dynamic lifting and lowering manual handling tasks" (Huysamen, 2018) help us keep focus on the users themselves.

2.3.2 Product Safety

The following section contains papers and regulations regarding the safety of the produce handled by the design, whether it be harm reduction to the produce, or regulations regarding the handling of food.

Resources such as Section five in "Wholesale Success: A Farmer's Guide to Selling, Postharvest Handling, and Packing Produce," (Slama, 2010) provide guidelines and suggestions for the handling of bulk product as is done in the food bank. The produce profiles at the end of the same paper provide additional information on the many types of produce handled at the food bank.

2.3.3 FDA Compliance

The FDA's "Standards for the Growing, Harvesting, Packing, and Holding of Produce for Human Consumption: Guidance for Industry" was consulted for food safety considerations. The main points applicable were found in Chapter 6.6, which advised those handling produce to consider the possible damages to produce when handled in the packing environment. Our design is focused on manipulating the box from outside, so this is not anymore of a concern than previously.

2.3.4 Design Mechanisms

The following section contains papers and regulations that are relevant to possible solutions to be built towards.

The paper "Algorithm for designing a hydraulic scissor lifting platform" (Ciupan, 2019) describes the optimization of hydraulic scissor lifting platforms, which may aid volunteers ergonomically, or be a part of the Gaylord tipping mechanism.

The paper "Effectiveness of a vacuum lifting system in reducing spinal load during airline baggage handling" (Lu, 2018) explores the ergonomic benefits of vacuum assistance in load lifting, while "Investigation of flow and vacuum lifting force on a noncontact end effector for robotic handling of non-rigid material" (Toklu, 2011) focuses on the uses and limits of vacuum lifting for produce in Gaylord boxes.

Further research with current patents can be found in Appendix C.

III. Objectives

The Alameda County Food Bank needs a way to more safely, efficiently, and comfortably aid its volunteers in removing loose produce from the bottom of Gaylord boxes because the current process is strenuous and inefficient, forcing volunteers to either strain to reach the bottoms of the boxes or render the boxes unusable.

The boundary diagram shown in Figure 8 gives a visual representation of the scope of this project. The dotted line drawn around the User, Gaylord, Pallet, and Produce demonstrates what we have the capability to directly influence. The objects outside of the dotted line, such as the bag and box that produce will be placed in, are objects that we must account for in our design.

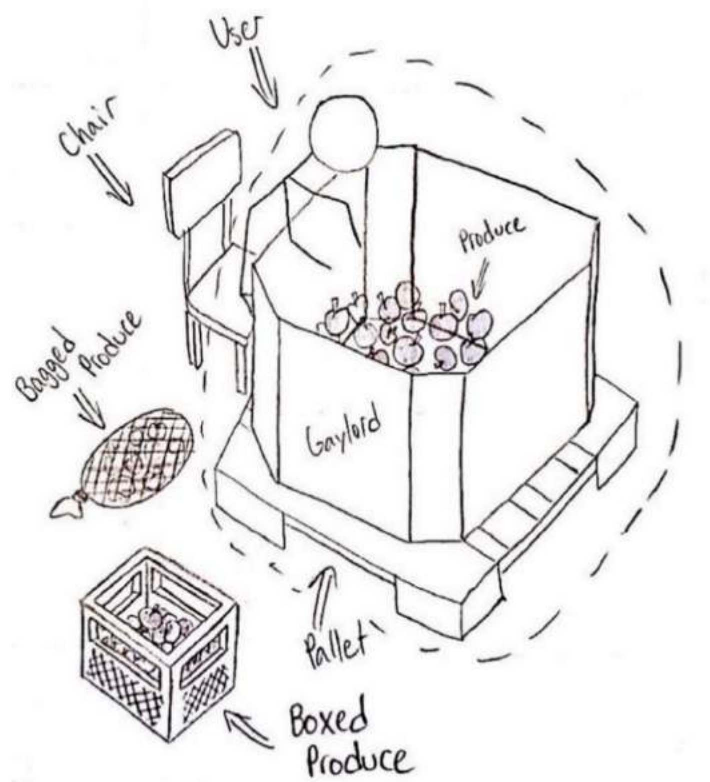

Figure 8. Boundary Diagram Illustrating Scope of Project Design

Our main stakeholders for this project are Marcos Trujillo, a Program Implementation Specialist, and Leif Magnuson, a dedicated volunteer, at Alameda County Food bank. Alameda County Food Bank needs a more ergonomically safe and efficient way of removing and bagging produce from large Gaylord Boxes. They need volunteers to be able to interact and continue manual work without the strenuous and inefficient task of bending over or cutting into Gaylord Boxes. Taking safety and efficiency into account, our team was able to classify customer requirements and come up with engineering specifications to create a House of Quality which can be found in Appendix A.

Table 2 lists the engineering specifications that we will test. There are many possible approaches to removing produce such as tilting the entire Gaylord Box on top of the pallet or directly removing fruit from inside the box so testing procedures may evolve as we ideate and get further into the design process.

Table 2. Demonstrates the engineering specifications, target values, risks, and methods for compliance pertaining to the scope of our design team. The compliance methods are: Analysis (A), Test (T), Similarity to Existing Designs (S), and Inspection (I). The risk scaling is high(H), medium(M), or low(L)

Spec #	Parameter Description	Requirements or Target	Tolerance	Risk	Compliance
1	Produce Count	7 produce	± 2 Produce	M	A, T
2	Weight	200 lb	Max	L	A, I
3	Produce Damage	1/100 produce damaged	± 3 produce	H	T, I
4	Cost	$750	± $100	M	A
5	Height	5 feet	Max	L	A, T
6	Bagging Rate	30 produce/minute	± 5 produce	M	T
7	Time to Use	20 minutes/Gaylord	± 10 minutes	M	T
8	Setup Time	10 minutes	± 5 minutes	L	T
9	Use Survey	95% approval	± 5%	M	A, I
10	Types of Produce Applicable	All types (excluding Cabbage)	Max	H	A, T
11	Time to Clean	10 minutes	± 5 minutes	L	T
12	Floor Area	9 ft^2	± 3 ft^2	L	A, S, I
13	# of Compatible End Containers	2 (boxes and mesh bags	Max	L	A, T
14	Bearable Load	1200 lb	Min	H	A, T

Our engineering specifications and their targets are as follow.

- *Produce Count*: In order to maximize the efficiency of our product, are tilting the entire bin in order to move all of the produce into a more ergonomic position and allow it to be easily removed from the Gaylord Box.
- *Weight*: This is an estimate based on creating a product that can be wheeled around and is also heavy enough to not pose a risk of tipping over while removing produce.
- *Produce Damage and Types of Produce*: Produce damage and types of produce that our product will be able to handle are the highest risk specifications. It is important not to damage produce but user error and the amount of touches on produce make this a difficult task. These specifications are high risk because if too much produce were damaged, the design would be unusable; additionally, it is required that almost all types of produce are able to be used in our design.
- *Cost:* We want the design to be strong, durable, and lightweight. This may increase the cost as well as many other aspects.

- *Height*: Our product must be able to reach over the Gaylord if ideation leads us down that path.
- *Bagging Rate and Number of Compatible End Containers*: Our design must be efficient at picking up/moving produce fast enough to be practical while also being gentle with soft produce such as apples and kiwi. It should be able to get produce into bags or boxes.
- *Time to Use, Setup Time, and Floor Area:* Our produce should be storable and easy to move around the warehouse for setup at different locations in a short amount of time. It must also not get in the way of walkways and easy to move between bins.
- *Time to Clean:* Due to its ability to be operated by different volunteers and types of produce, it is essential that it can be cleaned to maintain health standards.
- *Use Survey:* The goal is to design a product that still requires volunteers to operate or have direct contact with the produce while alleviating them of any physically strenuous activities. If volunteers prefer using their hands, it will not solve the problem.
- *Bearable Load:* As gaylord boxes full of produce are typically between 600-800 lb., the minimum load our design is capable to maintain without failure is 1200 lb. This specification is high risk because under failure, potential injuries occur.

IV. Concept Design

An essential step in our design process was concept ideation. The goal of this step is to use the information gathered in the background and technical research to generate possible solutions and overall find a design direction that best fits the needs of our sponsor. This ideation process consisted of a brainstorming/brainwriting phase, ideation, assessment, and concept development.

4.1 Ideation

To initially develop ideas for our design, we broke the solution down into its base functions in a functional decomposition shown in Figure 9.

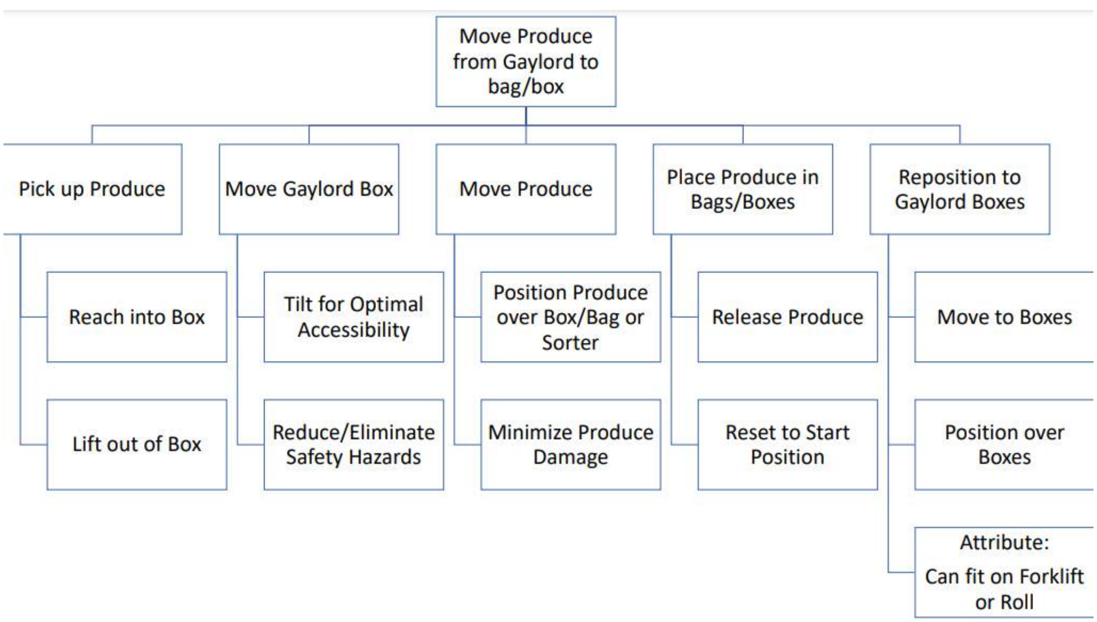

Figure 9. Functional Decomposition Diagram

The purpose of a functional decomposition is to break down the overall functions of our system into its base parts and steps. The advantage of this model is that it allows us to identify relationships between different functions and look for solutions in greater detail.

For the next step of the process, we brainstormed possible solutions for each function and ruled out the most impractical options. With our concepts from brainstorming, we then created ideation models from solutions for each function. By developing ideation models, we were able to test out and represent different solution ideas. Below are images of four of the ideation models created. Figure 10 shows a concept model for lifting and tilting the Gaylord box, in which one corner of the Gaylord is lifted while the other remains stationary. Figure 11 shows a vacuum mechanism, which would be used to lift produce. Figure 12 displays the concept of a scissor lift used to tilt the Gaylord, and Figure 13 demonstrates a pulley-system to lift a side of the gaylord box and tilt it. Additional ideation models can be found in Appendix D.

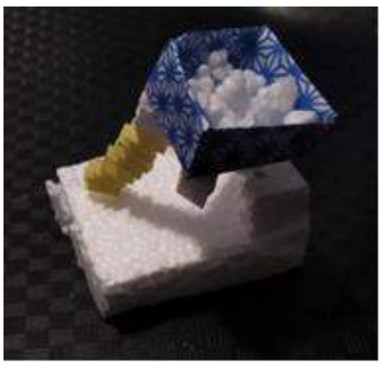

Figure 10. Gaylord Tilter Ideation Model

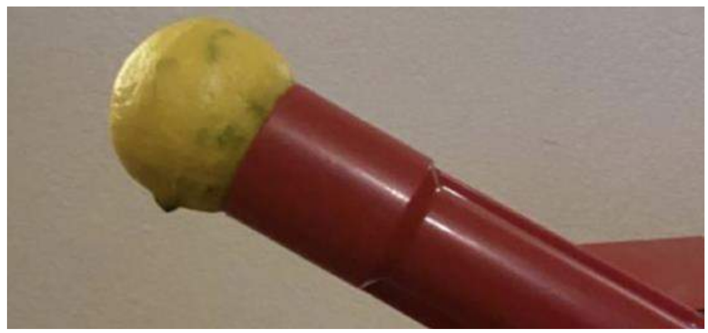

Figure 11. Vacuum Produce Lifter Ideation Model

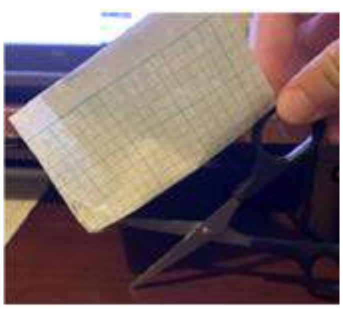

Figure 12. Scissor Lift Ideation Model

Figure 13. Pulley Lift Ideation Model

4.2 Concept Analysis

After our team developed multiple concepts for solutions for each function, we conducted analysis via Pugh matrices to select the best concepts to perform each concept. In a Pugh matrix, concepts are compared against each other by how well they adhere to customer needs and wants. Figures 14 and 15 display two of the top function concepts as determined by our Pugh Matrices. All Pugh matrices can be found in Appendix E.

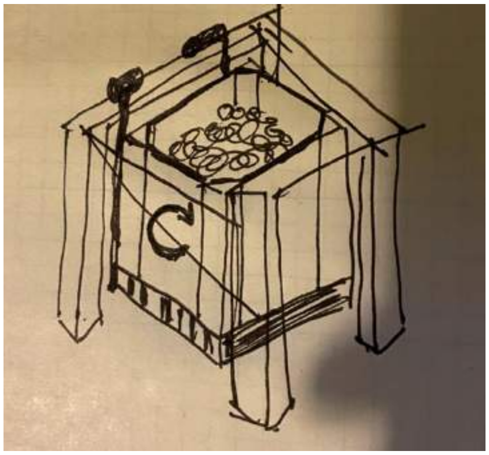

Figure 14. Center of Gravity Swing Tilter

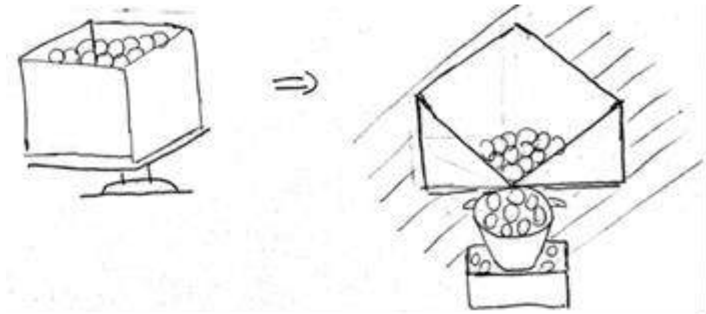

Figure 15. Tip Gaylord into Funnel or Chute

After using our Pugh matrices to obtain the top solutions for each function, the function concepts were compiled into a morphological matrix, which is used to combine different function concepts to form different system designs. From the morphological matrix, we developed seven concept designs, that were comprised of five different base functions: moving the device, securing the Gaylord box, tilting the Gaylord Box, removing produce, and bagging/boxing produce. Our morphological matrix, along with a table summarizing the resulting designs, can be found in Appendix F.

After developing these designs, we then used a weighted decision matrix to rate each design on how well it meets each engineering specification. We obtained weights for our decision matrix from the House of Quality QFD and rated each design with a score of 1-10 per specification. The weighted totals were then calculated to find which design best met the project qualifications. The resulting decision matrix and the sketches of each design mentioned are found in Appendix G. From our decision matrix analysis, we found that our top design options were Designs 4, 6, and 7. Although Design 7 had allocated the highest weighted score, we decided it was not as viable of an option due to its use of hydraulics. Therefore, we concluded that a final design direction similar to Design 6 would be the most optimal. Design 6 can be seen in the sketch below, in Figure 16.

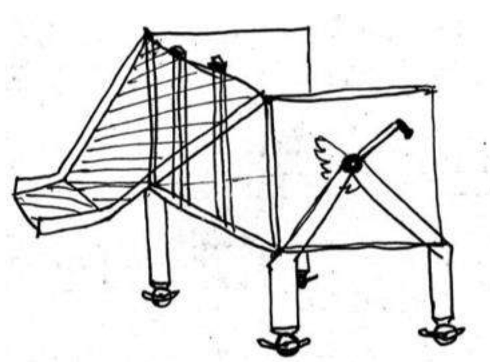

Figure 16. Design 6 of Decision Matrix

Design 6 consists of a tilting device balanced on the Gaylord box's center of gravity, tilted using a crank-like mechanism with ratchets. It also has locking wheels for movement and an attachable fruit chute to catch produce as it falls when tilted and channel it towards a bagging area. This design implements bars, some of which will be retractable, to hold the Gaylord box in place when it is tilting.

4.3 Design Decision

Our final decision for design direction is similar to that of Design 6 above; although, there are some adjustments we wish to make to best cater the design to the sponsors' and problem's needs. Instead of locking wheels, our design will be movable by forklift to keep it lower to the ground and to minimize locations of possible failure. Additionally, rather than a cranking device with ratchets, we are looking to implement a form of manual jack to lift one side of the box and tilt it. To test out the feasibility of the function of our design, we have built a concept prototype pictured in Figure 17.

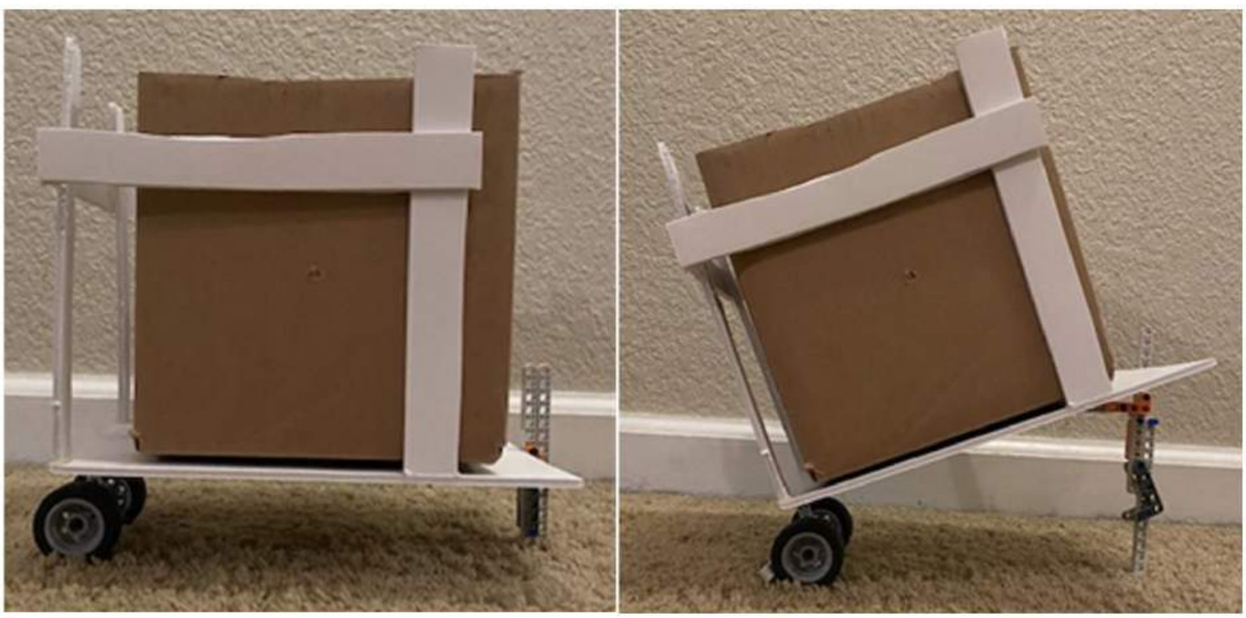

Figure 17. Concept Prototype in Loading and Tilted Positions

This prototype has allowed us to better demonstrate our design in practice and has led us to realize some strengths and shortcomings. Along with our concept prototype, we have also built a CAD SolidWorks Model to display our desired design direction. This model is displayed in Figure 18-21 below.

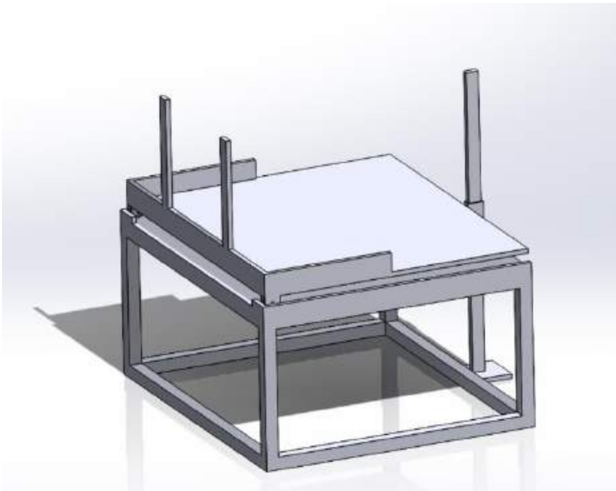

Figure 18. Concept Design in Starting Position

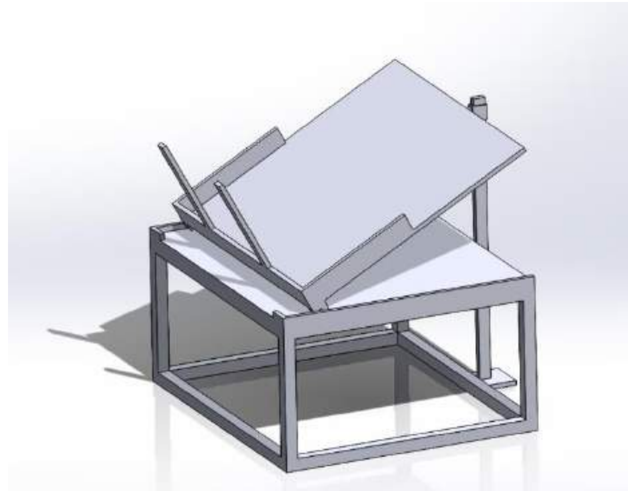

Figure 19. Concept Design Tilted

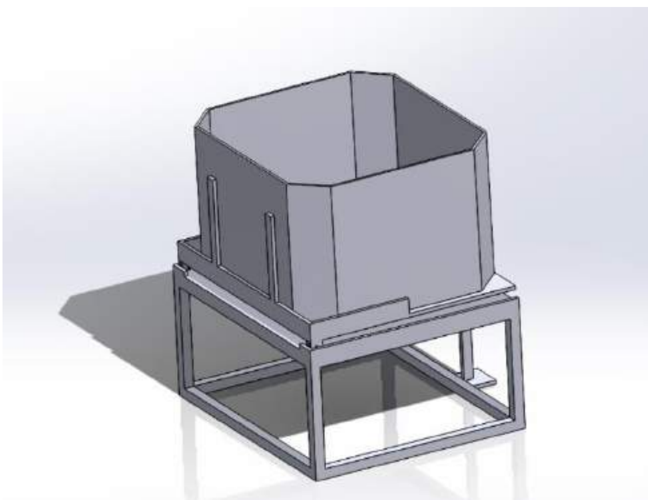

Figure 20. Concept Design Un-tilted with Gaylord Box

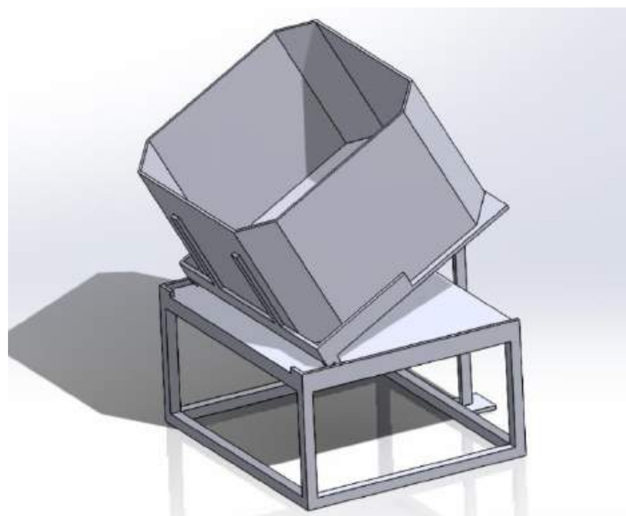

Figure 21. Concept Design Tilted with Gaylord Box

We plan to implement further detail into our CAD model and conduct finite element analysis, along with other analyses, to better strengthen and develop our design in the future.

4.4 Design Challenges

Design challenges we have moving forward are centered around making the device safe for users both ergonomically and mechanically, as well as making the device as purely mechanically powered as possible to avoid any cables. Design hazards that have been considered can be seen in the Design Hazard Checklist in Appendix H.

Most hazards and challenges related to this project stem from the fact that it will be raising a heavy gaylords box and tilting it. In order to ensure the safety of any users and passerby, the stability of the device at all expected weights and tilting angles must be secured. The lifting mechanism will bear large forces in multiple directions and must be designed and supported accordingly.

4.5 Design Structural Prototype

The purpose of the prototype was to examine the full-scale process of using the Hi-Lift Jack to tilt the securing table and examine how the wheels would react. We found that the casters responded well to the vertical lift of the jack and even responded exactly as we had hoped in the case of failure, since they rolled forward, and the tilting-base fell back to its starting position. Below, shown in figures 22 and 23 are pictures of our prototype.

Figure 22. Prototype starting position with High-Lift Jack at starting height

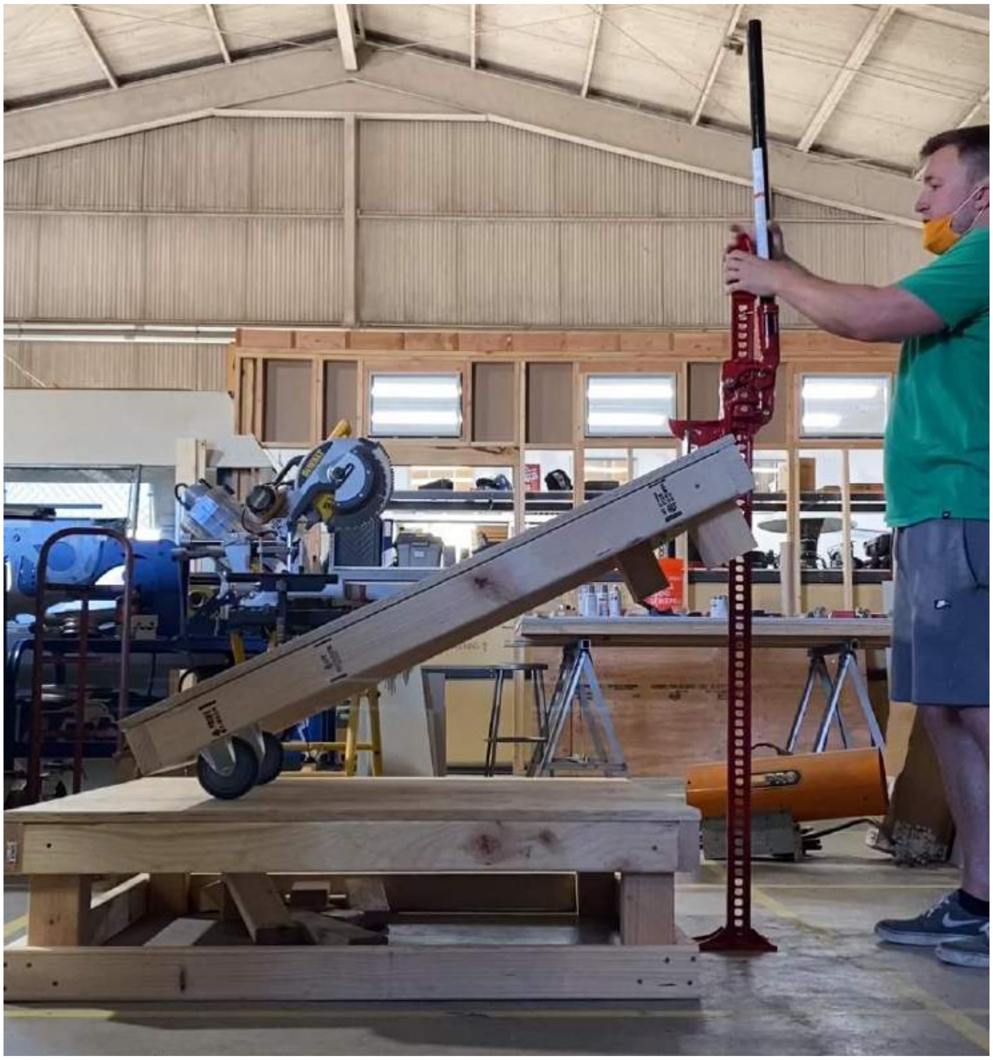

Figure 23. Prototype tilting table at maximum tilt angle

One issue we ran into was getting the jack to ratchet down, similarly to how it ratchets up. We suspect that the horizontal force being applied to the jack is causing the pins to not engage properly during descent, so we have modified the design for this. We have added in vertical sliders to the back corners where the jack is mounted to take the vertical force off the jack and place it on the base frame. We also have lowered the base frame in order to get a greater angle of tilt and have a lower starting position for the jack. See the final design portion following for this.

V. Final Design

This section discusses the final design of the Gaylord produce box tilting device. The design incorporates and builds on previous iterations and feedback given by sponsors, advisors, and peers. Sizing, material choice, and system design were justified through the manufacturing practicality and mechanical analysis.

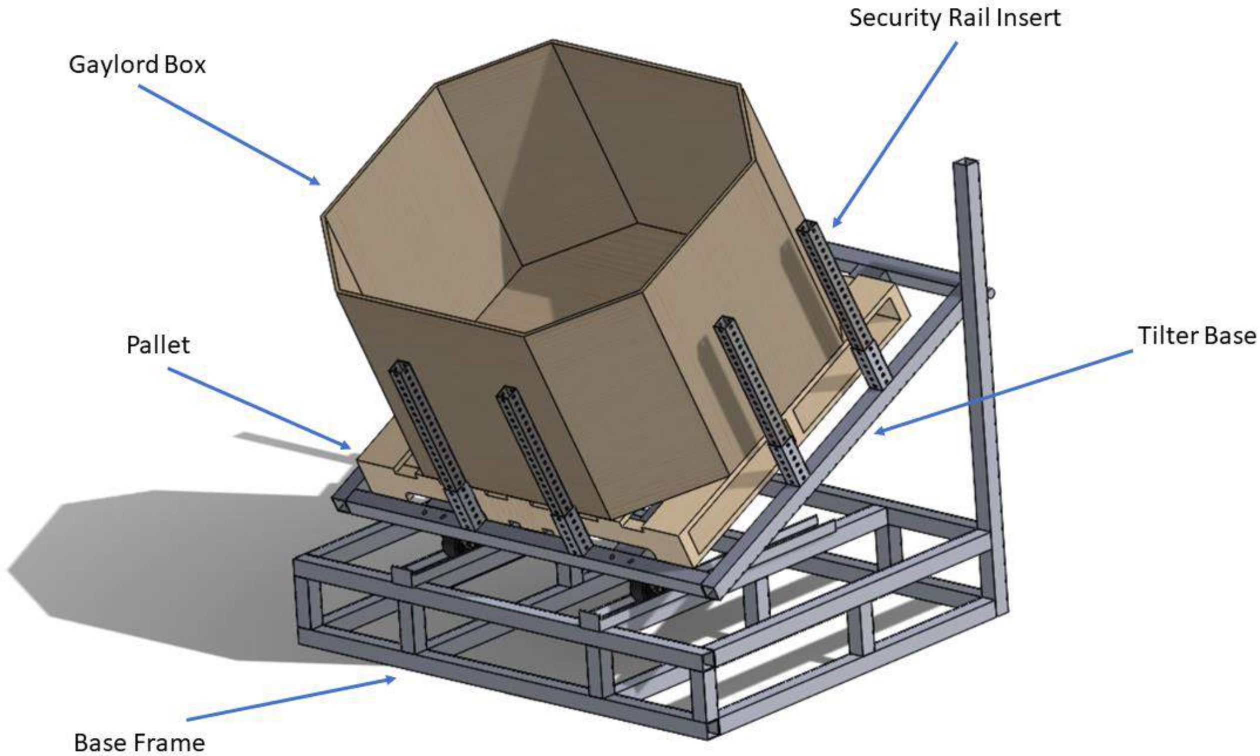

Figure 24. Final Design Assembly

5.1 Secure System Design

The primary function of this subsystem is to securely hold the Gaylord box in place as the device is tilted, while also offering an easy and efficient way to load the device. A big concern our sponsors had with the initial concept design is how the Gaylord boxes would be loaded onto the structure. This redesign of the subsystem offers a more streamline loading process while also giving more wiggle room for the forklift operator by having a large space where the Gaylord sits. The design uses standardized signpost anchors that are bolted onto the tilter base frame of the system. Customized post inserts are then able to be removed and reattached during the loading process to secure the Gaylords in place.

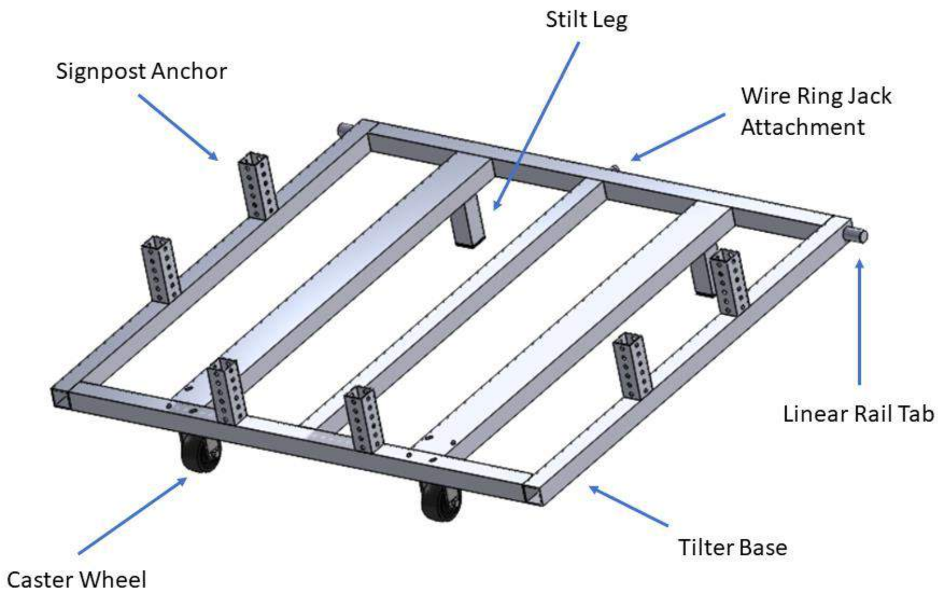

Figure 25. Secure System Base Plate

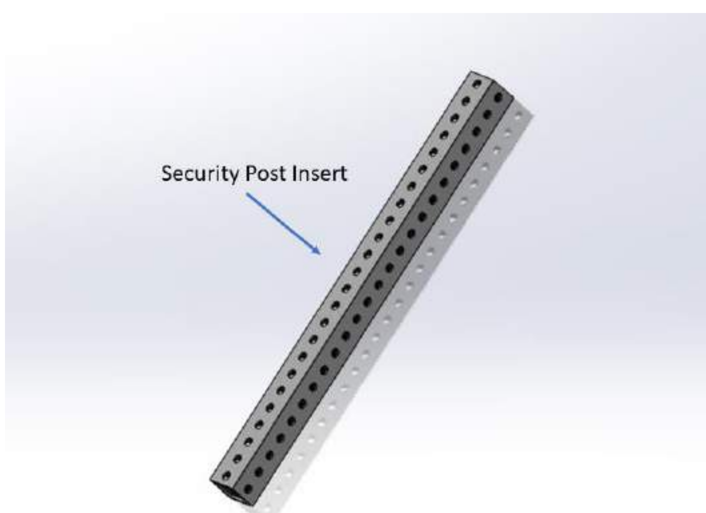

Figure 26. Secure System Rails

5.2 Base System Design

The base system is the most simplistic component of the design but has a key function for the overall functionality of the device. The base system will be constructed out of 2”x2” square steel tubing in a 61”x50”x10” cage configuration (see Figure 25) with steel U-channels attached to act as a track for the tilter sub system. The base frame also includes linear rails that the tilter base can be hooked on to in order to minimize the amount of horizontal force on the high lift jack. The base structure needs to be light enough for the device to remain portable while remaining strong enough to maintain a maximum load of 1000 lbs. Steel provided a good solution as it has competitive pricing compared to other metals while still meeting the necessary strength and rigidity requirements.

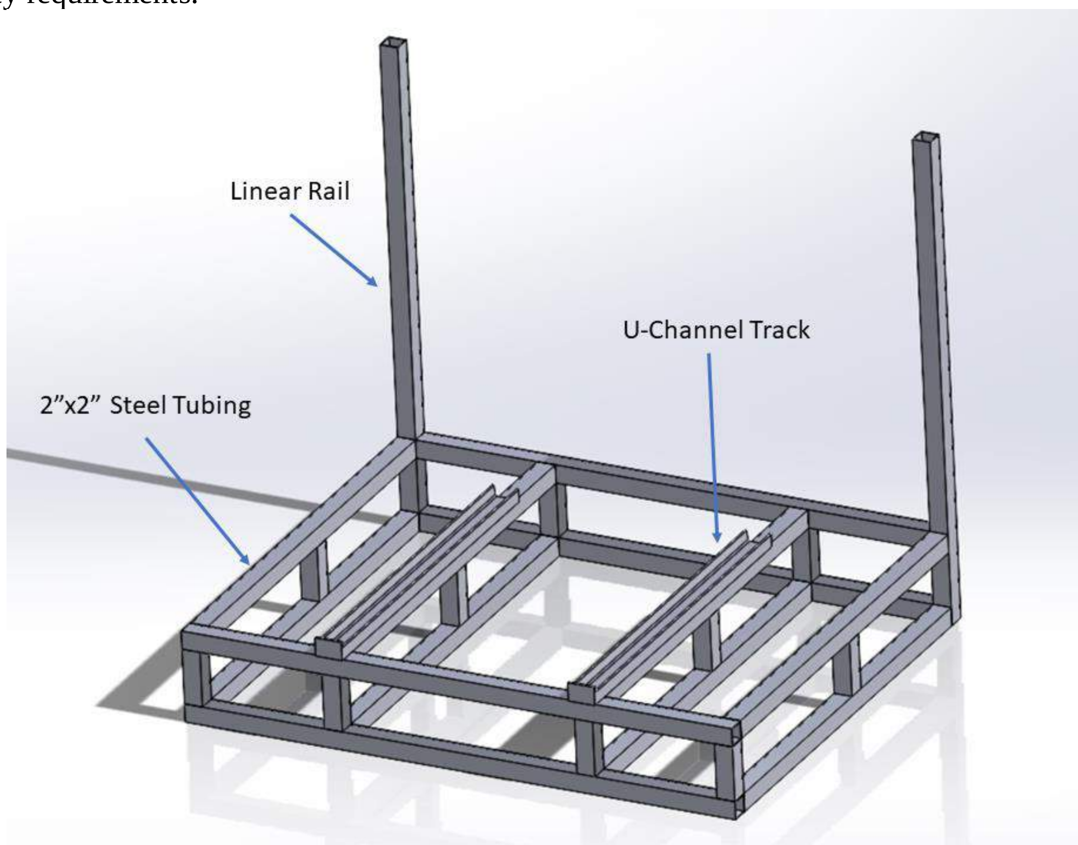

Figure 27. Base System Assembly

5.3 Lift System Design

The lift system serves the primary function of the device, tilting. A High Lift Jack with support is connected to the tilter base via an anchor ring. The jack is then able to lift the back side of the tilter base and Gaylord box up. The front of the tilter base will have wheels to allow for repositioning to allow the high lift jack to move straight up (See Figure 25.)

Figure 28. Lift System

5.4 Final Design Changes

During the summer of 2021 our team decided to continue to improve and adapt our design. Cost of steel during this time was over 20% inflated due to supply chain issues and we still had concerns about unskilled users operating the High Lift Jack. In order to decrease the cost of our product, we determined that the base frame was more economical compared to a fully steel system. Our initial wooden base frame is shown in Figure 28 below.

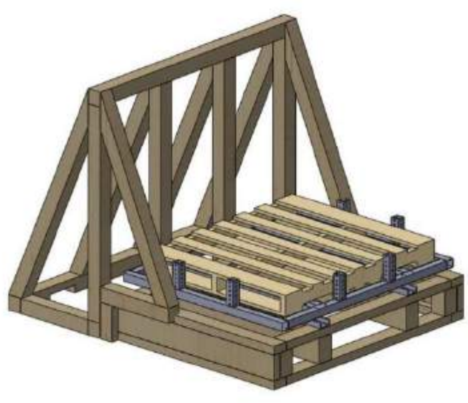

Figure 29. Initial Wooden Base Frame

For the lift system, we determined that minimal operating requirements would result in the fewest operating errors that could potentially result in harm to the users. Since the sponsors did not want to run wires to an outlet in the warehouse, a 40V battery was obtained to power an electric winch. The Badlands 3500lb winch would easily be able to tilt a full gaylord with on the press of a button. The design shown in Figure 28 required multiple 4”x4” posts but made it difficult to mount the winch and pulley wheel on. After consulting with a professional with years of experience in the construction industry, it became clear that the support could be drastically reduced without diminishing safety. After researching the strength of a single 4”x6” post, it was clear that one vertical post could easily support the required vertical compression and tension with the correct Simpson Strong Tie support. Figure 29. shows a table for Douglas-Fir Posts that was pulled from the Simpson Strong Tie Catalog.

Framing	Lumber		Perp. to Grain, $P_c\perp$	Compression Parallel to Grain, P_c (100)					Compression Parallel to Grain, P_c (160)				
				Nominal Top-Plate Height (ft.)					Nominal Top-Plate Height (ft.)				
	Size	Grade		8	9	10	11	12	8	9	10	11	12
4-Inch Wall	2x4	#2	3,280	3,170	2,565	2,105	1,755	1,485	3,345	2,665	2,170	1,795	1,510
	3x4	#2	5,470	5,285	4,275	3,510	2,930	2,475	5,570	4,440	3,615	2,995	2,520
	(2) 2x4	#2	6,565	6,340	5,130	4,215	3,515	2,970	6,685	5,330	4,335	3,590	3,020
	4x4	#2	7,655	7,395	5,985	4,915	4,100	3,465	7,800	6,215	5,060	4,190	3,525
	(3) 2x4	#2	9,845	9,510	7,695	6,320	5,270	4,455	10,030	7,995	6,505	5,390	4,535
	4x6	#2	12,030	11,540	9,360	7,700	6,425	5,430	12,215	9,745	7,935	6,575	5,535
	4x8	#2	15,860	15,090	12,270	10,105	8,440	7,140	16,035	12,805	10,435	8,650	7,285
	4x10	#2	20,235	19,080	15,555	12,835	10,730	9,085	20,365	16,285	13,280	11,015	9,280
6-Inch Wall	2x6	#2	5,155	8,970	7,940	6,935	6,025	5,235	11,030	9,230	7,740	6,535	5,575
	3x6	#2	8,595	14,945	13,235	11,560	10,040	8,725	18,385	15,380	12,895	10,895	9,290
	(2) 2x6	#2	10,315	17,935	15,885	13,875	12,050	10,470	22,060	18,455	15,475	13,075	11,145
	4x6	#2	12,030	20,925	18,530	16,185	14,060	12,215	25,735	21,530	18,055	15,255	13,005
	(3) 2x6	#2	15,470	26,905	23,825	20,810	18,075	15,705	33,090	27,685	23,215	19,610	16,720
	6x6	#1	18,905	25,260	23,500	21,505	19,415	17,375	34,255	30,035	26,025	22,475	19,450
	6x8	#1	25,780	34,450	32,045	29,320	26,475	23,690	46,715	40,955	35,485	30,645	26,520

Figure 30. Post Allowable Compression Loads for Douglas-Fir-Larch

This realization allowed our updated final design to utilize less timber which reduced the floor area and weight of our design. The final design placed utilized four 4x6 posts for the base frame. As shown in the Figure 31 below, three of the 4x6 posts run parallel to the ground. The Two outside posts act as channels for the secure system to roll on, and the middle post protrudes out the back to support the vertical post and mount the winch and pulled wheel.

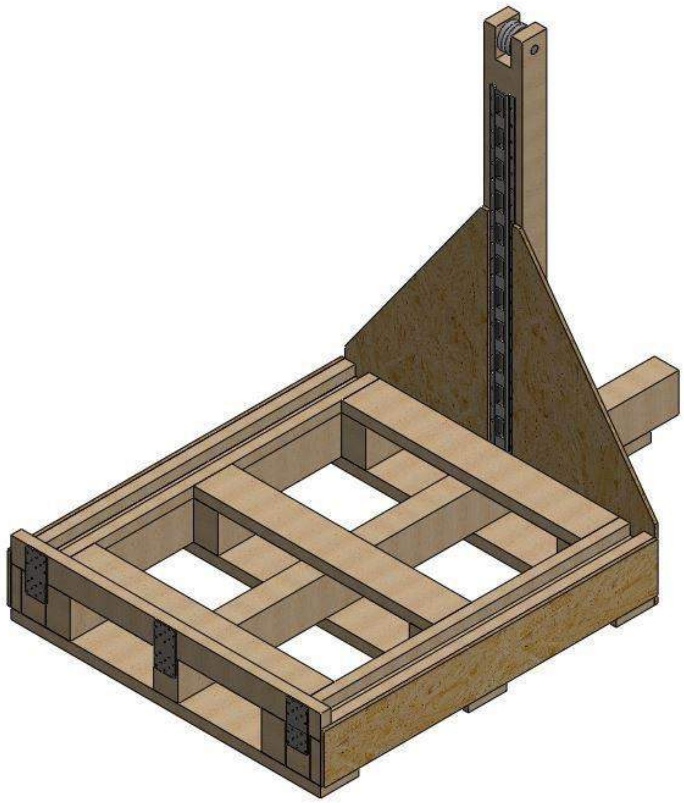

Figure 31. Updated Final Design of Base Frame (Winch is not shown in this Base Frame Assembly)

The vertical 4x6 beam is secured from horizontal motion by two ½" plywood pieces that are screwed into the vertical beam. On the back of the vertical beam is a HTT Tension Tie that supports the beam along the direction of the 4x6 beam in the middle that sits underneath the vertical beam. Figure 32 shows the full assembly from the rear where the winch is mounted. The HTT Tension Tie is shown clearly from this view. On the top and bottom of the vertical beam is a rectangular groove that mounts perfectly over the 4x6 on top of the 2x4 where the pulley is mounted. On top of the vertical beam is a DELRIN Wheel that was manufactured from a cylinder of DELRIN using a Lathe at the machine shop.

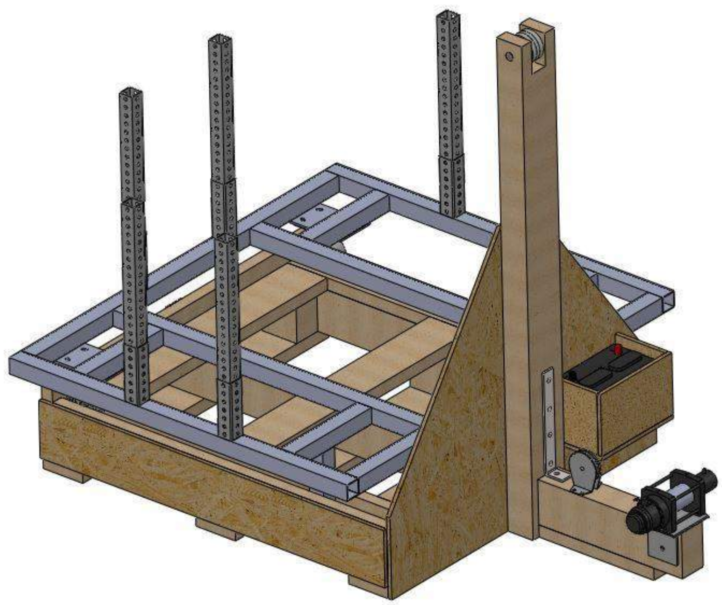

Figure 32. Rear View of the Full Assembly

This new base frame was only 4 feet wide and had a maximum length of 6 feet. The vertical post is 5 feet tall. The secure system is 8 inches wider than the base frame on each side for a maximum width of 57”. The total weight of the secure system is 150.4 lbs. and the total weight of the base frame with the winch and battery is 211.7 lbs. The entire system has a minimum factor of safety of 1.5 and was successful throughout multiple load and tilting tests that were well above the maximum Gaylord Box weight. Testing is discussed in Chapter VII. Design Verification.

VI. Manufacturing

6.1 Part Procurement and Budget

Below, in Table 6.1, we have the indented Bill of Material submitted to our sponsor, that lists the necessary materials by assembly. The sources we purchased each material from are listed under the Source column towards the right of the table; most items were purchased directly from Home Depot, McCarthy Steel, and Harbor Freight in or near San Luis Obispo, with other items being ordered online from NAPA Online, Amazon, and McMaster-Carr. Our design was luckily compatible with the 20-foot segments that were offered by McCarthy Steel, and we were able to keep scraps and costs low, but the lumber purchased from Home Depot left us with much more wasted material. Our extensive design changes, most notably changing the base system to be composed of wood strengthened with Simpson Strong Ties, allowed us to go under our sponsor's budget, which was estimated at $2,000.

Table 3. Indented Bill of Materials

W25 Gaylord Tilter

Indented Bill of Material (IBOM)

Level	Number		Descriptive Part Name	Qty	Cost	Total Cost	Part Source	More Info
0	100000	[illegible]						
1	110000		Base Assembly					
1	111000		2x4 x 8'	1	$ 6.60	$ 6.60	Home Depot	[illegible]
1	112000		4x6 x 10'	1	$ 30.00	$ 30.00	Home Depot	[illegible]
1	113000		4x6x12'	1	$ 35.00	$ 35.00	Home Depot	[illegible]
1	114000		2x6 x 8'	7	$ [illegible]	$ [illegible]	Home Depot	[illegible]
1	115000		1/2" Plywood 4'x8' sheet	1	$ 18.44	$ 18.44	Home Depot	[illegible]
1	116000		#9 x 4 in. General Purpose Screws (1 lb. pack)	1	$ 7.98	$ 7.98	Home Depot	[illegible]
1	117000		#9 x 3-1/2 in. General Purpose Screws (1 lb. pack)	1	$ 7.98	$ 7.98	Home Depot	[illegible]
1	118000		#8 x 1-1/4 in. #2 Philips, Wafer Head Wood Screw (100-Pack)	1	$ 11.53	$ 11.53	Home Depot	[illegible]
1	119000		#10 x 1-1/2 in. 1/4 Hex Drive, Strong-Drive SD Connector Screw (100)	1	$ 14.74	$ 14.74	Home Depot	[illegible]
1	120000		1/2 in. x 4-1/2 in. Hex Zinc Plated Lag Screw	1	$ 1.48	$ 1.48	Home Depot	[illegible]
1	121000		3/8 in. x 6 in. Hex Head Bolt, GR8	2	$ 1.75	$ 3.50	Tractor Supply Co.	[illegible]
1	122000		3/8 in. nut, GR8	2	$ 0.30	$ 0.60	Tractor Supply Co.	[illegible]
1	123000		3/8 in. Washer, GR8	2	$ 0.20	$ 0.40	Tractor Supply Co.	[illegible]
1	124000		7/16 in. x 6 in. Hex Head Bolt, GR8	2	$ 1.47	$ 2.94	Tractor Supply Co.	[illegible]
1	125000		7/16 in. nut, GR8	2	$ 0.29	$ 0.58	Tractor Supply Co.	[illegible]
1	126000		7/16 in. Washer, GR8	2	$ 0.18	$ 0.36	Tractor Supply Co.	[illegible]
1	127000		1/2 in. x 6 in. Hex Head Bolt	1	$ 1.78	$ 1.78	Tractor Supply Co.	[illegible]
1	128000		1/2 in. nut, GR8	1	$ [illegible]	$ [illegible]	Tractor Supply Co.	[illegible]
1	129000		1/2 in. Washer, GR8	1	$ 0.21	$ 0.21	Tractor Supply Co.	[illegible]
1	130000		1 in. x 8 in. Hex Head Bolt, GR8	1	$ 5.50	$ 5.50	Tractor Supply Co.	[illegible]
1	131000		1 in. nut, GR8	1	$ 2.00	$ 2.00	Tractor Supply Co.	[illegible]
1	132000		1 in. Washer, GR8	3	$ 0.98	$ 2.94	Tractor Supply Co.	[illegible]
1	133000		2 in. x 1-1/2 in. x 3-1/4 in. ZMAX Galvanized Angle	12	$ 0.85	$ 10.20	Home Depot	[illegible]
1	134000		HTP 3 in. x 7 in. ZMAX Galvanized Heavy Tie Plate	3	$ 2.41	$ 7.23	Home Depot	[illegible]
1	135000		HTT 16 in. 11-Gauge Galvanized Heavy Tension Tie	1	$ 10.33	$ 10.33	Home Depot	[illegible]
2	140000		Lift System (Attached to Base System)					
2	141000		ZXR 3500 lb. ATV/Powersport 12V Winch With Wire Rope	1	$ 189.55	$ 189.55	Harbor Freight	[illegible]
2	142000		NAPA 40 Battery [illegible] 450 A Wet	1	$ 104.99	$ 104.99	NAPA Online	[illegible]
2	143000		12V/24V Smart Battery Charger	1	$ [illegible]	$ [illegible]	Amazon	[illegible]
2	144000		Tuf-Tug - 3 in. Flat Mount Block 5/16 in.	1	$ 24.99	$ 24.99	Tractor Supply Co.	[illegible]
2	145000		Lynx Battery Box, Small	1	$ 21.99	$ 21.99	Tractor Supply Co.	[illegible]
2	146000		5 ft. Vertical E-Track Rail	1	$ 19.99	$ 19.99	Harbor Freight	[illegible]
2	147000		E-Track Tie-Down Anchor	1	$ 5.99	$ 5.99	Harbor Freight	[illegible]
2	148000		4 in. Diameter x 2 in. width Delrin Ring	1	$ -	$ -		
2	149000		Deka Quick Clamp Battery Terminals	1	$ 7.66	$ 7.66	Autozone	[illegible]
3	150000		Secure Gaylord					
3	151000		Food Industry Casters with Phenolic Wheels	2	$ 57.79	$ 115.57	McMaster	[illegible]
3	152000		20' Steel tubing	2	$ 131.00	$ 262.00	McCarthy Steel	
3	153000		Steel Bolt-Together Framing and Fitting	1	$82.24	$ 82.24	McCarthy Steel	
3	[illegible]		Galvanized Bolt-Together Framing	1	$146.02	$ 146.02	McCarthy Steel	
3	[illegible]		Heavy-Duty Wire Ring in Black	1	$ 9.97	$ 9.97	Home Depot	[illegible]
3	125000		3/8 in. Stainless Steel Quick Link	1	$ 9.98	$ 9.98	Home Depot	[illegible]
3	134000		Pin for Telescoping Tubing	6	$1.62	$ 9.72		
3	[illegible]		3/8 in.-24 tpi Yellow Zinc-Plated Grade 8 Hex Nut (2-Piece per Bag)	8	$1.70	$ 13.60	Home Depot	[illegible]
3	136000		1/2 in. x 25 ft. Double Braid Nylon Rope	1	$29.98	$ 29.98	Home Depot	[illegible]
[illegible]	137000		3/8 in.-24 tpi Yellow Zinc-Plated Grade 8 Hex Nut (2-Piece per Bag)	8	$0.92	$ 7.36	Home Depot	[illegible]
	Total Parts			97		$ 1,378.54		
			Total Cost + 10% Sales Tax			$ [illegible]		

6.2 Manufacturing Process

Below outlines the tasks completed in each step of the manufacturing process. This includes cutting and preparing all raw materials and joining, fastening, and assembling all sub-assemblies.

CUTTING

Wood

- 4x6
  - Mark out 1 length of 72 inches and cut with band saw.
  - Mark out 1 length of 60 inches and cut with band saw.
  - Mark out 2 lengths of 48 inches and cut with band saw.
  - Mark out 6 lengths of 5.5 inches and cut with band saw.
- 2x6
  - Mark out 4 lengths of 44.5 inches and cut with band saw.
  - Mark out 6 lengths of 5.5 inches and cut with band saw.
  - Mark out 3 lengths of 34 inches and cut with band saw.
- 2x4
  - Mark out a length of 24 inches and cut with band saw.
- 2x2
  - Mark out 4 lengths of 46.5 inches and cut with band saw.
- Smooth any edges with belt sander
- Plywood
  - Cut section:

Metal

- 20' 1/8" Wall Thickness Steel Tubing
  - Mark out 2 lengths of 47 inches and cut with abrasive saw (steel)
  - Mark out 2 lengths of 51 inches and cut with abrasive saw (steel)
  - Mark out 2 lengths of 43 inches and cut with abrasive saw (steel)
  - Mark out 2 lengths of 6.5 inches and cut with abrasive saw (steel)
  - Mark out 4 lengths of 13 inches and cut with abrasive saw (steel)
- Belt sand ends to smooth out connections for later welding

Figure 33. Cutting Steel Tube with Abrasive Saw

- Steel Plate
    - Cut 2 sections of 8 inches by 9 inches of steel plate
- Steel Bolt Together Framing and Fitting
    - Two lengths of 58”
    - Mark out lengths of (Insert here) and cut with abrasive saw
    - Belt sand ends to smooth out connections for welding and ensure anchoring function can be achieved by sleeving the *Galvanized Bolt Together Framing.*

Figure 34. Steel Bolt Together Framing and Fitting Cutting Set-up

- Galvanized Bolt Together Framing
    - Mark out lengths of 6 inches and cut with abrasive saw.
    - Belt sand ends to ensure anchoring function through sleeving with *Steel Bolt Together Framing and Fitting* can be achieved.

Figure 35. Secure System Assemblage

Secure System (Tilting Base) Assembly

- Gather the following materials that were cut to length:
  - (Insert lengths of steel tubing and anchor posts here)
- Orient the materials listed above to match the mock-up pictured below in (Figure Number) and clamp to a table for welding.
  - (Insert assembly drawing of secure system with dimensional callouts, label which materials go where)

Figure 36. Secure System Welding Set-up

- (Insert welding instructions [what parts to what parts, possibly call out by assembly numbers, include weld specifications])
- Once initial frame setup is complete, tack weld the frame of the cage together to minimize shifting and ensure fit.

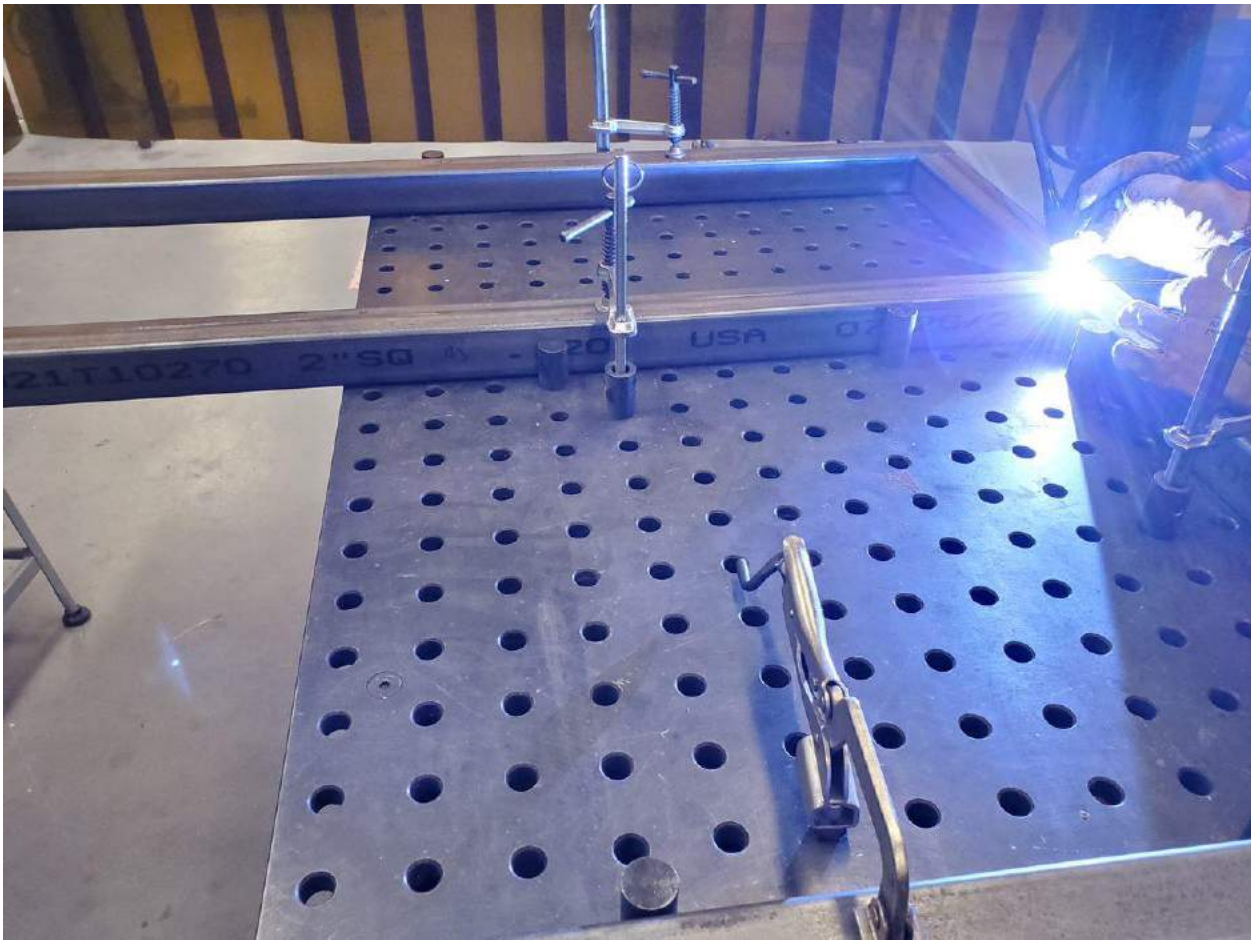

Figure 37. Secure System Welding

- Drill holes into 2 (length x width) steel plates as pictured below in (Figure Number)
    - (Insert Steel plate drawing)
- Weld (length x width) steel plate to “front” end corners
- Line up *Phenolic Wheels* with steel plate holes, screw and bolt to secure
- Weld WIRE RINGS IN BLACK to back section at: center

Base System Assembly

Wood Portion

- Gather the following materials that were cut to length and generally orient them as pictured in Appendix Fig. A.12
- At the bottom of the 60 inch vertical 4x6 post, cut a square U cut with the dimensions of 4 inches wide, 8 inches deep, for a press fit onto the center horizontal 4x6 section.
- At the top of the 60 inch vertical post, drill a 1 inch through hole at 1.75 inches down, and at the horizontal center of the section.
- Then cut a similar square U cut, this time with the dimensions of 3.5 inches deep, and 3 inches wide.
- Use wood glue to secure the wood cuts to each other, starting from the bottom and clamping them down for an ample amount of time (at least 30 minutes to allow setting, ideally 24 hours for complete load bearing setting)
- Place Simpson Strong Ties at key points of design to reinforce connections, and screw the assembly together

Figure 38. Drilling Screws into Bottom of Base System

DELRIN Pulley Wheel

- Cut a 2 in. length section of 3.5 in. diameter DELRIN cylinder
- Clamp DELRIN cylinder down into Mustang 60 Machine Shop lathe
- Face both sides of the DELRIN cylinder for aesthetic finish and smoother clamping to lathe
- Drill 1 in. Hole into center of DELRIN Cylinder (Center marked out as best as possible with intersection of perpendicular bisecting lines of straight lines from edges)
- Groove a 3/8 in. Wide and 3/8 in. Deep triangle V-groove into center of circular face of DELRIN cylinder (This was done by using a perfect triangle edge not meant for grooving, but performed perfectly with tap-grooving with a low RPM due to the softness of the DELRIN)
- One challenge we ran into was the axle shaft that fits into the DELRIN cylinder being slightly larger than the nominal 1 in. (it was larger by .06 inches). This was remedied by boring the inside of the drilled hole in the DELRIN cylinder with passes of .02 inches at a time until the shaft fit in a loose press fit that allowed the wheel to spin.
- Slot DELRIN wheel into vertical 4x6 post, then pass 1 in. Diameter axle shaft through the lined up holes drilled into both the 4x6 post and DELRIN wheel. Use J-B Weld KWIKWELD Epoxy to secure the wood to the axle shaft so the wheel can spin without wearing down the wood.

Finishing Base System

- Screw and bolt Winch Mounting Plate atop back end of horizontal center 4x6
- Screw and bolt Winch onto Winch Mounting Plate

FULL SYSTEM ASSEMBLY

- Sit Secure system atop base system so that wheels go into the channels on either side of the base system, and the back posts under the secure system sit atop the back beam of the base system
- Run winch metal wire over the DELRIN wheel, then secure to back of secure system

- Add additional nylon rope connections from either side of back edge of secure system to metal wire connection point.
- Mount solenoid and battery in connection to Winch
- Connect wired Remote to Winch
- Cover winch, moving wire, and pulley areas

6.3 Recommendations for Replication

This verification prototype was manufactured under time constraints for both materials acquisition and manufacturing, and many changes were considered without being implemented. For example, the DELRIN cylinder used as a pulley wheel can be replaced with a prefabricated pulley with a sufficient load capacity (2000 pounds and above) for easier manufacturing.

When manufacturing the secure system and welding the rail anchors into place, be sure to firmly clamp the rails onto the bars of the cage in order to ensure that there is no leakage of the weld in the inside of the anchors. Failure to do so can result in spillage around the inner perimeter of the anchor, creating an uneven surface and resulting in the rail inserts sitting at the incorrect height.

VII. Design Verification

The following section describes the measurements taken of the design's performance in regard to the specifications set in Appendix A.

7.1 Design Structural Integrity

One of the main concerns of the design was the safety of all personnel working with the device, and before any improvements on safety in the design could be made, the design must first be able to safely support the mass it is meant to. The prototype was tested with the weight of a full Gaylord box (600 lbs.), approximated at 900 lbs., with a factor of safety of two and one and a half for load testing and performance testing, respectively.

The load testing of the prototype was done for the Secure System alone first, incrementally raising the load up to 1200 lbs. The full prototype assembly was tested next, with 1200 lbs. being placed incrementally onto the Secure System sitting atop the Base System. Throughout the load tests, no strain or deformities were observed.

Figure 39. Drilling Screws into Bottom of Base System

The performance test of the prototype was performed by operating the prototype under incrementally increasing loads up to 900 lbs. The tests went smoothly, with the prototype comfortably tilting the loads stably, and operation of the prototype went as expected.

Figure 40. Drilling Screws into Bottom of Base System

There was an observation that the lower pulley has minor movement, in which a horizontal pulling towards the winch was observed. This was due to the wood compressing under a large angled force on the base of the pulley wheel. A metal plate could be placed under the pulley wheel so that the downward force could be distributed more evenly on the 4x6.

7.2 Design Efficacy

The prototype's use efficacy was tested in terms of forklift compatibility. For forklift compatibility, the designed use cases of moving the prototype via forklift, and loading the Secure System via forklift from both the front and sides were tested. The forklift was able to pick up, move in all directions, and set down the prototype without additional securing.

Figure 41. Drilling Screws into Bottom of Base System

The loading tests went just as smoothly, with the forklift loading an empty pallet into the Secure System from the front and sides with no issue. At one point the pallet caught on the securing bars

during the process of being lowered into the Secure System, but this was immediately noticed and corrected, increasing our confidence in the design's safety during actual operation.
Other planned tests, designed to test produce damage levels during operation, increases in produce removal efficiency, and other volunteer involved testing was unable to be completed due to complications in build completion and acquisition of a Gaylord box.

VIII. Project Management

8.1 Cost Analysis

With the design changes implemented, the total cost for the new design came out to *$1,513.75*, lower than our originally estimated final cost of about *$2,000*. The parts were sourced through physical locations, at Home Depot, Harbor Freight, and McCarthy Steel whom sourced the steel tubing for the Secure System, and online, at McMaster-Carr, Amazon, Harbor Freight, and NAPA Online. Wood and steel sources were compared to find the best cost for the sections that were to be cut. The costliest purchases were the steel tubing in the Secure System, the winch and winch accessories such as the car battery to power it, the various wood sections, and the Simpson Strong-Ties used to secure the Base System and its attached components such as the winch and pulleys. The project was able to be completed well within the sponsor's estimated budget of *$2,000*.

8.2 Design Process

Our design process followed the traditional designs steps of definition, ideation, prototyping, and testing. The total process spanned over three quarters following Cal Poly's academic calendar for winter 2021, spring 2021, and fall 2021.

Our first step was identifying the problem definition and the customers' needs and wants. We accomplished this through conducting background research to gain an understanding of the market and similar existing designs across different industries. We also created a specified problem statement and composed a list of customer needs/wants along with the engineering specifications our project must meet.

The next step of the process was to develop several concepts through the use of different ideation techniques and select a few of the concepts we would like to move forward with. We then built concept models of our chosen designs in order to benchmark them against one another and see which design best fits the specification criteria and offers the best solution to our problem. This selection process required the use of techniques such as decision matrices as well as further communication with our sponsor and ultimately the consumers of our final design. Table 3 shows key deliverable dates throughout or senior project.

Table 3. Key Deliverables

Key Deliverables	Due Date
Scope of Work	2/4/2021
Concept Prototype	2/23/2021
Preliminary Design Review	3/4/2021
Interim Design Review	4/8/2021
Critical Design Review	5/6/2021
Manufacturing and Test Review	6/3/2021
Senior Expo	11/18/2021
Final Design Review	12/2/2021

The final prototype was the result of a redesign due to issues with the prototype of the final design as of the Critical Design Review, in June 3rd, 2021. Specifics of tasks completed for this project can be seen in the Gantt Chart in Appendix B. With the Verification Prototype completed, and the Senior Project Expo finished, the W25 Gaylord Produce Removal Machine Project concluded with the submission of the Final Design Review.

IX. Conclusions and Recommendations

The objective of the project was to develop a device or system to assist volunteers at the Alameda County Food Bank to remove loose produce from Gaylord boxes in an ergonomically friendly and efficient manner. We researched customer needs, previous solutions, and technical requirements to fully understand the customer base and problem. From this research, we developed lists of customer requirements and engineering specifications for our design and used this to iterate a list of designs from which we chose our final concept. After prototyping and testing of this design, we implemented key design changes for a safe, practical, and user-friendly final design.

Due to budget and time constraints, our verification prototype has several key recommendations for a safer and smoother user experience. First and foremost, an automatic hoist, although pricier, has a safer failure mode than the automatic winch used in the prototype. Where the winch's catastrophic failure engages a drum break that is not meant to support hanging loads and could result in the line free spooling, a hoist would hold up the load even in failure. Additionally, the wire rope used to connect the secure system to winch line is strong enough for the load, but the cable connectors securing the wire rope to the wire rings on either side of the back end of the secure system are not designed to suspend loads, thus a similar wire rope with connectors at either end, or a simple chain link would be more reliable options for this component. The lower pulley directly in front of the winch is bolted through the horizontal base post, which braces it against vertical forces, but not against the horizontal components of the forces it experiences. Remedies for this issue include additional bracing or tilting the winch to have the line out be oriented straight towards the DELRIN pulley.

With the submission of our Final Design Review marking the end of this project, our team has been pleased to work with our faculty coach Eileen Rossman, our sponsors Leif Magnuson and Marcos Trujillo, and everyone who aided in the completion of the project.

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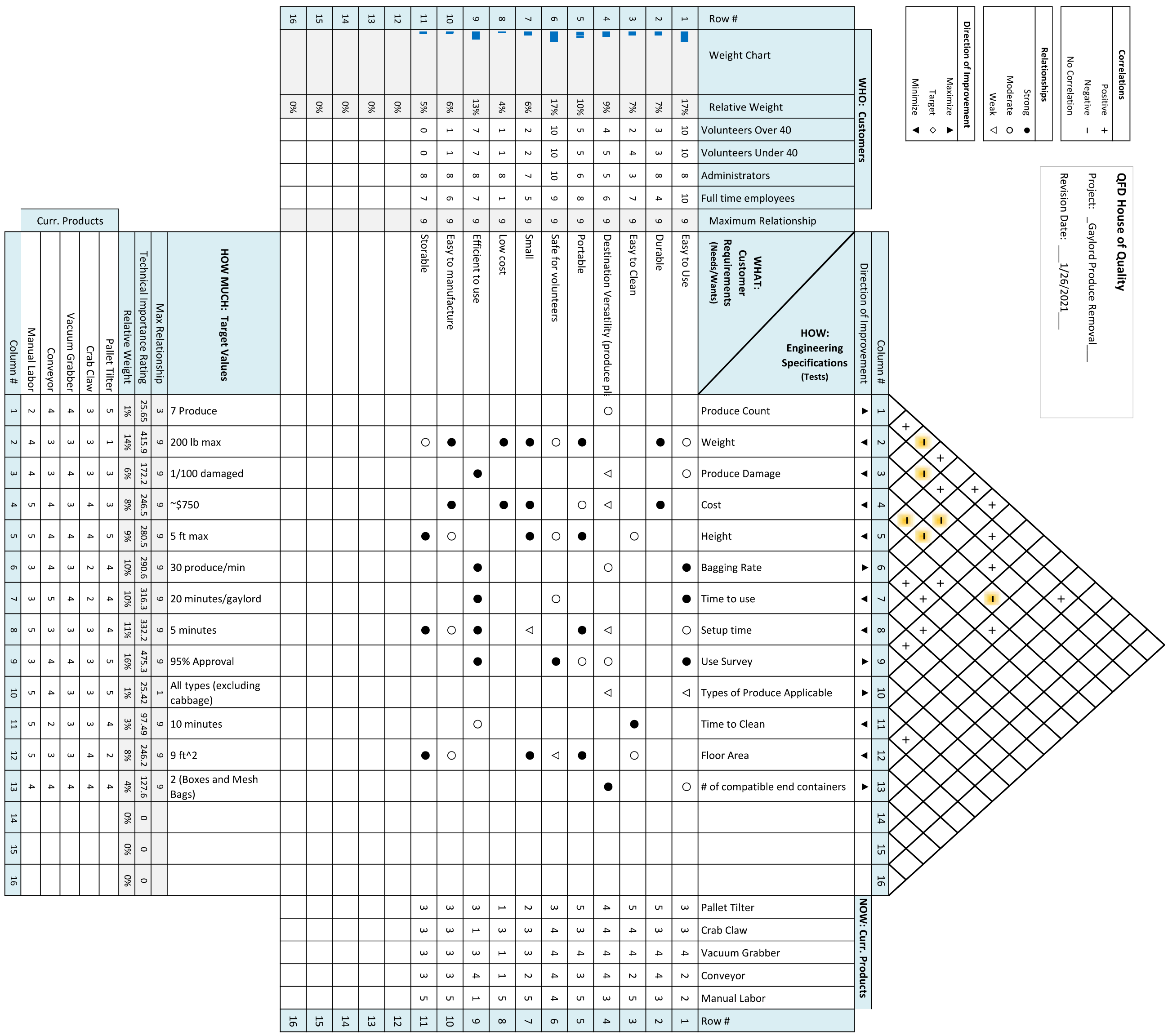
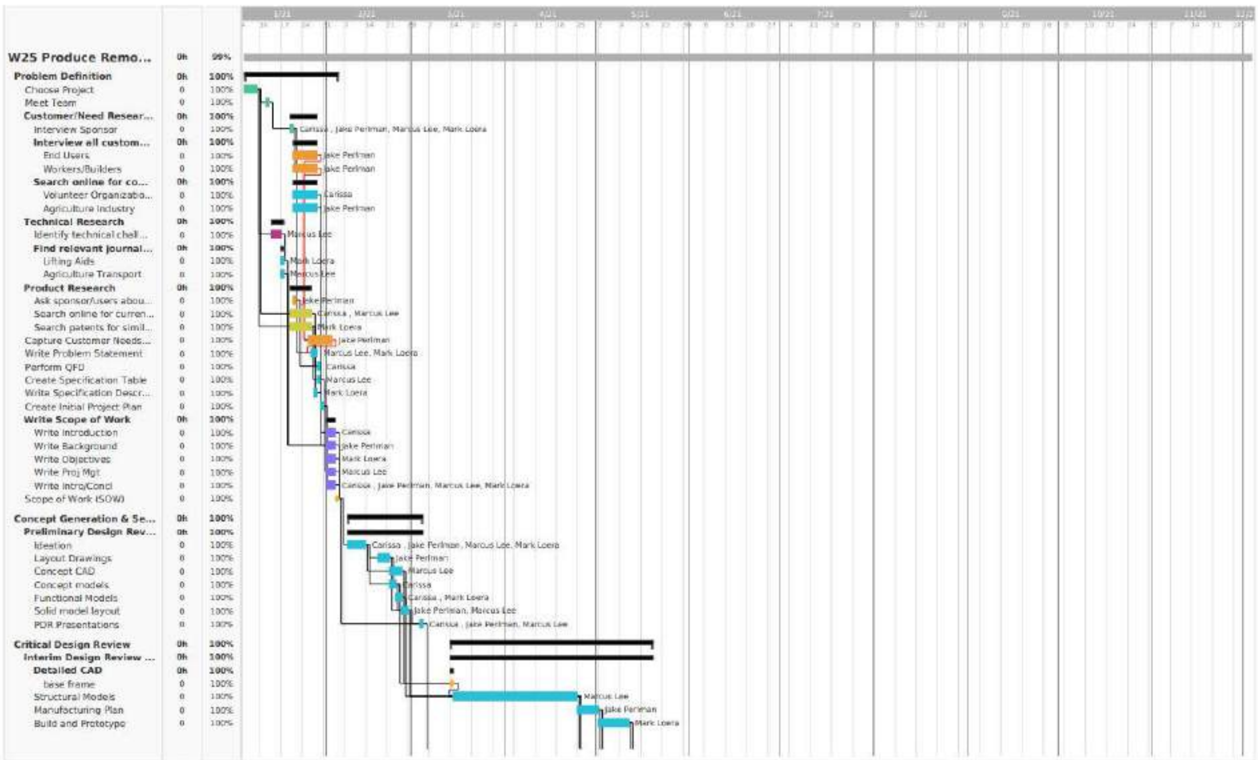
-All subsequent Figures taken or produced by team members.

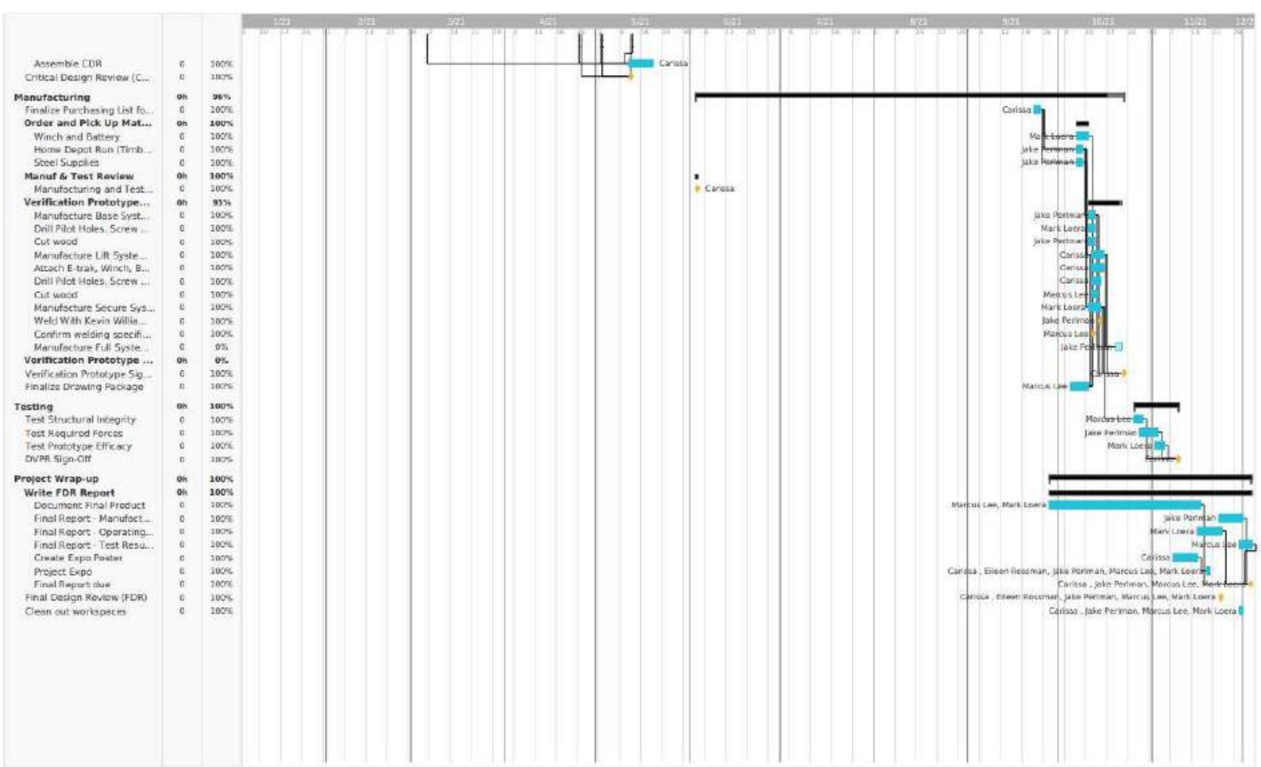
VII. Appendices

Appendix A: QFD House of Quality



Appendix B: Gantt Chart





Appendix C: Existing Patents

Patent Name	Patent Number	Description
Tiltable Portable Pallet	CA2189403C	• Pallet capable of being alternately lifted and tilted • Fits onto forklift prongs • Also has wheels and handle to manually move
Pallet Jack with Independently Elevatable Fork Arms	US7744335B1	• Pallet jack with elevating fork arms • Able to lift loaded pallets • Fork prongs move independently, allows pallet to be tilted for balance
Mechanical Produce Harvester with Gathering Belts	US9861037B2	• Includes chassis, cutting device, and transport assembly • Transport assembly has movable belts with produce grippers • Moves produces quickly
Automatic Fruit and Vegetable Packaging Machine	CN211593083U	• Motorized Packaging Machine • Electric lift, feeding plate, and grabbing plate • Feeds produce into bags automatically
Suction Lifter	US2247787A	• Suction cup that attaches to object • Movable crane arm • Adjustable relative pressures

Appendix D: Ideation Models

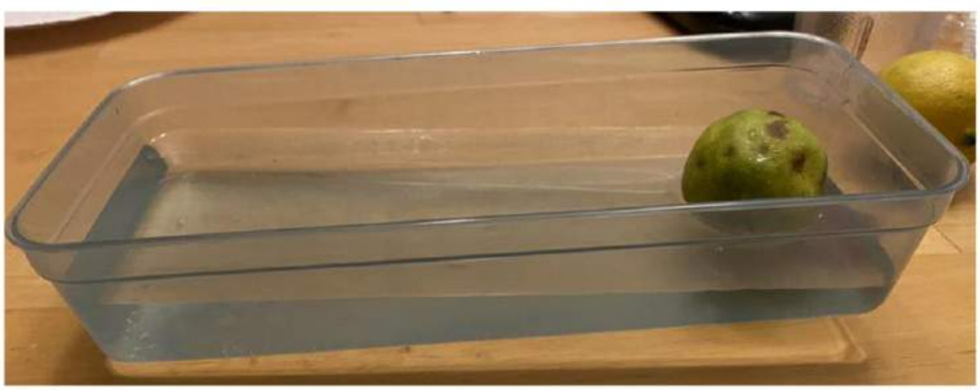
ME 428 Ideation Models

1. Vacuum Lift

This ideation model is simply a vacuum picking up a lemon. The concept is for lifting the fruit out of the Gaylord boxes. I wanted to see if it was feasible for a vacuum lift method to work. From testing this, I was able to find that the vacuum is able to lift fruit, at least lemons, extremely easily.

2. Fruit Water Canal

This concept model is of a form of water canal which would, in practice, transport fruit by slowly propelling water. In my model, I just used gravity to let the fruit roll down the canal. The benefit of this concept, as opposed to a ramp, is that the water slows the fruit's movement and would help prevent damage or bruising to the produce.

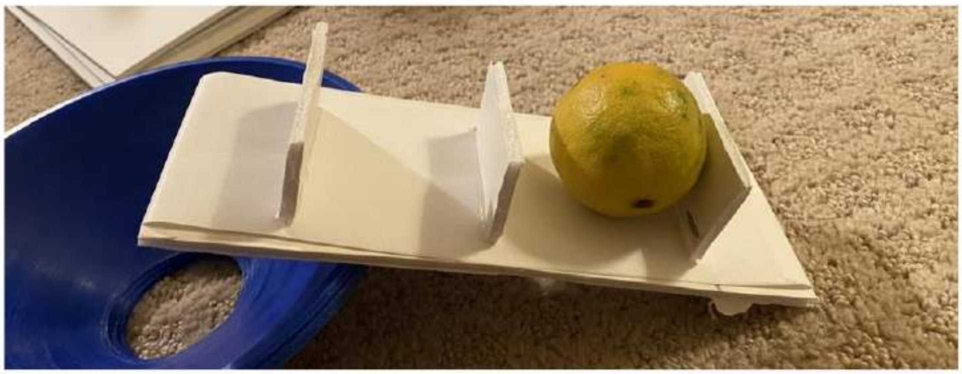


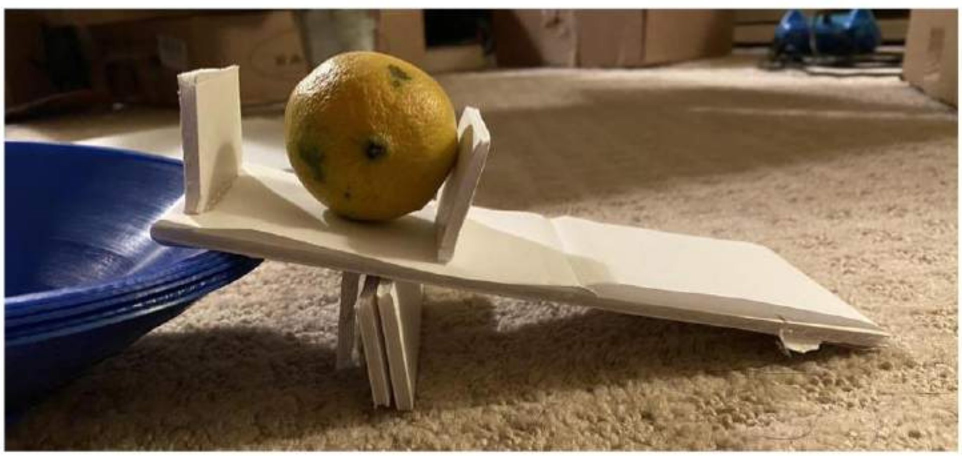
3. Scissor Lift to Tilt

This model is of a scissor lift mechanism to lift one edge/side of the Gaylord box, so the produce is more easily accessible to be removed. The first image shows the box before it is tipped, and the second image shows it after. I think this is definitely a viable option, although it is also possible to tilt the box using other methods, like a form of jack.

4. Conveyor Belt

This concept model is a possible method of both removing fruit from the Gaylord box and moving the fruit to the bags and boxes. The actual device would be much larger and able to lift much more produce at once. The images below depict the conveyor mechanism moving and lifting a lemon into a funnel device, which could potentially be used to drop produce into a bag or box.





5. Teeter Totter Mechanism

This concept is a teeter totter-like mechanism which would go inside the box underneath the produce and be tilted at an angle so when the box is tilted, the mechanism forms a ramp which leads all of the produce to the front of the Gaylord box. This concept would be very helpful; however, it would be difficult to implement it as a device which sits under the produce, as the produce is already in the containers in bulk before coming to the warehouse.

(Above) 1. A gaylords tilter with the support beams across the diagonals of the box. The tilter stays at one height at one corner, and tilts the other corner to various heights to tip the produce within the box.

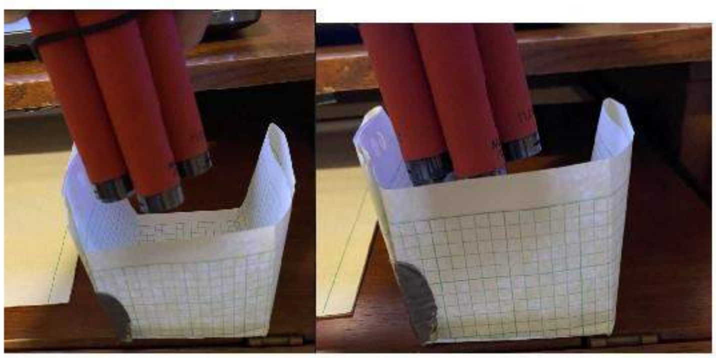
(Above) 2. For combined use with tilting or other forms of moving the gaylord itself. Supports to reduce damage and stresses to the box itself, and a grooved track to push produce up and towards corners and sides of the box for easier removal.

(Above) 3. A fishing rod style stick that is able to attach the mesh bags that the produce is placed in at the end. The stick can be secured for a mechanical advantage during its use, possibly after the user has already secured produce within the bag.

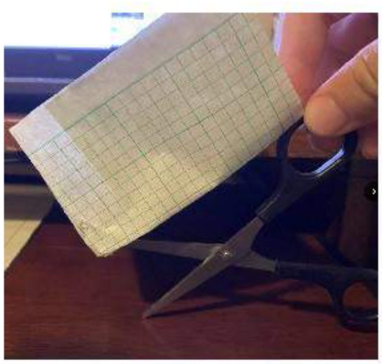
(Above) 4. An enclosure around the box, where the enclosure is filled with salt water so that the produce floats inside.

(Above) 5. The gaylords box is covered from above, with a vacuum pump attached above to vacuum the produce from within the box. Alternatively, the pump could be pushing air in to push produce out from another hole elsewhere.

1. Variable vacuum tubes: These vacuum tubes directly remove fruit from inside the Gaylord and move it outside into a bag or box.

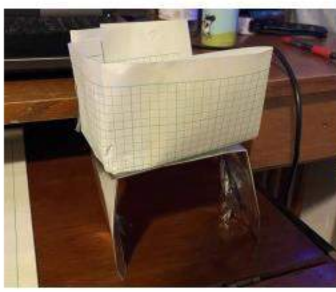
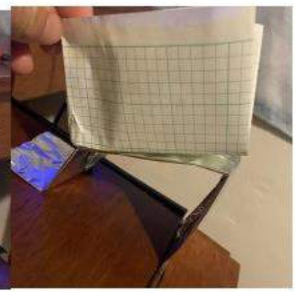


2. Scissor Lift: The scissor lift is offset to tilt fruit to one side to make produce removal more accessible

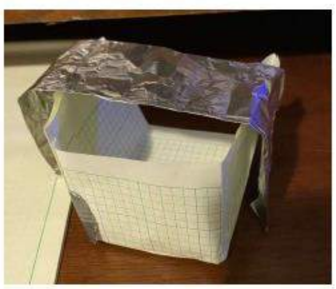


3. Attachable Conveyer belt: Fruit can be pushed onto conveyer belt to be removed without lifting fruit up. Adjustable height and depth.

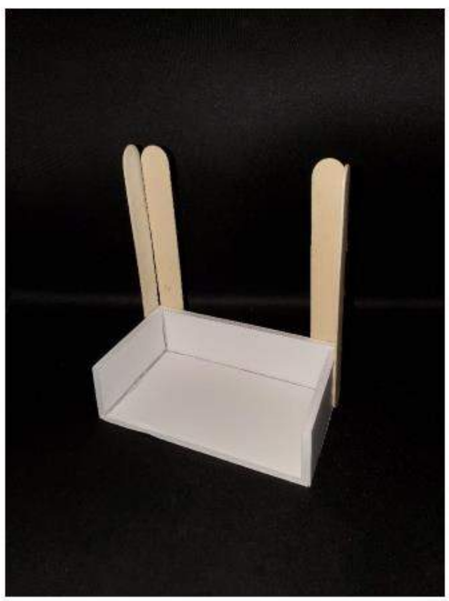
4. Variable platform to Tilt box: This platform holds the entire container and lowers one side as necessary.

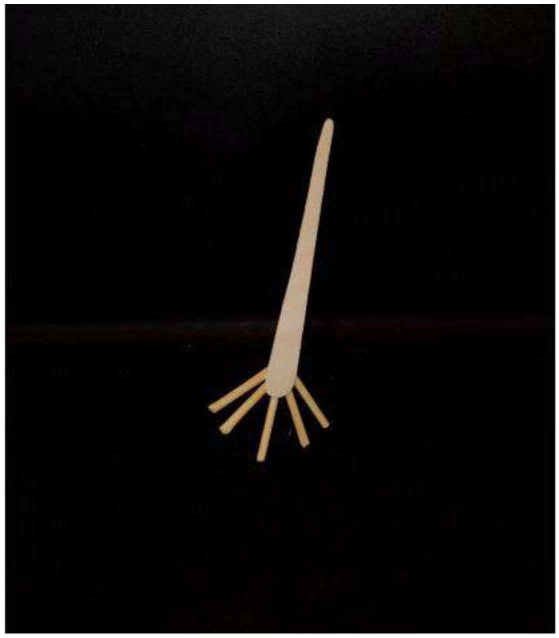
5. Platform to make picking fruit up easy on the back: this platform is for volunteers to lay/sit on so they do not have to bend over as much to reach fruit.



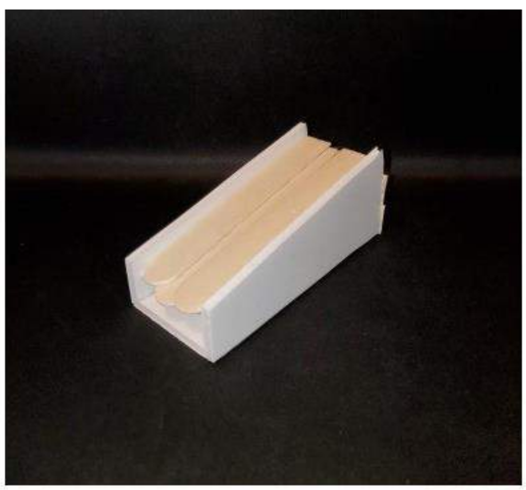
This ideation model is a hand held scooper to allow the volunteers to scoop out the produce at the very bottom of the Gaylord box without having to strain their backs by repeatedly bending over. The design includes very blunt edges to prevent the produce from being damaged. From this idea, I learned that the functions our design needs to address can be solved in many different ways, even if it is not what the sponsor originally asked for. This idea also made me think of other more simplistic devices that could help resolve current issues.



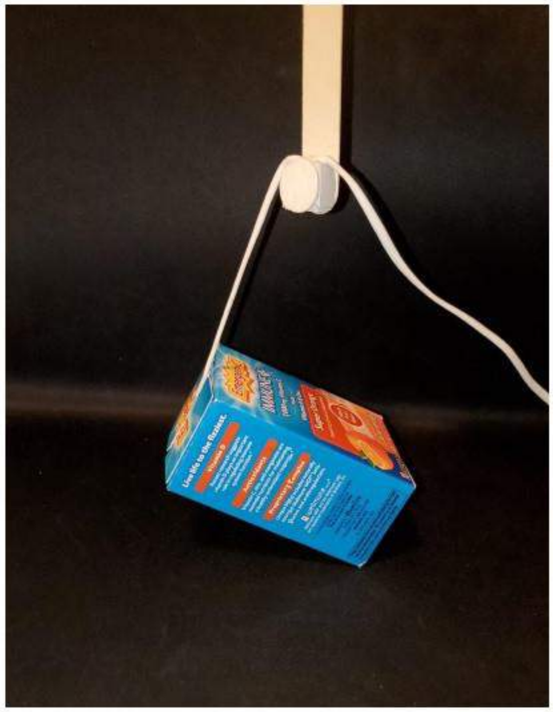
This ideation model is of a more creative idea to solve the produce removal problem. The model is rather rough, but the idea is that this automated device could be inserted into the Gaylord box and the stray produce at the bottom could be moved on top of the shelf (by tilting the box, using a broom, etc.) and then a small motor could move the shelf up along the rails (popsicle stick in model). This would alleviate the need to bend over to pick up the produce as the elevator like system would bring the produce to a height that is easier to access. I like the idea of an attachable device that could be stored and easily moved, while being a more imaginative solution to the problem.



This ideation model is of a rake-like device that would enable the volunteers to easily move the produce at the bottom of the Gaylord box to one side and possibly even use it against the wall of the box to pick up the produce fully. This is a simple design/concept but I wanted to create inexpensive ideas that would be readily available to the sponsor with a low manufacture time. If the sponsors like our final design, they may have multiple of the devices made in order to have them available at different food bank locations, so I think it is important to not over design the situation and create a final product that is effective and easy to manufacture.



This ideation model is of a produce chute that the volunteers could effectively empty the Gaylord box onto and have it funnel the produce onto a flat surface to be bagged without having to strain by reaching over into the Gaylord box. When discussing functions within our team, the idea of implementing a ramp like structure came up multiple times to perform functions such as moving the produce, picking the produce up, and bagging the produce. The initial ideas that were generated for this project were devices that picked up the Gaylord boxes or that placed inside of them; this idea made more external attachment devices be considered.



This ideation model is of a rope and pulley system that would attach to the Gaylord box (in the photo a blue Emergen-C box is used as a stand in for the Gaylord box) and allow the volunteers to tip the box to force the stray produce to one side of the box. This idea simplifies the solution as it would not require any forms of hydraulics or electricity to tilt the Gaylord box. This idea made more concepts of mechanical solutions to the problem rather than automated solutions that were commonly said in our team meetings.

Appendix E: Pugh Matrices

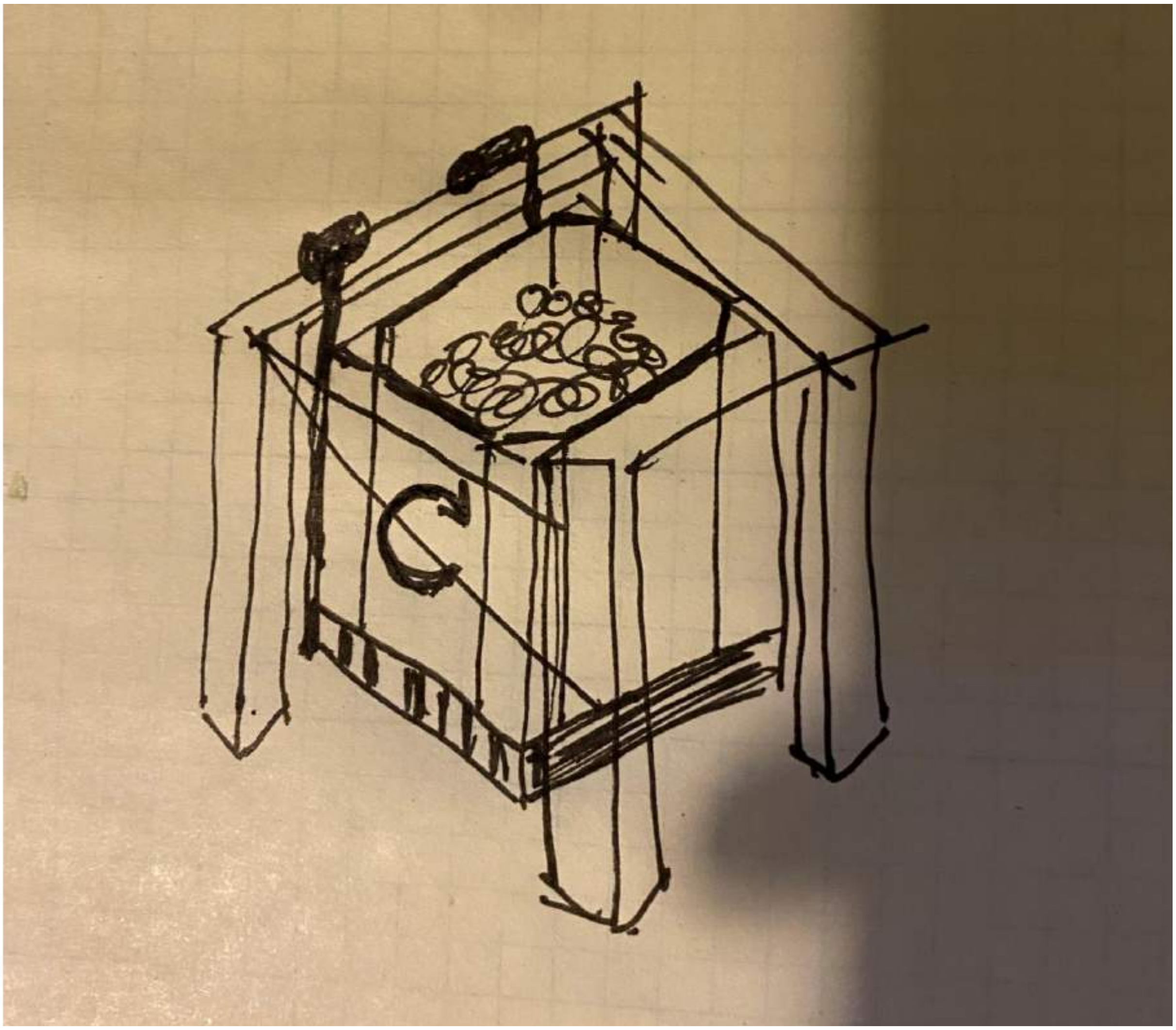
Tilting Gaylord Box Pugh Matrix:

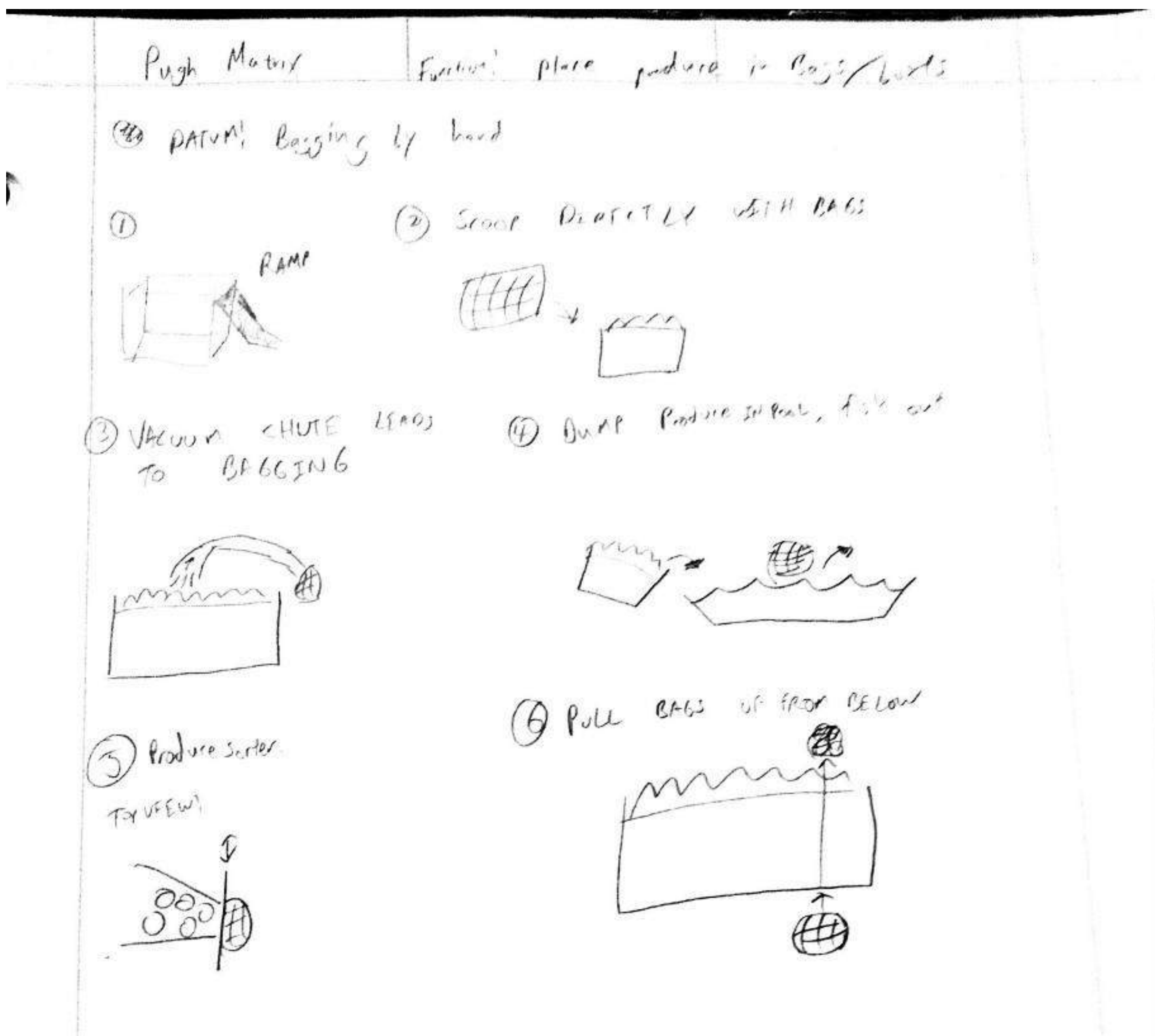
Criteria/Concept	Scissor Lift	Pulley Lift	Hydraulic Tilter	Ramp with increasing slope	Bottom swing system
Easy to Use	S	-	+	-	+
Durable	S	S	+	+	+
Destination Versatility	S	-	+	-	+
Safety	S	-	S	-	S
Size	S	-	S	-	S
Low Cost	S	-	-	+	-
Efficiency	S	-	+	-	+
Easy to Manufacture	S	-	S	+	S
Storable	S	-	S	-	-
TOTAL	0	-8	+3	-3	+3

Hydraulic Tilter is also an industry standard for dumping boxes. They can be connected to AC power and tilt heavy boxes like we need to. The challenge with this is damage to the produce and ability for volunteers to work with it.

(Above) 1. A gaylords tilter with the support beams across the diagonals of the box. The tilter stays at one height at one corner, and tilts the other corner to various heights to tip the produce within the box.

Bottom Swing system would be able to keep the box low to the ground and rotate it around the center of gravity of the box. Think about a camera stabilizer that purposefully moves the camera and the stabilizer stays still. This is the idea of the bottom swing system. It could require less energy than the hydraulic tilter and could be safer if it is lower to the ground




Pugh Matrix
DATUM: Bagging by hand
RAMP
2 SCOOP DIRECTLY WITH BAGS
3 VACUUM CHUTE LEADS TO BAGGING
4 DUMP
5 Produce sorter
6 PULL BAGS UP FROM BELOW

	CYHAND	1	2	3	4	5	6
- EASY USE	DATUM	S	S	-	-	+	S
- DURABLE		+	S	-	+	+	S
- WORKS WITH MULTIPLE KINDS OF PRODUCE		+	+	-	S	+	+
- PORTABLE		S	S	-	-	S	S
- SAFE FOR USER		+	-	+	+	S	F
- INEXPENSIVE		S	S	-	-	-	+
- EASY TO MANUFACTURE		+	+	-	+	-	S
- EFFICIENT		S	+	+	S	+	S
		4	2	-4	0	2	3

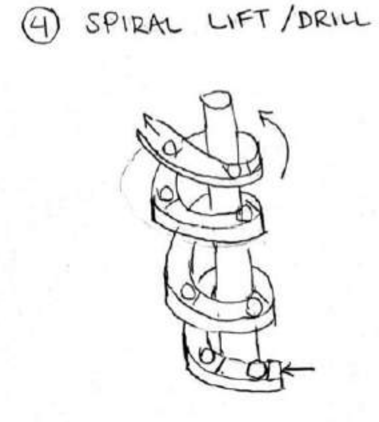
In this Pugh matrix, the datum was set to manual bagging by volunteers, the current method used at the Alameda County Foodbank. The solution with the most positives for implementation was the ramp system. The produce sorter is basically a ramp with added functionalities, so aspects of this should be incorporated as well, as they are the most compatible. Pulling bags through the gaylords box and scooping produce directly from the box are similar as well – they would both require additional support and modifications to the gaylords box, making them less easy to implement.

(Above) A ramp to guide produce to a bagging area or bags themselves.

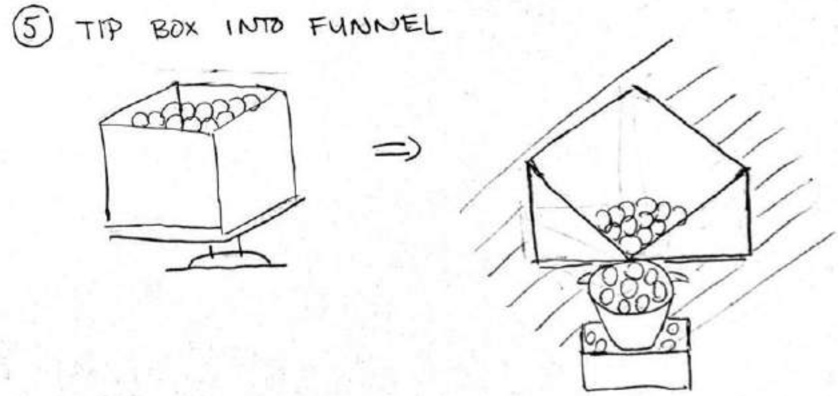
Pugh Matrix: Remove Produce from Gaylord Box

CONCEPT / CRITERIA	DATUM: CURRENT PROCESS (pick up by hand)	① scoop	② conveyor	③ vacuum	④ spiral/drill lift	⑤ tip box into funnel	⑥ claw grabber
easy to use	N/A	−	−	−	+	+	−
low cost	N/A	−	−	−	−	−	−
minimal produce damage	N/A	−	+	+	+	−	+
can lift different sized produce	N/A	+	+	−	+	+	−
easy to clean	N/A	−	−	−	−	−	−
efficient	N/A	+	+	+	+	+	−
TOTAL (negate low cost & easy to clean)		-0	2	0	+4 ★	2 ★	-2

Top Concepts:



This concept to lift produce is a spiral lifting mechanism which would carry produce up out of the Gaylord box. Its advantages are it would be very low impact on the produce and unlikely to damage it; however, it may be more expensive or slightly impractical. The fact that it would have to be set inside the box may lead to it taking more time to use and take away from its potential efficiency.

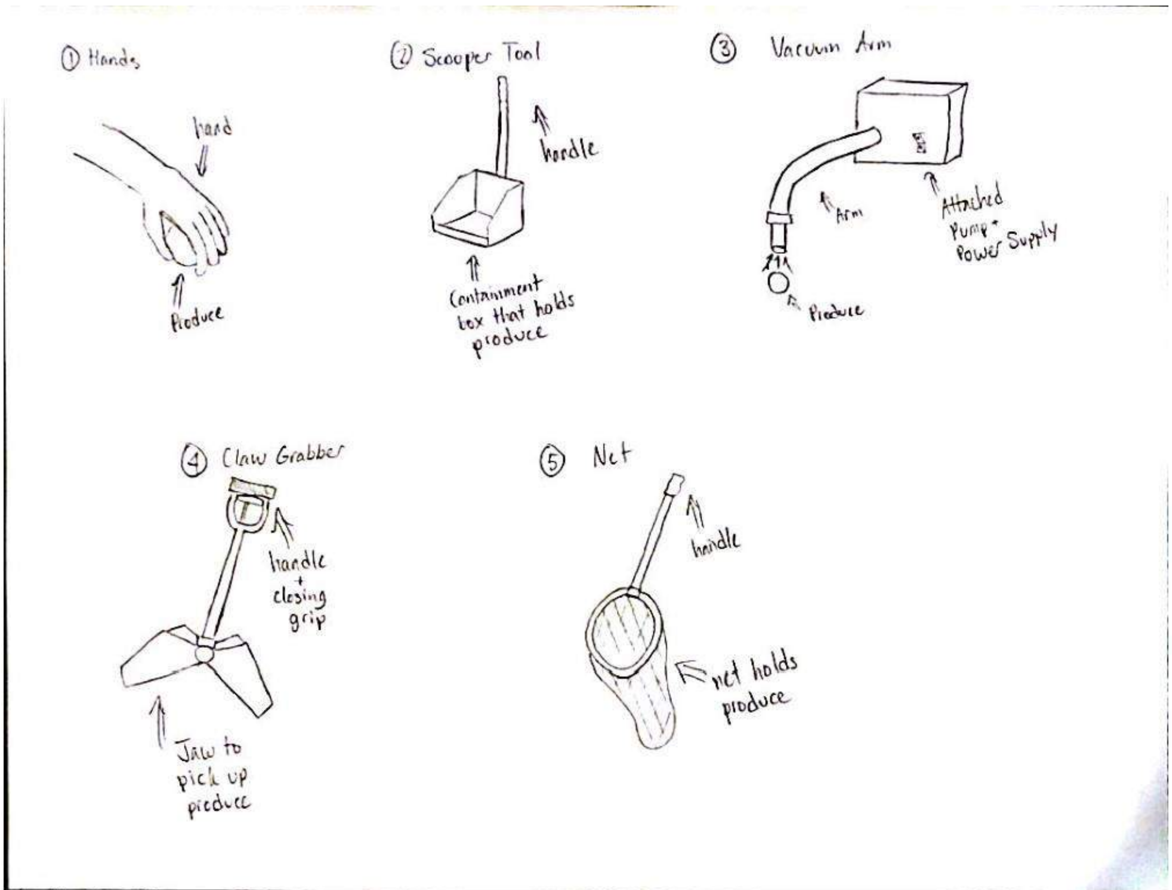


This concept would be to use a form of a palette tilter to tilt the gaylord box into a funnel, or some other system, to remove the produce from the box and transport it to bags and boxes. An upside to this would be that it would be among the most efficient processes and one of the easiest to use. It is also compatible with the most different types of produce; however, it does also have the highest likelihood of damaging produce. Therefore, an additive measure would need to be present to prevent the produce from encountering too much impact.

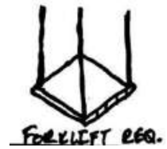
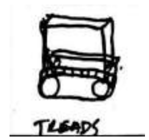
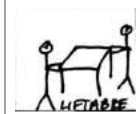
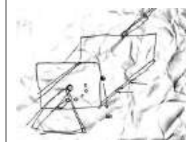
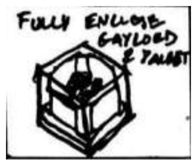
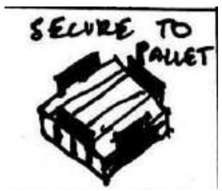
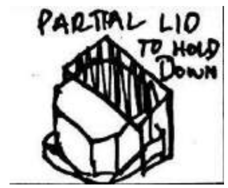
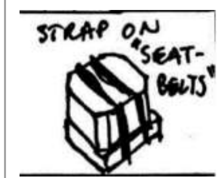
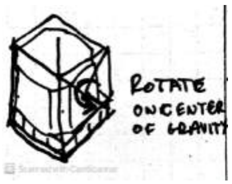
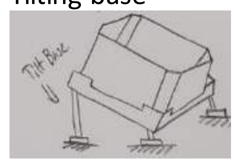
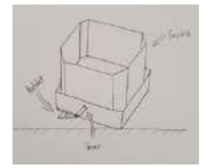
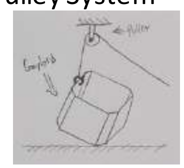
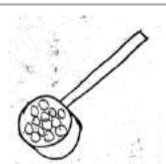
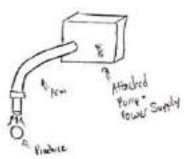
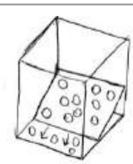
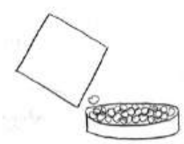
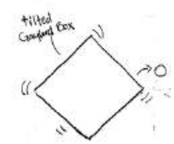
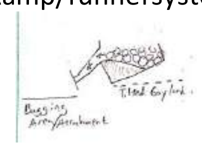
Function: Pick Up Produce

Criteria \ Concept	#1 Hands	#2 Scooper Tool	#3 Vacuum Arm	#4 Claw Grabber	#5 Net
Easy to Use	D	+	+	-	+
Durable	A	S	+	-	S
Easy to Clean	T	S	-	S	-
Safe for Volunteers	U	+	+	S	+
Efficient to Use	M	+	+	-	S
Easy to Manufacture	N/A	+	-	+	+
Total:	0	+4	+2	-2	+2

The best scoring concept was the scooper tool. It would enable the volunteers to easily pick-up produce while eliminating the need to bend over while also providing a way to pick up more produce at once compared to using their hands. This concept would be very easy to use as long as the volunteer has the grip strength to hold onto the tool. It could be very durable depending on the material used to manufacture it. In order to clean it, it would just have to be wiped down. It would greatly reduce the strain on the volunteer's backs. This concept serves the function well as well as could be used in tandem with other devices (such as a tilter) to further increase efficiency while not being redundant.


① Hands
hand
Produce
② Scooper Tool
handle
Containment box that holds produce
③ Vacuum Arm
Arm
Attached Pump + Power Supply
Produce
④ Claw Grabber
handle + closing grip
Jaw to pick up produce
⑤ Net
handle
net holds produce

Appendix F: Morphological Matrix

Function	Idea 1	Idea 2	Idea 3	Idea 4	Idea 5	Idea 6	Idea 7
Moving Device	 Locking wheels (human push)	 Forklift	 Tank Treads	 Motorized wheels	 Human-team liftable	 Modular Device	
Secure Gaylord & Pallet	 Box & Pallet enclosure on all sides	 Attach to Pallet	 Partial lid to secure	 Removable bars on top	 Seatbelt		
Tilting Gaylord	 Float box on CG	 Offset tilt so box wants to tilt initially	Tilting base 	Hydraulic tilter 	Hinge with ratchet 	Pulley System 	
Remove Produce	 Scooper tool	 Vacuum	 Angled platform	 Dump in pool	 Fruit chute	 Shake angled box	Hand 
Bag/Box Produce	Ramp/funnel system 	Bag attached to scooper 	Conveyor Belt 	Produce Sorter 			

Resultant Idea Combinations:

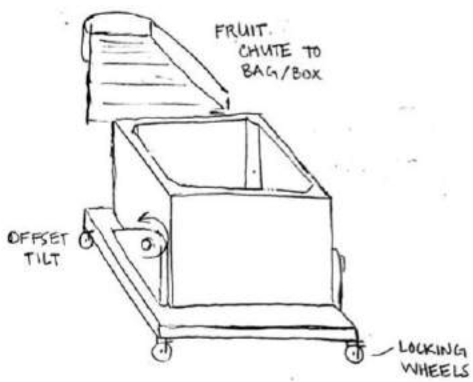
Function:	Moving Device	Secure Gaylord	Tilt Gaylord	Remove Produce	Bag Produce
Idea 1	1	1	2	5	1
Idea 2	2	1	2	1+3	4
Idea 3	1	1	1	1+7	4
Idea 4	5+6	4	1+_	6+7	4
Idea 5	1	3	2	2	1
Idea 6	6+1	4	1+_	5	1
Idea 7	2	3	4	5	3

Appendix G: Decision Matrix and Sketches

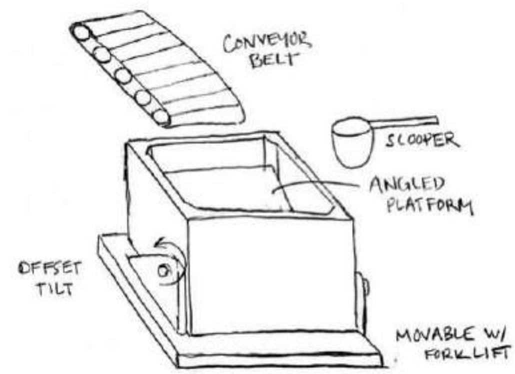
	Option:	Design 1		Design 2		Design 3		Design 4		Design 5		Design 6		Design 7	
	Description:	Locking Wheels, enclosure, offset tilt, Fruit chute, Ramp/funnel system		Forklift, Enclosure, Offset tilt, Scooper and angled platform, Conveyor belt		Locking wheels, enclosure, float on center of gravity, scooper or hands, produce sorter		Modular Device, removable bars for securing, Rotates around center of gravity, scoop out with hands into chute		Locking wheels, partial lid securing, offset tilt, vacuum to bag/box		Locking wheels & modular, Adjustable bars to secure, tilt around center of gravity, Fruit chute to bag/box		forklift, partial lid, hydraulic tilter, fruit chute, conveyor belt	
Specification:	Weight	Score	Total	Score	Total	Score	Total	Score	Total	Score	Total	Score	Total	Score	Total
Produce Count	0.07	10	0.7	6	0.42	5	0.35	6	0.42	3	0.21	9	0.63	8	0.56
Weight	0.12	5	0.6	5	0.6	6	0.72	7	0.84	5	0.6	6	0.72	5	0.6
Produce Damage	0.06	4	0.24	6	0.36	8	0.48	8	0.48	5	0.3	4	0.24	4	0.24
Cost	0.10	5	0.5	4	0.4	5	0.5	5	0.5	3	0.3	5	0.5	4	0.4
Height	0.15	5	0.75	6	0.9	7	1.05	8	1.2	5	0.75	7	1.05	9	1.35
Bagging Rate	0.10	8	0.8	6	0.6	5	0.5	5	0.5	4	0.4	7	0.7	7	0.7
Time to use	0.10	9	0.9	6	0.6	8	0.8	8	0.8	5	0.5	8	0.8	7	0.7
Setup time	0.02	7	0.14	5	0.1	7	0.14	4	0.08	8	0.16	6	0.12	5	0.1
Use Survey	0.15	6	0.9	6	0.9	6	0.9	6	0.9	5	0.75	6	0.9	8	1.2
Types of Produce Applicable	0.02	10	0.2	10	0.2	10	0.2	10	0.2	5	0.1	10	0.2	10	0.2
Time to Clean	0.01	4	0.04	4	0.04	5	0.05	5	0.05	3	0.03	4	0.04	4	0.04
Floor Area	0.07	6	0.42	5	0.35	7	0.49	7	0.49	6	0.42	7	0.49	6	0.42
# of compatible end containers	0.03	10	0.3	10	0.3	10	0.3	10	0.3	10	0.4	10	0.3	10	0.3
Total	1.00	**6.49**		**5.77**		**6.48**		**6.76**		**4.82**		**6.69**		**6.81**	

Design Sketches:

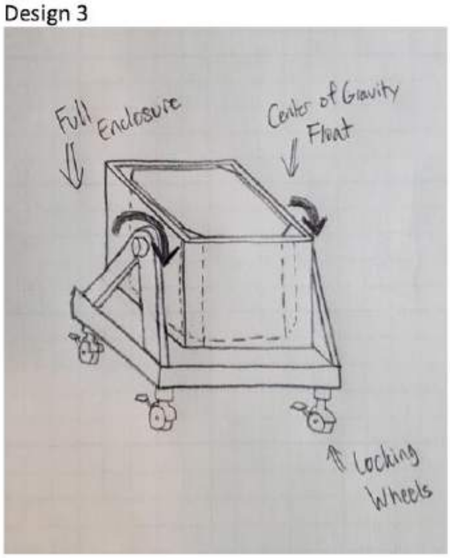
Design 1



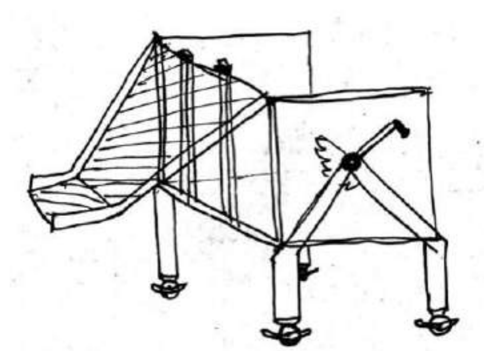
Design 2



Design 3

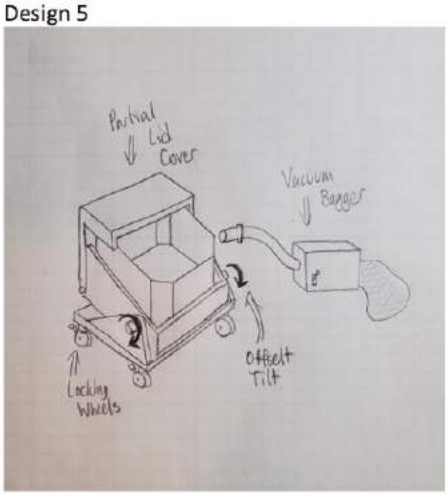


Design 4

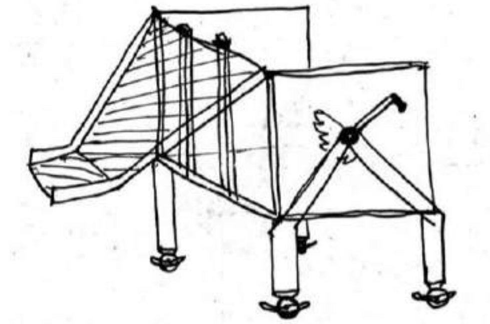


Modular Device, removable bars for securing, Rotates around center of gravity, scoop out with hands into chute (note: No locking wheels or chute connected)

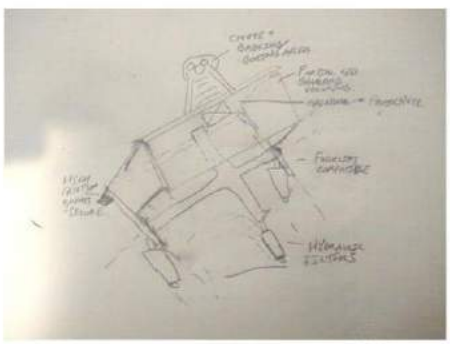
Design 5



Design 6



Design 7



Design concept 7 consists of a partial lid-like enclosure that secures the gaylord to a floor-level hydraulic tilter. The gaylords box is tilted to push produce down the fruit chute that a door in the lid leads to.

Appendix H: 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.

For any "Y" responses, on the reverse side add:

(1) a complete description of the hazard,
(2) the corrective action(s) you plan to take to protect the user, and
(3) a date by which the planned actions will be completed.

Description of Hazard	Planned Corrective Action	Planne d Date	Actua l Date
The connection to the lifting mechanism of the tilter may have a pinch point, as well as the area in between the gaylord base and the tilter base when the device is in action.	Alter design to make any pinching risk areas inaccessible during operation. (Most pinch points covered up by plywood, or marked off by hazard markers)	3/10	9/7
Parts of the device may undergo high acceleration and/or deceleration if it malfunctions.	Implement proper failsafe mechanisms so that the gaylord will not undergo extreme acceleration. (Winch speed can be controlled, backed up by extra connections and E-track system)	3/14	9/14
The system will be moving large masses at slightly elevated heights.	Design robust securing mechanisms to ensure gaylords box is securely placed and tilted. (Secure system includes securing on sides, E-track system and extra connections to winch ensure gaylord security)	3/17	9/14
The system could fall, tilt, or drop the gaylords box, causing injury.	Calculate forces that would tip the device at various tipping angles and weights, and design to avoid any risk of tipping. (Center of gravity, tipping force calculations used to verify design)	3/20	10/5
Users could be exposed to overhanging weights as part of the design.	Alter design to make users unable to be in any area where weights could fall in case of failure. (Design made more compact, users not subjected to overhang areas)	3/24	9/7
Users could use the device in an unsafe manner.	Design use manual, and properly add warnings and labels to any mechanisms that could be used unsafely. (STILL IN PROGRESS)	3/30	-
-			

Appendix I: Indented Bill of Materials

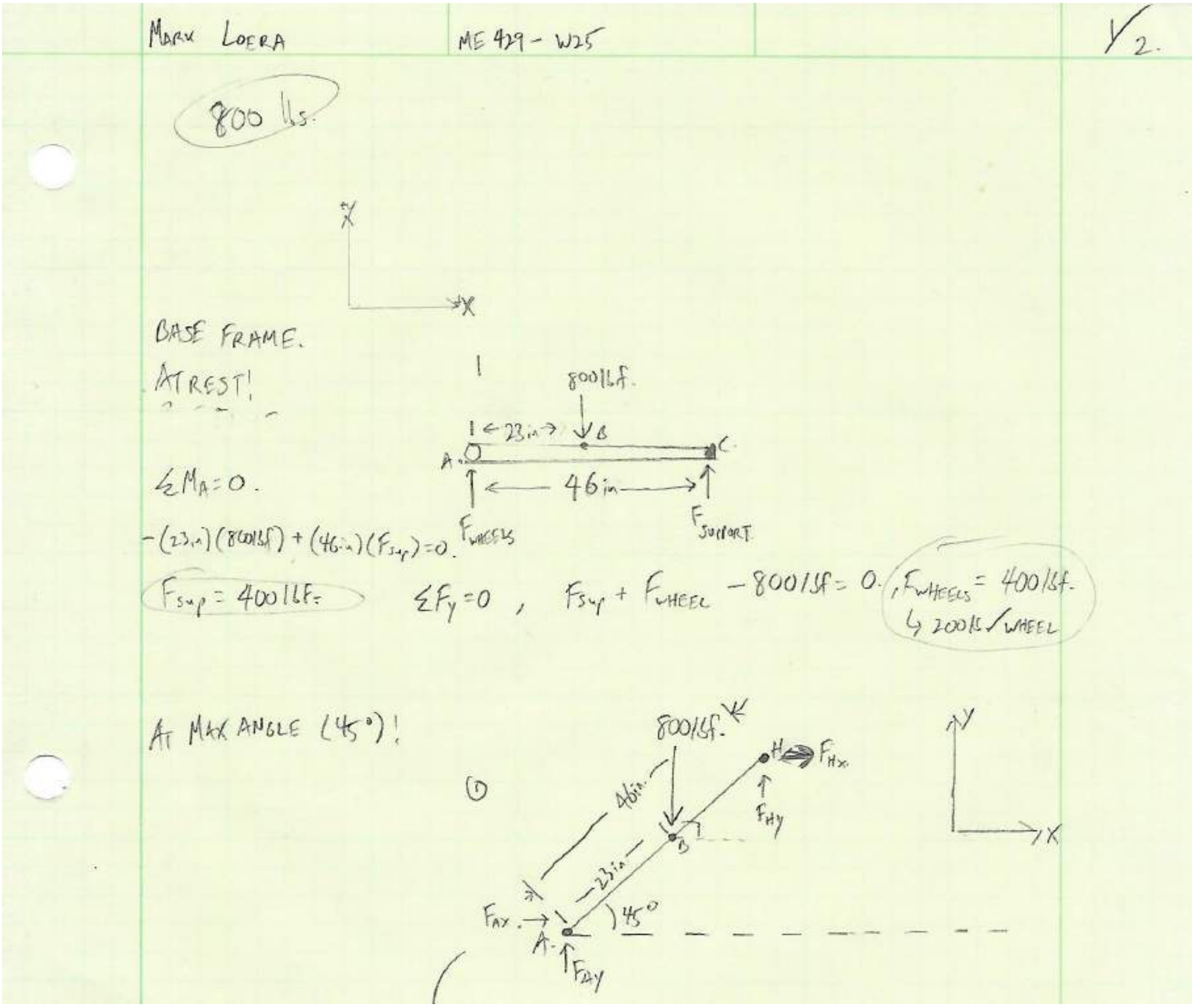
W25 Gaylord Tilter

Indented Bill of Material (IBOM)

Level	Number	LvID	Descriptive Part Name	Qty	Cost	Total Cost	Part Source	More Info
0	100000	Final Assy					----	
1	110000		Base Assembly				----	
1	111000		2x4 x 8'	1	$ 3.60	$ 3.60	Home Depot	https://www.homedepot.com/p/2-in-x-4-in-x-8-ft-Premium-Standard-and-Better-Douglas-Fir-Lumber-441317/202094172
1	112000		4x6 x 10'	1	$ 30.00	$ 30.00	Home Depot	https://www.homedepot.com/p/4-in-x-6-in-x-10-ft-Premium-2-and-Better-Douglas-Fir-Lumber-603783/202094390?MERCH=REC-_-searchViewed-_-NA-_-202094390-_-N&
1	113000		4x6x12'	1	$ 35.00	$ 35.00	Home Depot	https://www.homedepot.com/p/4-in-x-6-in-x-12-ft-Premium-2-and-Better-Douglas-Fir-Lumber-441019/202094372?MERCH=REC-_-searchViewed-_-NA-_-202094372-_-N&
1	114000		2x6 x 8'	7	$ 5.65	$ 39.55	Home Depot	https://www.homedepot.com/p/2-in-x-6-in-x-8-ft-2-and-Better-Douglas-Fir-Lumber-D2065EC-185-08/313817070
1	115000		1/2" Plywood 4'x8' sheet	1	$ 58.44	$ 58.44	Home Depot	https://www.homedepot.com/p/Columbia-Forest-Products-1-2-in-x-4-ft-x-8-ft-PureBond-Birch-Plywood-833185/100020218
1	116000		#8 x 3 in. General Purpose Screws (1 lb. pack)	1	$ 7.98	$ 7.98	Home Depot	https://www.homedepot.com/p/Grip-Rite-8-x-3-in-Philips-Bugle-Head-Coarse-Thread-Wood-Screws-1-lb-Pack-3G51/100134103
1	117000		#6 x 1-1/4 in. General Purpose Screws (1 lb. pack)	1	$ 7.08	$ 7.98	Home Depot	https://www.homedepot.com/p/Grip-Rite-6-x-1-1-4-in-Philips-Bugle-Head-Coarse-Thread-Gold-Screws-1-lb-Pack-114G51/100129041
1	118000		#8 x 1-1/4 in. #2 Philips, Wafer-Head Wood Screw (100-Pack)	1	$ 11.53	$ 11.53	Home Depot	https://www.homedepot.com/p/Simpson-Strong-Tie-8-x-1-1-4-in-2-Phillips-Wafer-Head-Wood-Screw-100-Pack-SDBX1-25-R/206101781
1	119000		#10 x 1-1/2 in. 1/4-Hex Drive, Strong-Drive SD Connector Screw (100-	1	$ 13.74	$ 13.74	Home Depot	https://www.homedepot.com/p/Simpson-Strong-Tie-8-x-1-1-4-in-2-Phillips-Wafer-Head-Wood-Screw-100-Pack-SDBX1-25-R/206101781
1	120000		1/2 in. x4-1/2 in. Hex Zinc Plated Lag Screw	1	$ 1.48	$ 1.48	Home Depot	https://www.homedepot.com/p/Everbilt-1-2-in-x-4-1-2-in-Hex-Zinc-Plated-Lag-Screw-801696/204645676
1	121000		3/8 in. x6 in. Hex Head Bolt, GR8	2	$ 1.75	$ 3.50	Tractor Supply Co.	https://www.tractorsupply.com/tsc/product/hexagonal-head-bolt-grade-8
1	122000		3/8 in. nut, GR8	2	$ 0.30	$ 0.60	Tractor Supply Co.	https://www.tractorsupply.com/tsc/product/hexagonal-head-bolt-grade-9
1	123000		3/8 in. Washer, GR8	2	$ 0.20	$ 0.40	Tractor Supply Co.	https://www.tractorsupply.com/tsc/product/hexagonal-head-bolt-grade-10
1	124000		7/16 in. x 6 in. Hex Head Bolt, GR8	2	$ 1.47	$ 2.94	Tractor Supply Co.	https://www.tractorsupply.com/tsc/product/hexagonal-head-bolt-grade-11
1	125000		7/16 in. nut, GR8	2	$ 0.29	$ 0.58	Tractor Supply Co.	https://www.tractorsupply.com/tsc/product/hexagonal-head-bolt-grade-12
1	126000		7/16in. Washer, GR8	2	$ 0.19	$ 0.38	Tractor Supply Co.	https://www.tractorsupply.com/tsc/product/hexagonal-head-bolt-grade-13
1	127000		1/2 in. x6 in Hex Head Bolt	1	$ 1.78	$ 1.78	Tractor Supply Co.	https://www.tractorsupply.com/tsc/product/hexagonal-head-bolt-grade-14
1	128000		1/2 in. nut, GR8	1	$ 0.31	$ 0.31	Tractor Supply Co.	https://www.tractorsupply.com/tsc/product/hexagonal-head-bolt-grade-15
1	129000		1/2 in. Washer, GR8	1	$ 0.21	$ 0.21	Tractor Supply Co.	https://www.tractorsupply.com/tsc/product/hexagonal-head-bolt-grade-16
1	130000		1 in. x 8 in. Hex Head Bolt, GR8	1	$ 5.50	$ 5.50	Tractor Supply Co.	https://www.tractorsupply.com/tsc/product/hexagonal-head-bolt-grade-17
1	131000		1 in. nut, GR8	1	$ 2.00	$ 2.00	Tractor Supply Co.	https://www.tractorsupply.com/tsc/product/hexagonal-head-bolt-grade-18
1	132000		1 in. Washer, GR8	3	$ 0.98	$ 2.94	Tractor Supply Co.	https://www.tractorsupply.com/tsc/product/hexagonal-head-bolt-grade-19
1	133000		2 in. x 1-1/2 in. x 2-2/4 in ZMAX Galvanized Angle	12	$ 0.85	$ 10.20	Home Depot	https://www.homedepot.com/p/Simpson-Strong-Tie-2-in-x-1-1-2-in-x-2-3-4-in-ZMAX-Galvanized-Angle-A23Z/100375310
1	134000		HTP 3 in. x 7 in. ZMAX Galvanized Heavy Tie Plate	3	$ 2.41	$ 7.23	Home Depot	https://www.homedepot.com/p/Simpson-Strong-Tie-HTP-3-in-x-7-in-ZMAX-Galvanized-Heavy-Tie-Plate-HTP37Z/202329565
1	135000		HTT 16 in. 11-Gauge Galvanized Heavy Tension Tie	1	$ 30.22	$ 30.22	Home Depot	https://www.homedepot.com/p/Simpson-Strong-Tie-HTT-16-in-11-Gauge-Galvanized-Heavy-Tension-Tie-HTT5/202193557
2	140000		Lift System (Attached to Base System)					
2	141000		2X8 3500 Lb. ATV/Powersport 12v Winch With Wire Rope	1	$ 189.55	$ 189.55	Harbor Freight	https://www.harborfreight.com/zxr-3500-lb-atvpowersport-12v-winch-with-wire-rope-56259.html
2	142000		NAPA 40 Battery BCI No. 26R 450 A Wet	1	$ 104.99	$ 104.99	NAPA Online	https://www.napaonline.com/en/p/BAT4026R?nid=paidsearch_shopping
2	143000		12V/24V Smart Battery Charger	1	$ 36.45	$ 36.45	Amazon	https://www.amazon.com/Intelligent-Overvoltage-Protection-Temperature-Monitoring/dp/B081191772/ref=asc_df_B081191772/?tag=hyprod-20&linkCode=df0&hvadid=385178051407&hvpos=&hvnetw=g&hvrand=1006632342357879660&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=1014232&hvtargid=pla-851511588217&psc=1&tag=&ref=&adgrpid=78533818717&hvpone=&hvptwo=&hvadid=385178051407&hvpos=&hvnetw=g&hvrand=1006632342357879660&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=1014232&hvtargid=pla-851511588217
2	144000		Tuf-Tug - 3 in. Flat Mount Block 5/16 in.	1	$ 24.99	$ 24.99	Tractor Supply Co.	https://www.tractorsupply.com/tsc/product/tuf-tug-3-in-flat-mount-block?cm_vc=-10005&sl=tuf%20tub
2	145000		Lynx Battery Box, Small	1	$ 21.99	$ 21.99	Tractor Supply Co.	https://www.tractorsupply.com/tsc/product/traveller-lynx-battery-box-small?cm_vc=-10005
2	146000		5 Ft. Vertical E-Track Rail	1	$ 19.99	$ 19.99	Harbor Freight	https://www.harborfreight.com/5-ft-vertical-e-track-rail-56754.html
2	147000		E-Track Tie-Down Anchor	1	$ 5.99	$ 5.99	Harbor Freight	https://www.harborfreight.com/e-track-ring-66728.html
2	148000		4 in. Diameter x 2 in. width Delrin Ring	1	$ -	$ -		
2	149000		Deka Quick Clamp Battery Terminals	1	$ 7.66	$ 7.66	Autozone	https://www.finditparts.com/products/5542566/deka-battery-terminals-08767?srcid=CHL01SCL010-Nala-Dmdt-Gusa-Sale-Mnsur-K5542566-L217&srcid=CHL01SCL004&promo=CYBER15&gclid=Cj0KCQiAtieNBhCVARIsANUI2EaCdMeBWfIrbgE-v9kvOgkKftLUQA4UP3ZIppvs8ZMhAida8rBMtEaAhFEALw_wcB
3	130000		Secure System					
3	131000		Food Industry Casters with Phenolic Wheels	2	$ 57.79	$ 115.57	McMaster	casters/caster-type~rigid/high-capacity-plate-casters-with-polyurethane-
3	110000		20' Steel tubing	2	$ 131.00	$ 262.00	McCarthy Steel	
3	132000		Steel Bolt-Together Framing and Fitting	1	$82.24	$ 82.24	McCarthy Steel	
3	133000		Galvanized Bolt-Together Framing	1	$146.02	$ 146.02	McCarthy Steel	
3	124000		Heavy-Duty Wire Ring in Black	1	$ 9.97	$ 9.97	Home Depot	in-Black-FH41227/312994492
3	125000		3/8 in. Stainless Steel Quick Link	1	$ 9.98	$ 9.98	Home Depot	https://www.homedepot.com/p/Everbilt-3-8-in-Stainless-Steel-Quick-Link-42794/205883033
3	134000		Pin for Telescoping Tubing	6	$1.62	$ 9.72		
3	135000		3/8 in.-24 tpi Yellow Zinc-Plated Grade 8 Hex Nut (2-Piece per Bag)	8	$1.70	$ 13.60	Home depot	https://www.homedepot.com/p/Everbilt-3-8-in-24-tpi-Yellow-Zinc-Plated-Grade-8-Hex-Nut-2-Piece-per-Bag-846218/204836082
3	136000		1/2 in. x 25 ft. Double Braid Nylon Rope	1	$29.98	$ 29.98	Home Depot	https://www.homedepot.com/p/Everbilt-1-2-in-x-25-ft-Double-Braid-Nylon-Dock-Line-Rope-70712/205804710
3	137000		3/8 in.-24 tpi Yellow Zinc-Plated Grade 8 Hex Nut (2-Piece per Bag)	8	$0.92	$ 7.36	Home depot	https://www.homedepot.com/p/Everbilt-3-8-in-24-tpi-Yellow-Zinc-Plated-Grade-8-Hex-Nut-2-Piece-per-Bag-846218/204836082
Total Parts				92		$ 1,378.14		
			Total Cost + 10% Sales Tax			$ 1,515.75		

Appendix K: Design Calculations

Force Calculations



2/2

② $\Sigma M_A = 0: -(23in)(800lbf)(\sin 45°) + (46in)(F_{HY}) = 0.$

~~$F_{HY} = -282.81lbf$~~

$\Sigma M_H = 0: (23in)(800lbf)(\sin 45°) - (46in)(F_{AY}) = 0.$

~~$F_{AY} = 282.81lbf$~~

① $\Sigma M_A = 0: -(23in)(\cos 45°)(800lbf) + (46in)(\cos 45°)F_{HY} - (46in)(\sin 45°)F_{HX} = 0$

Ⓐ $\hookrightarrow (32.53)_{in}F_{HY} - (32.53)_{in}F_{HX} = 13{,}010.8\ lbf\text{-}in \rightarrow F_{HY} - F_{HX} - 200 = 0.$

$\Sigma M_H = 0: -(23in)(\cos 45°)(800lbf) - (46in)(\cos 45°)F_{AY} + (46in)(\sin 45°)F_{AX} = 0$

Ⓑ $(32.53in)F_{AY} - (32.53)F_{AX} = 13{,}010.8\ lbf\text{-}in \rightarrow F_{AY} - F_{AX} - 200 = 0.$

$\Sigma F_x = 0: F_{AX} + F_{HX} = 0, \quad F_{AX} = -F_{HX}.$ Ⓒ

$\Sigma F_Y = 0: F_{AY} + F_{HY} - 800lbf = 0., \quad F_{AY} + F_{HY} = 800lbf.$ Ⓓ

Ⓐ=Ⓑ: $F_{HY} - F_{HX} - 200 = F_{AY} - F_{AX} - 200$, sub. $F_{AX} = -F_{HX}$.

$F_{HY} - F_{HX} = F_{AY} - (-F_{HX})$

$F_{HY} = F_{AY} \rightarrow$ Ⓓ $F_{AY} + F_{HY} = 800lbf \rightarrow F_{AY} + F_{AY} = 800lbf.$

$F_{AY} = F_{HY} = 400lbf$

Ⓐ $F_{HY} - F_{HX} = 200\ lbf.$

$F_{HX} = F_{HY} - 200lbf$

$= (400 - 200)lbf$

$F_{HX} = 200lbf \quad F_{AX} = -F_{HX} \rightarrow F_{AX} = -200lbf$

$\theta_A = \tan^{-1}\left(\frac{400}{-200}\right) = -63.4°, \quad \theta_H = 63.4°$

$F_A = \sqrt{(400)^2 + (-200)^2} = 447.2\ lbf \angle -63.4°$

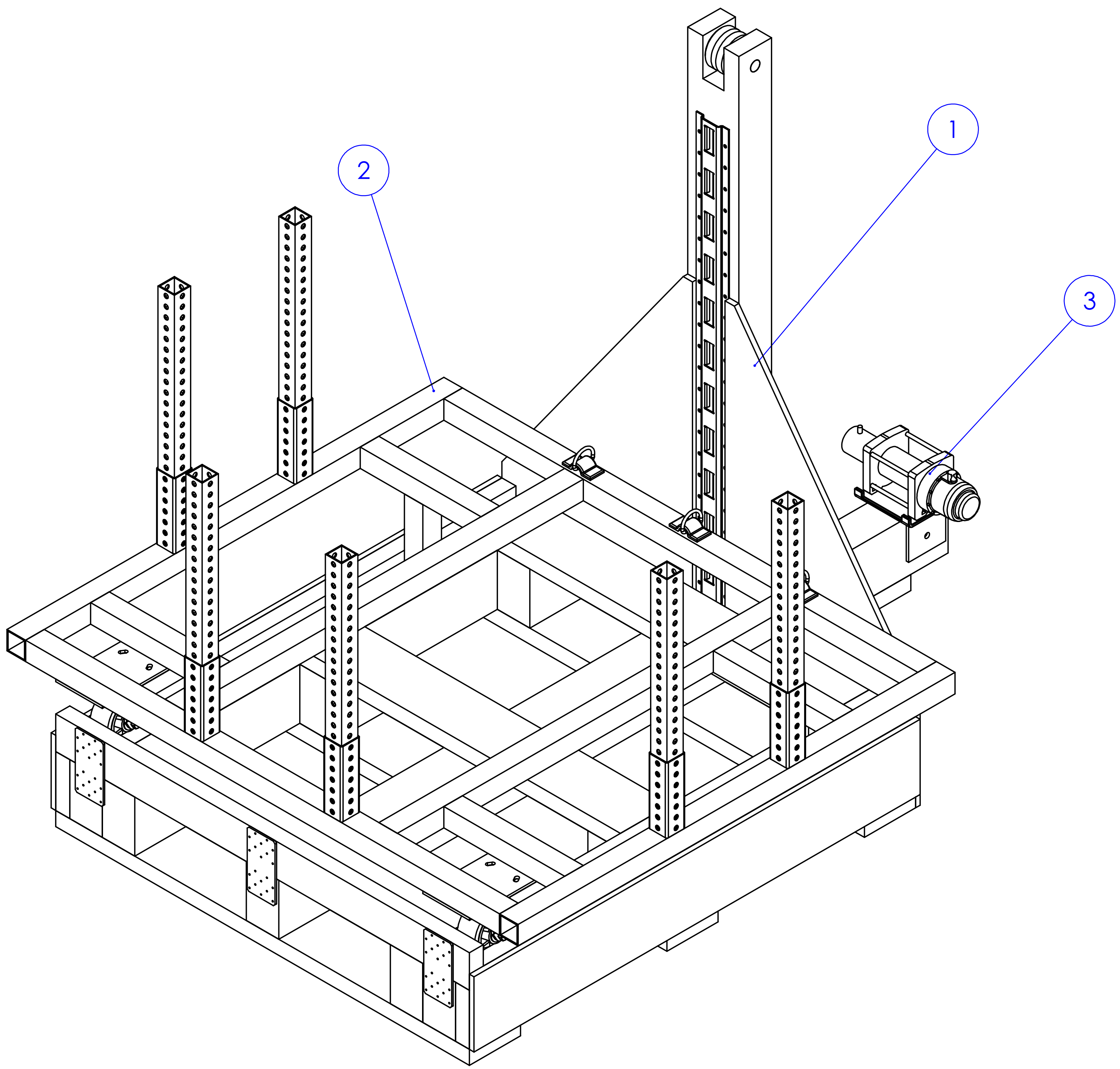
$F_H = \sqrt{(400)^2 + (200^2)} = 447.2\ lbf \angle 63.4°$

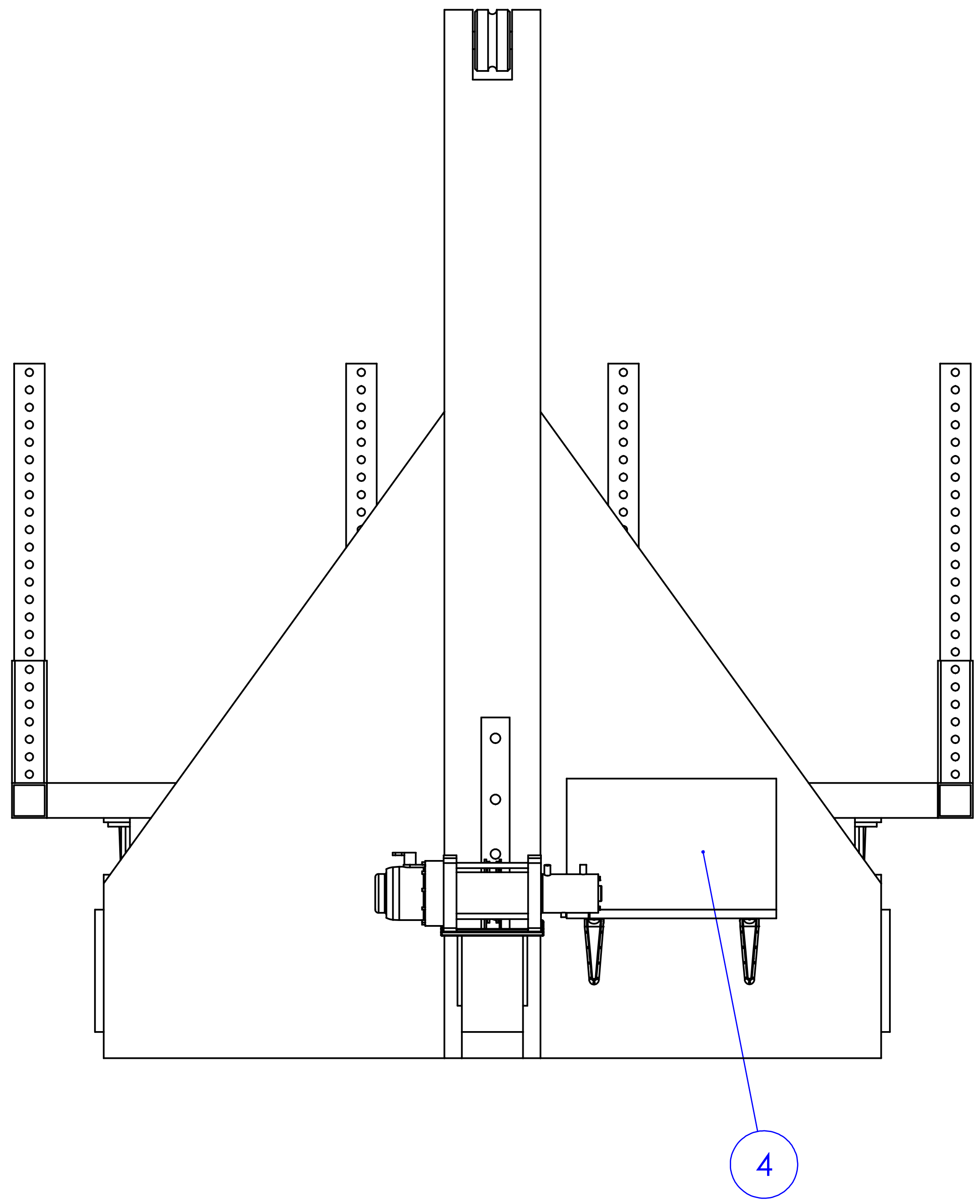
$F_H = 447.2\ lbf \angle 63.4°$

Maximum force at hinge and both wheels calculated to be ~447lbf, which both parts are rated for well above.

The vertical 4x6 post is mainly in compression due to horizontal forces being dispersed by the plywood, and is rated for much higher forces in compression.

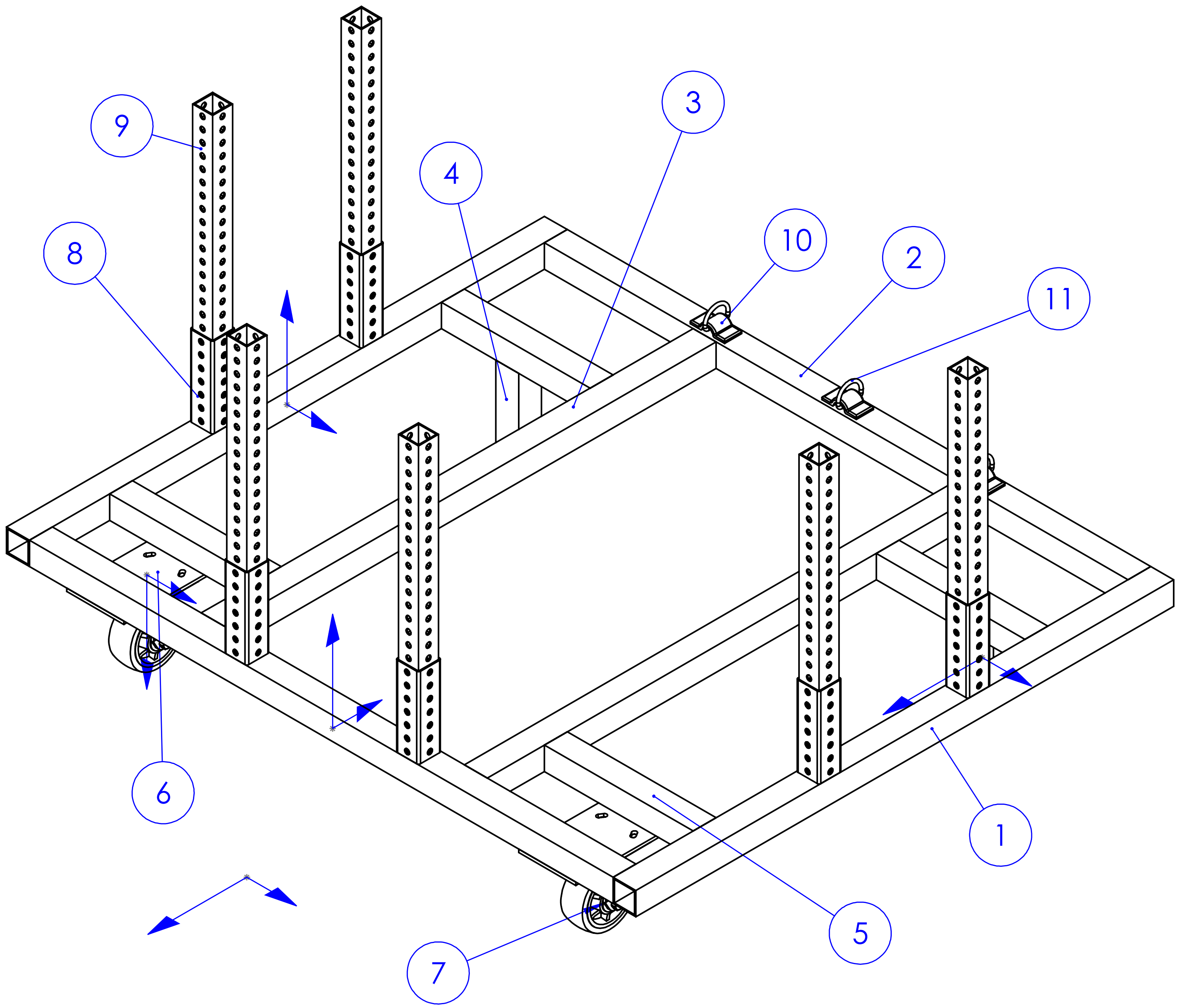
Appendix J: Design Drawings





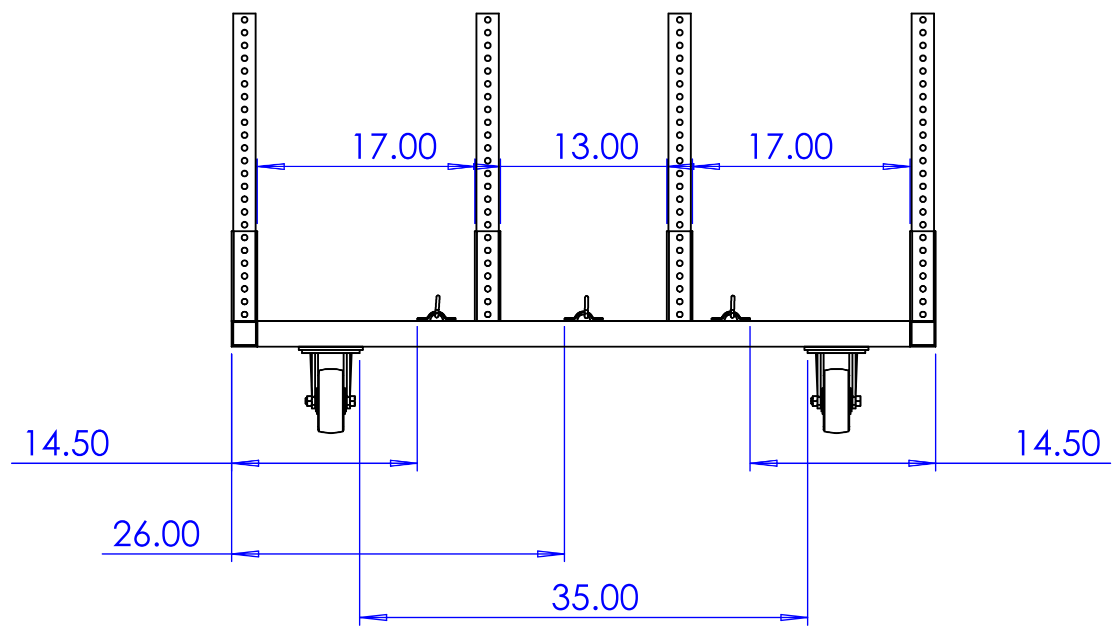
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1.2.B0	Base Frame	1
2	1.1.B0	Secure System	1
3	1.3.B0	Winch	1
4	1.4.B0	Battery Box	1

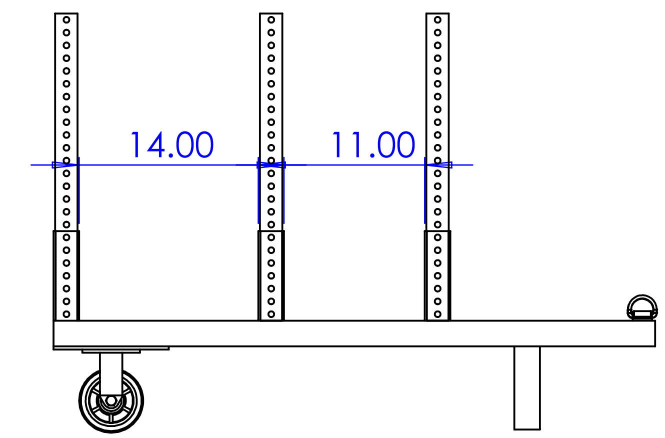
Cal Poly Mechanical Engineering ME 430 - Fall 2021	Lab Section: 02	Sub-Assembly #2	Title: Base Frame		Drwn. By: Team W25
	Dwg. #: 1.2.B0	Nxt Asb:	Date:	Scale: 1:10	Chkd. By: ME STAFF

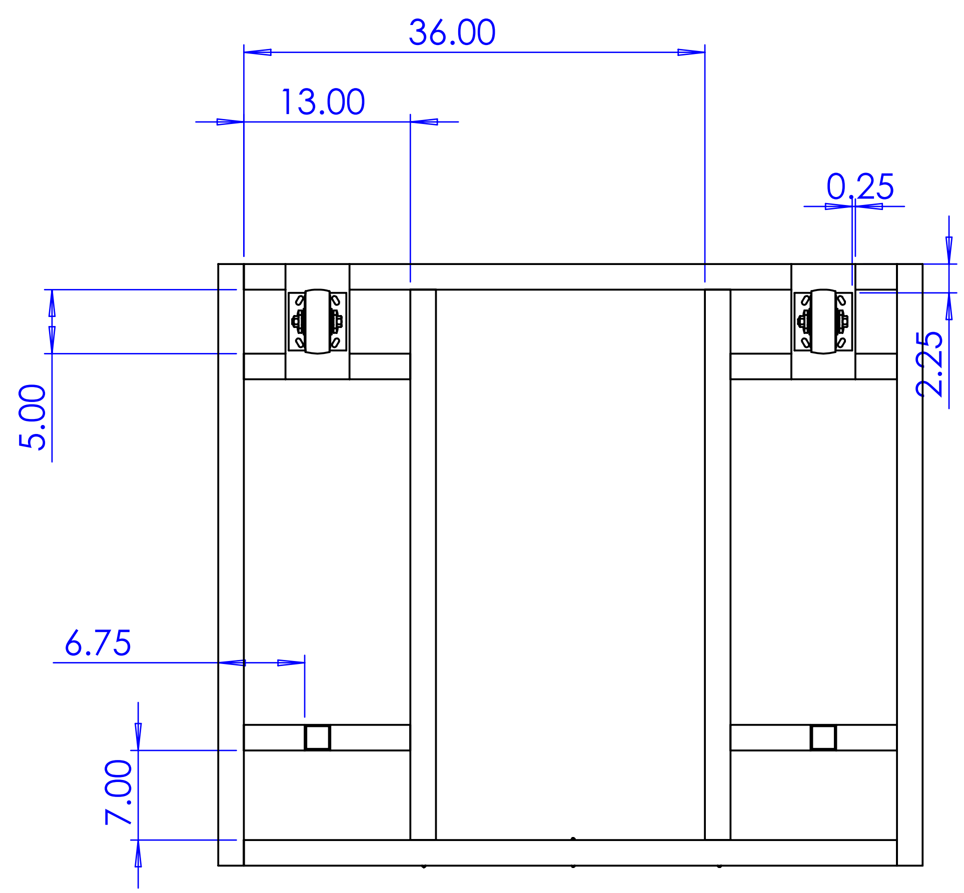


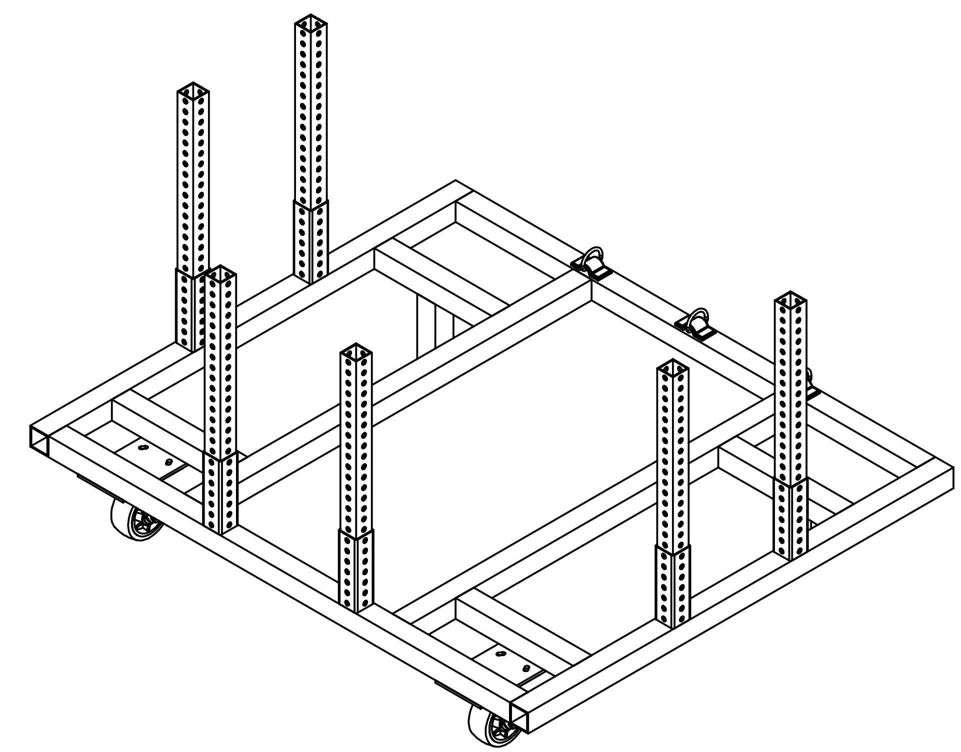
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1.1.1	47 Inch Cut Square Steel Tubing	2
2	1.1.2	51 Inch Cut Square Steel Tubing	2
3	1.1.3	43 Inch Cut Square Steel Tubing	2
4	1.1.4	Leg Stand 6.5 Cut Square Steel Tubing	2
5	1.1.5	13 Inch Cut Square Steel Tubing	4
6	1.1.6	8in x 9in Cut Steel Plate	2
7	49915T52	5 inch Food Industry Casters with Phenolic Wheels	2
8	1.1.8	2in x 2in x 7in Bolt-Together Framing	6
9	1.1.9	Cut Telescoping Bolt-Together Framing Inserts	6
10	1.1.10	Wire Ring Anchor	3
11	1.1.11	Wire Ring	3

Cal Poly Mechanical Engineering ME 430 - Fall 2021	Lab Section: 02	Sub-Assembly #1	Title: Secure System	Drwn. By: Team W25
	Dwg. #: 1.1.B0	Nxt Asb:	Date: / Scale: 1:10	Chkd. By: ME STAFF





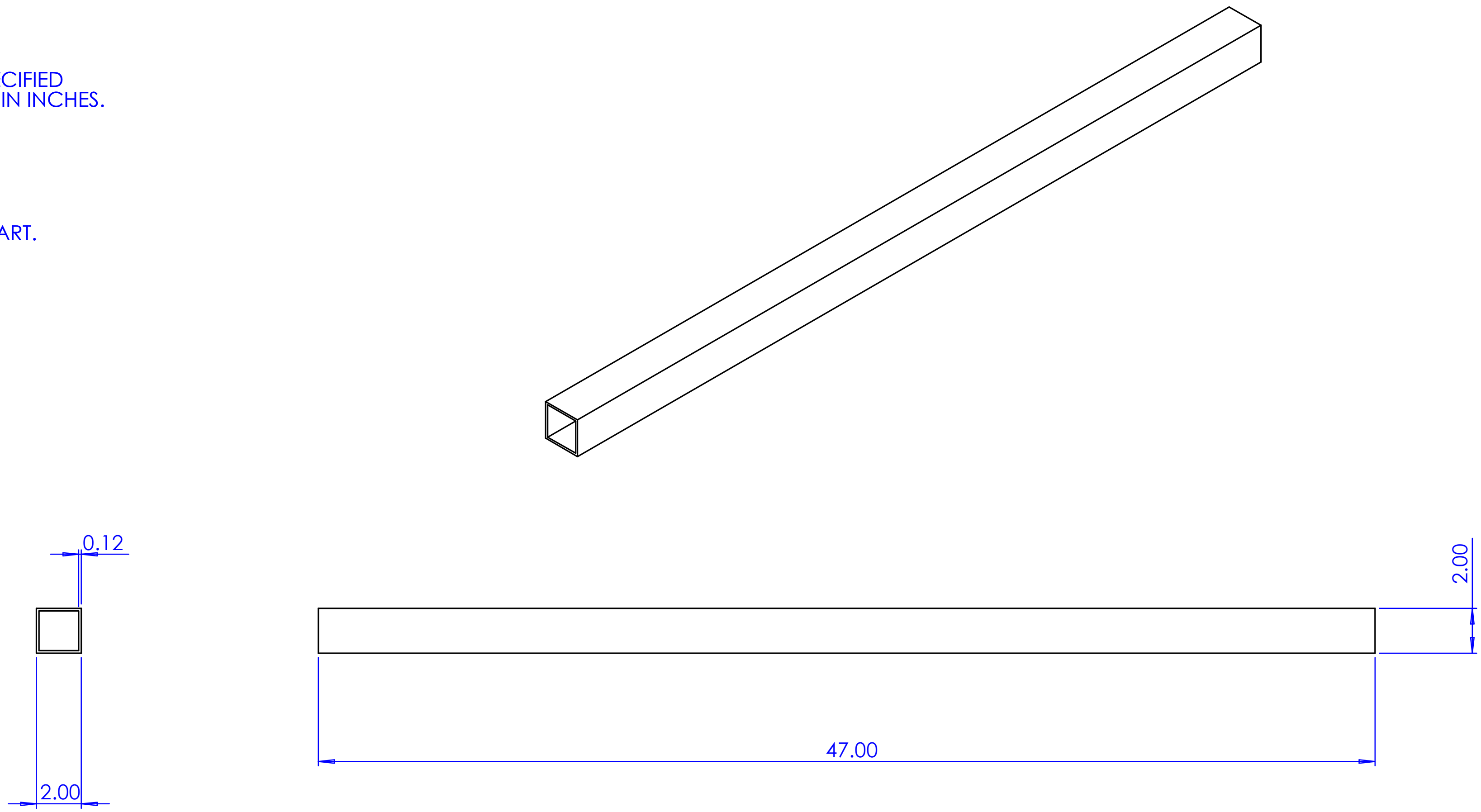




Cal Poly Mechanical Engineering ME 430 - Fall 2021	Lab Section: 02	Sub-Assembly#1	Title: Secure System Sub Assembly		Drwn. By: Team W25
	Dwg. #: 1.1.D0	Nxt Asb:	Date:	Scale: 1:15	Chkd. By: ME STAFF

NOTES:

UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES.
2. TOLERANCES
   1. X.X = ±.1
   2. X.XX = ±.01
   3. X.XXX = ±.005
3. 63 ▽ FOR ENTIRE PART.

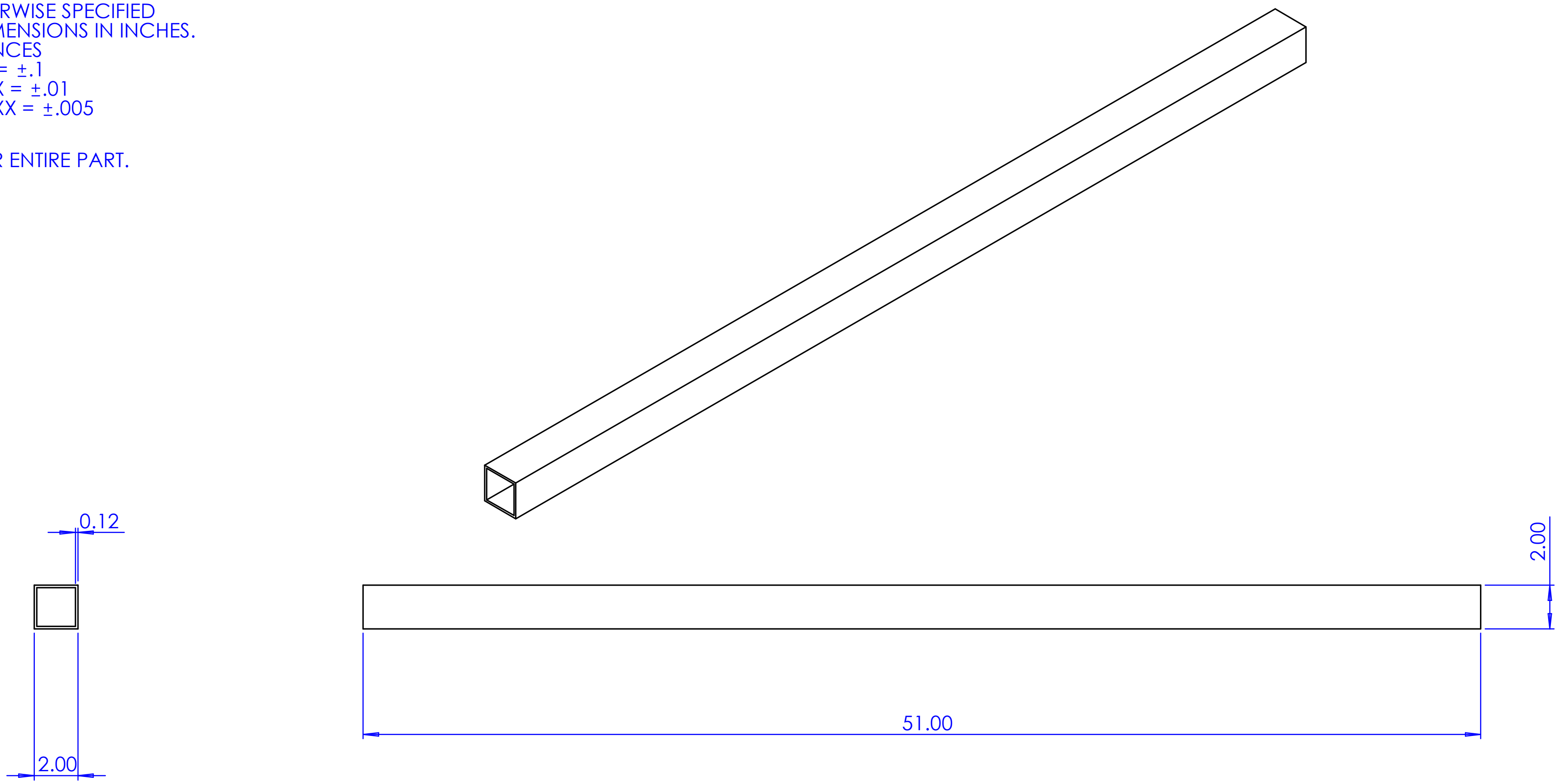


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.	MATERIAL
1	1.1.1	47 Inch Cut Square Steel Tubing	2	2"x 2" 11 Gage Steel Tubing

Cal Poly Mechanical Engineering	Lab Section: 02	Component #1	Title: 47 in Square Steel Tubing	Drwn. By:
ME 430 - Fall 2021	Dwg. #: 1.1.1	Nxt Asb:	Date: / Scale: 1:5	Chkd. By: ME STAFF

NOTES:

UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES.
2. TOLERANCES
   1. X.X = ±.1
   2. X.XX = ±.01
   3. X.XXX = ±.005
3. 63 FOR ENTIRE PART.

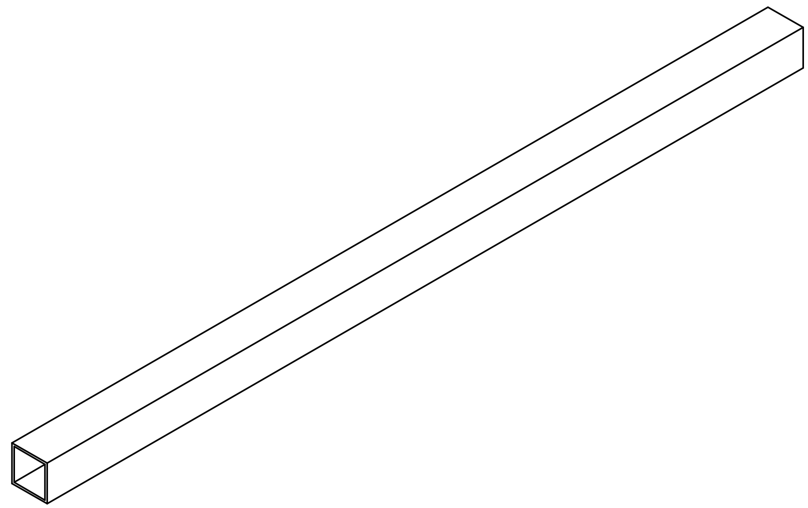


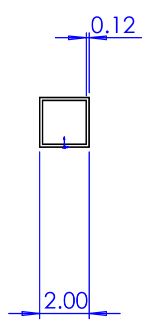
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.	MATERIALS
1	1.1.2	51 Inch Cut Square Steel Tubing	2	2"x 2" 11 Gage Steel Tubing

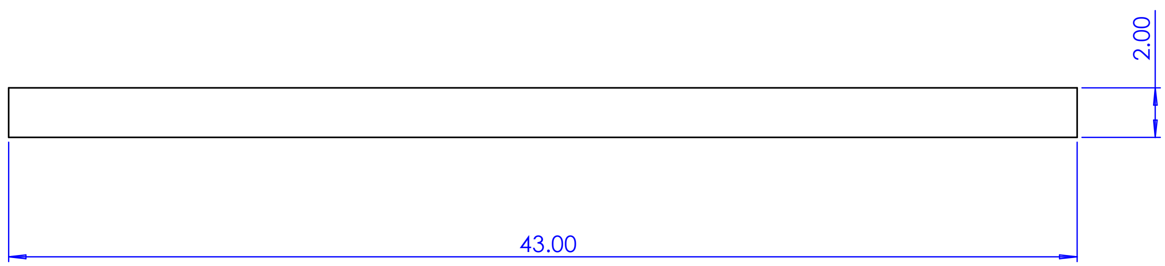
Cal Poly Mechanical Engineering ME 430 - Fall 2021	Lab Section: 02	Component #2	Title: 51 in Steel Square Tubing	Drwn. By:
	Dwg. #: 1.1.2	Nxt Asb:	Date: Scale: 1:5	Chkd. By: ME STAFF

NOTES:

UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES.
2. TOLERANCES
   1. X.X = ±.1
   2. X.XX = ±.01
   3. X.XXX = ±.005
3. 63 (surface finish symbol) FOR ENTIRE PART.





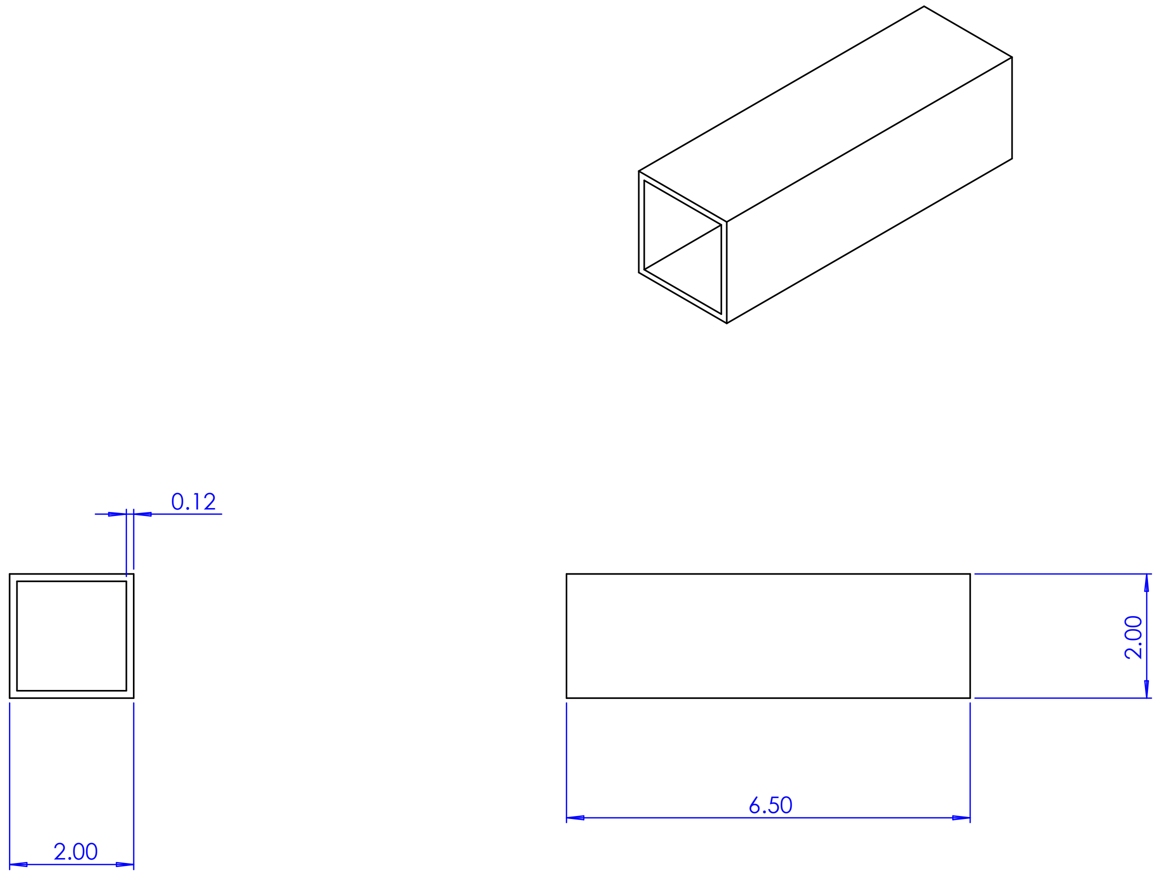


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.	MATERIALS
1	1.1.3	43 Inch Cut Square Steel Tubing	2	2"x 2" 11 Gage Steel Tubing

Cal Poly Mechanical Engineering ME 430 - Fall 2021	Lab Section: 02	Component #3	Title: 51 in Steel Square Tubing		Drwn. By: Team W25
	Dwg. #: 1.1.3	Nxt Asb:	Date:	Scale: 1:5	Chkd. By: ME STAFF

NOTES:

UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES.
2. TOLERANCES
   1. X.X = ±.1
   2. X.XX = ±.01
   3. X.XXX = ±.005
3. 63 (surface finish symbol) FOR ENTIRE PART.

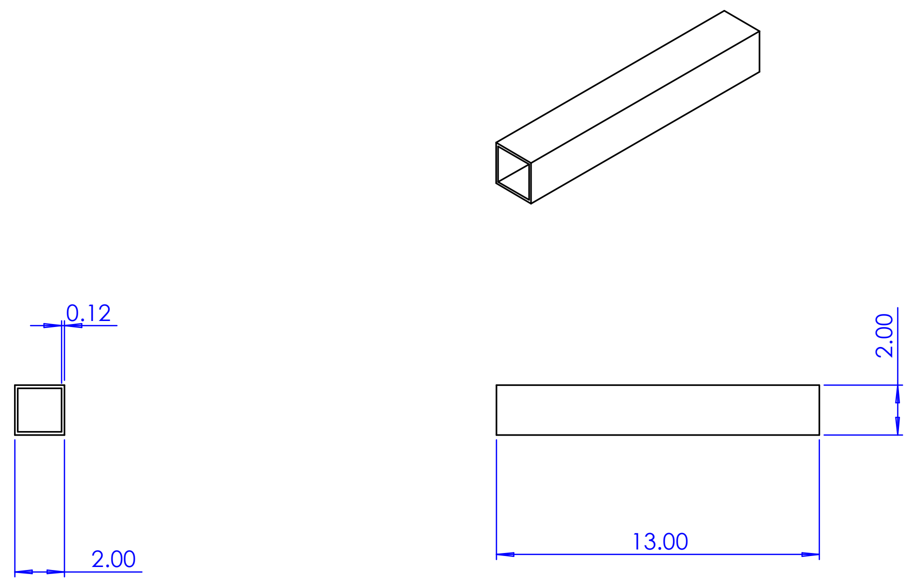


ITEM NO.	PART NAME	DESCRIPTION	QTY.	MATERIAL
1	1.1.4	Leg Stand 6.5 Cut Square Steel Tubing	2	2"x 2" 11 Gage Steel Tubing

Cal Poly Mechanical Engineering ME 430 - Fall 2021	Lab Section: 02	Component #4	Title: Leg Stand	Drwn. By:
	Dwg. #: 1.1.4	Nxt Asb:	Date: Scale: 1:2	Chkd. By: ME STAFF

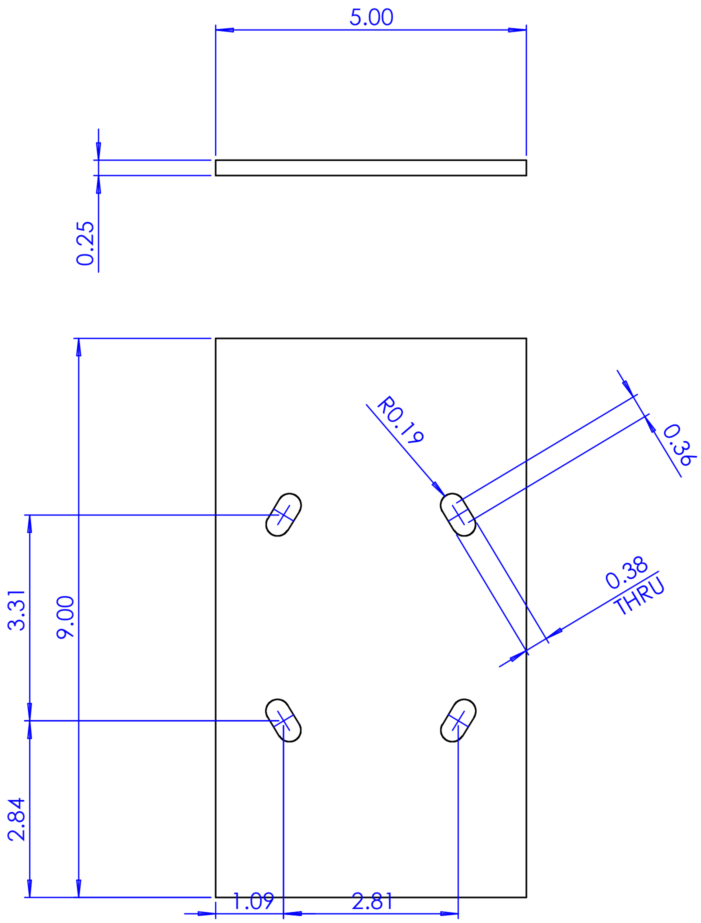
NOTES:

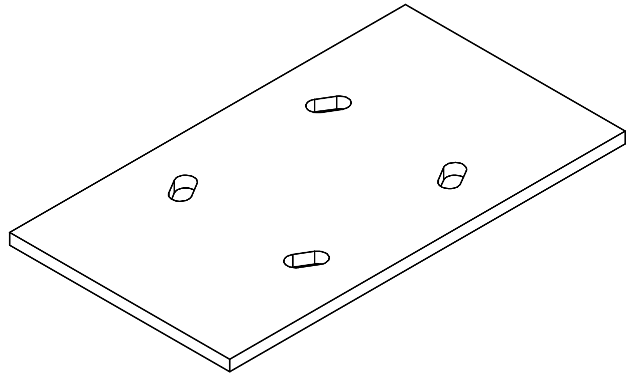
UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES.
2. TOLERANCES
    1. X.X = ±.1
    2. X.XX = ±.01
    3. X.XXX = ±.005
3. 63 FOR ENTIRE PART.



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.	MATERIALS
1	1.1.5	13 Inch Cut Square Steel Tubing	2	2"x2" 11 Gage Square Steel Tubing

Cal Poly Mechanical Engineering	Lab Section: 02	Component #5	Title: 13 in Steel Square Tubing	Drwn. By:
ME 430 - Fall 2021	Dwg. #: 1.1.3	Nxt Asb:	Date: / Scale: 1:5	Chkd. By: ME STAFF



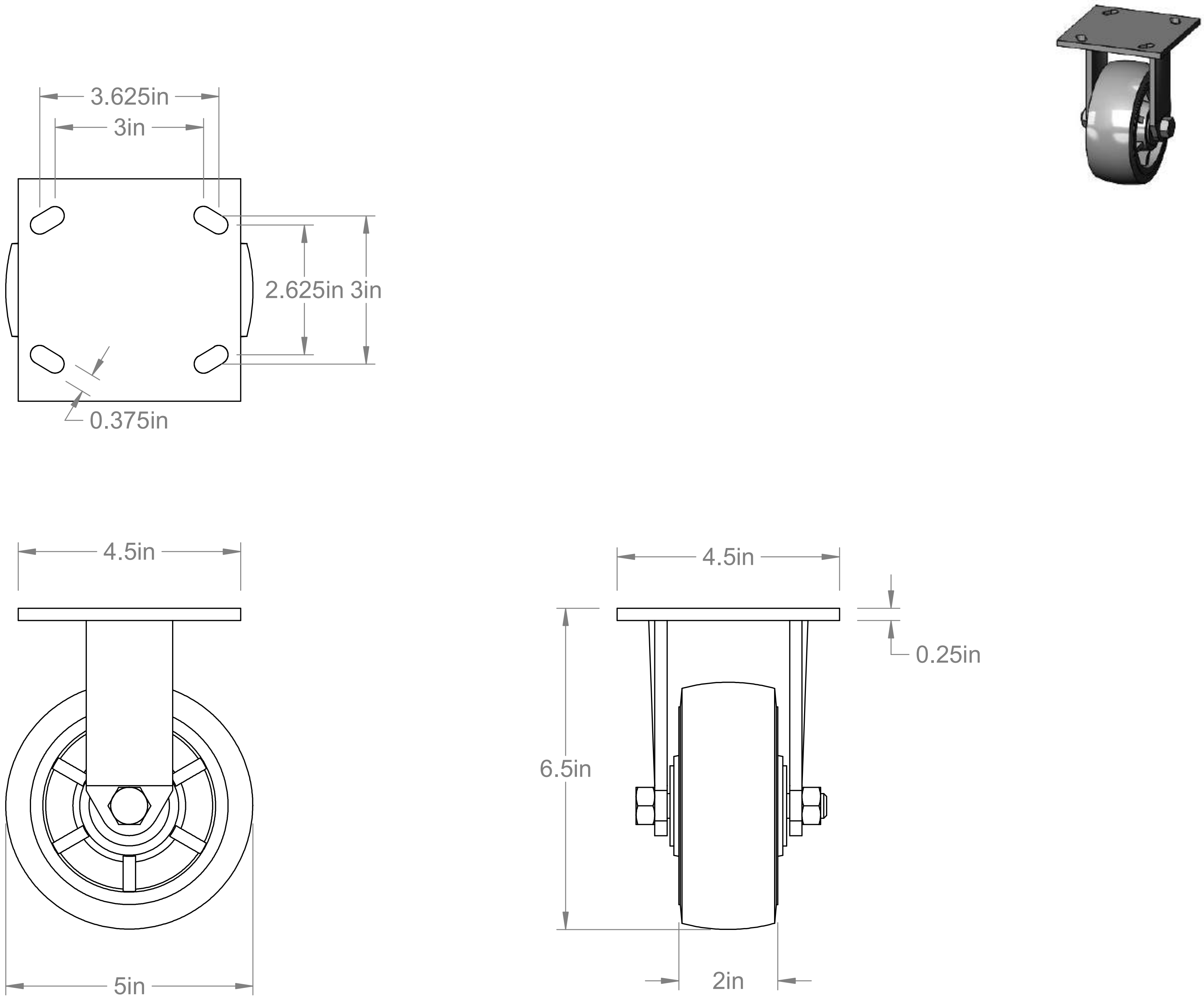


NOTES:

UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES.
2. TOLERANCES
   1. X.X = ±.1
   2. X.XX = ±.01
   3. X.XXX = ±.005
3. 63 ▽ FOR ENTIRE PART.

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.	MATERIAL
1	1.1.6	8in x 9in Cut Steel Plate	2	Carbon Steel Sheet

Cal Poly Mechanical Engineering ME 430 - Fall 2021	Lab Section: 02	Component #6	Title: Wheel Plate	Drwn. By: Team W25
	Dwg. #: 1.1.6	Nxt Asb:	Date: / Scale: 1:2	Chkd. By: ME STAFF



McMASTER-CARR CAD

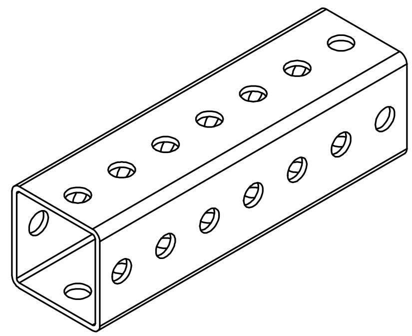
PART NUMBER **5 inch Caster Wheel**

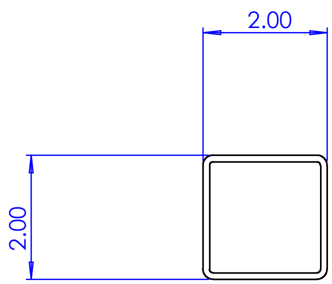
http://www.mcmaster.com

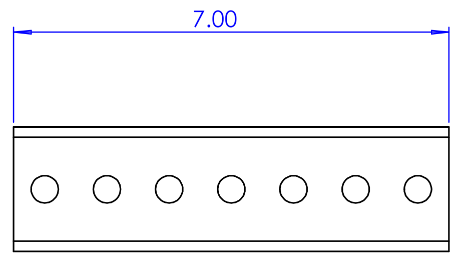
Food Industry Casters
with Phenolic Wheels

NOTES:

UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES.
2. TOLERANCES
   1. X.X = ±.1
   2. X.XX = ±.01
   3. X.XXX = ±.005
3. 63 ▽ FOR ENTIRE PART.





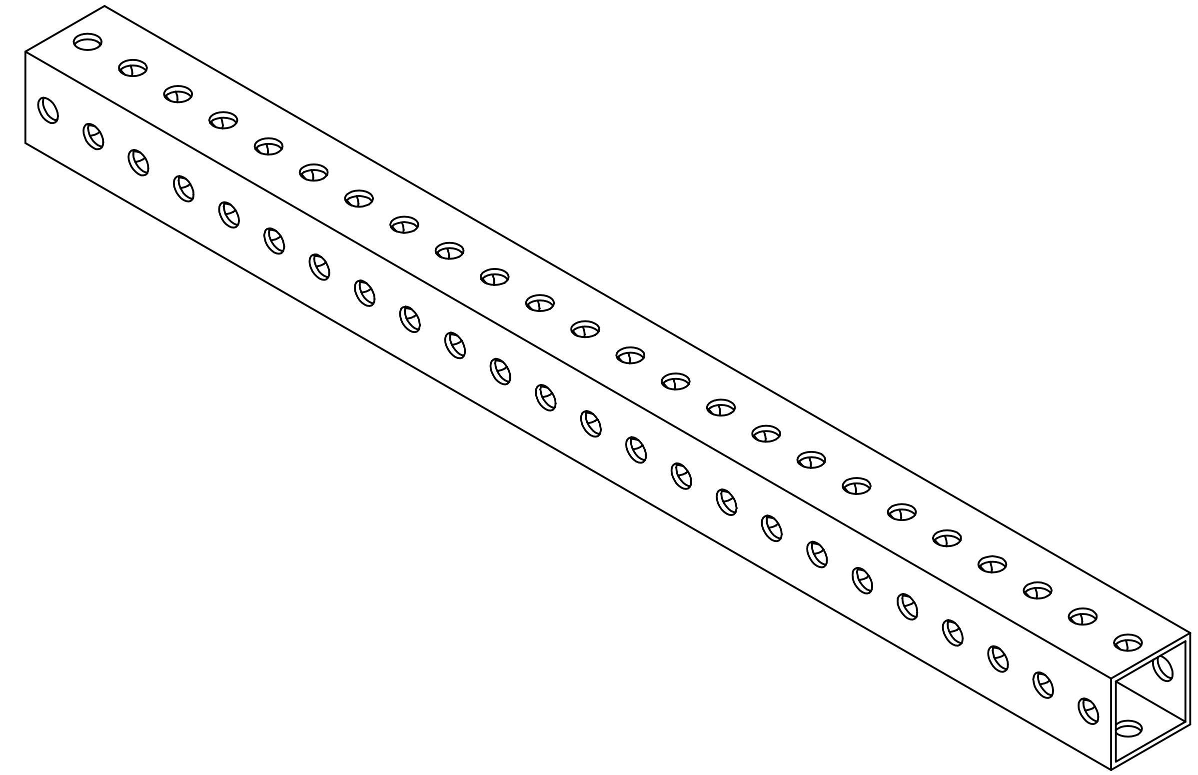


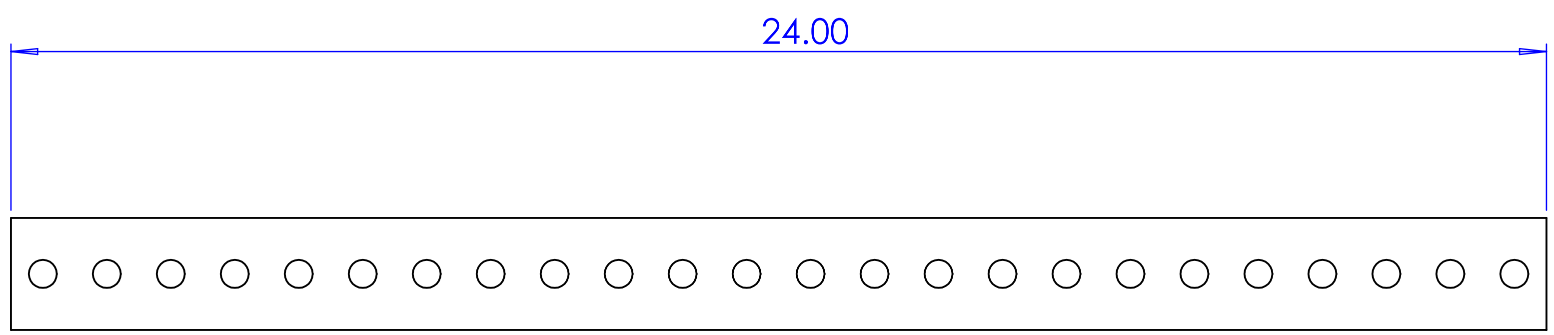
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.	Material
1	1.1.8	2in x 2in x 7in Bolt-Together Framing	6	2in x 2in Bolt Together Framing

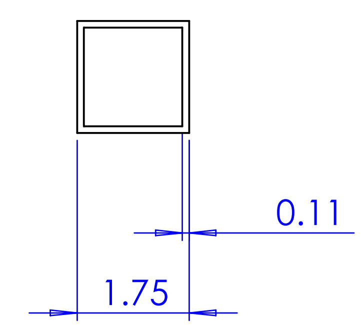
Cal Poly Mechanical Engineering ME 430 - Fall 2021	Lab Section: 02	Component #8	Title: Rail Anchors		Drwn. By: Team W25
	Dwg. #: 1.1.8	Nxt Asb:	Date:	Scale: 1:2	Chkd. By: ME STAFF

NOTES:

UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES.
2. TOLERANCES
   1. X.X = ±.1
   2. X.XX = ±.01
   3. X.XXX = ±.005
3. 63 (surface finish symbol) FOR ENTIRE PART.





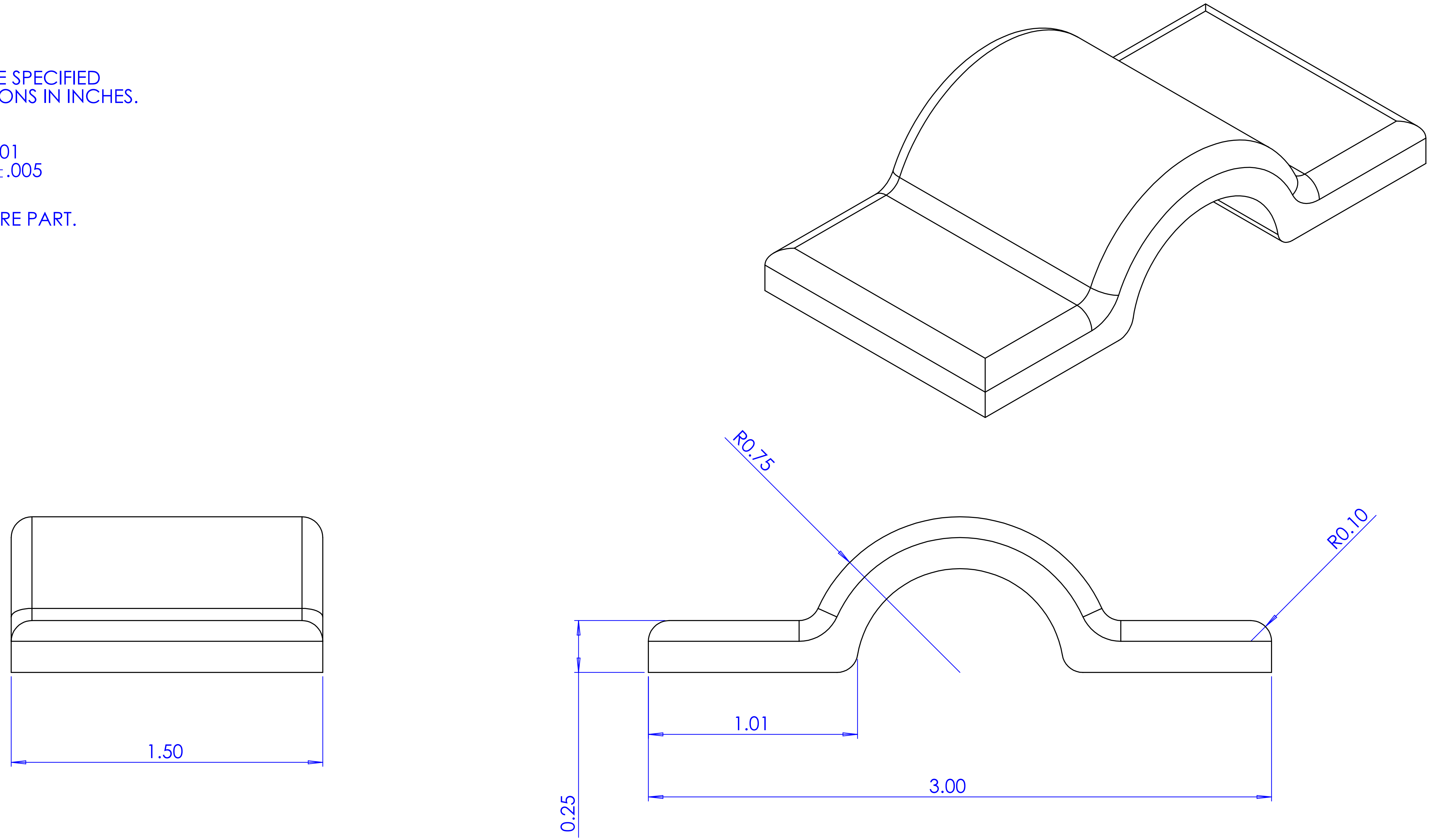


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1.1.9	Cut Telescoping Bolt-Together Framing Inserts	6

Cal Poly Mechanical Engineering ME 430 - Fall 2021	Lab Section: 02	Component #16	Title: Rail Inserts		Drwn. By: Team W25
	Dwg. #: 1.1.9	Nxt Asb:	Date:	Scale: 1:3	Chkd. By: ME STAFF

NOTES:

UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES.
2. TOLERANCES
   1. X.X = ±.1
   2. X.XX = ±.01
   3. X.XXX = ±.005
3. 63 (surface finish symbol) FOR ENTIRE PART.

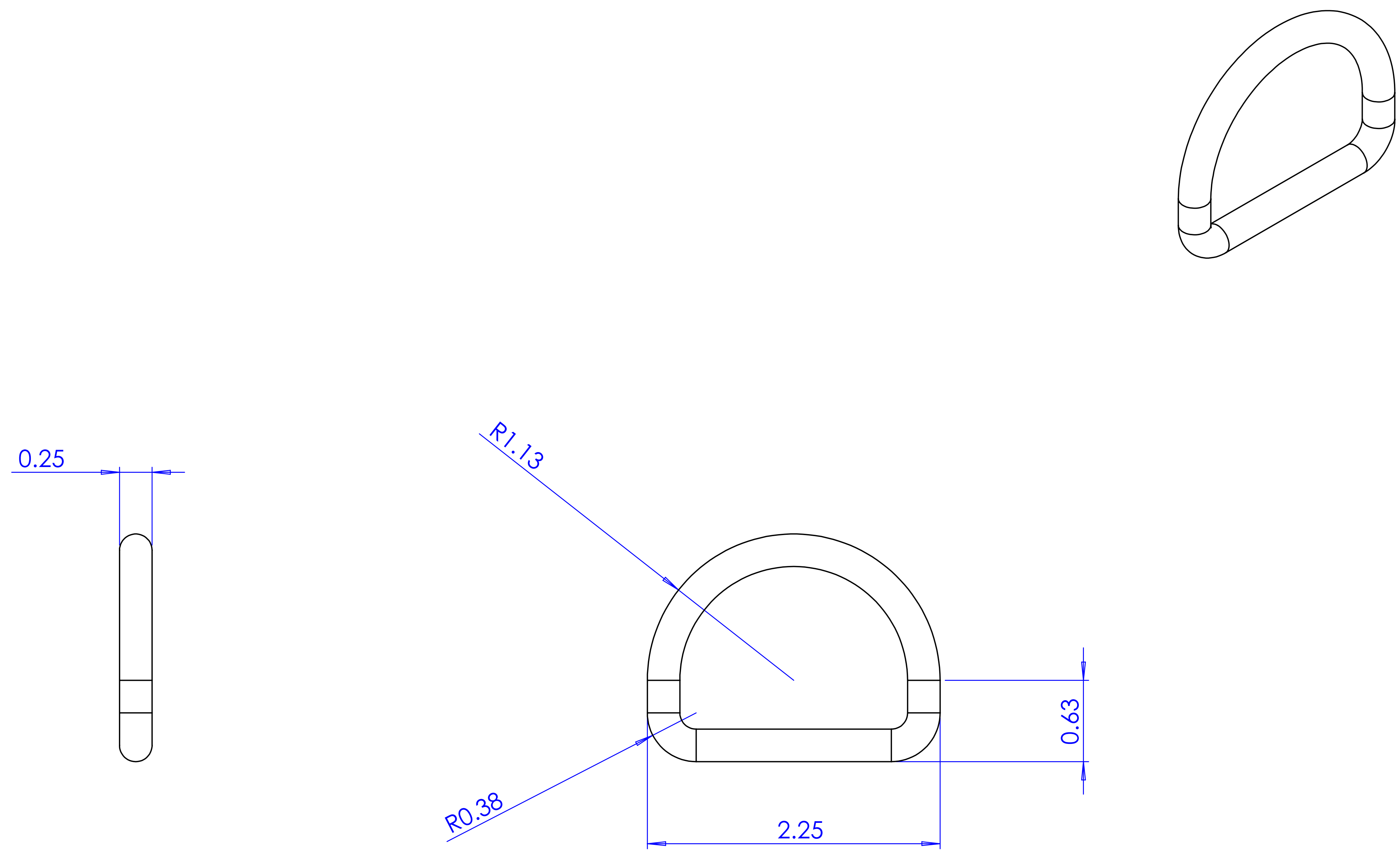


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1.1.10	Wire Ring Anchor	3

Cal Poly Mechanical Engineering ME 430 - Fall 2021	Lab Section: 02	Component #10	Title: Wire Ring Anchor	Drwn. By: Team W25
	Dwg. #: 1.1.10	Nxt Asb:	Date: / Scale: 2:1	Chkd. By: ME STAFF

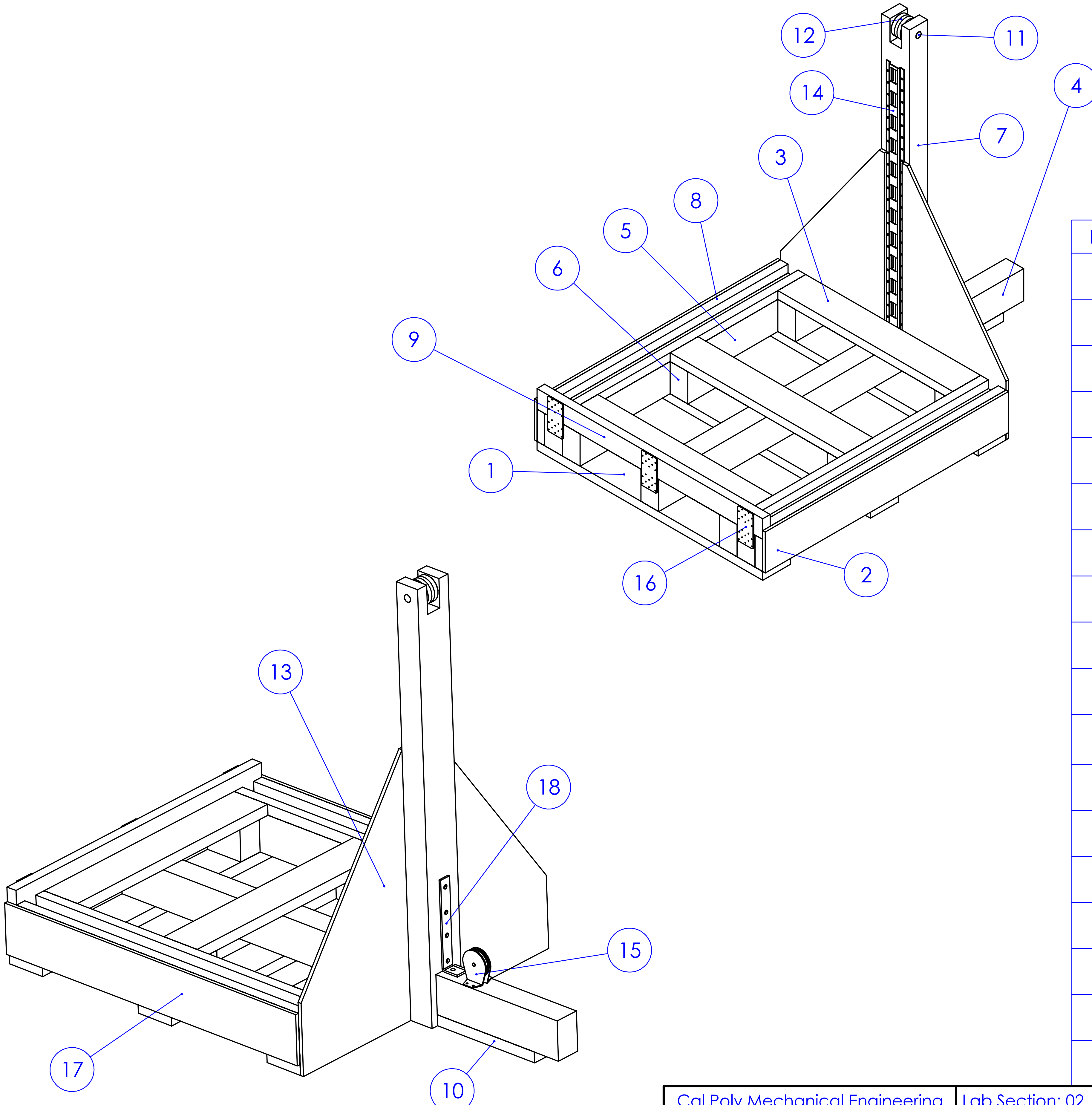
NOTES:

UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES.
2. TOLERANCES
   1. X.X = ±.1
   2. X.XX = ±.01
   3. X.XXX = ±.005
3. 63 √ FOR ENTIRE PART.



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1.1.11	Wire Ring	3

Cal Poly Mechanical Engineering ME 430 - Fall 2021	Lab Section: 02	Component #11	Title: Wire Ring		Drwn. By: Team W25
	Dwg. #: 1.1.11	Nxt Asb:	Date:	Scale: 1:1	Chkd. By: ME STAFF

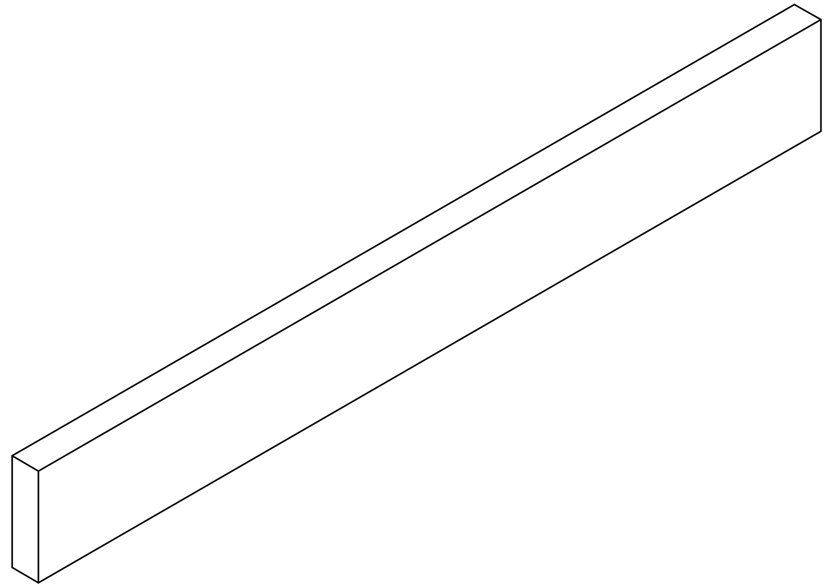


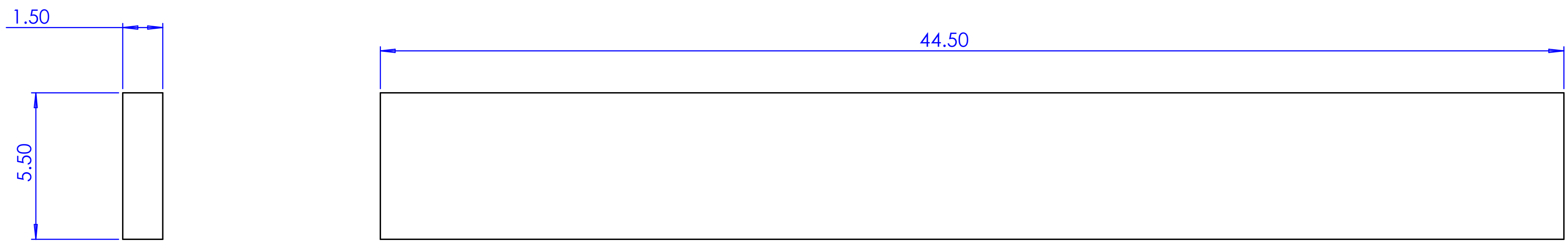
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1.2.1	44.5 inch Cut of 2"x 6" Douglass Fir Wood	3
2	1.2.2	5.5 inch Cut of 2"x 6" Douglass Fir Wood	6
3	1.2.3	34 inch Cut of 2"x 6" Douglass Fir Wood	3
4	1.2.4	72 inch Cut of 4"x 6" Douglass Fir Wood	1
5	1.2.5	48 inch Cut of 4"x 6" Douglass Fir Wood	2
6	1.2.6	5.5 Inch Cut of 4"x 6" Douglass Fir Wood	6
7	1.2.7	60 inch Cut of 4"x 6" Douglass Fir Wood	1
8	1.2.8	46.5 inch Cut of 2"x 2" Douglass Fir Wood	4
9	1.2.9	44.5 inch Cut of 2"x 4" Douglass Fir Wood	1
10	1.2.10	24 inch Cut of 2"x 4" Douglass Fir Wood	1
11	1.2.11	Manufactured Shaft From 1 inch Steel Rod	1
12	1.2.12	Manufactured Wheel From 3.5 inch Delrin Stock	1
13	1.2.13	Plywood Support Wings	2
14	88525T42	Snap-in Load-Securing Track	1
15	3099T4	Pulley for Wire Rope-for Lifting	1
16	1.2.16	Flat Simpson Strong Tie	3
17	1.2.17	Plywood Support Wall	2
18	1.2.18	L Bracket Support	1

Cal Poly Mechanical Engineering ME 430 - Fall 2021	Lab Section: 02	Sub-Assembly #2	Title: Base Frame		Drwn. By: Team W25
	Dwg. #: 1.2.B0	Nxt Asb:	Date:	Scale: 1:16	Chkd. By: ME STAFF

NOTES:

UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES.
2. TOLERANCES
   1. X.X = ±.1
   2. X.XX = ±.01
   3. X.XXX = ±.005
3. 63 (surface finish symbol) FOR ENTIRE PART.



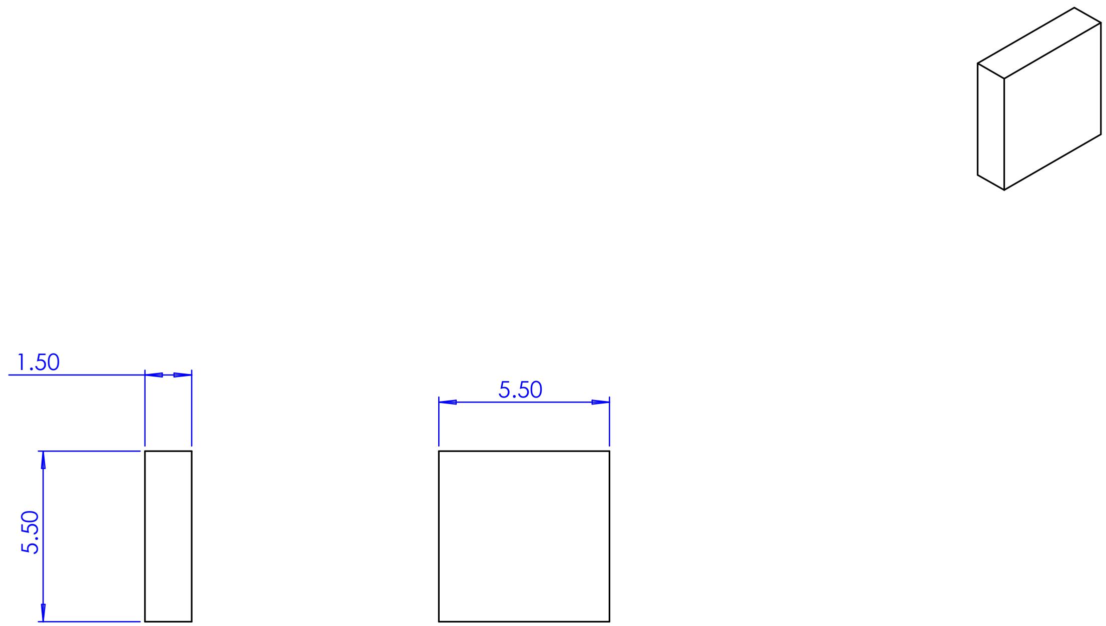


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1.2.1	44.5 inch Cut of 2"x 6" Douglass Fir Wood	3

Cal Poly Mechanical Engineering ME 430 - Fall 2021	Lab Section: 02	Component #1	Title: 44.5 inch 2in x 6in Beam		Drwn. By: Team W25
	Dwg. #: 1.2.1	Nxt Asb:	Date:	Scale: 1:4	Chkd. By: ME STAFF

NOTES:

UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES.
2. TOLERANCES
   1. X.X = ±.1
   2. X.XX = ±.01
   3. X.XXX = ±.005
3. 63 ▽ FOR ENTIRE PART.

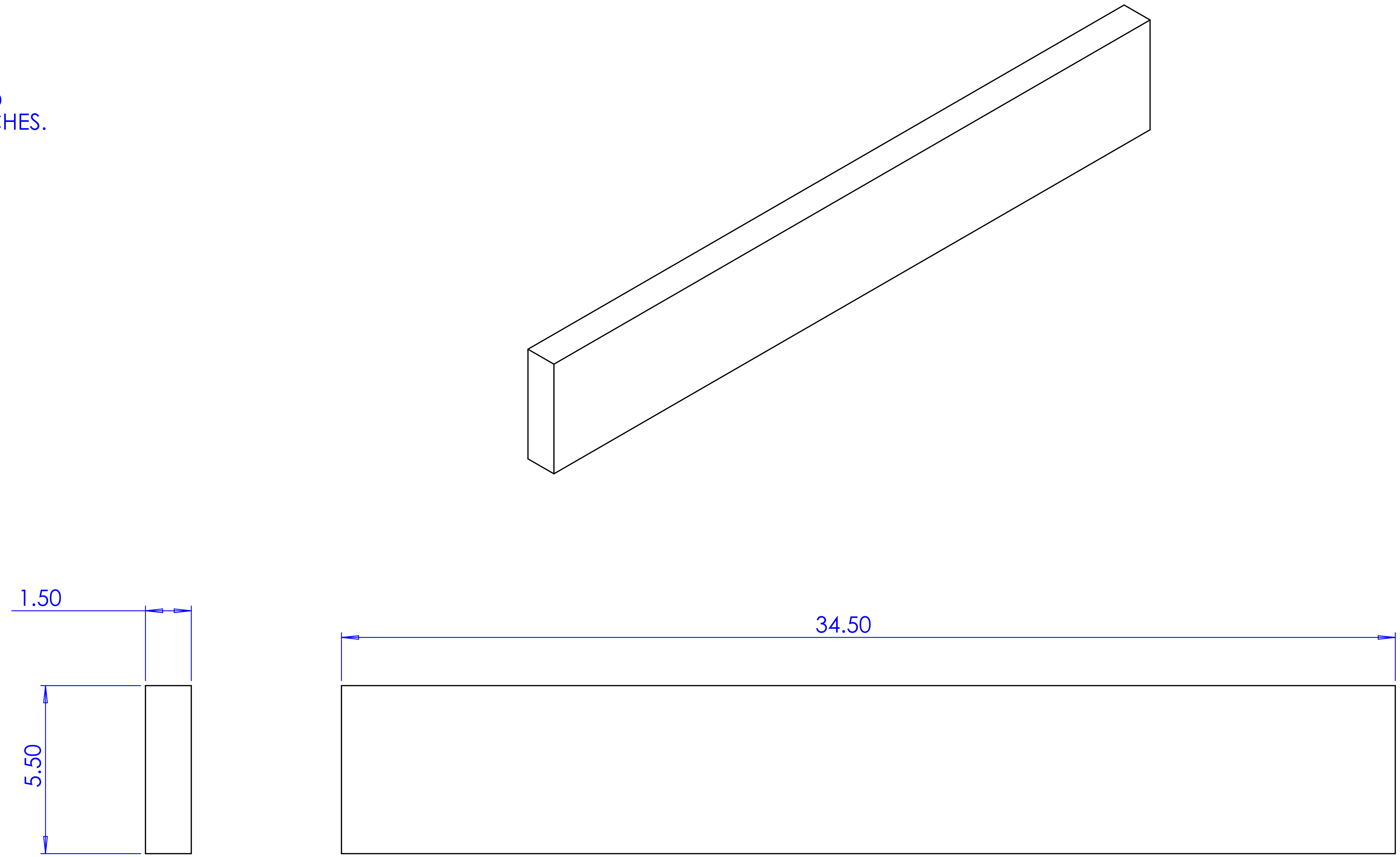


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1.2.2	5.5 inch Cut of 2"x 6" Douglass Fir Wood	6

Cal Poly Mechanical Engineering	Lab Section: 02	Component #2	Title: 5.5 inch 2in x 6in Beam		Drwn. By: Team W25
ME 430 - Fall 2021	Dwg. #: 1.2.2	Nxt Asb:	Date:	Scale: 1:4	Chkd. By: ME STAFF

NOTES:

UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES.
2. TOLERANCES
   1. X.X = ±.1
   2. X.XX = ±.01
   3. X.XXX = ±.005
3. 63 ▽ FOR ENTIRE PART.

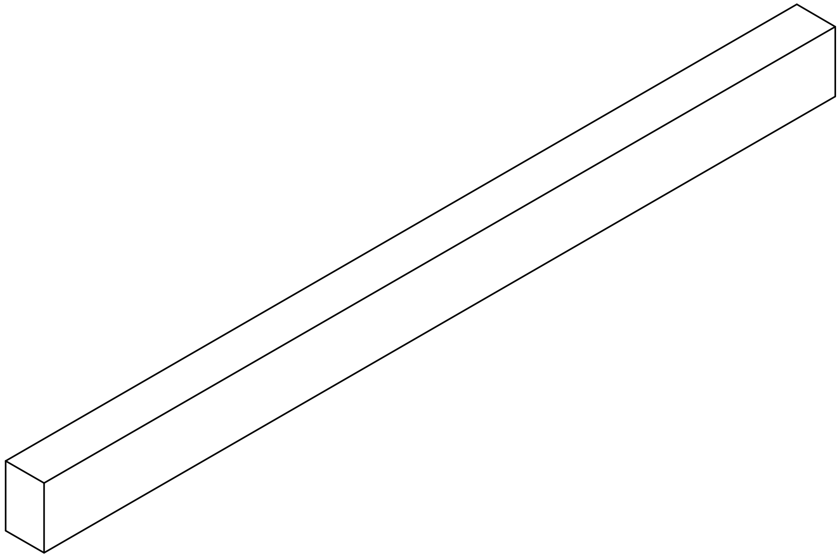


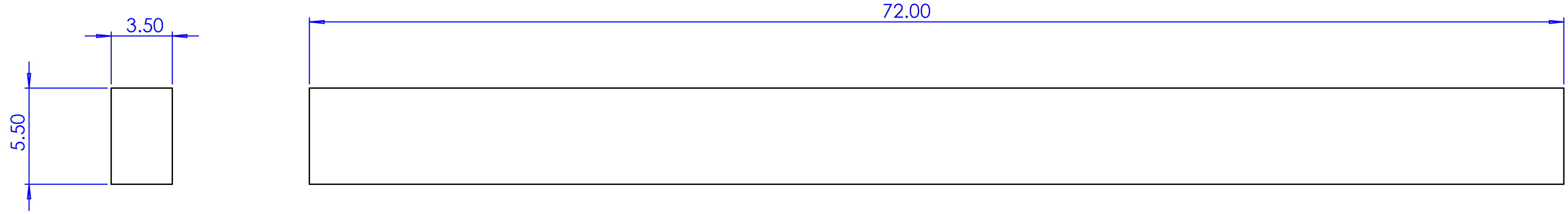
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1.2.3	34 inch Cut of 2"x 6" Douglass Fir Wood	3

Cal Poly Mechanical Engineering	Lab Section: 02	Component #3	Title: 34.5 inch 2in x 6in Beam		Drwn. By: Team W25
ME 430 - Fall 2021	Dwg. #: 1.2.3	Nxt Asb:	Date:	Scale: 1:4	Chkd. By: ME STAFF

NOTES:

UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES.
2. TOLERANCES
   1. X.X = ±.1
   2. X.XX = ±.01
   3. X.XXX = ±.005
3. 63 (surface finish symbol) FOR ENTIRE PART.



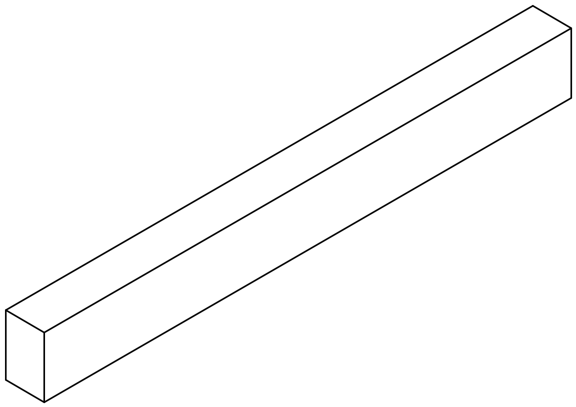


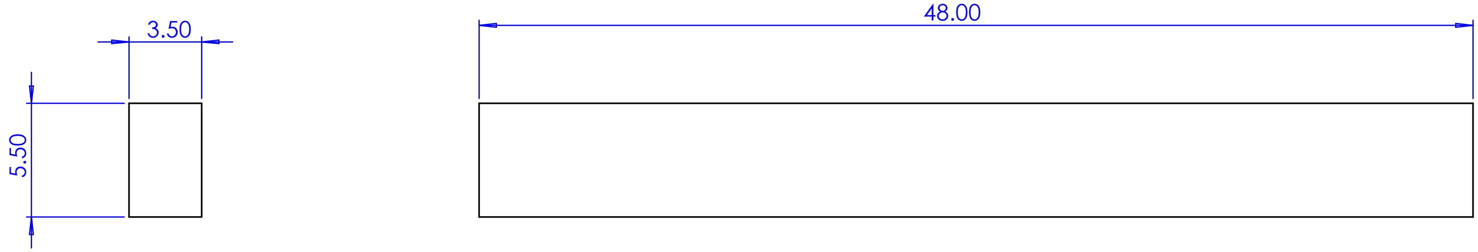
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1.2.4	72 inch Cut of 4"x 6" Douglass Fir Wood	1

Cal Poly Mechanical Engineering ME 430 - Fall 2021	Lab Section: 02	Component #4	Title: 72 inch 4in x 6in Beam	Drwn. By: Team W25
	Dwg. #: 1.2.4	Nxt Asb:	Date: / Scale: 1:6	Chkd. By: ME STAFF

NOTES:

UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES.
2. TOLERANCES
   1. X.X = ±.1
   2. X.XX = ±.01
   3. X.XXX = ±.005
3. 63 (surface finish symbol) FOR ENTIRE PART.



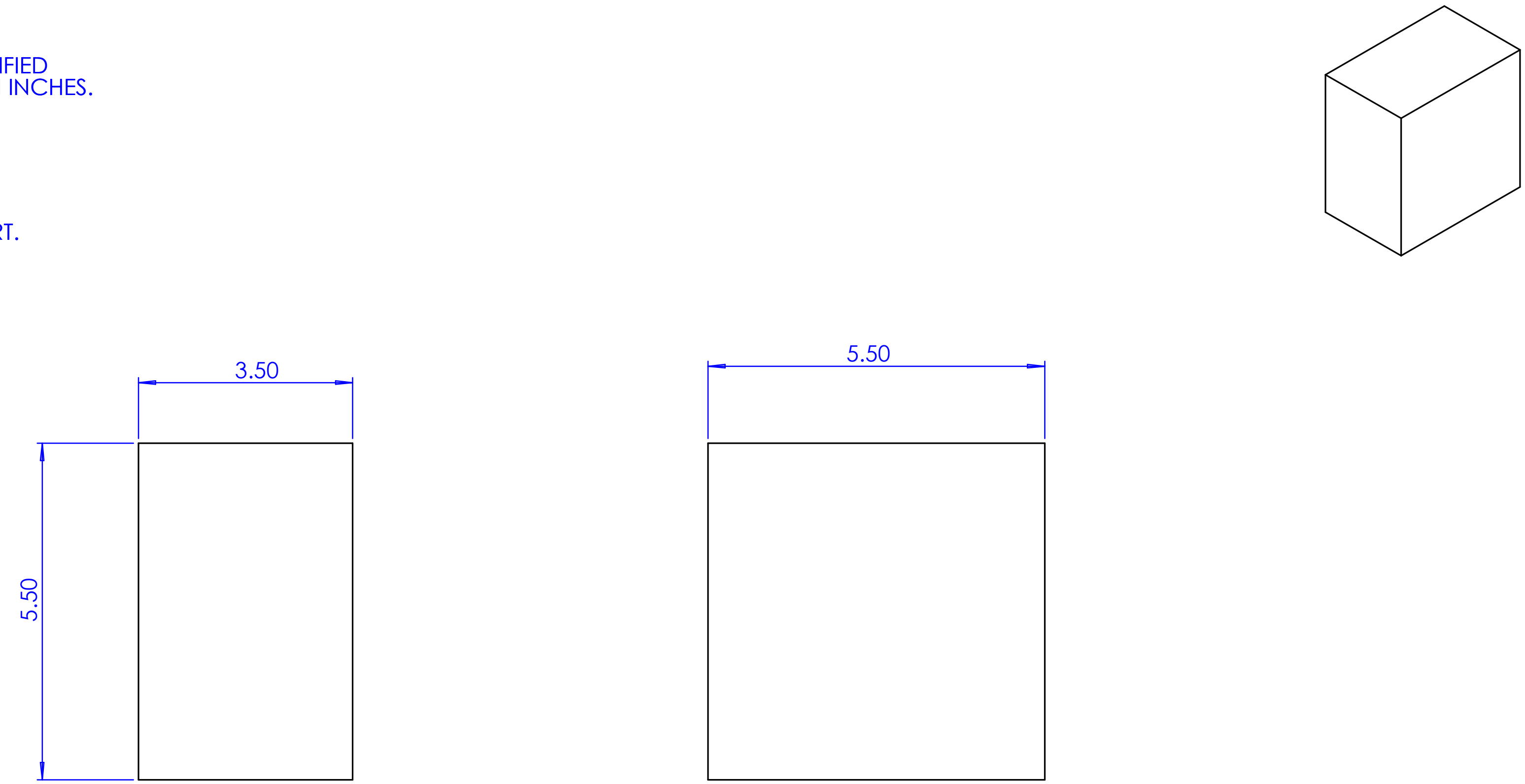


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1.2.5	48 inch Cut of 4"x 6" Douglass Fir Wood	2

Cal Poly Mechanical Engineering ME 430 - Fall 2021	Lab Section: 02	Component #5	Title: 48 inch 4in x 6in Beam	Drwn. By: Team W25
	Dwg. #: 1.2.5	Nxt Asb:	Date: / Scale: 1:6	Chkd. By: ME STAFF

NOTES:

UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES.
2. TOLERANCES
   1. X.X = ±.1
   2. X.XX = ±.01
   3. X.XXX = ±.005
3. 63 ▽ FOR ENTIRE PART.

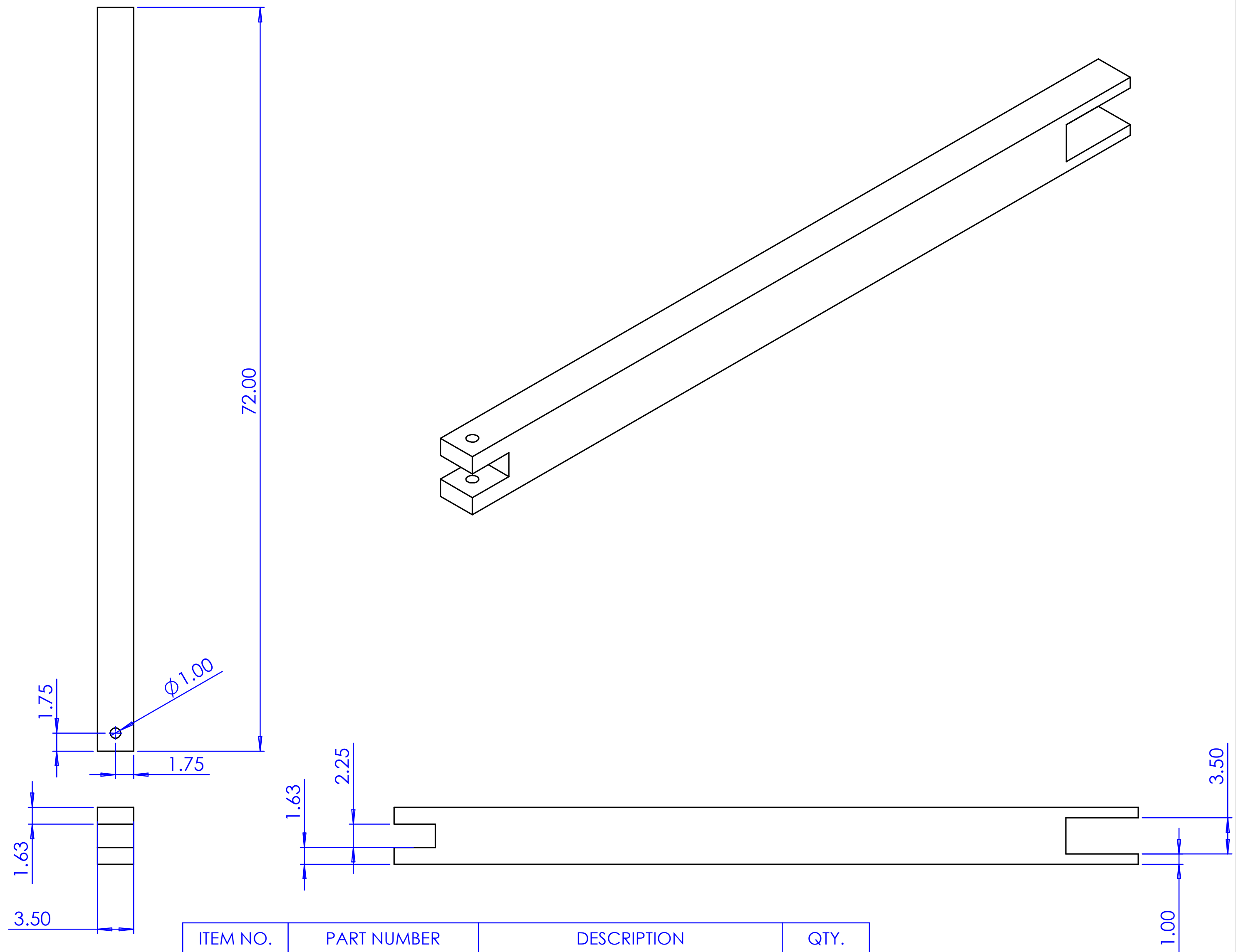


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1.2.6	5.5 Inch Cut of 4"x 6" Douglass Fir Wood	6

Cal Poly Mechanical Engineering ME 430 - Fall 2021	Lab Section: 02	Component #6	Title: 5.5 inch 4in x 6in Beam		Drwn. By: Team W25
	Dwg. #: 1.2.6	Nxt Asb:	Date:	Scale: 1:2	Chkd. By: ME STAFF

NOTES:

UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES.
2. TOLERANCES
   1. X.X = ±.1
   2. X.XX = ±.01
   3. X.XXX = ±.005
3. 63 (surface finish symbol) FOR ENTIRE PART.

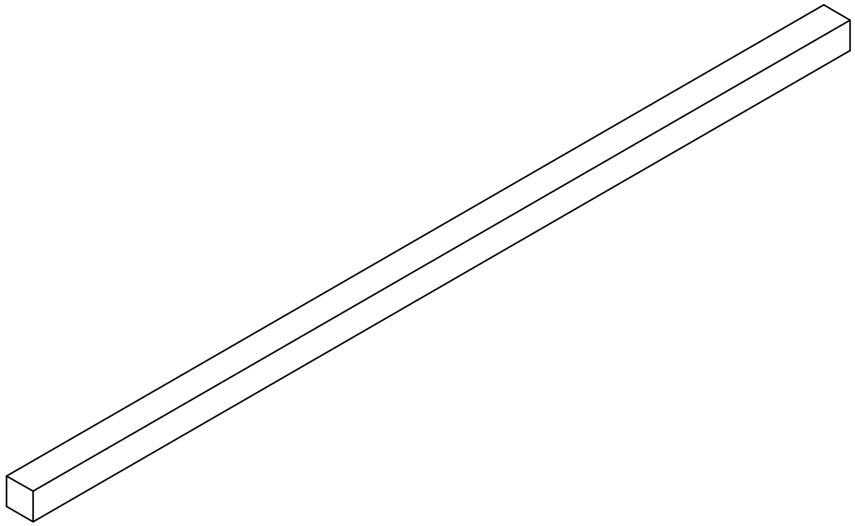


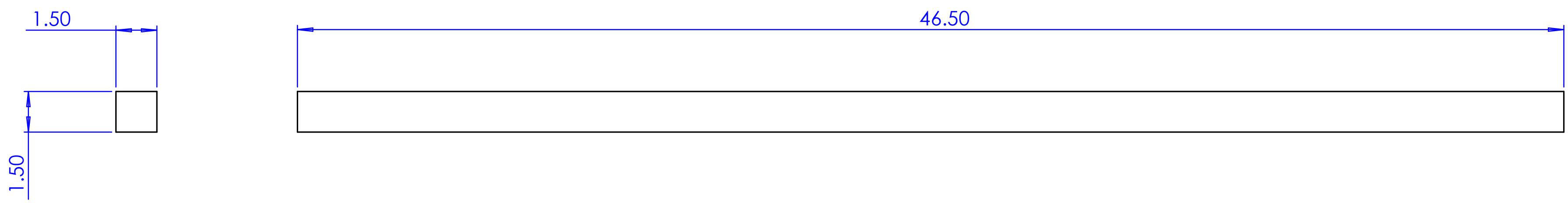
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1.2.7	60 inch Cut of 4"x 6" Douglass Fir Wood	1

Cal Poly Mechanical Engineering ME 430 - Fall 2021	Lab Section: 02	Component #7	Title: 60 inch 4in x 6in Beam	Drwn. By: Team W25
	Dwg. #: 1.2.7	Nxt Asb:	Date: / Scale: 1:10	Chkd. By: ME STAFF

NOTES:

UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES.
2. TOLERANCES
   1. X.X = ±.1
   2. X.XX = ±.01
   3. X.XXX = ±.005
3. 63 (surface finish symbol) FOR ENTIRE PART.



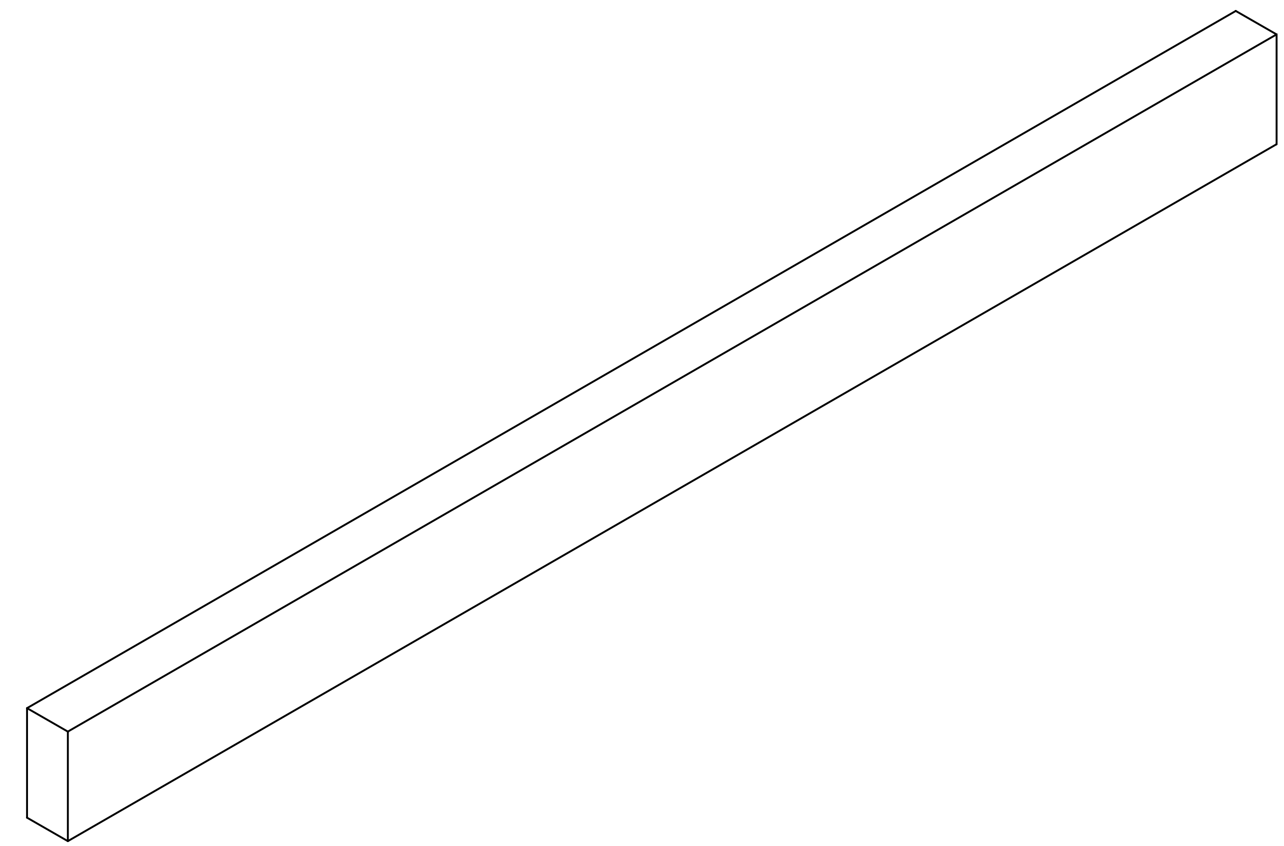


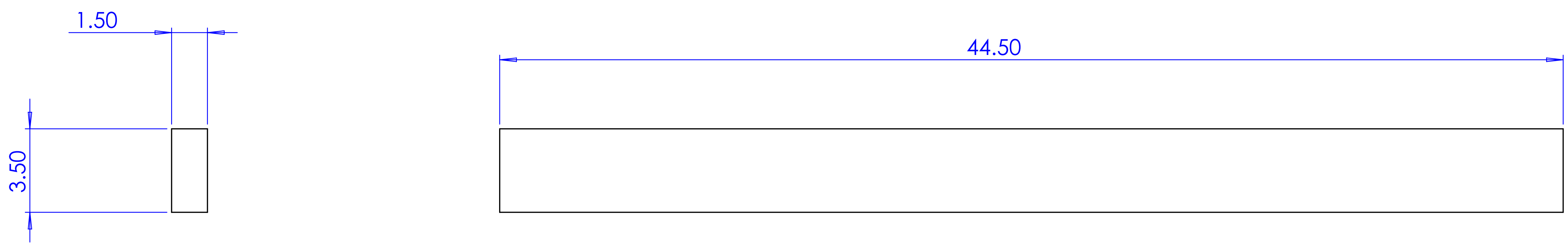
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1.2.8	46.5 inch Cut of 2"x 2" Douglass Fir Wood	1

Cal Poly Mechanical Engineering ME 430 - Fall 2021	Lab Section: 02	Component #8	Title: 46.5 inch 2in x 2in Beam	Drwn. By: Team W25
	Dwg. #: 1.2.8	Nxt Asb:	Date: / Scale: 1:4	Chkd. By: ME STAFF

NOTES:

UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES.
2. TOLERANCES
   1. X.X = ±.1
   2. X.XX = ±.01
   3. X.XXX = ±.005
3. 63 (surface finish symbol) FOR ENTIRE PART.



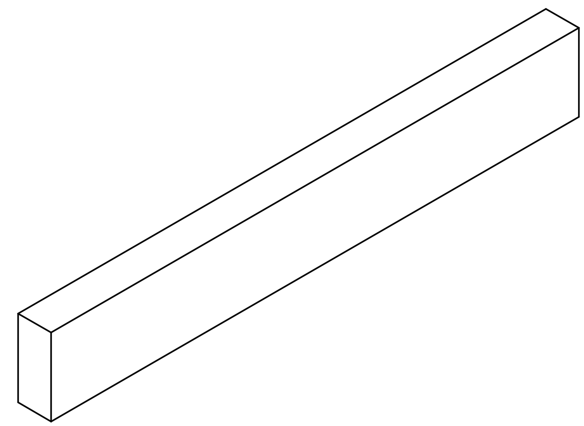


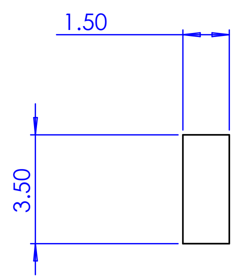
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1.2.9	44.5 inch Cut of 2"x 4" Douglass Fir Wood	1

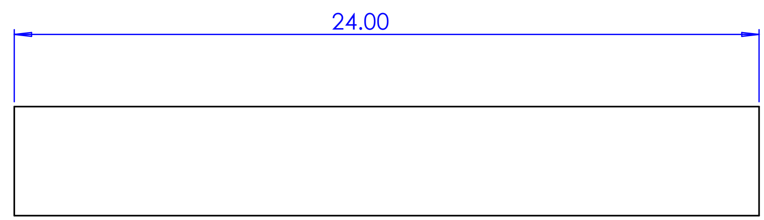
Cal Poly Mechanical Engineering ME 430 - Fall 2021	Lab Section: 02	Component #9	Title: 44.5 inch 2in x 4in Beam	Drwn. By: Team W25
	Dwg. #: 1.2.9	Nxt Asb:	Date: / Scale: 1:5	Chkd. By: ME STAFF

NOTES:

UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES.
2. TOLERANCES
   1. X.X = ±.1
   2. X.XX = ±.01
   3. X.XXX = ±.005
3. 63 ▽ FOR ENTIRE PART.





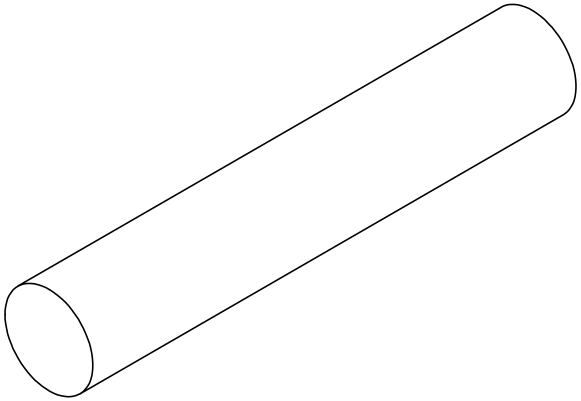


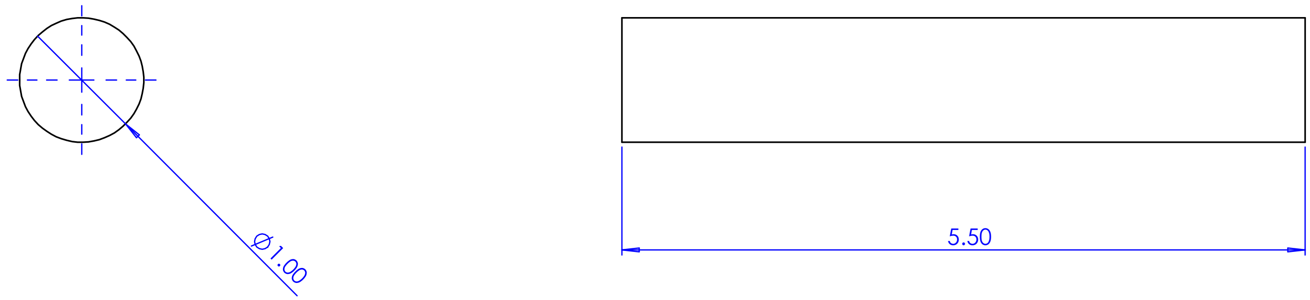
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1.2.10	24 inch Cut of 2"x 4" Douglass Fir Wood	1

Cal Poly Mechanical Engineering ME 430 - Fall 2021	Lab Section: 02	Component #10	Title: 24 inch 2in x 4in Beam		Drwn. By: Team W25
	Dwg. #: 1.2.10	Nxt Asb:	Date:	Scale: 1:4	Chkd. By: ME STAFF

NOTES:

UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES.
2. TOLERANCES
   1. X.X = ±.1
   2. X.XX = ±.01
   3. X.XXX = ±.005
3. 63 (surface finish symbol) FOR ENTIRE PART.



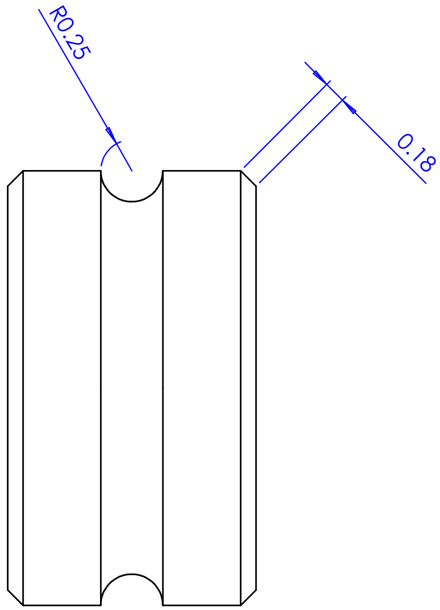


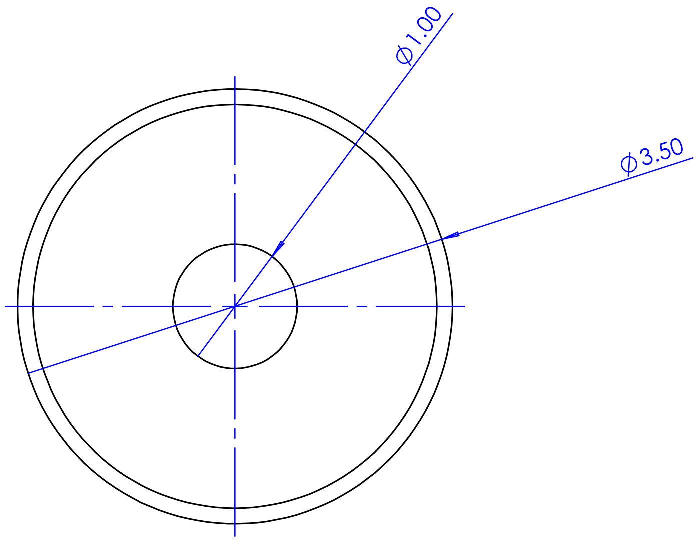
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1.2.11	Manufactured Shaft From 1 inch Steel Rod	1

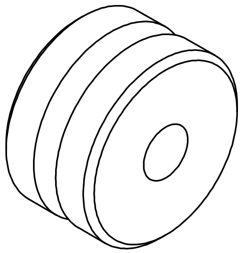
Cal Poly Mechanical Engineering ME 430 - Fall 2021	Lab Section: 02	Component #11	Title: Top Shaft	Drwn. By: Team W25
	Dwg. #: 1.2.11	Nxt Asb:	Date: / Scale: 1:1	Chkd. By: ME STAFF

NOTES:

UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES.
2. TOLERANCES
   1. X.X = ±.1
   2. X.XX = ±.01
   3. X.XXX = ±.005
3. 63 (surface finish symbol) FOR ENTIRE PART.







ITEM NO.	PART NUMBER	DESCRIPTION	QTY.	MATERIALS
1	1.2.12	Manufactured Wheel From 3.5 inch Delrin Stock	1	3.5 inch Delrin Stock

Cal Poly Mechanical Engineering ME 430 - Fall 2021	Lab Section: 02	Component #12	Title: Delrin Wheel		Drwn. By: Team W25
	Dwg. #: 1.2.12	Nxt Asb:	Date:	Scale: 1:1	Chkd. By: ME STAFF

NOTES:

UNLESS OTHERWISE SPECIFIED
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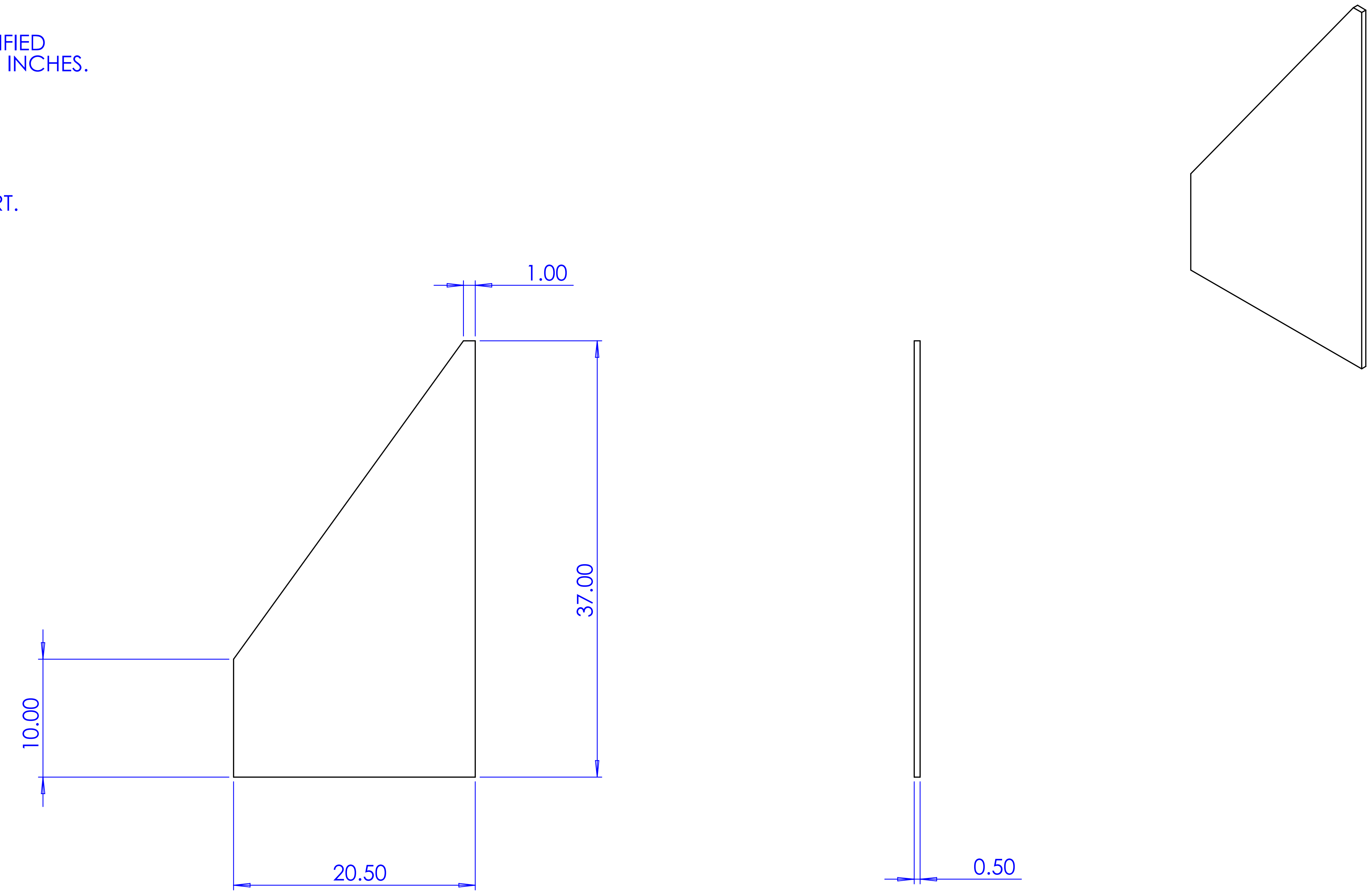
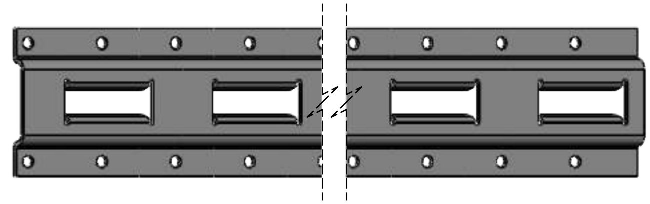
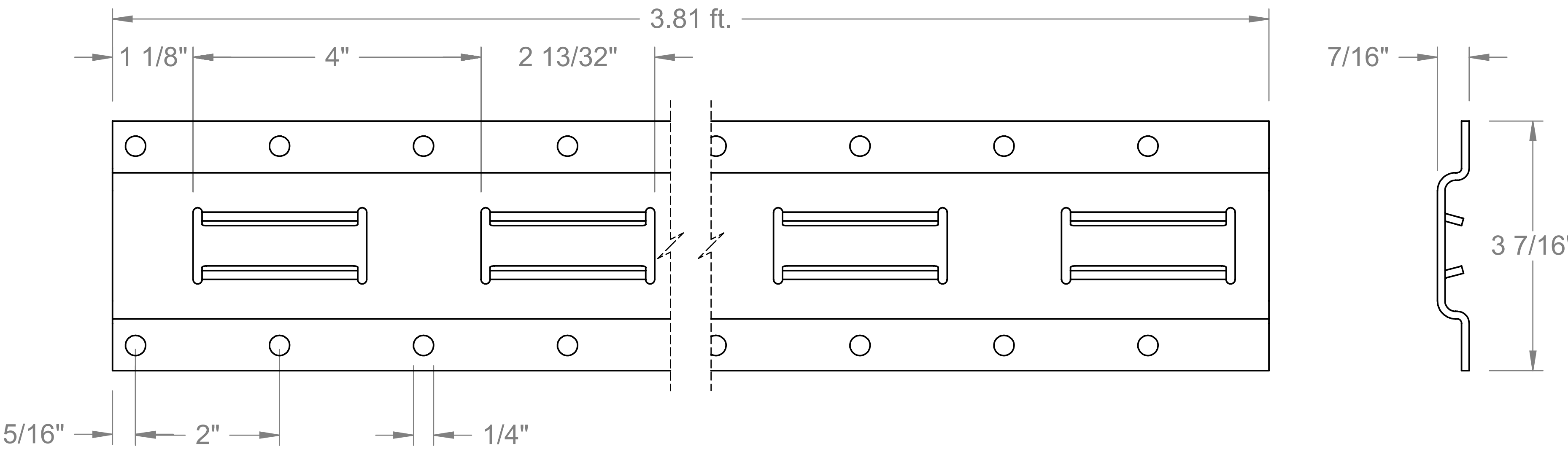
2. TOLERANCES
   1. X.X = ±.1
   2. X.XX = ±.01
   3. X.XXX = ±.005
3. 63 (surface finish symbol) FOR ENTIRE PART.



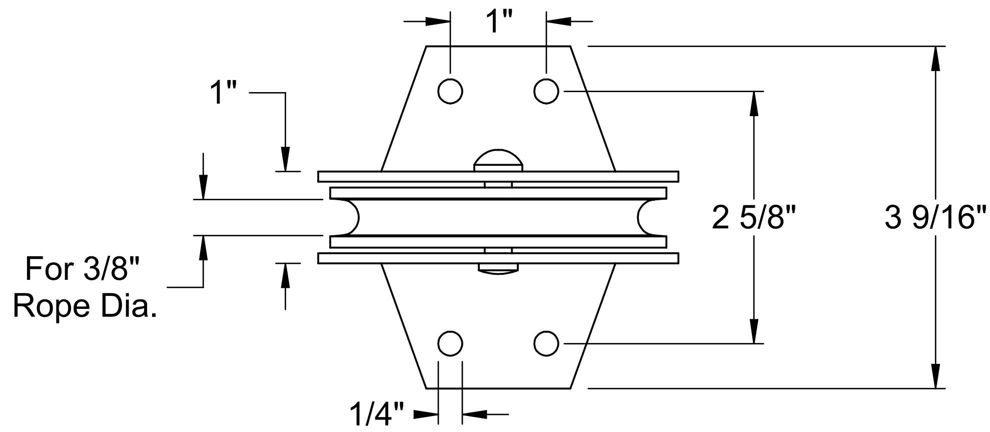
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1.2.13	Plywood Support Wings	2

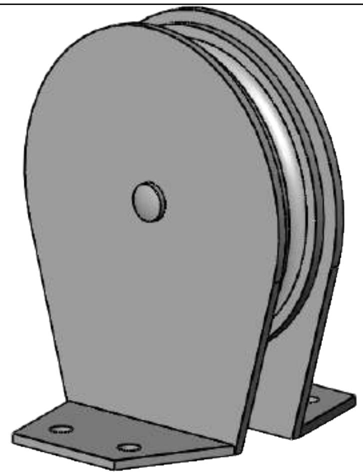
Cal Poly Mechanical Engineering ME 430 - Fall 2021	Lab Section: 02	Component #13	Title: Plywood Wings	Drwn. By: Team W25
	Dwg. #: 1.2.13	Nxt Asb:	Date: / Scale: 1:1	Chkd. By: ME STAFF

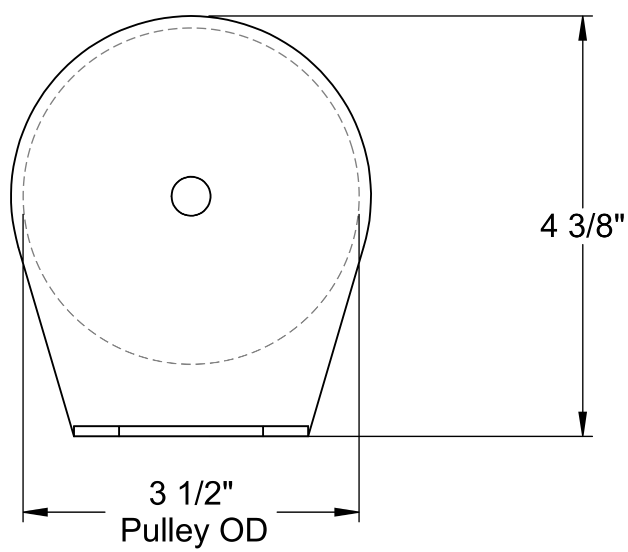




McMASTER-CARR	PART NUMBER	88525T42
http://www.mcmaster.com © 2021 McMaster-Carr Supply Company	Snap-in Load-Securing Track	
Information in this drawing is provided for reference only.		







McMASTER-CARR® CAD	PART NUMBER	3099T4
http://www.mcmaster.com © 2021 McMaster-Carr Supply Company Information in this drawing is provided for reference only.	Pulley for Wire Rope-for Lifting	

NOTES:

UNLESS OTHERWISE SPECIFIED
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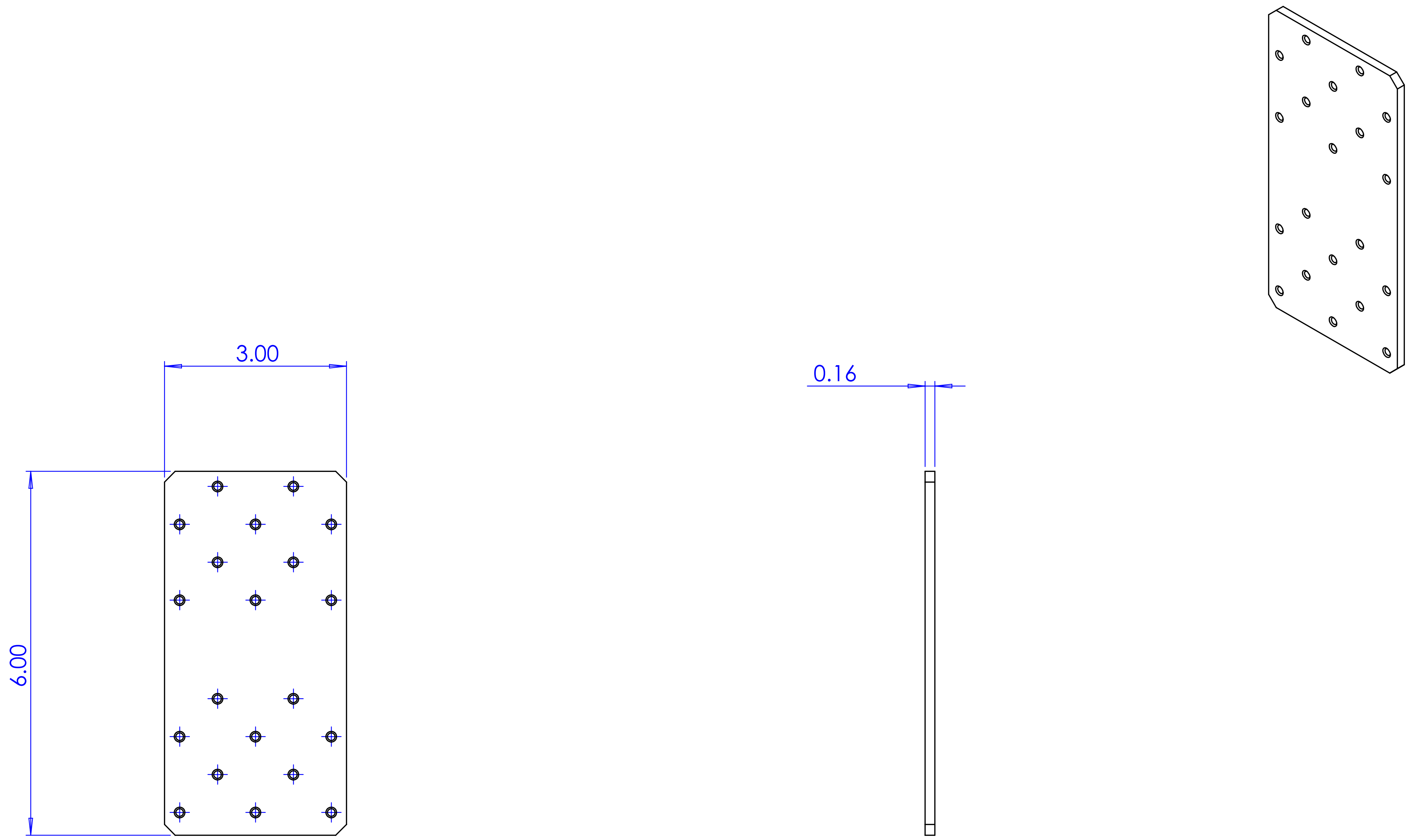
2. TOLERANCES
   1. X.X = ±.1
   2. X.XX = ±.01
   3. X.XXX = ±.005
3. 63 √ FOR ENTIRE PART.

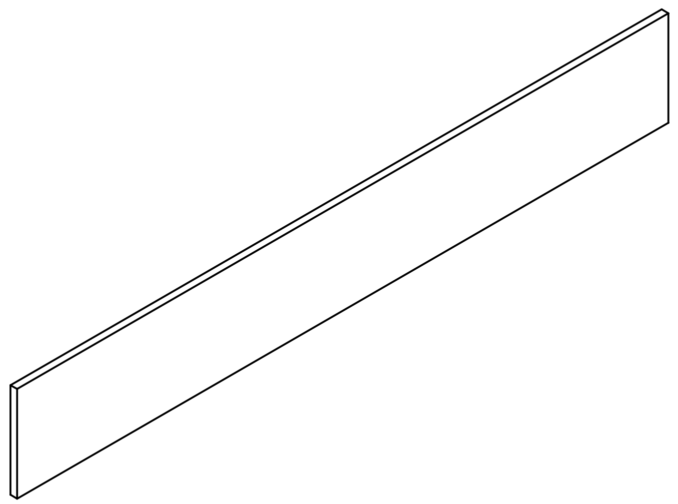


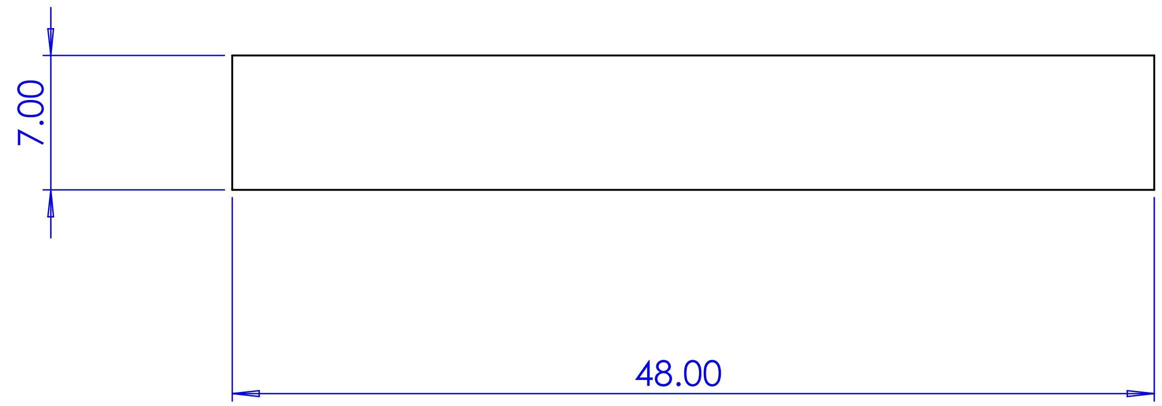
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1.2.16	Flat Simpson Strong Tie	1

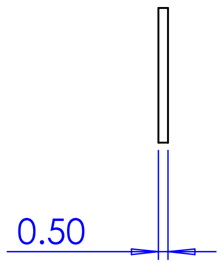
Cal Poly Mechanical Engineering	Lab Section: 02	Component #16	Title: Flat Simpson Strong Tie		Drwn. By: Team W25
ME 430 - Fall 2021	Dwg. #: 1.2.16	Nxt Asb:	Date:	Scale: 1:2	Chkd. By: ME STAFF

NOTES:

UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES.
2. TOLERANCES
   1. X.X = ±.1
   2. X.XX = ±.01
   3. X.XXX = ±.005
3. 63 √ FOR ENTIRE PART.





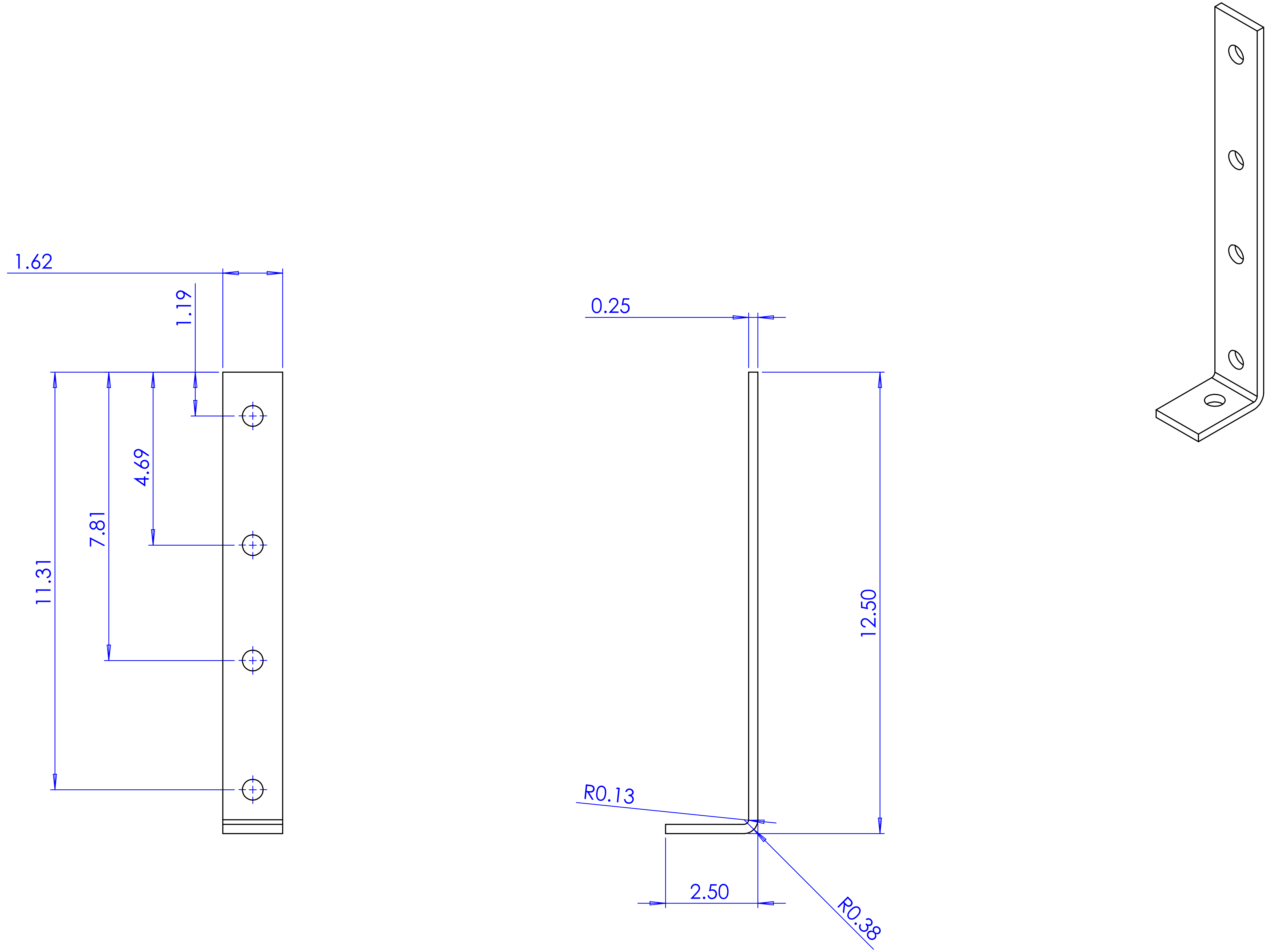


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1.2.17	Plywood Support Wall	2

Cal Poly Mechanical Engineering ME 430 - Fall 2021	Lab Section: 02	Component #17	Title: Plywood Walls		Drwn. By: Team W25
	Dwg. #: 1.2.17	Nxt Asb:	Date:	Scale: 1:1	Chkd. By: ME STAFF

NOTES:

UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES.
2. TOLERANCES
   1. X.X = ±.1
   2. X.XX = ±.01
   3. X.XXX = ±.005
3. 63 (surface finish symbol) FOR ENTIRE PART.



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1.2.18	L Bracket Support	1

Cal Poly Mechanical Engineering	Lab Section: 02	Component #16	Title: L bracket		Drwn. By: Team W25
ME 430 - Fall 2021	Dwg. #: 1.2.16	Nxt Asb:	Date:	Scale: 1:2	Chkd. By: ME STAFF

Appendix N: User's Manual

ALAMEDA COUNTY COMMUNITY FOOD BANK
Until everyone's fed

CAL POLY

Produce Removal User Manual

Parts:

Base Frame (1x)

Securing Bars (6x)

Tilting Frame(1x)

E-Track Linkage (1x)

Badland ZXR 3500 lb.
ATV/Powersport 12v Winch with Wire
Rope (1x)

Battery Terminals (2x)

Battery (1x)

Battery Charger (1x)

Set-up:

1. Remove secure system from the base frame. Pick up base frame from the front with forklift and position in desired location.

2. With a forklift or users, place the tilting frame next to the base frame.

3. Manually set the tilting frame on base frame so the wheels and legs of the tilting frame lie in the tracks on the base frame as pictured.

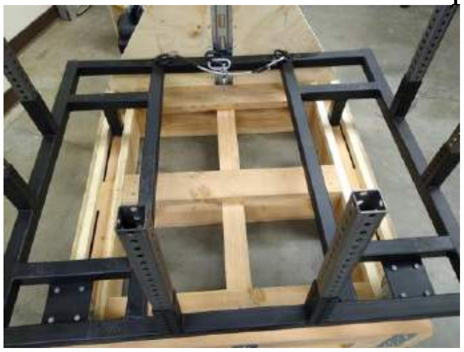


Figure 1: Tilting base in tracks

4. Connect winch wiring to battery by attaching the red cable and red wire to the positive battery terminal and the black cable to the negative battery terminal (as pictured). [**Make sure battery is charged prior to operation.**]

Figure 2: Battery and Winch Connections for operation

5. Switch winch to free spool and run the wire rope under the pulley attached to the bottom of the base frame, and then up and over the Delrin wheel at the top of the base frame before hooking it onto the wire rope attached to the tilting base(as pictured).

Figure 3: DELRIN Wheel with wire rope

6. Switch winch to engaged.
7. Using forklift, load palette and box onto tilting frame.
8. Insert securing bars on all sides of tilting frame.
9. Insert pins to through secure bars to lock into place with tilting frame.

Operation:

[NEVER PLACE ANY BODY PART UNDER TILTING BASE]

Figure 4: Winch Control; “IN” vs. “OUT”

1. Using winch remote, engage winch by pressing “IN”. This will pull the wire rope to lift and tilt the tilting frame. [CAUTION: DO NOT PUT FINGERS OR LOOSE CLOTHING NEAR ANY SECTION OF WIRE ROPE OR WHEELS]

2. When it has reached its desired height, place lock into E-track to lock the tilting base into place and lower winch by pressing “OUT” to disengage winch.

3. Remove items from the box as much as needed.

4. When removal is complete, re-engage winch by pressing “IN” in order to disconnect E-track and lower tilting base by pressing “OUT” on winch remote until it is fully lowered.

Unloading:

1. Remove the two securing bars from the side the palette will be unloaded from.

2. Use forklift to remove palette and Gaylord box.

3. Replace empty Gaylord box

4. Reattach securing bars.

WARNINGS:

1. Do not place any body parts under or near the Tilting Frame, or the wire rope from the winch, during operation.

2. Disengage the E-Track before operation.

3. Do not move assembly without properly strapping down to forklift.

Troubleshooting:

1. For winch troubleshooting, see attached winch manual.

2. For battery charger troubleshooting, see attached charger manual.

Personal Protective Equipment:

1. Closed toes shoes

2. No loose clothing

Maintenance:

No active maintenance should be required in order for the tilting device to properly operate, expect for the battery needing to be charged after every ~10 hours of use. The device can be used both inside and outside but it is highly recommended that it remains indoors. Exposure to prolonged moisture can possibly cause deterioration of the base frame's structural integrity.

Repair procedure

The tilting device should not require major repairs. If the repair is in a larger structural component of the device whether it is in the secure system or the base frame, then the device needs to be reassessed to ensure safety for continued use. If the repair involves a smaller component see attached IBOM for repair/replacement.