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EML4551-2

Team 506: Corning Plugger Pallet Short Part Stabilization

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Abstract

Our Corning sponsors, Jeffery Roche and Jeffery Stott, experience unstable conditions in their plant. They are part of a company that makes ceramics to filter harmful emissions. While shorter ceramics are on the conveyor pallets, they risk falling off because of quick stops and vibrations, resulting in damage. The way that Corning corrects this issue lowers the risk of pieces falling but needs extra labor. Ceramic cylinders moving down the conveyor need to keep their faces bare for quality testing. The plant has various constraints that our design can't interfere with. The team created a mechanical lifting design that will combat the unstable conditions in the plant while lowering the need for extra labor. Inspiration for the design's look came from the shape of a T, our team has named the design the "Self-nesting T's." These Self-nesting T's raise and lower on both sides of the ceramic faces. The design uses no grease and relies on shoulder bolts to move. Considering the dust present in the plant environment, standard grease won't work. To engage, the design uses overhangs placed along the conveyor to lift and drop the T's when needed. Our T's go low enough so the ceramic faces will uncover during testing. The light materials selected allows the design to move with less forces needed. The motion of the design allows it to fully integrate with factory conditions. This range of motion protects the ceramic and brings down the labor cost. Adding thin foam padding prevents further ceramic damage. Various tests confirmed the design's ability to perform its goals. After senior design day, Corning can adjust the design and apply it in their factory to reduce their labor costs while protecting the ceramics from damage.

Keywords: Ceramics, Stabilization, Manufacturing

Acknowledgement

Team 506 would like to thank their Corning sponsor representatives Jeffery Roche and Jeffery Stott. The success of this project would not have been capable without their continual communication. They were able to provide the team with the necessary data to complete this project. If it wasn’t for their continual feedback the project would not have been as successful.

Team 506 would like to thank Dr. Eric Hellstrom for providing feedback and knowledge of ceramic materials. His knowledge on materials allowed the team to learn about better material that can work with ceramic dust. His feedback and support allowed for the team to create, design, and select materials for a device that was able to work for the design problem.

Team 506 would like to thank Dr. Carl Moore for his help and knowledge of 4-bar mechanisms. With his assistance the team was able to create the optimal required height for the device while also hitting the required retracted height. His support in the project was critical to the success of making the teams device function as desired.

Team 506 would like to thank Professor Keith Larson for his knowledge and expertise in machining parts and hardware. His knowledge allowed the team to learn more about available hardware to put together the device as to create the needed joints. His advise in this project was valuable as it was able to provide the team the necessary information to allow the device to be machined and assembled properly.

Finally, team 506 would like to thank the Faculty of the FAMU-FSU College of Engineering, Mechanical and Electrical Engineering departments. Their teaching through the years has provided the team with the necessary information needed to make the project work successfully.

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Notation

DOF	Degrees of Freedom
OSHA	Occupational Safety and Health Administration

Chapter One: EML 4551C

1.1 Project Scope

Project Description

The team was able to determine the project description by meeting with the project sponsor representatives, Jeffery Roche and Jeffery Stott, and discussing their current needs. Based on these meetings with the Corning representatives the team has determined that the goal of the project is to improve the current device that is being used to protect the ceramics. The objective of the project is to prevent the ceramics from falling off the conveyor in the Corning's manufacturing plant, while also decreasing the cost in labor by minimizing the number of employees needed along the conveyor.

Key Goals

After developing the project description, the team was able to come up with a list of key goals that the design must achieve. The first key goal of this project is to design a method to prevent damage to ceramic filters and substrates while on the production line in Corning's manufacturing plant. Their current design utilizes a "T" shaped piece of plexiglass that is placed upside down and inside the slots on their chuck system. This method adequately prevents short part ceramics from falling and obtaining damage. Another goal of the team's design is to limit human interaction compared to the current system. The system currently in place requires two plant workers to place the T's on the chuck at the beginning of the line and remove them before the imaging process. The design used for this project should also be able to seamlessly integrate with the current conveyor system. There are several overhangs and space limitations on their current conveyor and the team's design needs to fit within these parameters.

Market

The primary market of this project is the end-user of the pallet ceramic stabilizer, Corning. The company will use the project in the manufacturing process of their ceramic parts benefiting the company directly. Secondary markets for this project include any manufacturing services that maneuver fragile cylindrical parts along a conveyor. This would consist of other ceramic manufacturers, motor vehicle manufacturers, and other companies developing emission control systems.

Assumptions

In order to complete the project in the required timeframe, the team needs to make some vital assumptions. The team is assuming that the pallets and conveyor itself remain level during the transporting process. Additionally, the team expects the data and measurements received from our sponsor to be accurate and precise. This means that the pallets are uniform across the plant. Lastly, the team assumes that the manufacturing plant conditions will remain the same throughout the project duration.

Stakeholders

The major stakeholders for this project include the sponsors from Corning, Jeffery Roche and Jeffery Stott, the team's academic advisor Dr. Eric Hellstrom, and the senior design instructor Dr. Shayne McConomy. Each of these stakeholders have an interest in or will benefit from the successful completion of the project. Although this project is a custom design for Corning's manufacturing plant, the team was able to establish other possible stakeholders that could benefit from this project. These other stakeholders include other ceramic manufacturers, such as FineWay Ceramics, who are part of the secondary market.

1.2 Customer Needs

The critical factors in the project's success are the needs, attributes, and requirements of the customer. These needs are not tied to any specific design concepts but instead reflect the functions that the customer desires from our solution. During multiple meetings with the Corning project sponsor representatives, Jeffrey Stott and Jeffrey Roche, the team asked numerous questions in order to get a better understanding of the customer’s needs. The feedback received will be used in determining the device functions and design constraints. These questions are listed below along with their responses and the team’s interpreted needs based on Corning’s responses.

Table 1: Interpreted Customer Needs

Customer Needs Q & A			
Number	Question	Customer Statement	Interpreted Need
1.	What is the goal of our project?	The goal of the project is to prevent ceramics from tipping off the conveyor belt.	The solution protects the ceramics from being damaged.
2.	Which ceramics are being damaged during the	The shorter ceramics are being damaged due to vibration on the conveyor.	The solution works for short ceramics.

	manufacturing process?		
3.	What is the issue with the system currently in place?	The system in place requires manual labor to install and return to the beginning of the conveyor.	The design has limited human interaction.
4.	Are there any limited spaces that should be taken into consideration?	Some restrictions include: limited space on return conveyors that run under the normal belts, space underneath the base plate is extremely limited, inability to change conveyor design, and must conform with the half-moon pickup and unload system.	The project works with the given space of the conveyer.
5.	Any concerns with other nearby equipment (electric)?	Edges of the conveyor have sensors and readers that hang over the conveyor.	The solution works with current conveyor conditions.
6.	What size ceramics will we be working with?	Ideally, the system can work with multiple different ceramic size lines. However, there is the option that different variants of the design can be used for specific manufacturing needs.	The design can be scaled for different sized ceramics.

Number	Question	Customer Statement	Interpreted Need
7.	What activities are the Ceramics undergoing at each station?	Imaging, which requires both surfaces to be uncovered so the laser imaging can access the ceramics. Orthogonal and directional changes to pallet travel. Vibrations of the ceramics while the pallet is stationary at stops on the conveyor.	The solution complies with several different motions and orientations during the travel process. This includes uncovering the ceramic for imaging.
8.	Are there any material restrictions?	There are no current material restrictions for the different stations such as the imaging system.	The solution complies with any material restrictions.
9.	How is the problem being handled currently?	The method that currently exists is placing 'T' shaped plexi-glass stabilizers at both ends of the ceramic. The current method is successful but requires a significant amount of manual labor.	The solution improves upon the current method.
10.	What is the average amount of ceramics damaged when shorter parts are being produced?	Without using the current stabilizing method around 15% of the ceramics are damaged.	This design allows for fewer ceramics to get damaged.

Explanation of Results

Team 506 is tasked with designing a method to prevent ceramics from falling off of the pallet during conveyor use. The team had several meetings with the representatives of Corning in order to inquire further details regarding the needs of the project. After analyzing the customer's statements, the table above was generated to list the interpretations of each independent need.

From these discussions with the customer, the team has gained a better understanding of the needs that are to be incorporated into the design.

The solution that the team develops will protect the ceramic cylinders from being damaged while on the conveyor system. This design will limit the need for human interaction and therefore cut down on the human resources currently being expended on the protection of these ceramics. The design will comply with the current space limitations of the Corning conveyor system. Additionally, the various sizes of the ceramics will be addressed and taken into careful consideration. With the project conclusion, Team 506 will provide a design that fulfills the desired customer needs.

1.3 Functional Decomposition

Team 506 used the functional decomposition to breakdown the required systems for our project. These systems are the major components of the project and will provide the essential functions needed. The team used a hierarchy chart and cross reference table to depict the breakdown of the project's major systems and their functions. The major systems of our project are: stabilization, compatibility, and support. These systems are then broken down into the major functions they provide to the project. The breakdown can be seen in the hierarchy chart. The hierarchy chart displays the functions under the system that it pertains to. On the cross reference table, the functions that can apply to any of the systems will contain an “X”. This shows the overlap of the functions between the different systems.

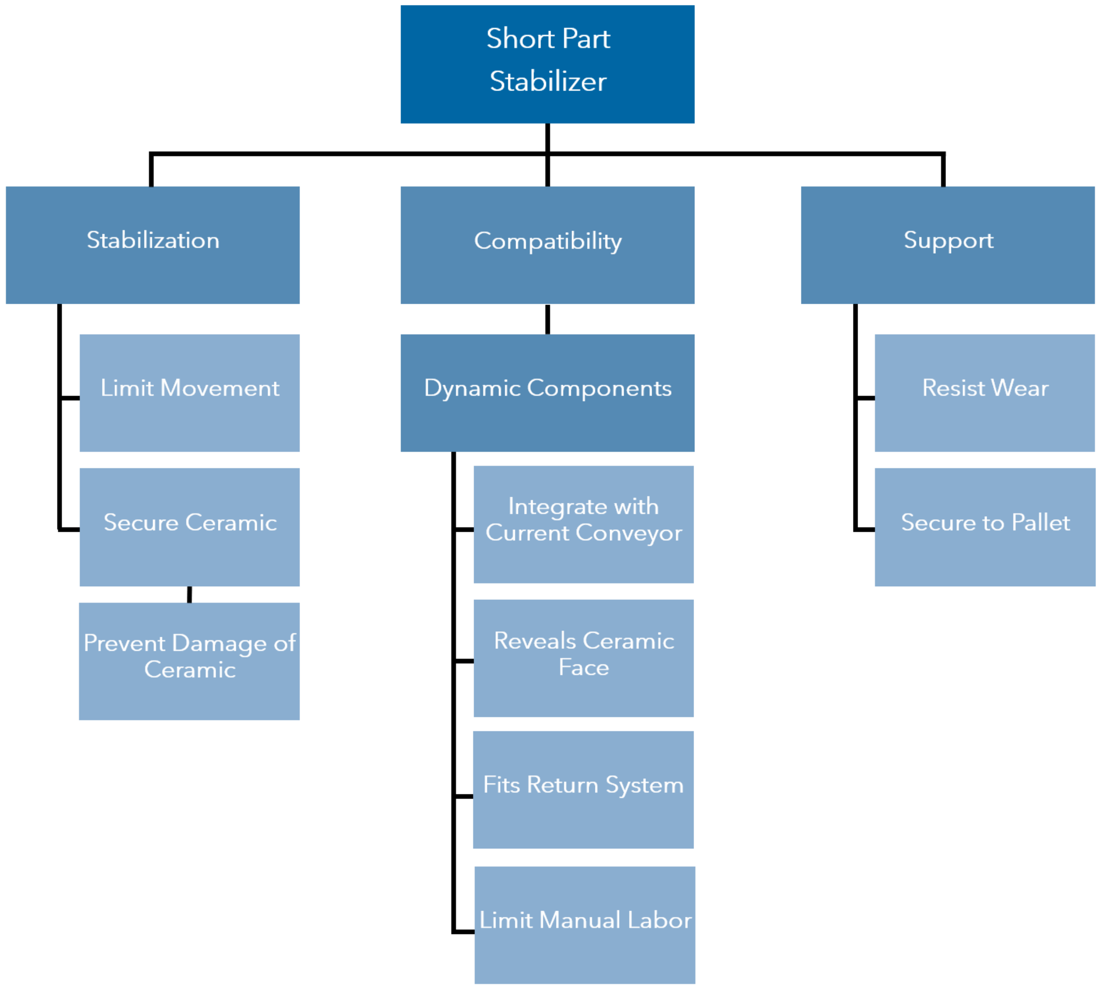


Figure 1: Hierarchy Chart

Table 2: Cross Reference Table

	System		
Functions	Stabilization	Compatibility	Support
Secure Ceramic	X	X	
Prevent Damage of Ceramic	X	X	
Reveal Ceramic Face		X	X
Secure to Pallet		X	X
Dynamic Components		X	
Resist Wear			X
Limit Movement	X		X
Integrate with Current Conveyor		X	X
Fits Return System		X	
Limit Manual Labor		X	

Explanation of Results:

The data that was used to generate the system and function breakdowns was gathered through several meetings with the project sponsor representatives, Jeffery Roche and Jeffery Stott. From these meetings the team was able to determine the major systems that our design would contain and the functions these systems need to complete. The major systems the team was able to determine were stabilization, compatibility, and support. Our design's main goal is to stabilize the short ceramics while they are being transported on the Corning conveyor system. The design also needs to be compatible with the current conveyor that the Corning factory uses.

The last system of the team's design is to have the support capable of withstanding multiple cycles.

The stabilization subsystem’s primary goal is to stabilize the ceramic while it is being transported on the conveyor. Within this subsystem the primary functions the team determined were to limit movement, secure ceramics, and prevent damage of the ceramics. The stabilization subsystem should limit the movement of the ceramics while they are being transported across the Corning conveyor. Currently, the ceramics will fall off the conveyor due to vibration from the belt and sudden stops. This knowledge allowed the team to then determine that, in order to limit the movement, the ceramics must be secured to the pallet. The security of the ceramics will prevent the ceramics from moving and therefore prevent the damage of their ceramics.

The compatibility subsystem’s primary goal is to guarantee the compatibility of the device with the current conveyor system. Within the compatibility subsystem the primary functions were determined to be the dynamic components of the device. The dynamic components consist of integration with the conveyor, reveals ceramic face, fits the return system of the conveyor, and limits manual labor needed to operate the device. The device needs to integrate with the current conveyor such that it does not obstruct any current overhangs, sensors, stopping mechanics, or directional changes along the rolling system. The device needs to be capable of revealing the ceramic face so the surface can be examined at different stations along the conveyor. The design needs to be compatible with the conveyor's current return system of the conveyor. The current conveyor uses an elevator mechanism to lower the pallets to a bottom level and return the pallets under the original conveyor. The device being compatible with the current system will limit the manual labor needed to operate the device. The current system in place requires an employee to manually remove and replace the stabilizer on the pallet at workstations and at the beginning and end of the conveyor. With the device being compatible with the current conveyor system it will lower the manual labor needed with the ceramic stabilizer therefore lowering labor costs.

The support subsystem's primary goal is to ensure the lifespan of the device under the conveyor condition. This subsystem has two primary functions which are to resist wear and to secure the device to the pallet. The resist wear function of this subsystem focuses on the ability for the device to not wear away over time. The device created should have the ability to be used repeatability without major impact to its functionality. Our team's design should also have a way for the device to secure to the pallet to ensure it is supported during operations. This function will allow for the device to remain on the pallet while in operation and prevent it from being easily pushed off due to conveyor vibrations and jerking.

All three main subsystems of the short part stabilizer have an influence on the overall usability of the design. Multiple functions overlap into different systems. This shows how the functions have cross subsystem relationships, the functions of the system may be important in a different category. Using the cross reference table these relationships between systems and functions are marked with an "X". The functional decomposition has helped the team determine that the short part stabilizer will need to be secure, interacted with minimally, easily integrated into the current conveyor system, and have a life expectancy capable of withstanding multiple cycles. These major functions will enable the team to develop targets and metrics of the designs key goal and prioritize the overall functionality of the project.

1.4 Target Summary

The targets for our project establish numerical values for what our project must accomplish in order to be deemed successful. These targets were derived from the customer needs and functional decomposition, as well as through ongoing feedback from the sponsors. The customer needs express what the project sponsor desires for the final project to accomplish. Each function established in the functional decomposition lays out the tasks the device must perform in order to achieve its purpose. Using these needs and functions the team then met with the project sponsor in order to gather exact numbers and units that need to be reached by the team's various systems.

Critical Targets

The critical targets, shown in *Table 3*, are what will be used in order to determine if the project is successful and meets the customer's needs. These metrics and their corresponding targets are the project's most important values to attain. The success of this project is dictated by the device's ability to accomplish these targets and metrics.

Table 3: Critical Targets

Systems	Functions	Metric	Target
Stabilization	Limit Movement	Max Distance (in)	0.6
Compatibility	Integrate with Current Conveyor	Top Area (in^2)	370
Compatibility	Integrate with Current Conveyor	Bottom Volume (in^3)	43 (x4)
Compatibility	Fits Return System	Return Height Limit (in)	6
Compatibility	Limit Manual Labor	Interactions per One Pallet Cycle (people)	1
Support	Withstand Load	Weight Capacity (lbs)	8

Validation and Discussion of Measurement

The stabilization system refers to the overall stabilization of the short part ceramics while the device is being used. The critical target in this system is the maximum amount of space that the ceramic will be able to move while using the stabilizer. This function will be validated by placing the smallest ceramic part produced by corning on the chucks and utilizing a caliper to measure the distance between the face of the ceramic and the surface of the stabilizer.

The system of compatibility refers to the design being capable of being placed in the current manufacturing environment and not causing any disturbances with the conveyor. One critical target for this system includes the maximum amount of area on the top side of the pallet, meaning if the design has any overhang, it would interfere with the conveyor system. Another critical target includes the volume allowed for the device along the bottom side of the pallet. The underside of the pallet needs a cross-shaped free space to allow for the stopping mechanism to stop the pallet as needed. This only leaves the team with the four corners of the underside of the pallet for available space if fasteners are needed. Subsequently, the device on the pallet needs to fit the return system of the conveyor. The biggest concern of the pallet feedback system is the height constraint. The device itself needs to be a maximum of 6 inches when going through the feedback system. All three of these functions will be virtually validated using Solidworks to check for the correct dimensions. These functions will further be tested in real-world applications by taking careful measurements and sending the prototypes through space-constrained testing scenarios. To limit manual labor, a test scenario will be utilized to see if the design will be capable of completing the necessary functions without needing assistance. To succeed the device will need to have a maximum of 1 interaction.

The stabilizer will need to be capable of withstanding impacts from ceramic movement. The stabilizer will also need to be capable of supporting the relative weight of the ceramic. The support will need to withstand a capacity of 8 pounds. This will be tested by applying a load against the stabilizer until failure.

Arriving at Targets and Metrics

To arrive at these targets and metrics, background research was conducted on each function. To define the target for limit movement, the team investigated the current design being used by Corning. Currently, Corning is using plexiglass T-shaped stabilizers. Corning reports that no damage occurs to the ceramics using the current design. Using Corning's shortest ceramic and the plexiglass T, the maximum distance of movement between the ceramic and glass was able to be measured. With this measurement, the team knows in order to keep the ceramic stable the project's design must have a maximum range of movement that is the same as the current design.

The second key system is compatibility. The first function of this system is for the device to integrate with the current conveyor. The surface area of the top of the pallets was measured by subtracting the area of the holes and slot design. The final product has to fit within the surface area so the design does not overly extend and interfere with the conveyor. The pallet also includes open space on the bottom side. However, a portion of this area is needed for the stopping mechanisms. The team took a volumetric measurement of the four corners of available space on the underside of the pallet. For the design to be successful, any fasteners the design may utilize will need to fit in one of these four locations while not exceeding the volumetric limit that could impact the rollers or stopping mechanism. Limiting the manual labor needed to operate the device is another critical function of the system. Due to the placement and size of the current design, two employees are needed for the placement and removal of the T’s at specified locations along the conveyor. For the team's device to be successful at reducing manual labor costs the number of these interactions will need to be reduced.

The critical target of the support system is the amount of weight the device will be capable of supporting while a ceramic impacts or rests against it. The current short-part ceramics weigh approximately 7-13 lbs, depending on the dimensions of the part. In a worst-case scenario a ceramic would tip, not return to an upright position, and continue resting against the stabilization design. The design must have enough support in itself to brace the relative weight of the ceramic resting against it. With the majority of the ceramic’s weight still resting on the chucks of the pallet, the design will still need to support some of this weight and be strong enough to withstand the impact force.

Targets Beyond Functions

Along with these targets and metrics, we also have a number of other values that fall outside the categories of systems and functions. Targets outside the main functions of the project can be found in the full table of targets in Appendix C. These characteristics do not necessarily determine the success or failure of the project but are included to ensure the project is as beneficial to the sponsors as it possibly can be.

One of these targets includes the overall weight of the design. Ideally, the design should not have to be interacted with frequently, although when the manufacturing plant is switching to longer ceramics it may need to be removed from the pallet. Due to the plant using as many as 15-20 pallets in circulation the team would like to keep the weight of the design relatively low to maximize maneuverability.

The second is assembly time. The manufacturing plant can take about 1-2 hours while calibrating the manufacturing line for a different-sized ceramic. While this is being done a worker stands on the line adjusting the V chuck's slot positioning. The change takes roughly 30 seconds because of the quick-release pin and the smooth-fitted slots. To benefit Corning and the employees, the team would like the device to integrate with the system and take no longer than the current adjustment time.

The third target that goes beyond the functions is the recyclability of the device. To be more environmentally friendly the team would like the majority of the design to be made from recyclable or biodegradable materials.

Summary

The targets and metrics for each of the functions of our three systems along with those that fall outside of the device's functions clearly lay out numerical specifications for our project to reach. These values were obtained through numerous meetings with Corning as well as benchmarking our project with a similar method currently in use on their conveyor line. These values illustrate what the team and sponsors desire from the device in order for the project to be successful. Various procedures will be used during early prototyping to validate the team's design and ensure that the targets of the project are met.

1.5 Concept Generation

Concept generation is a process in which the team collaborated to idealize possible solutions for our design problem. The team was tasked with generating 100 ideas. This was done in order to stimulate new perspectives on how to best solve the engineering problem brought forth by Corning. A variety of methods were used to generate ideas.

Concept Generation Tools

The team utilized a few concept generation tools to branch new ideas while completing the 100 design concepts. Using biomimicry, the team analyzed the movements and activities of animals and discussed how these properties could be applied. For example, concept 22 is a bird wing inspired gate mechanism. Crapshoot was utilized to produce out of the box ideas based on the different functions we needed out of the design. The team also utilized a lot of brainstorming to inspire each other and branch off our individual thoughts.

Medium Fidelity Concepts

Five medium fidelity concepts were selected out of the 100 design concepts. These medium fidelity concepts achieve most of the necessary goals, but due to conflicting opinions the team is unsure of their overall success.

Table 4: Medium Fidelity

Concept #	Description
8	Self-nesting T's
42	Have Swedish wheels moving mechanically in opposite direction
45	Add 2 long poles on sides of V's
50	Pressure sensor gate between V's
72	Add sandbag weights to pallet

High Fidelity Concepts

Three high fidelity concepts were selected out of the 100 design concepts. The team is highly confident these designs will satisfy the needs and have very high chances at being successful. The medium and high fidelity concepts will be compared against each other throughout the concept selection process.

Table 5: High Fidelity

Concept #	Description
5	Four bar mechanical system with an overhang where needed
34	Weight-activated pincers
65	Magnetic locking swivel

High Fidelity Concept #5

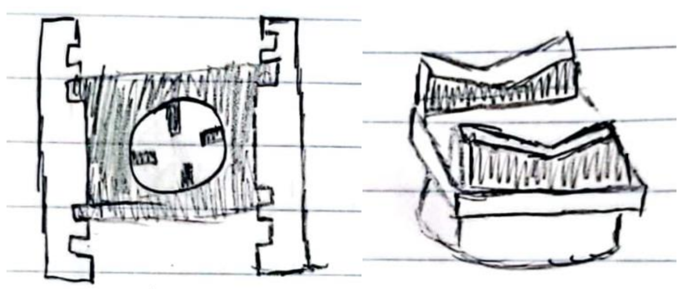


Figure 2: High Fidelity Concept #5

High Fidelity Concept #34

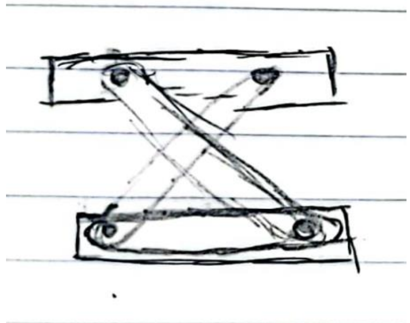


Figure 3: High Fidelity Concept #34

High Fidelity Concept #65

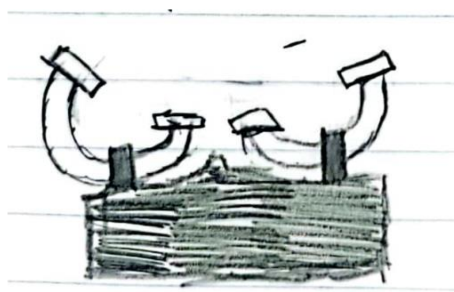


Figure 4: High Fidelity Concept #65

1.6 Concept Selection

House of Quality

To analyze our customer needs gathered from Corning, the team used the binary pairwise comparison chart shown in *Table 6* below. During this process, the customer needs are weighed against each other and given a 1 or 0 correlating to more importance or less importance respectively. The result of this is an importance weight factor for each of the customer needs which depicts protection of the ceramic and conveyor compatibility as the most critical needs for our project to accomplish.

Using the importance weight factor that the pairwise analysis provided, the House of Quality (HOQ) was created to determine the rankings of the engineering characteristics of the device. The HOQ scores the correlation of the weighted customer needs with the engineering characteristics of the project targets. The correlation score is multiplied by the weight factor of each of the customer needs to get a weighted ranking of the team's engineering characteristics. This ranking revealed that the most important characteristics are the return height, pallet securability, pallet surface area, and human interactions. These rankings allowed us to separate out the top characteristics to use as selection criteria when comparing the concepts against each other.

Table 6: Binary Pairwise Comparison

	Customer Needs
1	Protects ceramic
2	Scaleable for ceramics
3	Limit human interaction
4	Works with given space
5	Works with conveyor conditions
6	Material choice
7	Improves current method

Customer Need	#1	#2	#3	#4	#5	#6	#7	Sum
#1	-	1	1	0	1	1	1	5
#2	0	-	0	0	0	1	0	1
#3	0	1	-	0	0	1	0	2
#4	1	1	1	-	1	1	1	6
#5	0	1	1	0	-	1	1	4
#6	0	0	0	0	0	-	0	0
#7	0	1	1	0	0	1	-	3

Table 7: House of Quality

		Engineering Characteristics											
Improvement Directions		↓	↓	↓	↓	↓	↓	↓	↑	↓	↓	↓	
Units		in	%	in2	in3	sec	in	#	lbs	#	lbs	sec	n/a
Customer Needs	**Importance Weight**	1	2	3	4	5	6	7	8	9	10	11	12
Protects Ceramics	5	9	9	0	0	0	0	0	9	9	0	0	0
Scaleable for Ceramics	1	0	1	3	1	0	1	0	9	0	0	9	0
Limit Human Interaction	2	0	0	0	0	9	9	9	0	1	0	3	0
Works with Given Space	6	0	0	9	9	0	9	3	0	3	0	0	0
Works with Conveyor Conditions	4	0	1	9	9	9	9	9	0	9	9	3	0
Material Choice	0	3	3	0	0	0	0	0	9	1	9	1	9
Improves Current Method	3	9	9	9	0	3	9	9	0	9	0	1	0
Raw Score	559	72	77	120	91	63	136	99	54	128	36	30	0
Relative Weight %		13	14	21	16	11	24	18	10	23	6	5	0
Rank Order		7	6	3	5	8	1	4	9	2	10	11	12

	Targets/Metrics
1	Limit Movement
2	Damaged Percent
3	Top Pallet Area
4	Bottom Pallet Volume
5	Time Before Scanability
6	Return Height
7	Interactions Per cycle
8	Weight Capacity
9	Secure to pallet DOF
10	Max device weight
11	Assembly Time
12	Recycleability

Up	Down	Null
↑	↓	

Scale	
0	Not at All
1	Slightly
3	Moderatly
9	Significantly

Pugh Chart

Pugh charts are a simple method of comparing the high and medium fidelity concepts and narrowing down possible designs into a smaller group that can more feasibly be tested in the time allowed for the project. To start the Pugh chart analysis, a datum that is known to perform similar functions as the project is chosen and compared to the high and medium fidelity concepts. Each concept is rated on how well it fulfills the customer's needs compared to the datum and is given a plus (+), minus (-), or satisfactory (s). This process is repeated after eliminating the concept(s) given more negative ratings than others. The first iteration of the Pugh charts shown in *Table 8* compares the three high and five medium fidelity concepts to the selected datum, this being Corning's current stabilization method, the plexiglass T supports.

Table 8: Initial Pugh Chart

Selection Criteria	Datum: Current T System	Magnetic Swivel	Pincer	4 Bar	Sand Bag	Sensor Gate	2 Long Poles	Swedish Wheels	Self-nesting T
Protects Ceramics		s	s	s	s	s	s	s	s
Scaleable for Ceramics		+	+	s	+	s	+	+	s
Limit Human Interaction		+	+	+	+	+	+	+	+
Works with Given Space		+	s	+	s	s	-	+	+
Works with Conveyor Conditions		+	s	+	+	s	+	+	+
Material Choice		-	-	-	s	-	s	-	-
Improves Current Method		+	+	+	s	s	s	s	+
# of Pluses		5	3	4	3	1	3	4	4
# of Satisfactory		1	3	2	4	5	3	2	2
# of Minuses		1	1	1	0	1	1	1	1

After consideration of each idea's potential performance, the scores were tallied with the sensor gate design being eliminated for meeting the least amount of customer needs. Swedish wheels had a significant amount of positives but were removed due to the negative scoring in protecting the ceramic. The magnetic swivel concept earned the most positive scores and was then used as the datum for the next iteration of the Pugh charts. Following iterations of Pugh charts can be found in Appendix F.

Table 9: Final Pugh Chart

Selection Criteria		Concepts			
		Magnetic Swivel	Pincer	[redacted]	Self-nesting T
Protects Ceramics	Datum: Pincer	s	s	[redacted]	+
Scaleable for Ceramics		s	s		-
Limit Human Interaction		s	s		s
Works with Given Space		s	s		+
Works with Conveyor Conditions		s	s		-
Material Choice		s	s		-
Improves Current Method		s	s		s
# of Pluses		0	0		2
# of Satisfactory		7	7		2
# of Minuses		0	0		3

On the final iteration of the Pugh charts, shown in *Table 9*, the concepts that were determined to be most suitable at satisfying the customer needs were the magnetic swivel, pincer, and self-nesting T designs.

Analytical Hierarchy Process

The Analytical Hierarchy Process is another method used in the concept selection process that mathematically evaluates the importance of each criteria of the project. This method helps to remove any personal bias the team may have towards any one or more concepts. To do this, each of the customer's needs are compared to one another based on their importance and a score of 1, 3, 5, 7, or 9 is given to reflect that relative importance where 1 shows equal significance and 9 means an extreme difference in significance. These scores can be found in Appendix G. The sums of each need's scores are used in the Normalized Comparison Matrix in *Table 10*.

Table 10: Normalized Comparison Matrix

	Normalized Criteria Comparison Matirx [NormC]								
		1	2	3	4	5	6	7	Criteria Weights {W}
1	Protects Ceramics	0.046	0.039	0.043	0.020	0.161	0.055	0.158	0.075
2	Scaleable for Ceramics	0.418	0.352	0.304	0.415	0.290	0.382	0.158	0.331
3	Limit Human Interaction	0.046	0.050	0.043	0.020	0.032	0.042	0.053	0.041
4	Works with Given Space	0.139	0.050	0.130	0.059	0.161	0.055	0.053	0.093
5	Works with Conveyor Conditions	0.009	0.039	0.043	0.012	0.032	0.042	0.053	0.033
6	Material Choice	0.325	0.352	0.391	0.415	0.290	0.382	0.474	0.376
7	Improves Current Method	0.015	0.117	0.043	0.059	0.032	0.042	0.053	0.052
	Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

In this Matrix, the scores given in each comparison are then divided by the sum of each need's score and then the average value is determined to get the Criteria weights. The Criteria weights are further used in the Consistency Check table shown in *Table 11* to create the weighted sum and consistency vector.

Table 11: Consistency Check

Consistency Check		
Weighted Sum	Criteria	Consistency Vector
0.557553809	0.075	7.469371743
2.766375086	0.331	8.349286392
0.320443704	0.041	7.808246878
0.757455667	0.093	8.185058034
0.237870159	0.033	7.206816237
3.010201813	0.376	8.014437331
0.395484937	0.052	7.628974353

Average Consistency (λ)	7.808884
Number of Criteria	7
Consistency Index	0.134814
Random Index Value (RI)	1.35
Consistency Ratio (CR <0.10)	0.10

The average of these consistency vectors is taken and used to determine the consistency index which was determined to be approximately 0.1348. Dividing the consistency index by the random index value of 1.35, a number determined by the number of criteria, gives a consistency ratio of 0.10. This number is the most that this value is allowed to be but still states that the team's bias is successfully eliminated.

Analytical Hierarchy Process Alternatives

For the final step of concept selection the top three concepts are compared against one another for each engineering need. This analysis allowed the team to see how each concept worked better than the other. The designs were given a score of 1, 3, or 5 on how well they would satisfy each of the customer's needs. The sums of each score are normalized and compared to get their criteria weights before being put through another consistency check to ensure a lack of bias by having a consistency ratio of less than 0.1. This process is repeated for each of the customer's needs and the criteria weights for each concept are used in the Final Rating Matrix in *Table 12* to determine our final concept. The tables of values for each repetition of this procedure can be found in Appendix G.

Table 12: Final Rating Matrix and Concept Alternative Values

Final Rating Matrix	Pincer	Swivel	Spring T
Protects Ceramics	0.600	0.200	0.200
Scaleable for Ceramics	0.333	0.333	0.333
Limit Human Interaction	0.333	0.333	0.333
Works with Given Space	0.600	0.200	0.200
Works with Conveyor Conditions	0.299	0.106	0.633
Material Choice	0.143	0.429	0.429
Improves Current Method	0.619	0.143	0.429

Concept	Alternative Value
Pincer	0.320057036
Swivel	0.329440441
Self-nesting	0.361652386

From the Alternative Values chart above, the weights of each need are compared to the score each concept received in the Final Rating Matrix. Here it shows that, while each alternative value is fairly close to one another, the self-nesting T is the most suitable design for the project.

Final Selected Concept

The final selected concept is the self-nesting T design. This design had the highest alternative value among our final 3 concepts in the AHP chart. Also, this design received the most support from our academic advisor because it is utilizing a stabilization method that has been proven to effectively protect the ceramic.

This concept utilizes a self-nesting design with the same dimensions as the current T being used by corning. The T will be locked upright by a spring or a scissor mechanism and locked down by a trigger clip. The unlocking of the T will be done by a switch at the beginning of the conveyor system and the locking will be done by a switch right before the imaging station. This design allows us to use the aspect of Corning's solution that worked well, while also eliminating the height, positioning, and required interaction issues that they experienced.

1.8 Spring Project Plan

Table 13: Spring Project Plan

Spring 2023 Project Plan				
	Milestone	Tasks	Description	People
	Poster Day			
		Combining Information	Gathering information from all previous work	Pawel
		Future Work	Gather information of work still needed to be completed	Jared
		Create Poster	Design poster with size specifications in mind	Jared, Robert
		Review Rubric	Make sure the poster fits the needs of the rubric	Taylor
		Print Poster	Have TAs print the final poster	Segundo
		Attend Poster Day	Attend the assigned poster presentation	All
	Finalize Design			
		Review Design Requirements	Review the requirements of the design	Taylor
		Review Design Requirements	Discuss issues with the current design	Jared

		Review Design Requirements	Remeasure and refine the CAD models	Robert
		Review Design Requirements	Finalizing CAD models to begin prototype 2	Segundo, Pawel
	Rebuild Protoype			
		Convert CAD to STL	Convert CAD files to STL files for printing	Taylor
		Print STL Files	3D print the STL files to prepare for building	Segundo, Jared, Robert
		Assemble Prototype	Assemble the new prototype	Pawel
	Test Prototype			
		Review Prototype Specifications	Review how the prototype should work	Pawel
		Ensure Prototype Performs	Make sure the prototype performs as intended	Taylor
		Make Changes to Prototype	Make changes to anything that does not perform well	Jared
		Rebuild Prototype	Rebuild the prototype with changes made	Robert
		Performance Check	Ensure the prototype performs as intended	Segundo
	VDR4			
		Summarize Previous Work	Summarize work already completed before this point	Pawel
		Summarize Current Work	Summarize work already completed at this point	Robert
		Create Powerpoint Presentation	Use information gathered to create a powerpoint presentation	Jared
		Review Rubric	Make sure powerpoint presentation meets requirements	Segundo
		Submit VDR4 Powerpoint	Submit VDR4 presentation to Canvas	Taylor
		Practice Presentation	Practice presenting powerpoint	All
		Present Presentation	Present Powerpoint to professor	All
	Update Bill of Materials			
		Determine Major Components	Make changes to the bill of materials to account for design changes	Pawel, Robert
		Check Vendors	Compare different vendors and their prices to determine the best one	Taylor
		Record Changes	Update the original BOM created in Fall 2023	Segundo

		Initial Order	Order the initial list of components and update dates/times/prices	Jared
	Develop Virtual Simulations			
		Develop Motion Simulation	Create motion simulation in creo to check device movement	Robert
		Develop Vibration Simulation	Create a vibration simulation in drake to check oscillation patterns	Pawel
		Develop Friction Simulation	Create a friction simulation in creo between the parts	Taylor
	Machining Parts			
		CAD Files to Machine Shop	Send CAD files to machine shop	Jared
		Send Material to Machine Shop	Send material to machine shop to begin machining	Segundo
		Update Status of Machined Parts	Keep an updated list of finished and in progress parts	Taylor
	Build Physical Prototype			
		Review CAD Models	Review the CAD models to ensure proper assembly	Jared,Pawel
		Review Machined Parts	Review machine shop parts to make sure they are machined properly	Robert, Taylor
		Assemble Physical Prototype	Assemble the first physical prototype	Segundo
	Testing			
		Run Motion Test	Run motion test to check that the ceramic does not fall off during stops	Pawel
		Analyze Motion Data	Analyze the data and make changes to the CAD models if needed	Jared, Robert
		Run Vibration Test	Run vibration test using accelerometer to make sure ceramic can handle the vibrations on the conveyor	Segundo
		Analyze Vibration Data	Analyze the data and make changes to the CAD models if needed	Jared, Taylor
		Run Dust Test	Run dust test to ensure that the device can handle the amount of dust at the facility	Taylor

		Analyze Dust Data	Analyze the data and make changes to the CAD models if needed	Segundo, Pawel
	VDR5			
		Summarize Previous Work	Summarize previous VDR presentations	Pawel
		Summarize Current Work	Summarize work already completed at this point	Segundo
		Create Powerpoint Presentation	Use information gathered to create a powerpoint presentation	Jared
		Review Rubric	Make sure powerpoint presentation meets requirements	Robert
		Submit VDR5 Powerpoint	Submit VDR5 presentation to Canvas	Taylor
		Practice Presentation	Practice presenting powerpoint	All
		Present Presentation	Present Powerpoint to professor	All
	Finalize Design			
		Review Previous Testing Analysis	Review the analysis from the previous testing	Taylor, Pawel
		Discuss Problem Areas	Discuss issues with the current design	Segundo
		Refine CAD	Remeasure and refine the CAD models	Jared
		Finalizing CAD	Finalzing CAD models for changes to the physical prototype	Robert
	Build Physical Prototype			
		Review CAD Models	Review the CAD models to ensure proper assembly	Robert, Taylor
		Review Machined Parts	Review new machined parts or parts that had to be changed	Pawel, Segundo
		Change Physical Prototype	Make changes to the second physical prototype	Jared
	Testing			
		Run Motion Test	Run motion test to check that the ceramic does not fall off during stops	Taylor
		Analyze Motion Data	Analyze the data and make changes to the CAD models if needed	Pawel, Segundo
		Run Vibration Test	Run vibration test using accelerometer to make sure	Robert

			ceramic can handle the vibrations on the conveyor	
		Analyze Vibration Data	Analyze the data and make changes to the CAD models if needed	Jared, Taylor
		Run Dust Test	Run dust test to ensure that the device can handle the amount of dust at the facility	Segundo
		Analyze Dust Data	Analyze the data and make changes to the CAD models if needed	Pawel, Robert
	VDR6			
		Summarize Previous Work	Summarize work already completed before this point	Pawel
		Summarize Current Work	Summarize work already completed at this point	Segundo
		Create Powerpoint Presentation	Use information gathered to create a powerpoint presentation	Jared
		Review Rubric	Make sure powerpoint presentation meets requirements	Robert
		Submit VDR6 Powerpoint	Submit VDR6 presentation to Canvas	Taylor
		Practice Presentation	Practice presenting powerpoint	All
		Present Presentation	Present Powerpoint to professor	All
	Finalize Evidence Manual			
		Review All Previous Submissions	Review comments and edits on all previous evidence manual submissions	Pawel, Segundo
		Make Changes to Evidence Manual	Make changes from the previous review	Jared, Robert
		Submit Final Evidence Manual	Submit the final evidence manual to canvas	Taylor
	Engineering Design Day			
		Prepare Presentation	Compile information from previous presentations and make PowerPoint	Jared, Robert, Segundo
		Prepare Poster	Complie information for poster and edit previous poster	Pawel, Taylor
		Practice Presentation	Practice presenting powerpoint	All
		Practice Elevator Pitch	Practice presenting elevator pitchs for poster	All

		Evaluate Other Poster	Review other groups posters and ask any questions	All
		Watch Other Presentations	Watch other groups present there project and ask any questions	All
		Network With Industry Professonals	Connect with industry professionals and get information about being in the industry	All
	Finals			
		Study for Finals	Prepare for any finals that are needed to be taken	All
		Take Finals	Pass finals	All
	Graduation			
		Prepare Cap and Gown	Make sure cap and gown are ready for graduation day	All
		Graduate on May 9, 2023	Attend graduation	All

Chapter Two: EML 4552C

2.1 Restated Project Definition and Scope

Project Description

The team was able to determine the project description by meeting with the project sponsor representatives, Jeffery Roche and Jeffery Stott, and discussing their current needs. Based on these meetings with the Corning representatives the team has determined that the goal of the project is to improve the current device that is being used to protect the ceramics. The objective of the project is to prevent the ceramics from falling off the conveyor in the Corning's manufacturing plant, while also decreasing the cost in labor by minimizing the number of employees needed along the conveyor.

Key Goals

After developing the project description, the team was able to come up with a list of key goals that the design must achieve. The first key goal of this project is to design a method to prevent damage to ceramic filters and substrates while on the production line in Corning's manufacturing plant. Their current design utilizes a "T" shaped piece of plexiglass that is placed upside down and inside the slots on their chuck system. This method adequately prevents short part ceramics from falling and obtaining damage. Another goal of the team's design is to limit human interaction compared to the current system. The system currently in place requires two plant workers to place the T's on the chuck at the beginning of the line and remove them before the imaging process. The design used for this project should also be able to seamlessly integrate with the current conveyor system. There are several overhangs and space limitations on their current conveyor and the team's design needs to fit within these parameters.

Market

The primary market of this project is the end-user of the pallet ceramic stabilizer, Corning. The company will use the project in the manufacturing process of their ceramic parts benefiting the company directly. Secondary markets for this project include any manufacturing services that maneuver fragile cylindrical parts along a conveyor. This would consist of other ceramic manufacturers, motor vehicle manufacturers, and other companies developing emission control systems.

Assumptions

In order to complete the project in the required timeframe, the team needs to make some vital assumptions. The team is assuming that the pallets and conveyor itself remain level during the transporting process. Additionally, the team expects the data and measurements received from our sponsor to be accurate and precise. This means that the pallets are uniform across the plant. Lastly, the team assumes that the manufacturing plant conditions will remain the same throughout the project duration.

Stakeholders

The major stakeholders for this project include the sponsors from Corning, Jeffery Roche and Jeffery Stott, the team's academic advisor Dr. Eric Hellstrom, and the senior design instructor Dr. Shayne McConomy. Each of these stakeholders have an interest in or will benefit from the successful completion of the project. Although this project is a custom design for Corning's manufacturing plant, the team was able to establish other possible stakeholders that could benefit from this project. These other stakeholders include other ceramic manufacturers, such as FineWay Ceramics, who are part of the secondary market.

2.2 Results

The result of our project was the Self-Nesting T concept. *Figure 5* shows the final device in the expanded stage on the pallet provided by Corning.

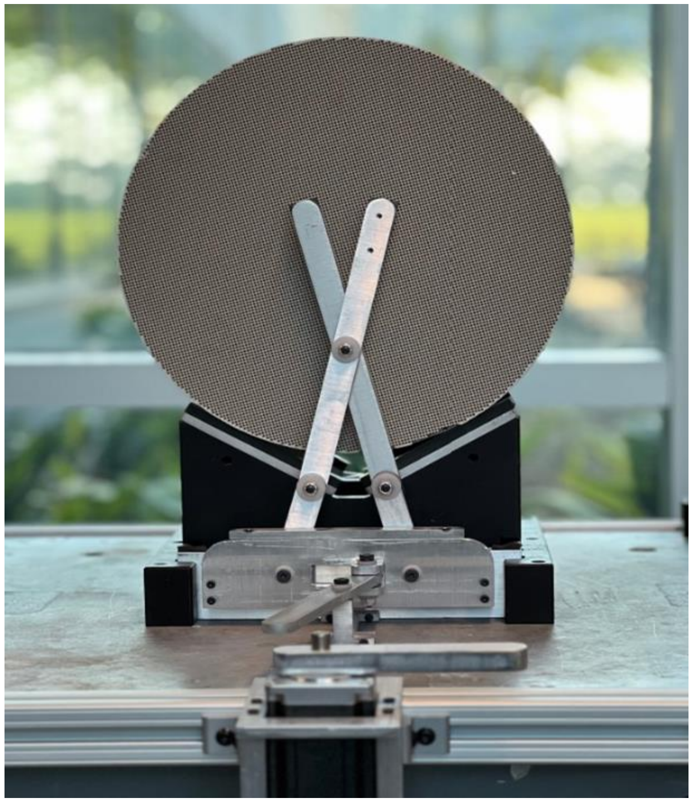


Figure 5: Final Self-Nesting T Device.

Prevent Damage

The device can protect the ceramics based on the testing done for vibration, impact force, and expansion height. The device created can withstand the maximum available vibrations during testing which was 3600 vpm (vibrations per minute). This level of vibration was applied for 15 minutes to validate that the device would not show signs of failure during the time it is traveling on the conveyor.

Along the conveyor line, the pallet experiences multiple sudden stops. Our sponsors recorded the acceleration of the pallet on their conveyor line with an accelerometer. The acceleration from their data peaked when the pallet hit these sudden stops. To test our device's ability to withstand these stops, several impact tests were carried out. During these tests, the pallet was traveling at a medium velocity and then suddenly brought to a halt. An accelerometer was placed on the pallet to record the acceleration that the pallet experienced. *Figure 6* shows the section from Corning's data that peaks at about 4 G's.

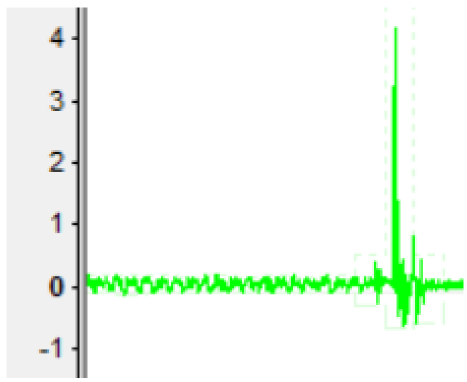


Figure 6: Corning's Accelerometer Data at Impact in G's

Due to our testing limitations, a max acceleration of 28.5 meters per second, or 2.9 G's was reached. *Figure 7* shows a table of the accelerometer data recorded. During this test, the Self-Nesting T was in the expanded position and was able to withstand this sudden spike in acceleration without collapsing. The ability for our device to withstand this test multiple times provides confidence that our device will successfully endure the travel on Corning's conveyor line.

	1 X	2 Y	3 Z
77	-0.4217	-0.7764	9.0541
78	3.1066	-0.3199	10.1990
79	-28.5064	-16.8925	14.7240
80	6.6272	5.8783	12.3423
81	-0.6685	-4.0420	20.2792

Figure 7 Accelerometer Test Data (Separated by axis in meters per second)

The device was also validated to be able to prevent damage to the ceramics due to its ability to prevent them from falling off the pallet, much like the Plexiglas T does. This was tested by ensuring that the height of the device was, at minimum, the same height as the device Corning currently uses. Corning's Plexiglas T has a height of 11 inches (27.94 cm) and can keep the ceramics from falling off the pallet. The device created has a total extended height of 12 inches (30.48 cm) and when tested, does not allow for the ceramics to fall off the pallet. This data is listed in *Table 14* as expansion height, along with other important measured heights that are further discussed in the following subsections.

Table 14: Validation of Device Heights

Testing	Target	Measured
Retraction Height	< 6 in	4.3 in
Middle Joint Height	< 4 in	3.6 in
Expansion Height	11 in	12 in

Fit Return System

The device had to be lower than 6 inches (15.24 cm) to fit into the return system. When the device was fully retracted, the highest point was measured to be no more than 4.3 inches (10.92 cm) tall. This meant that the device was fully capable of fitting in the feedback system without causing any issues. This data is recorded in *Table 14* and demonstrated in *Figure 8*.

Limit Manual Labor

The device needed to be able to actuate with the assistance of at most 1 person. The design was made in a manner that requires very little force on the lever arm to enable it to fall with the assistance of gravity. Through testing with a stepper motor, it was determined that the device was able to lower without human assistance.

It was further evaluated and tested to determine the need for a person to lift the device as well. Also using the stepper motor, it was found that, with an applied force greater than 4 lb. (1.81 kg), the stepper motor was able to use the lever arm to actuate the device to the up-right position. This then validated that there was zero manual labor needed to actuate the device.

Withstanding Load

The testing of the load withstood by the device was completed by applying a load to the side of the device the ceramics would hit. This applied force was measured to determine how much load could be applied before the device bends or flexes. From this testing, it was determined that over 10 lb. (0.454 kg) of load could be applied before significant bending occurred. This amount of load did not cause permanent damage to the device. The device is believed to be able to withstand more than this 10 lb. (0.454 kg) of load before showing signs of permanent damage.

Reveal Ceramic Face

The device was given a maximum time of 48 seconds to raise or lower itself. This is the amount of time that is allowed before causing a major backup on the conveyor line. From the testing of manual powering and motor powering, it was determined that the maximum time the device should take to raise is no more than 20 seconds. While the maximum time for the device to lower was under 10 seconds. This time difference was affected by the speed of the testing motors, as well as the force required to raise the device being higher than that needed to lower the device.

To reveal the face of the ceramic, the device must also go below the chucks that the ceramics sits on. These chucks have a maximum height of 6 inches (15.24 cm) and a middle notch height of 4 inches. The device was able to be validated by measuring that the outside height is no more than 4.3 inches (10.92 cm). Similarly, the middle notch height is no more than 3.6 inches (9.14 cm) (*Fig. 8*). Both heights fit the required height to reveal the face. This data is shown in *Table 14*.

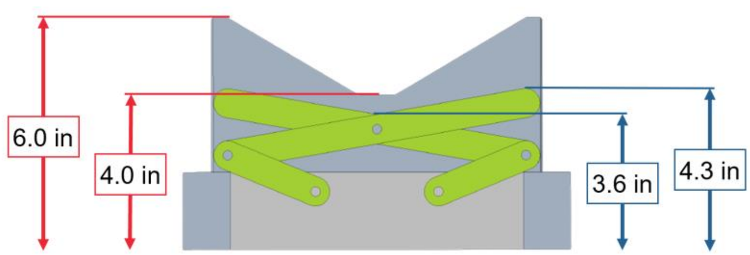


Figure 8: Retraction Heights of Device.

2.3 Discussion

Each parameter tested during validation was used to prove that the device will be able to integrate with the conditions in Corning's manufacturing plant. The self-nesting T created by the team was able to hit all critical targets and metrics that were required by the project. The device was able to meet expansion and retraction metrics, it was able to raise and lower within the allotted 48 seconds and it was able to be fully actuated with mechanical power.

There are several improvements that could be made to this device to make it more efficient. One of those is the engagement method. The team chose to use a switch with an s-shaped rack and pinion system. The engagement method was a motor that would sit on the outside of the conveyor line, along the aluminum extrusion rails. Corning uses a pressure activated system that can close and open by pushing air through it. This could be used to replace the motors, allowing for easier integration into Corning's plant. Removing the switch all together, a linear actuator, with a motor attached at the tip, could be used to engage the two gears and rotate them, raising or lowering as needed. Both engagement changes would allow for a simpler, more efficient device.

While testing the initial motion of the device, it was noticed that the gears would sometimes slip, and the device would resist after several sets of motion. This would cause the device to fail and require maintenance. To fix this issue, the team changed the rack to be an s-shape and added a top plate to prevent the rack from shifting up during motion. This provided a fix for this specific issue but there was still a problem with how smooth the device moved. There are two possible fixes for this issue. The first would be to take the pivot point and make the piece out of a single piece of aluminum. Currently, that part is three different pieces, screwed together.

If this were a single piece of aluminum, there would be less of a moment created in the part. The second fix would be to make that pivot out of a different material. In its current state, this piece contacts another piece of aluminum; this is causing metal on metal contact. If this part was made of a frictionless material, the device would move more smoothly.

The final issue that the team had with the device was the electronics. The initially purchased motor drivers (TB6600) seemed to not allow the power supply to provide enough current to the motors. Due to this, the motors were not providing enough torque to raise the device. To fix this issue, the team changed motor drivers to a Fuyu module driver. This driver provided the required current to the device and allowed for proper motion. A problem with the programing of the motors was also present. The device would work as intended for around 27 cycles before the motor would overheat, reducing the amount of torque it could produce. Adding a passive cooling method for the motor, like a heat sink, could mitigate this issue. Another problem with the programming was found on design day. The motor would function as required for a period, but after sitting with the power supply on, for an extended amount of time, it began to rotate in the wrong direction and at the wrong intervals. This is a programming issue and could be fixed with more time put into the code.

2.4 Conclusions

Our project was made for our sponsors to use on their conveyor line in their manufacturing plant. Through the testing conducted, the Self-Nesting T we designed is able to satisfy the goals set for us by our sponsor's needs. It is able to achieve all critical targets set for it, validating that it is capable of preventing damage to Corning's ceramics, limiting required interactions, and integrating with the conveyor system. On top of accomplishing the needs of our sponsor, the Self-Nesting T can be used with minimal changes to the conveyor.

2.5 Future Work

To continue building off the current Self-Nesting T, the engagement method from the conveyor to the Self-Nesting T would be investigated. Although the current engagement method serves the purpose it was intended for, a different variant may provide more efficient results. Currently the device is engaged using a fulcrum like engagement lever, the team would like to explore variations using a linear actuator or air compressed system. Developing one of these new methods may produce results of actuation with less resistance than the lever system used.

Another stage of this project that can be continued would be better selection of the hardware. Currently all hardware serves the purpose it was intended for but requires 4 different sized allen wrenches to assemble or disassemble the device. Due to the project being in a manufacturing facility, the team would like to use hardware with matching hex sizes so only one tool would be required for any modification or maintenance.

Lastly, the team would further evaluate the durability of the UHMW. Currently there is a UHMW Polyethylene block that acts as a slider in the outer wall of the device. Throughout testing and operations, it has been observed that this block has slightly worn. The team would like to either reevaluate the slider material, style, or accessibility so the slider would work more efficiently with less deterioration.

Appendices

Appendix A: Code of Conduct

I. Mission Statement

Team 506 strives to exceed the expectations of the project. Through constant communication and cooperation, the team will successfully navigate all presented problems. Team success is dictated by communication and punctuality.

II. Outside Obligations

Pawel Grum - Work every weekday starting at 8 pm (hours are flexible).

Robert Kosmas - During the academic school year will have job responsibilities up to 20 hours a week as an academic tutor. During the academic year will have outside obligations to FSU scuba club.

Taylor Larson - Works 10:00-11:30AM Monday, Friday, and Sunday; 11:00-12:15 PM Tuesday and Thursday; 3:30-5:30 PM.

Segundo Sanchez - No outside obligations.

Jared White - Works off campus 2-3 days a week except Tuesday and Thursday, between 7:00 AM - 11:00 PM.

III. Team Roles

The following roles of individual team members reflect an area of specialization required to complete the project and are assigned based on the member's interests and specialization. While the member assigned to each area is ultimately responsible for that area, other members may contribute towards completing the work of different roles as needed. If changes to these roles occur, a formal amendment process is not necessary; notifying the team is sufficient.

Pawel Grum - Mechanical Test Engineer

The mechanical test engineer is responsible for all testing, preparation, simulation, and data reporting.

Robert Kosmas - Structural Design Engineer

The structural design engineer is responsible for mechanical design aspects including CAD, mechanical calculation, drafts, and design review.

Taylor Larson - Dynamics Engineer

The dynamics engineer is responsible for dynamic design including oscillation, vibration, and motion controls.

Segundo Sanchez - Materials Analysis Engineer

The materials analysis engineer is responsible for materials selection and design. They are responsible for analyzing the quality of the material chosen.

Jared White - Manufacturing Engineer

The manufacturing engineer is responsible for coordinating and planning protocol for the manufacturing and assembly. They are responsible for smooth operation during the manufacturing process.

In the event that there is work outside of any particular role, the team will discuss this workload. Someone may volunteer to cover this task but if no one volunteers, a vote will occur to distribute the tasks evenly.

IV. Communications

The team will communicate internally through FSU email, Microsoft Teams, and text messaging. Team members are expected to respond to any form of communication within 24 hours. When communicating with sponsors or individuals outside of the team the team will use

FSU email or Microsoft Teams based on the preference of the individual the team will communicate with. Microsoft Teams will be used for formal meetings with project sponsors.

V. Dress Code

Classroom and Team Meeting Dress Code - For all classroom and inner team meetings, all team members will be responsible for environmentally friendly attire.

Presentation and Senior Design Day Dress Code - The dress code for the first three VDRs will be business professional without full suits. Afterward, all presentations will be in full professional dress attire, including suit jackets or blazers.

VI. Attendance Policy

There will be at least 2 formal team meetings per week where all members are expected to attend and participate. These meetings can be in person or online depending on the required work at the time. These meetings should be expected to last until 7:45pm during the allotted time of senior design. Attendance for impromptu meetings is not required, however may be expected in emergency situations. Attendance for a formal meeting may be excused if a valid excuse is provided 24 hours before or if there is an emergency situation.

If a team member misses a formal meeting without a reasonable prior notice to the team, that member then becomes responsible for bringing snacks to the next meeting. Three attendance violations without proper notice or valid excuse will result in a meeting with Dr. McConomy.

VII. Notifying the Team

Group notifications will be done through Microsoft Teams, email, and text messages. Any rapid notifications to the team can be done through phone calls to each individual team member.

VIII. Responding to People in Professional Meeting

During professional meetings the team members will address other individuals by their preferred pronouns such as Sir/Ma'am or Mr/Ms/Mrs/Miss. If an individual prefers to be addressed by their first name or any other name, the team will respect their request and abide by their preference.

IX. Actions to Be Taken Upon Participation Infractions

If an individual is not participating in group meetings, assignments, or other aspects of the project the team will select another individual to check in with the individual to discuss any possible conflict or issues that need to be addressed. If the actions of the individual continue, the team will have an intervention with the individual to discuss solutions to the problem. Upon a third infraction, the team will reach out to Dr. McConomy in order to intervene with the individual. The team would like for Dr. McConomy to set up a meeting with the individual to discuss their absence from the project and come to a solution.

X. Amendment Procedure

This document can be amended with a formal team vote. This vote will require a majority vote (3 of 5 members) and **all** members must sign the amendment. The amendment will be included as an attached appendix to this document. All necessary parties will be notified of the amendment and will receive a copy of the new document.

XI. Statement of Understanding

I understand that all content included in this code of conduct is expected of each member as part of this project team. I understand that this content is subject to change upon review by the team. Signing this document is an agreement to adhere to the standards as written above.

Pawel Grum

Pawel Grum *Pawel Grum*

Signature

Robert Kosmas

Robert Kosmas *Robert Kosmas (01/12/2023)*

Signature

Taylor Larson

Taylor Larson *Taylor Larson (01/12/2023)*

Signature

Segundo Sanchez

Segundo Sanchez *Segundo Sanchez (01/12/2023)*

Signature

Jared White

Jared White *Jared White*

Signature

Date Originally Signed: September 6th, 2022

Revision Signed: January 12, 2023

Appendix B: Work Breakdown Structure

Project	Fall 2022	Deliverable	Work Pack x.x	Work Pack x.x.x	Team Member	Status	Date Completed
		Code of Conduct					
			Set Meeting			100	8/30/2022
				Discuss Content of Code of Conduct	All	100	8/30/2022
			Write Code of Conduct			100	8/30/2022
				Mission Statement	Segundo	100	8/30/2022
				Outside Obligation	Pawel	100	8/30/2022
				Team Roles	Pawel	100	8/30/2022
				Communications	Taylor	100	8/30/2022
				Dress Code	Robert	100	8/30/2022
				Attendance Policy	Jared	100	8/30/2022
				Notifying the Team	Segundo	100	8/30/2022
				Responding to People in Professional Meeting	Taylor	100	8/30/2022
				Actions to Be Taken Upon Participation Infractions	Taylor	100	8/30/2022
				Amendment Procedure	Pawel	100	8/30/2022
				Statement of Understanding	Segundo	100	8/30/2022
			Review Rubric		Jared	100	8/30/2022

			Review Code of Conduct		Robert, Taylor	100	9/1/2022
			Submit Code of Conduct		Taylor	100	9/1/2022

Project	**Fall 2022**	**Deliverable**	**Work Pack x.x**	**Work Pack x.x.x**	**Team Member**	**Status**	**Date Completed**
		Work Breakdown Structure					
			List Evidence Book Milestones		Taylor	100%	9/13/2022
			Break Down Tasks		Robert, Pawel, Jared, Segundo	100%	9/13/2022
			Assign Tasks		Taylor	100%	9/13/2022
			Complete Written Assignment		Jared	100%	9/15/2022
			Review Rubric		Robert	100%	9/15/2022
			Review Written Assignment		Taylor	100%	9/15/2022
			Submit WBS		Tayor	100%	9/16/2022
		Project Scope					
			Get Sponsor Meeting		Taylor	100%	9/7/2022
			Have Meeting With Sponsor			100%	9/14/2022
				Discuss Sponsor Needs	All	100%	9/14/2022
			Write Final Report				
				Project Description	Taylor	100%	9/22/2022
				Key Goals	Jared	100%	9/22/2022
				Markets	Robert	100%	9/22/2022
				Stakeholders	Pawel	100%	9/22/2022
				Assumptions	Segundo	100%	9/22/2022
			Review Rubric		Jared	100%	9/22/2022

			Write Report		Jared	100%	9/22/2022
			Review Report		Robert	100%	9/22/2022
			Submit Final Report		Taylor	100%	9/22/2022

Project	**Fall 2022**	**Deliverable**	**Work Pack x.x**	**Work Pack x.x.x**	**Team Member**	**Status**	**Date Completed**
		Customer Needs					
			Meet With Customer		All	100%	9/28/2022
			Interpret Needs				
				Form List of Needs	Jared	100%	9/28/2022
				Determine Categories of Needs	Robert	100%	9/28/2022
			Write Report		Segundo	100%	9/29/2022
			Review Rubric		Segundo	100%	9/29/2022
			Review Report		Robert, Pawel	100%	9/29/2022
			Submit Report		Taylor	100%	9/29/2022

Project	**Fall 2022**	**Deliverable**	**Work Pack x.x**	**Work Pack x.x.x**	**Team Member**	**Status**	**Date Completed**
		Functional Decomposition					
			Meet With Team				
				Discuss Function Decomposition	All	100%	10/4/2022
			Create Functional Decomposition				
				Assign Major Functions	Robert	100%	10/4/2022
				Create Graphic Representation	Taylor	100%	10/5/2022
				Connect to Systems	Pawel	100%	10/5/2022
				Integrate Cross Subsystem Relationships	Segundo	100%	10/5/2022
				Explain Results	Jared	100%	10/6/2022
				Describe Expected Outcome	Jared	100%	10/6/2022
			Review Rubric		Robert	100%	10/7/2022
			Write Report		Robert	100%	10/7/2022
			Review Report		Segundo, Pawel	100%	10/7/2022
			Submit Report		Taylor	100%	10/7/2022

Project	**Fall 2022**	**Deliverable**	**Work Pack x.x**	**Work Pack x.x.x**	**Team Member**	**Status**	**Date Completed**
		VDR1					
			Meet With Team				
				Discuss Contents of Presentation	All	100%	10/4/2022
			Review Previous Work		Jared	100%	10/4/2022
			Design Presentation				
				Project Summary	Robert	100%	10/10/2022
				Project Scope	Jared	100%	10/10/2022
				Customer Backgrounds	Jared	100%	10/10/2022
				Customer Needs	Segundo	100%	10/10/2022
				Future Work	Taylor	100%	10/10/2022
			Practice Presentation 1		Jared, Segundo	100%	10/6/2022
			Practice Presentation 2		Jared, Segundo	100%	10/8/2022
			Practice Presentation 3		Jared, Segundo	100%	10/22/2022
			Give Presentation		All	100%	10/25/2022
			Review Feedback		Jared	100%	10/25/2022

Project	**Fall 2022**	**Deliverable**	**Work Pack x.x**	**Work Pack x.x.x**	**Team Member**	**Status**	**Date Completed**
		Targets					
			Meet With Team		All	100%	10/11/2022
				Characterize Metrics for Each Target	Jared	100%	10/11/2022
				Tests That Will Validate Metrics	Robert	100%	10/11/2022
				Derive How Metrics Were Determined	Segundo	100%	10/11/2022
			Review Rubric		Robert	100%	10/20/2022
			Write Report		Robert, Segundo, Jared	100%	10/23/2022
			Review Report		Taylor	100%	10/25/2022
			Submit Report		Robert	100%	10/252022
		Ideation Research					
			Benchmarking		Pawel	100%	10/26/2022
			Current State of the Art		Segundo	100%	10/26/2022
			Biomimicry		Jared	100%	10/26/2022
			Patent Search		Taylor	100%	10/26/2022

Project	**Fall 2022**	**Deliverable**	**Work Pack x.x**	**Work Pack x.x.x**	**Team Member**	**Status**	**Date Completed**
		Concept Generation					
			Meet With Team		All	100%	10/24/2022
			Generate Concepts				
				Come Up With 5 Medium Fidelity Concepts	Robert	100%	10/27/2022
				Come Up With 3 High Fidelity	Jared	100%	10/27/2022
				Discuss Concept Generation Tools	Pawel	100%	10/27/2022
				Reach 100 Concept Goals	Segundo, Taylor	100%	10/27/2022
			Review Rubric		Robert	100%	10/31/2022
			Write Final Report		Robert	100%	10/31/2022
			Review Report		Taylor	100%	10/31/2022
			Submit Final Report		Taylor	100%	10/31/2022

Project	**Fall 2022**	**Deliverable**	**Work Pack x.x**	**Work Pack x.x.x**	**Team Member**	**Status**	**Date Completed**
		Prototype Research					
			Retrieve Constraints of Conveyor		Taylor	100%	10/26/2022
			Investigate Mechanical Linkages		Pawel	100%	10/26/2022
			Investigate Materials To Be Used		Segundo	100%	10/26/2022
			Investigate Shapes of Stabilizers		Robert	100%	10/26/2022
			Investigate Dynamic Dampeners		Pawel	100%	10/26/2022
				Determine Ceramic Speeds	Taylor	100%	10/26/2022
				Determine Stopping Forces	Taylor	100%	10/26/2022
		Prototyping 1					
			Design CAD		Robert, Taylor	100%	11/4/2022
			3D Printing		Jared	100%	
			Examine Design				
				Test Smaller Designs	Segundo	100%	
				List Pros and Cons of Design	Pawel	100%	
			Discuss Results with Advisor		All	100%	

Project	**Fall 2022**	**Deliverable**	**Work Pack x.x**	**Work Pack x.x.x**	**Team Member**	**Status**	**Date Completed**
		Sponsor Meeting					
			Discuss Final Concepts with Sponsor		All	100%	10/26/2022
		Concept Selection					
			Meet With Team			100%	10/31/2022
				Discuss Criteria	All	100%	10/31/2022
				List All Criteria to Be Evaluated		100%	10/31/2022
			Evaluate Criteria				
				Generate House of Quality		100%	11/1/2022
				Generate Pairwise Matrix for Criteria	Jared	100%	11/1/2022
				Normalize the Comparison Matrix	Pawel	100%	11/1/2022
				Calculate Criteria Weights	Taylor	100%	11/1/2022
				Do a Consistency Check on Criteria Weights	Segundo	100%	11/1/2022
			Formulate a Decision Matrix		Taylor	100%	11/1/2022
			Clarify Design Concepts		Taylor	100%	11/1/2022
			Choose Datum Concepts		Jared	100%	11/1/2022
			Complete the Design Matrix		Robert	100%	11/1/2022
			Evaluate Ratings		Segundo	100%	11/1/2022
			Establish a New Datum - Rerun Design Matrix		Pawel	100%	11/1/2022

			Generate Final Rating Matrix		Pawel	100%	11/1/2022
Project	**Fall 2022**	**Deliverable**	**Work Pack x.x**	**Work Pack x.x.x**	**Team Member**	**Status**	**Date Completed**
			Examine the Selected Concept for Improvement		Segundo	100%	11/1/2022
			Select the Final Concept		Robert	100%	11/1/2022
			Review Rubric		Robert	100%	11/2/2022
			Write Final Report		Jared	100%	11/3/2022
			Review Report		Robert, Jared	100%	11/3/2022
			Submit Final Report		Taylor	100%	11/4/2022
		VDR2					
			Meet with Team			100%	11/3/2022
				Discuss Contents of the Presentation	All	100%	11/3/2022
			Discuss What Part Each Person is Preparing				
				Summarize VDR1	Segundo	100%	11/3/2022
				Targets	Jared	100%	11/3/2022
				Concept Generation	Robert	100%	11/3/2022
				Concept Selection	Taylor	100%	11/3/2022
				Prototyping	Pawel	100%	11/20/2022
			Assemble PowerPoint Presentation		Taylor	100%	11/20/2022
			Practice Presentation 1		Pawel, Jared,	100%	11/20/2022

					Segundo		
			Practice Presentation 2		Pawel, Jared, Segundo	100%	11/20/2022
			Practice Presentation 3		Pawel, Jared, Segundo	100%	11/20/2022
			Present VDR2		All	100%	11/20/2022

Project	**Fall 2022**	**Deliverable**	**Work Pack x.x**	**Work Pack x.x.x**	**Team Member**	**Status**	**Date Completed**
		Risk Assessment					
			Meet With Team				11/11/2022
				Read Lab Safety Expectations/ Rules	All	100%	11/11/2022
			Review Rubric		Pawel	100%	11/12/2022
			Complete Project Hazard Assessment Worksheet		Robert	100%	11/13/2022
			Complete Project Hazard Control Worksheet		Jared	100%	11/13/2022
			Review Worksheets		Segundo	100%	11/17/2022
			Submit Worksheets		Taylor	100%	11/18/2022
		Bill of Materials					
			Meet with Team				11/18/2022
				Determine Dates to Meet With Customer	All	100%	11/18/2022
				Email Customer	Taylor	100%	11/18/2022
			Meet With Customer		All	100%	11/19/2022
			Review Assignment Rubric		Jared	100%	11/22/2022
			Write Report				11/26/2022
				Determine Materials Necessary	Segundo	100%	11/26/2022
				Determine Material Manufacturers	Robert	100%	11/26/2022

			Review Assignment/ Report		Taylor	100%	11/27/2022
			Submit Assignment		Taylor	100%	11/28/2022

Project	**Fall 2022**	**Deliverable**	**Work Pack x.x**	**Work Pack x.x.x**	**Team Member**	**Status**	**Date Completed**
		Poster Presentation					
			Meet with Team				
				Discuss Contents of the Presentation	All	100%	01/06/2023
			Discuss What Part Each Person is Preparing				
				Summarize VDR1	Taylor	100%	01/06/2023
				Summarize VDR2	Pawel	100%	01/06/2023
				Risk Assessment	Jared	100%	01/06/2023
				Bill of Materials	Segundo	100%	01/06/2023
			Create Project Board		Robert	100%	01/10/2023
			Practice Board Pitch 1		All	100%	01/10/2023
			Practice Board Pitch 2		All	100%	01/10/2023
			Practice Board Pitch 3		All	100%	01/10/2023
			Attend Poster Presentation		All	100%	01/12/2023
		Spring Project Plan					
			Meet With Team				
				Discuss The Task Of The Project During Spring	All	100%	02/15/2023
			Breakdown Spring Project				
				Create List of Milestones	Taylor	100%	3/26/2023
				Define a Timeline for Milestones	Robert, Jared	100%	3/26/2023

			Review Assignment Rubric		Pawel	100%	3/26/2023
			Write Report		Segundo	100%	3/26/2023
			Review Report		Taylor	100%	4/01/2023
			Submit Report		Taylor	100%	4/01/2023
Project	**Spring 2023**	**Deliverable**	**Work Pack x.x**	**Work Pack x.x.x**	**Team Member**	**Status**	**Date Completed**
			Engineering Design Day				
				Prepare Results	Jared	100%	4/06/2023
				Display Results on Poster	Robert	100%	4/06/2023
				Rehearse	All	100%	4/06/2023
				Present	All	100%	4/06/2023
			Finals				
				Plan Study Schedule	All	100%	4/25/2023
				Study	All	100%	4/30/2023
				Take Exams	All	100%	5/01/2023
			Graduation		All	100%	5/06/2023

Appendix C: Target Catalog

Systems	Functions	Metric	Target
Stabilization	Limit Movement	Max Distance (in)	0.6
		Min Distance (in)	0.2
Stabilization	Secure Ceramic	Degrees of Freedom	1
Stabilization	Prevent Damage of Ceramics	Percent (%)	0%
Compatibility	Integrate with Current Conveyor	Top Area (in^2)	370
		Bottom Volume (in^3)	43 (x4)
Compatibility	Reveal Ceramic Face	Time (sec)	48
Compatibility	Fits Return System	Height (in)	6
Compatibility	Limit Manual Labor	Interactions per One Pallet Cycle (people)	1
Support	Withstand Load	Weight Capacity (lbs)	8
Support	Secure to Pallet	Degrees of Freedom	0
N/A		Max Weight of Device (lbs)	25
N/A		Max Assembly Time (secs)	30
N/A		Recyclable (Yes/No)	Yes

Appendix D: Concept Generation

1. Robot Arm to remove T’s
2. Add springs in chucks
3. Tension-Based Mechanical System
4. Coded Lift Gate
5. Four bar mechanical system with an overhang where needed
6. Inflatable barriers on sides of faces
7. Rubber friction on V-chucks
8. Spring loaded T-self nesting
9. Change v-chuck angle
10. Make v-chuck circular
11. Electro mechanical Side clamps
12. Strap around the ceramic
13. T-hinged (Hinges on Ts)
14. Camshaft leverage mechanism
15. Actuator on chuck to Release T-pin and T’s lay down
16. Drones flying over to pick up T’s
17. Rail to ceiling to wrap around ceramic and follow conveyor
18. Bumps on conveyor to eject T’s
19. Pinball punchout T’s
20. Rod-slide mechanism
21. Drop down walls

22. Bird wing inspired open and close flaps
23. Slap-bracelet style brace
24. Foam dampener in v-chuck
25. Overhang to click the spring up/down like a pen
26. Vibration offset machine
27. Electro mechanical shock absorbers on chucks (self adjusting)
28. Extend v-chucks inward
29. Extend v-chuck using spring (fold out)
30. Net on outside of conveyor
31. Add a heavyweight onto pallet
32. Add PTFE layer on bottom of pallet
33. Bridge between V’s made of foam
34. Weight-activated pincer
35. Rollers on face of V’s
36. Swedish wheels on V
37. Lay ceramic flat on face and change the direction of the imaging system
38. Lay ceramic flat on face and add more mirrors in the imaging system
39. Add net to V to hold the ceramic
40. Lay ceramic flat on the face and add robot arm to move ceramic on chucks for imaging
41. Spray ceramic with sticky coating then wash and dry
42. Have Swedish wheels moving mechanically in opposite direction

43. Have Swedish wheels moving electro-mechanical in opposite direction
44. Add bumpy surface to V’s to ad friction
45. Add 2 long poles on sides of V’s
46. Make V’s thicker to account for all length ceramics
47. Make V’s thicker to account for all length ceramics and add material to close off hole
48. Sorbothane V’s
49. Add safety net between V’s
50. Pressure sensor gate between V’s
51. Have the robot hit the switch for the closure of lift gate
52. Have the robot hit switch camshaft leverage
53. Roller to brace ceramics (dumbbell shape)
54. Strap with magnetic connectors
55. Magnetic V’s and magnetic spray ceramics
56. Gyroscope V
57. Get rid of V’s and make a hammock out of elastic material to hold ceramics
58. Make the V’s hover by attaching to poles and elastic band
59. Add IMU inside V’s
60. Change T material to make it allow for imaging
61. Hydraulic shocks
62. Mechanical swivel mechanism to chucks
63. Add velcro to ceramics and V’s

64. Electro-Mechanical swivel
65. Magnetic locking swivel
66. Combined swivel and gyroscope
67. Add springs to mechanical swivel
68. Add springs to electro-mechanical swivel
69. Add spring to magnetic swivel
70. Rotating upper section of T
71. Mimic mountain goat hooves
72. Add sandbag weights to pallet
73. Put bubble wrap on the bottom
74. Add carpet to plant floor
75. Train switch swivel with built-in dampening
76. Magnetorheological fluid
77. Electrorheological fluid
78. Silly putty cushion with conforming bowl
79. Add silly putty and sandbags
80. V-shaped fins 90 degrees from v chuck
81. Foam pit around conveyor
82. Add a cutting station and keep the part long for conveyor transport
83. Make V's always in tension
84. Magnets on tops of T's, large overhead magnet
85. Drones carry ceramics

86. AC motor to fold/raise the T’s

87. Cut hole in top of imaging system and add robot to grab T’s

88. Magnetize entire conveyor so pallets float (bullet train)

89. Make conveyor actually stop so there is no vibrations

90. T’s made from ice that dissolve at imaging system

91. Bubble wrap ceramics

92. rope around ceramic with snipper robot

93. Set ceramics on top of sand

94. Enclose pallets with clear material

95. Make pallet out of foam

96. Romba(™) that drives T carts back to start

97. Smaller T’s that can be scanned through

98. Add a C slot and extra V’s

99. Add sand around conveyor

100. Put wall on conveyor

Appendix E: House of Quality

Binary Pairwise Comparison

	Customer Needs
1	Protects ceramic
2	Scaleable for ceramics
3	Limit human interaction
4	Works with given space
5	Works with conveyor conditions
6	Material choice
7	Improves current method

Customer Need	#1	#2	#3	#4	#5	#6	#7	Sum
#1	-	1	1	0	1	1	1	5
#2	0	-	0	0	0	1	0	1
#3	0	1	-	0	0	1	0	2
#4	1	1	1	-	1	1	1	6
#5	0	1	1	0	-	1	1	4
#6	0	0	0	0	0	-	0	0
#7	0	1	1	0	0	1	-	3

House of Quality

	Targets/Metrics
1	Limit Movement
2	Damaged Percent
3	Top Pallet Area
4	Bottom Pallet Volume
5	Time Before Scanability
6	Return Height
7	Interactions Per cycle
8	Weight Capacity
9	Secure to pallet DOF
10	Max device weight
11	Assembly Time
12	Recycleability

		Engineering Characteristics											
Improvement Directions		↓	↓	↓	↓	↓	↓	↓	↑	↓	↓	↓	
Units		in	%	in2	in3	sec	in	#	lbs	#	lbs	sec	n/a
Customer Needs	Importance Weight	1	2	3	4	5	6	7	8	9	10	11	12
Protects Ceramics	5	9	9	0	0	0	0	0	9	9	0	0	0
Scaleable for Ceramics	1	0	1	3	1	0	1	0	9	0	0	9	0
Limit Human Interaction	2	0	0	0	0	9	9	9	0	1	0	3	0
Works with Given Space	6	0	0	9	9	0	9	3	0	3	0	0	0
Works with Conveyor Conditions	4	0	1	9	9	9	9	9	0	9	9	3	0
Material Choice	0	3	3	0	0	0	0	0	9	1	9	1	9
Improves Current Method	3	9	9	9	0	3	9	9	0	9	0	1	0
Raw Score	559	72	77	120	91	63	136	99	54	128	36	30	0
Relative Weight %		13	14	21	16	11	24	18	10	23	6	5	0
Rank Order		7	6	3	5	8	1	4	9	2	10	11	12

Up	Down	Null
↑	↓	

Scale	
0	Not at All
1	Slightly
3	Moderatly
9	Significantly

Appendix F: Pugh Chart

Pugh chart Iteration 1

Selection Criteria	Datum: Current T System	Magnetic Swivel	Pincer	4 Bar	Sand Bag	Sensor Gate	2 Long Poles	Swedish Wheels	Self-nesting T	
Protects Ceramics		s	s	s	s	s	s	-	s	
Scaleable for Ceramics		+	+	s	+	s	+	+	s	
Limit Human Interaction		+	+	+	+	+	+	+	+	s=equal to datum
Works with Given Space		+	s	+	s	s	-	+	+	+=better
Works with Conveyor Conditions		+	s	+	+	s	+	+	+	-=worse
Material Choice		-	-	-	s	-	s	-	-	
Improves Current Method		+	+	+	s	s	s	s	+	
# of Pluses		5	3	4	3	1	3	4	4	
# of Satisfactory		1	3	2	4	5	3	1	2	
# of Minuses		1	1	1	0	1	1	2	1	

Pugh chart Iteration 2

Selection Criteria	Datum: Magnetic Swivel	Magnetic Swivel	Pincer	4 Bar	Sand Bag	[redacted]	2 Long Poles	[redacted]	Self-nesting T
Protects Ceramics		s	+	+	-		-		+
Scaleable for Ceramics		s	-	-	+		s		-
Limit Human Interaction		s	s	s	-		s		s
Works with Given Space		s	s	s	-		-		s
Works with Conveyor Conditions		s	s	s	s		s		s
Material Choice		s	+	s	+		+		s
Improves Current Method		s	s	s	s		s		s
# of Pluses		0	2	1	2		1		1
# of Satisfactory		7	4	5	2		4		5
# of Minuses		0	1	1	3		2		1

Pugh chart Iteration 3

Selection Criteria		Concepts						
		Magnetic Swivel	Pincer	4 Bar	[redacted]	2 Long Poles	[redacted]	Self-nesting T
Protects Ceramics	Datum: Pincer	s	s	+	[redacted]	-	[redacted]	+
Scaleable for Ceramics		s	s	-	[redacted]	s	[redacted]	-
Limit Human Interaction		s	s	s	[redacted]	s	[redacted]	s
Works with Given Space		s	s	+	[redacted]	s	[redacted]	+
Works with Conveyor Conditions		s	s	s	[redacted]	+	[redacted]	-
Material Choice		s	s	-	[redacted]	+	[redacted]	-
Improves Current Method		s	s	s	[redacted]	-	[redacted]	s
# of Pluses		0	0	2	[redacted]	2	[redacted]	2
# of Satisfactory		7	7	3	[redacted]	3	[redacted]	2
# of Minuses		0	0	2	[redacted]	2	[redacted]	3

Pugh chart Iteration 4

Selection Criteria		Concepts			
		Magnetic Swivel	Pincer	[redacted]	Self-nesting T
Protects Ceramics	Datum: Pincer	s	s	[redacted]	+
Scaleable for Ceramics		s	s	[redacted]	-
Limit Human Interaction		s	s	[redacted]	s
Works with Given Space		s	s	[redacted]	+
Works with Conveyor Conditions		s	s	[redacted]	-
Material Choice		s	s	[redacted]	-
Improves Current Method		s	s	[redacted]	s
# of Pluses		0	0	[redacted]	2
# of Satisfactory		7	7	[redacted]	2
# of Minuses		0	0	[redacted]	3

Appendix G: Analytical Hierarchy Process

Target Comparison

	Development of Candidate Set of Criteria Weights {W}							
	Criteria Comparison [C]							
		1	2	3	4	5	6	7
1	Protects Ceramics	1.00	0.11	1.00	0.33	5.00	0.14	3.00
2	Scaleable for Ceramics	9.00	1.00	7.00	7.00	9.00	1.00	3.00
3	Limit Human Interaction	1.00	0.14	1.00	0.33	1.00	0.11	1.00
4	Works with Given Space	3.00	0.14	3.00	1.00	5.00	0.14	1.00
5	Works with Conveyor Conditions	0.20	0.11	1.00	0.20	1.00	0.11	1.00
6	Material Choice	7.00	1.00	9.00	7.00	9.00	1.00	9.00
7	Improves Current Method	0.33	0.33	1.00	1.00	1.00	0.11	1.00
	Sum	21.53	2.84	23.00	16.87	31.00	2.62	19.00

Normalized Target Comparison

	Normalized Criteria Comparison Matirx [NormC]								
		1	2	3	4	5	6	7	Criteria Weights {W}
1	Protects Ceramics	0.046	0.039	0.043	0.020	0.161	0.055	0.158	0.075
2	Scaleable for Ceramics	0.418	0.352	0.304	0.415	0.290	0.382	0.158	0.331
3	Limit Human Interaction	0.046	0.050	0.043	0.020	0.032	0.042	0.053	0.041
4	Works with Given Space	0.139	0.050	0.130	0.059	0.161	0.055	0.053	0.093
5	Works with Conveyor Conditions	0.009	0.039	0.043	0.012	0.032	0.042	0.053	0.033
6	Material Choice	0.325	0.352	0.391	0.415	0.290	0.382	0.474	0.376
7	Improves Current Method	0.015	0.117	0.043	0.059	0.032	0.042	0.053	0.052
	Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Consistency Check

	Consistency Check		
Target #	Weighted Sum Vector	Criteria Weights	Consistency Vector
1	0.557553809	0.075	7.469371743
2	2.766375086	0.331	8.349286392
3	0.320443704	0.041	7.808246878
4	0.757455667	0.093	8.185058034
5	0.237870159	0.033	7.206816237
6	3.010201813	0.376	8.014437331
7	0.395484937	0.052	7.628974353

Average Consistency (λ)	7.80888442
Number of Criteria	7
Consistency Index	0.13481407
Random Index Value (RI)	1.35
Consistency Ratio (CR <0.10)	0.10

Target #1 Comparison

Protects Ceramics

Development of Candidate Set of Criteria Weights {W}			
Criteria Comparison [C]			
	Pincer	Swivel	Self-nesting T
Pincer	1.00	3.00	3.00
Swivel	0.33	1.00	1.00
Self-nesting T	0.33	1.00	1.00
Sum	1.67	5.00	5.00

Target #1 Normalized Comparison

Normalized Criteria Comparison Matirx [NormC]				
	Pincer	Swivel	Self-nesting T	Criteria Weights {W}
Pincer	0.600	0.600	0.600	0.600
Swivel	0.200	0.200	0.200	0.200
Self-nesting	0.200	0.200	0.200	0.200
Sum	1.000	1.000	1.000	1.000

Target #1 Consistency

Consistency Check		
Weighted Sum Vector	Criteria Weights	Consistency Vector
1.8	0.600	3
0.6	0.200	3
0.6	0.200	3

Average Consistency (λ)	3
Number of Criteria	3
Consistency Index	0
Random Index Value (RI)	0.52
Consistency Ratio (CR <0.10)	0.00

Target #2 Comparison

Scaleable for Ceramics

Development of Candidate Set of Criteria Weights {W}			
Criteria Comparison [C]			
	Pincer	Swivel	Self-nesting T
Pincer	1.00	1.00	1.00
Swivel	1.00	1.00	1.00
Self-nesting T	1.00	1.00	1.00
Sum	3.00	3.00	3.00

Target #2 Normalized Comparison

Normalized Criteria Comparison Matirx [NormC]				
	Pincer	Swivel	Self-nesting T	Criteria Weights {W}
Pincer	0.333	0.333	0.333	0.333
Swivel	0.333	0.333	0.333	0.333
Self-nesting	0.333	0.333	0.333	0.333
Sum	1.000	1.000	1.000	1.000

Target #2 Consistency

Consistency Check		
Weighted Sum Vector	Criteria Weights	Consistency Vector
1	0.333	3
1	0.333	3
1	0.333	3

Average Consistency (λ)	3
Number of Criteria	3
Consistency Index	0
Random Index Value (RI)	0.52
Consistency Ratio (CR <0.10)	0.00

Target #3 Comparison

Limit Human Interaction

Development of Candidate Set of Criteria Weights {W}			
Criteria Comparison [C]			
	Pincer	Swivel	Self-nesting T
Pincer	1.00	1.00	1.00
Swivel	1.00	1.00	1.00
Self-nesting T	1.00	1.00	1.00
Sum	3.00	3.00	3.00

Target #3 Normalized Comparison

Normalized Criteria Comparison Matirx [NormC]				
	Pincer	Swivel	Self-nesting T	Criteria Weights {W}
Pincer	0.333	0.333	0.333	0.333
Swivel	0.333	0.333	0.333	0.333
Self-nesting	0.333	0.333	0.333	0.333
Sum	1.000	1.000	1.000	1.000

Target #3 Consistency

Consistency Check		
Weighted Sum Vector	Criteria Weights	Consistency Vector
1	0.333	3
1	0.333	3
1	0.333	3

Average Consistency (λ)	3
Number of Criteria	3
Consistency Index	0
Random Index Value (RI)	0.52
Consistency Ratio (CR <0.10)	0.00

Target #4 Comparison

Works with Given Space

Development of Candidate Set of Criteria Weights {W}			
Criteria Comparison [C]			
	Pincer	Swivel	Self-nesting T
Pincer	1.00	3.00	3.00
Swivel	0.33	1.00	1.00
Self-nesting T	0.33	1.00	1.00
Sum	1.67	5.00	5.00

Target #4 Normalized Comparison

Normalized Criteria Comparison Matirx [NormC]				
	Pincer	Swivel	Self-nesting T	Criteria Weights {W}
Pincer	0.600	0.600	0.600	0.600
Swivel	0.200	0.200	0.200	0.200
Self-nesting	0.200	0.200	0.200	0.200
Sum	1.000	1.000	1.000	1.000

Target #4 Consistency

Consistency Check		
Weighted Sum Vector	Criteria Weights	Consistency Vector
1.8	0.600	3
0.6	0.200	3
0.6	0.200	3

Average Consistency (λ)	3
Number of Criteria	3
Consistency Index	0
Random Index Value (RI)	0.52
Consistency Ratio (CR <0.10)	0.00

Target #5 Comparison

Works with Conveyor Conditions			
Development of Candidate Set of Criteria Weights {W}			
Criteria Comparison [C]			
	Pincer	Swivel	Self-nesting T
Pincer	1.00	3.00	0.33
Swivel	0.33	1.00	0.20
Self-nesting T	3.00	5.00	1.00
Sum	4.33	9.00	1.53

Target #5 Normalized Comparison

Normalized Criteria Comparison Matirx [NormC]				
	Pincer	Swivel	Self-nesting T	Criteria Weights {W}
Pincer	0.231	0.333	0.333	0.299
Swivel	0.077	0.111	0.130	0.106
Self-nesting	0.692	0.556	0.652	0.633
Sum	1.000	1.000	1.116	1.039

Target #5 Consistency

Consistency Check		
Weighted Sum Vector	Criteria Weights	Consistency Vector
0.82872951	0.299	2.770324362
0.332540567	0.106	3.132555426
2.061563235	0.633	3.255036182

Average Consistency (λ)	3.052638657
Number of Criteria	3
Consistency Index	0.026319328
Random Index Value (RI)	0.52
Consistency Ratio (CR <0.10)	0.05

Target #6 Comparison

Material Choice

Development of Candidate Set of Criteria Weights {W}			
Criteria Comparison [C]			
	Pincer	Swivel	Self-nesting T
Pincer	1.00	0.33	0.33
Swivel	3.00	1.00	1.00
Self-nesting T	3.00	1.00	1.00
Sum	7.00	2.33	2.33

Target #6 Normalized Comparison

Normalized Criteria Comparison Matirx [NormC]				
	Pincer	Swivel	Self-nesting T	Criteria Weights {W}
Pincer	0.143	0.143	0.143	0.143
Swivel	0.429	0.429	0.429	0.429
Self-nesting	0.429	0.429	0.429	0.429
Sum	1.000	1.000	1.000	1.000

Target #6 Consistency

Consistency Check		
Weighted Sum Vector	Criteria Weights	Consistency Vector
0.428571429	0.143	3
1.285714286	0.429	3
1.285714286	0.429	3

Average Consistency (λ)	3
Number of Criteria	3
Consistency Index	0
Random Index Value (RI)	0.52
Consistency Ratio (CR <0.10)	0.00

Target #7 Comparison

Improves Current Method

Development of Candidate Set of Criteria Weights {W}			
Criteria Comparison [C]			
	Pincer	Swivel	Self-nesting T
Pincer	1.00	3.00	1.00
Swivel	0.33	1.00	0.33
Self-nesting T	1.00	3.00	1.00
Sum	2.33	7.00	2.33

Target #7 Normalized Comparison

Normalized Criteria Comparison Matirx [NormC]				
	Pincer	Swivel	Self-nesting T	Criteria Weights {W}
Pincer	0.429	1.000	0.429	0.619
Swivel	0.143	0.143	0.143	0.143
Self-nesting	0.429	0.429	0.429	0.429
Sum	1.000	1.571	1.000	1.190

Target #7 Consistency

Consistency Check		
Weighted Sum Vector	Criteria Weights	Consistency Vector
1.476190476	0.619	2.384615385
0.492063492	0.143	3.444444444
1.476190476	0.429	3.444444444

Average Consistency (λ)	3.091168091
Number of Criteria	3
Consistency Index	0.045584046
Random Index Value (RI)	0.52
Consistency Ratio (CR <0.10)	0.09

Final Matrix Rating and Concept Alternative Values

Final Rating Matrix	Pincer	Swivel	Spring T
Protects Ceramics	0.600	0.200	0.200
Scaleable for Ceramics	0.333	0.333	0.333
Limit Human Interaction	0.333	0.333	0.333
Works with Given Space	0.600	0.200	0.200
Works with Conveyor Conditions	0.299	0.106	0.633
Material Choice	0.143	0.429	0.429
Improves Current Method	0.619	0.143	0.429

Concept	Alternative Value
Pincer	0.320057036
Swivel	0.329440441
Self-nesting	0.361652386

Appendix H: Operation Manual

Project Overview

Project Description

The team was able to determine the project description by meeting with the project sponsor representatives, Jeffery Roche and Jeffery Stott, and discussing their current needs. Based on these meetings with the Corning representatives the team has determined that the goal of the project is to improve the current device that is being used to protect the ceramics. The objective of the project is to prevent the ceramics from falling off the conveyor in Corning's manufacturing plant, while also decreasing the cost in labor by minimizing the number of employees needed along the conveyor.

Key Goals

After developing the project description, the team was able to come up with a list of key goals that the design must achieve. The first key goal of this project is to design a method to prevent damage to ceramic filters and substrates while on the production line in Corning's manufacturing plant. Their current design utilizes a "T" shaped piece of plexiglass that is placed upside down and inside the slots on their chuck system. This method adequately prevents short part ceramics from falling and obtaining damage. Another goal of the team's design is to limit human interaction compared to the current system. The system currently in place requires two plant workers to place the T's on the chuck at the beginning of the line and remove them before the imaging process. The design used for this project should also be able to seamlessly integrate with the current conveyor system. There are several overhangs and space limitations on their current conveyor and the team's design needs to fit within these parameters.

Assumptions

In order to complete the project in the required timeframe, the team needs to make some vital assumptions. The team is assuming that the pallets and conveyor itself remain level during the transporting process. Additionally, the team expects the data and measurements received from our sponsor to be accurate and precise. This means that the pallets are uniform across the plant. Lastly, the team assumes that the manufacturing plant conditions will remain the same throughout the project duration.

Module Description

CAD Overview

This project contains a multitude of parts and several other components tied to the project that make it whole. The following figure is a depiction of the complete CAD model.

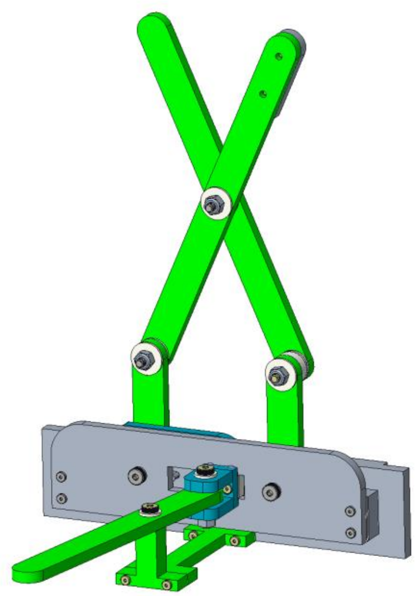


Figure 1: Assembled CAD Front View

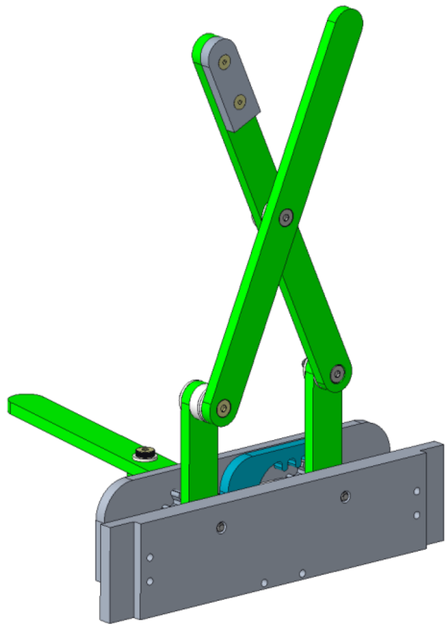


Figure 2: Assembled CAD Back View

The next figure below shows an exploded view on the assembly.

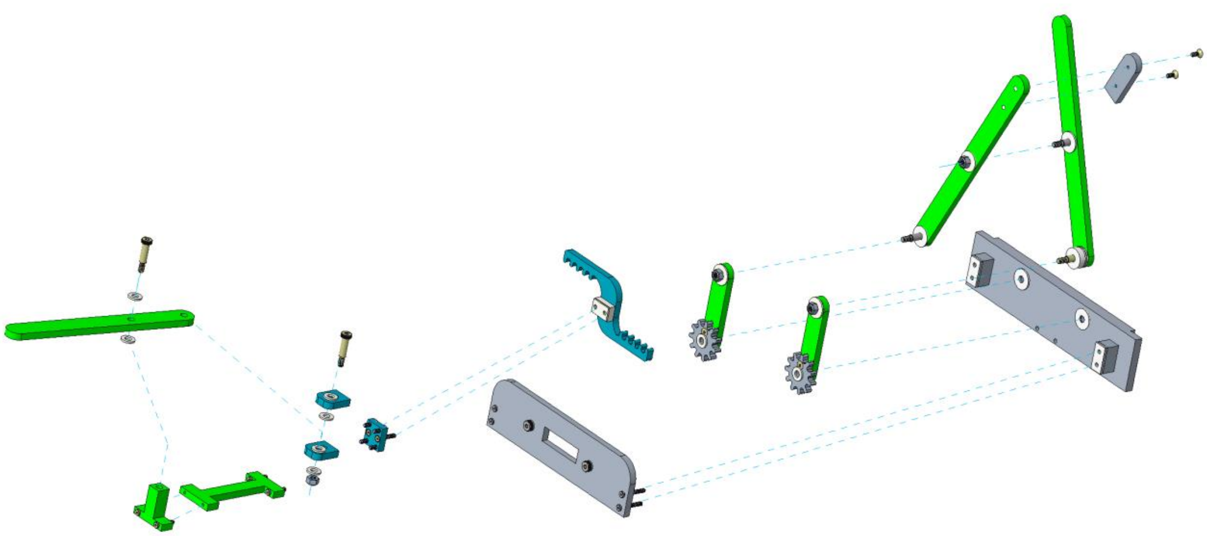


Figure 3: CAD Exploded View

Modules

There are 3 main modules in this project: the linkage assembly, the lifting and protection wall, and the engagement switch assembly. The linkage assembly module includes information about the assembly of the linkages. The lifting and protection wall module includes information about the gears and mechanisms actuating the device. It also includes the assembly and connection of the linkages to the base and the outer wall. The engagement switch assembly module includes information about the slider connection and switch assembly.

Linkage Assembly

This module includes all components that make up the linkages that will raise and lower to protect the ceramic. The linkages are fabricated out of 1/4" thick 6061 Aluminum. The washers are made of 1/16" thick UHMW Polyethylene. Included in this module are the connection points to each linkage. This module acts as the barrier and protection to the ceramics. This module does not include how the linkages will be attaching to the base and outer wall. That connection will be described in the lifting and protection wall module. Photos of the assembled and exploded view of the linkage assembly are shown below in Figure 4 and 5.

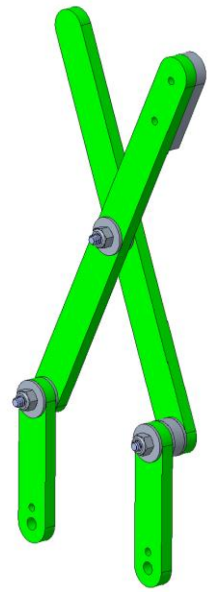


Figure 4: Assembled View of Linkage Assembly

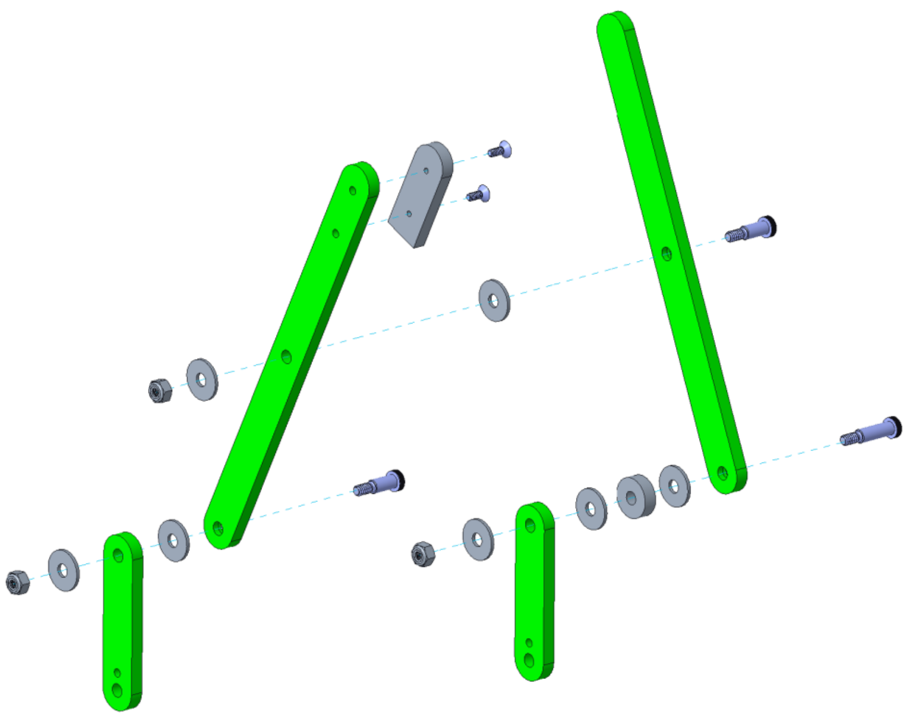


Figure 5: Exploded View of Linkage Assembly

Lifting and Protection Wall

This Module includes all the components that make up the lifting mechanism. The lifting mechanism acts as a rack and pinion, utilizing a Z shaped rack that will move the gears in an opposite motion allowing the linkages to rise and lower simultaneously. This module will show the connection points of this mechanism and show the connection points of the linkages to the device. Included in this assembly is the outer wall which acts as a protection barrier to any outside obstruction. The outer wall also secures the entire mechanism together. The Z shaped rack will be interacting with the engagement switch, which will be explained more in the following section. When the switch is being interacted with it will move the rack to rotate the gears causing the linkages to raise or lower into position. The base is made of 1/2" thick 6061 Aluminum, as well as the square spacers in between the walls. The outer wall, gears and rack are made of 1/4" thick 6061 Aluminum. All thin light gray components are 1/16" thick UHMW Polyethylene washer/spacers. Photos of the assembled and exploded views of the lifting mechanism and outer wall are shown below in Figure 6-8.

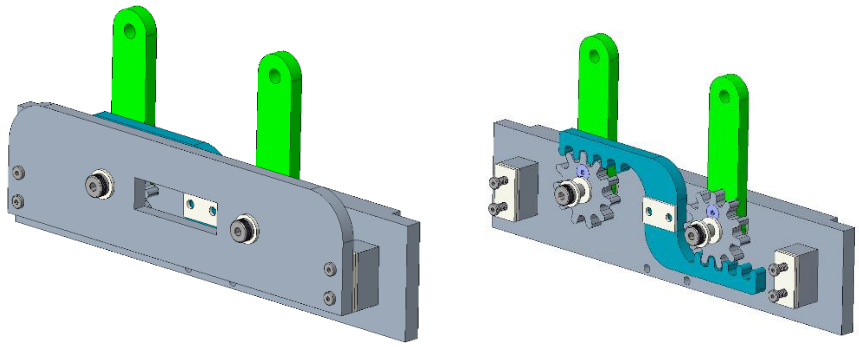


Figure 6: Assembled View of Lifting Mechanism (with and without outer wall)

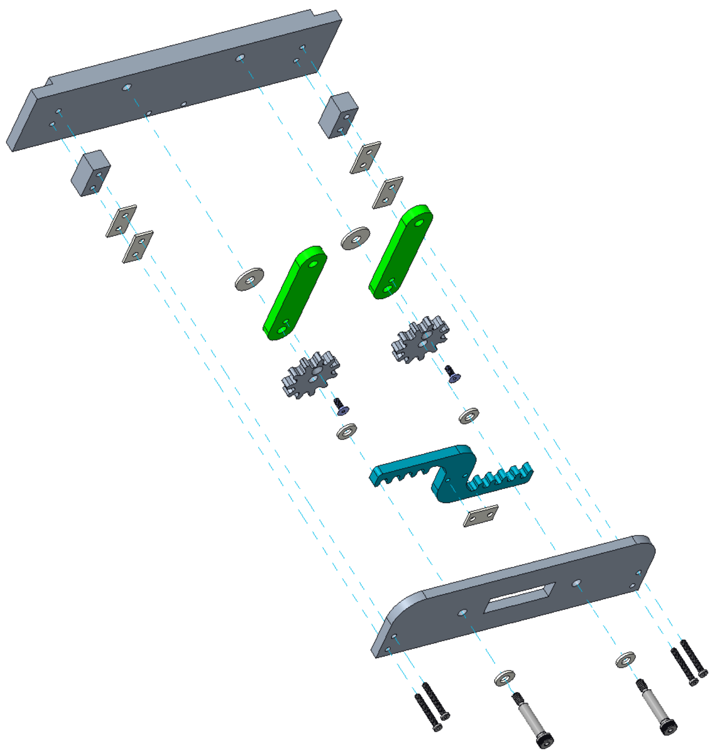


Figure 7: Exploded View of Lifting Assembly

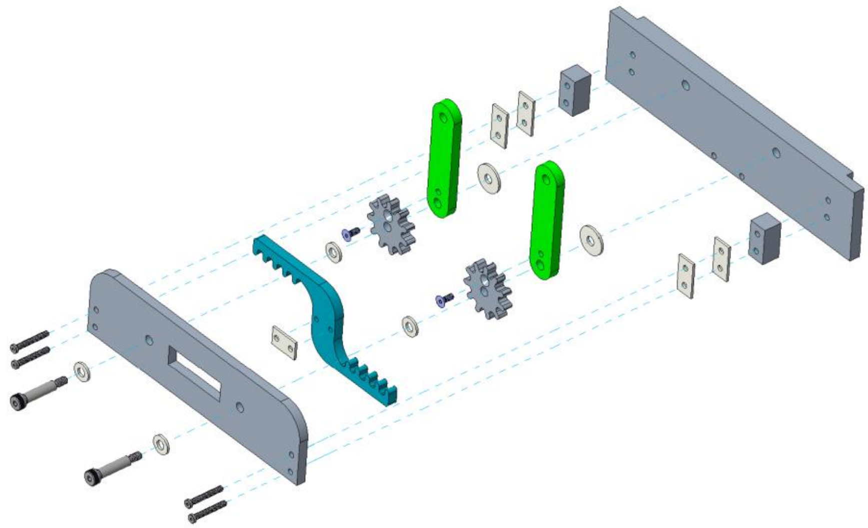


Figure 8: Exploded View of Lifting Assembly

Engagement Switch

The engagement switch of the device acts as the physical interface between the conveyor and physical device. When a pallet with the device on it is moved to a specific location, the manufacturing plant can use overhangs to engage the switch, raising or lowering the mechanism. The base, switch, and slot slider of the switch are all made of 1/4” thick 6061 Aluminum. The pivot block is made of 1/2” thick 6061 Aluminum. All white components are 1/16” thick UHMW Polyethylene washer/spacers. Photos of the assembled and exploded views of the lifting mechanism and outer wall are shown below in Figure 9-11.

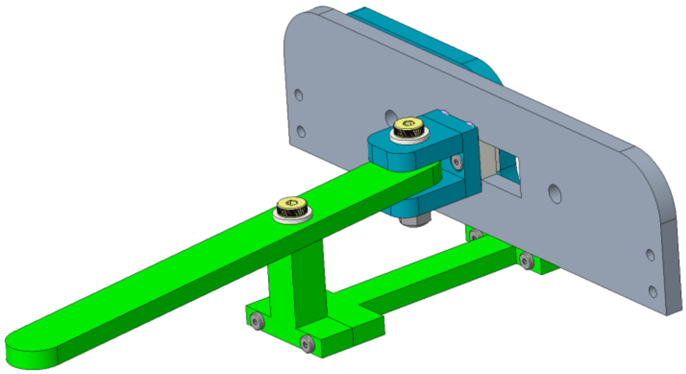


Figure 9: Assembled View of Switch Assembly

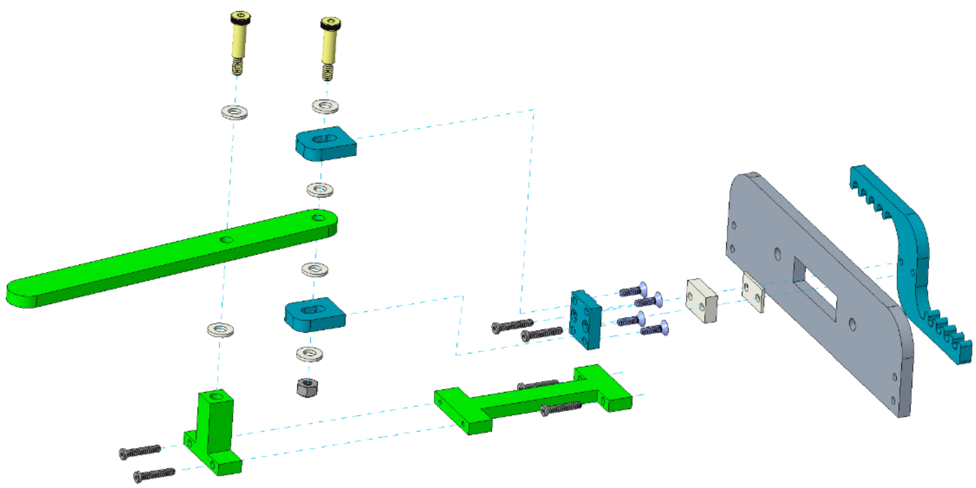


Figure 10: Exploded View of Switch Assembly

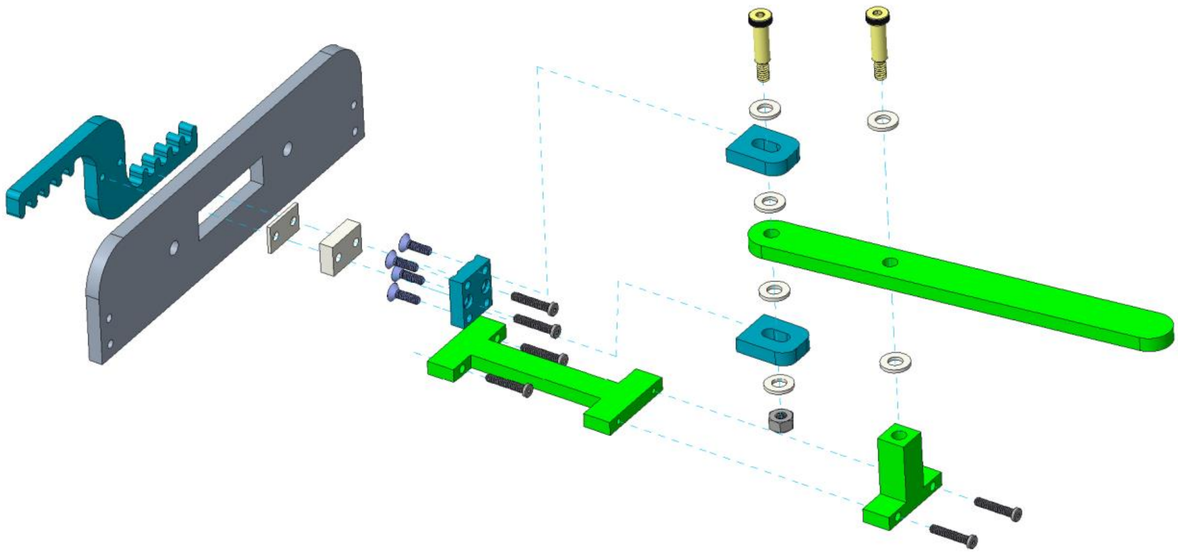


Figure 11: Exploded View of Switch Assembly

Integration

To start the assembly of the device, the user would first begin with the linkage assembly. Place a 1/2” long shoulder bolt with a 10-24 thread through the middle hole connecting the two long links. Place a washer in between the links and on the outside before screwing on the nut. Place another 1/2” long shoulder bolt with a 10-24 thread through the bottom of the link with 4 holes, this will be connected to one of the smaller linkages. Place a washer in between the links and before placing the nut. Next place a 1” long shoulder bolt with a 10-24 thread through the long link with 2 holes. This will be connected to the last smaller linkage. To accommodate for the offset use two 1/16” washers and a 1/4” washer in between the connection. Then place an outer washer and screw on the nut. It is important to not over tighten the nuts or it will cause to much friction and lock the linkages from moving. Once this is done, secure the bumper on to the top of linkage with four holes using two 3/8” long 6-32 flat head screws.

Next start with the two smaller linkages and connect the gears to them using two 3/8” long 6-32 flat head screws. Use one of the shoulder bolts to make sure both the holes of the gear and linkage align while tightening. After this lay the base down on flat surface and carefully place and align the components that go in between the walls as shown in Figure 7 and 8. Once the holes are aligned place a 1” long 6-32 socket head screw into the outer 4 holes of the outer wall. Carefully tighten until the outer wall and the components are secure. Place two 1” long 10-24 shoulder bolt screws through the pivot holes close the square slot. These bolts will act as a shaft for the smaller linkages to swivel around.

Once the linkages and wall components are assembled the final stage is to assemble the engagement switch. Start with the outer rack wall that has six holes and the slotted slider. Using four 3/8” long 6-32 flat head screws carefully tighten the two slot sliders to the top and bottom of the outer rack. Next carefully position the outer rack on the outer wall aligning the holes with Z rack that will be in between the base and the outer wall. Using two 1/2” long 6-32 socket head screws carefully tighten the outer rack the Z rack. Next place the “I” shaped pivot against the bottom of the base and secure using two 3/4” long 6-32 socket head screws. Once secure, place the pivot block at the end of the pivot base and secure using two 3/4” long 6-32 socket head screws. The device can now be sat right side up. The last step is to connect the engagement switch by aligning the holes with the slots and the hole in the pivot block. Place 1/16” washers where needed to avoid metal on metal contact. With the switch in place, use two 3/4” long shoulder bolt screws, one to go through the slot and the switch bar and one to go through the switch bar and into the pivot block. Secure the shoulder bolt through the slot slider with a nut. Finally do a final check on all connections to ensure any pivot points are not overly tightened.

Table 1: Self-Nesting T Screw Size Chart

Assembly Description	Bolt/Screw Type	Nut Required
Linkage Assembly	1/4" Shoulder Diameter, 1/2" Shoulder Length, 10-24 Thread	Yes
Linkage Assembly	1/4" Shoulder Diameter, 3/4" Shoulder Length, 10-24 Thread	Yes
Linkage Assembly	6-32 Thread Size, 3/8" Long, Flat head	No
Lifting and Protection Wall	1/4" Shoulder Diameter, 1" Shoulder Length, 10-24 Thread	No
Lifting and Protection Wall	Hex Drive, Black Oxide, 6-32 Thread Size, 1" Long, Socket Head	No
Lifting and Protection Wall	6-32 Thread Size, 3/8" Long, Flat head	No
Engagement Switch	6-32 Thread Size, 1" Long, Flat head	No
Engagement Switch	Hex Drive, Black Oxide, 6-32 Thread Size, 3/4" Long, Socket Head	No
Engagement Switch	Hex Drive, Black Oxide, 6-32 Thread Size, 1" Long, Socket Head	No
Engagement Switch	1/4" Shoulder Diameter, 3/4" Shoulder Length, 10-24 Thread	Yes
Engagement Switch	1/4" Shoulder Diameter, 3/4" Shoulder Length, 10-24 Thread	No

Operation

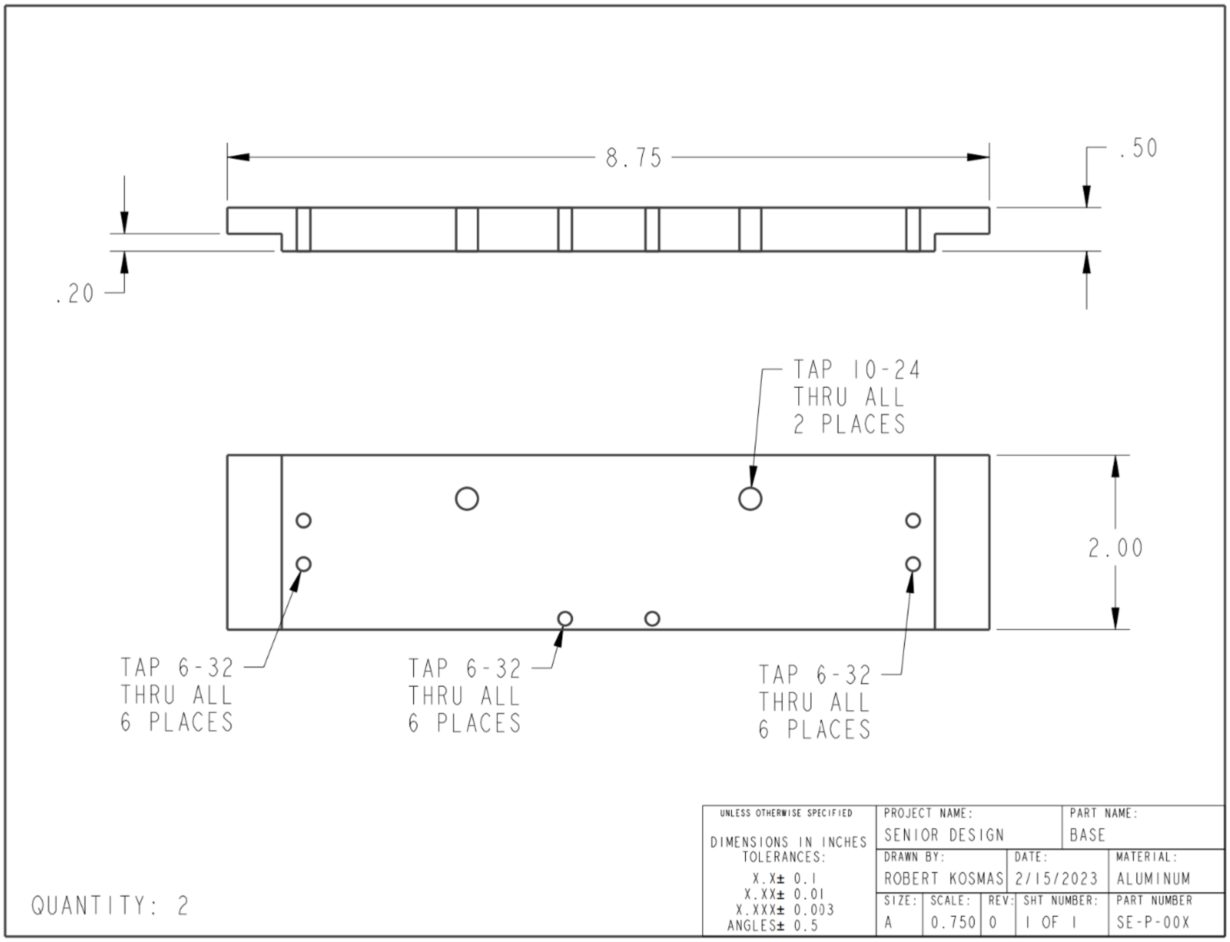
Once the device has been fully assembled it is now ready for use. Begin by placing two devices in both “C” chuck slot positions on the pallet. A ceramic will then be placed on the pallet by the mechanical arms of the manufacturing plant. When the pallet reaches its desired stop, RFID sensors will notify the system that a pallet is in position. Mechanical overhangs placed on the conveyor will then engage with the two devices raising the linkages into their protection position. The pallet will travel the desired length on the conveyor until it is desired for the face of the ceramic to be revealed. At which point another stop will be performed where the mechanical overhangs will interact with the devices again lowering the linkages and revealing the ceramic face. Once the ceramics undergo the imaging process it is no longer necessary for the linkages to lift again. The pallet will travel the remainder of the conveyor and then go through the feedback system. Once the pallet has completed travel through the feedback system it will be back at the beginning ready to repeat the process again.

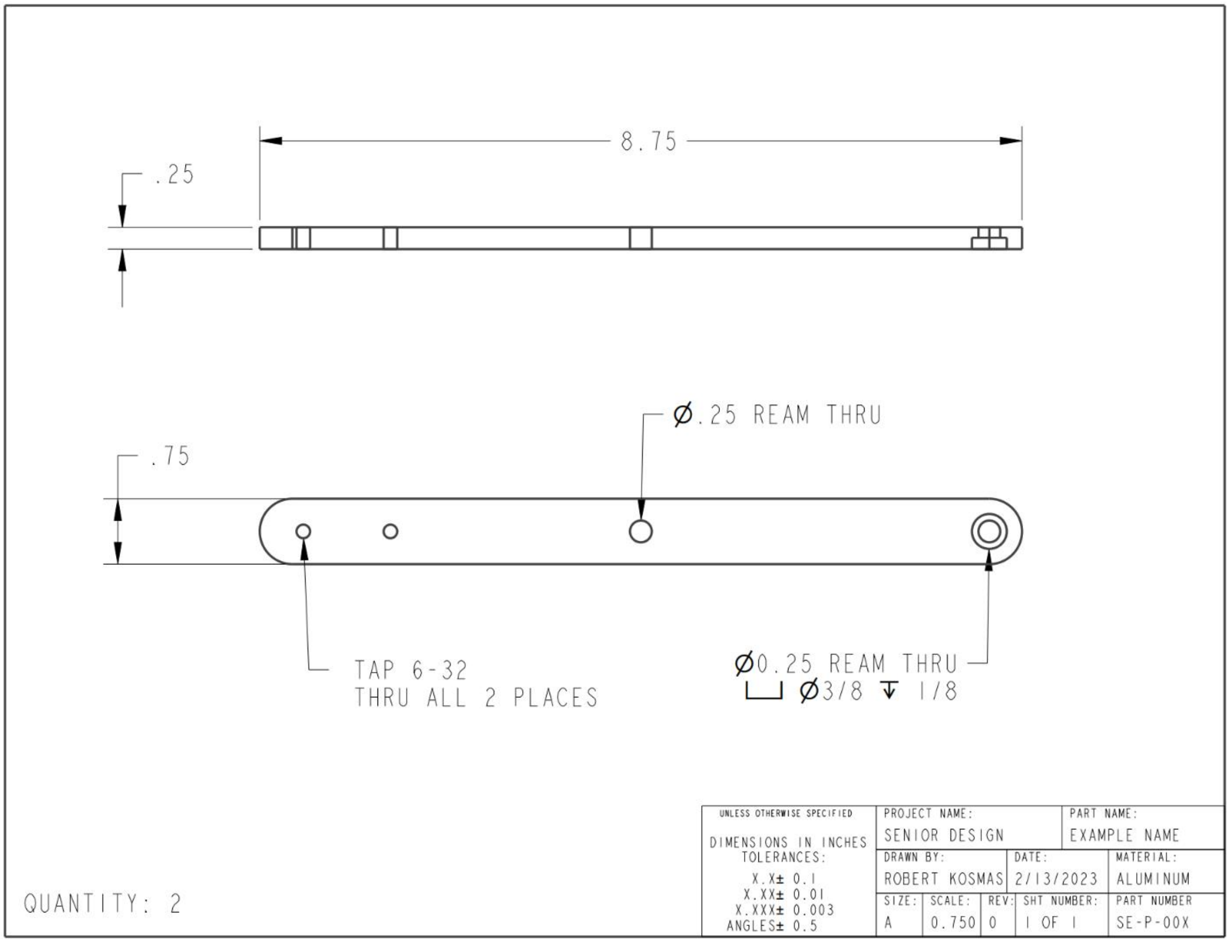
Troubleshooting

If there are issues while operating the self-nesting T's, there are a few aspects to check for that may be causing the problem. First double check all bolts and nuts to make sure no joint has been over tightened. Loosening these connections may help with the mobility of the switch and smoothness of the linkages. Another problem may arise from particle or dust build up within the factory setting. To try and remove any particle or dust build up, blow out the device with pressurized air. Be sure to actuate the device up and down to make sure no dust is left. If the device is wiggling, there may have been wear to some of the polyethylene washers or the slider. Check these components for wear as they will be easily replaceable by deconstructing the device and replacing the worn piece. It is especially important to make sure the shoulder bolts are tightened enough to not allow dust to infiltrate the gaps but still allow the linkages to rotate freely. Foam adhesives may wear down on the front of the linkage arms. Remove any worn foam pieces and replace them with a new foam adhesive.

Appendix I: Engineering Drawings

The following images are drawings brought to the FAMU-FSU College of Engineering Machine shop to be machined.


8.75
.50
.20
TAP 10-24
THRU ALL
2 PLACES
2.00
TAP 6-32
THRU ALL
6 PLACES
TAP 6-32
THRU ALL
6 PLACES
TAP 6-32
THRU ALL
6 PLACES
QUANTITY: 2
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
X.X± 0.1
X.XX± 0.01
X.XXX± 0.003
ANGLES± 0.5
PROJECT NAME:
SENIOR DESIGN
PART NAME:
BASE
DRAWN BY:
ROBERT KOSMAS
DATE:
2/15/2023
MATERIAL:
ALUMINUM
SIZE:
A
SCALE:
0.750
REV:
0
SHT NUMBER:
1 OF 1
PART NUMBER
SE-P-00X


8.75
.25
.75
Ø.25 REAM THRU
TAP 6-32
THRU ALL 2 PLACES
Ø0.25 REAM THRU
⌴ Ø3/8 ↧ 1/8
QUANTITY: 2
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
X.X± 0.1
X.XX± 0.01
X.XXX± 0.003
ANGLES± 0.5
PROJECT NAME:
SENIOR DESIGN
PART NAME:
EXAMPLE NAME
DRAWN BY:
ROBERT KOSMAS
DATE:
2/13/2023
MATERIAL:
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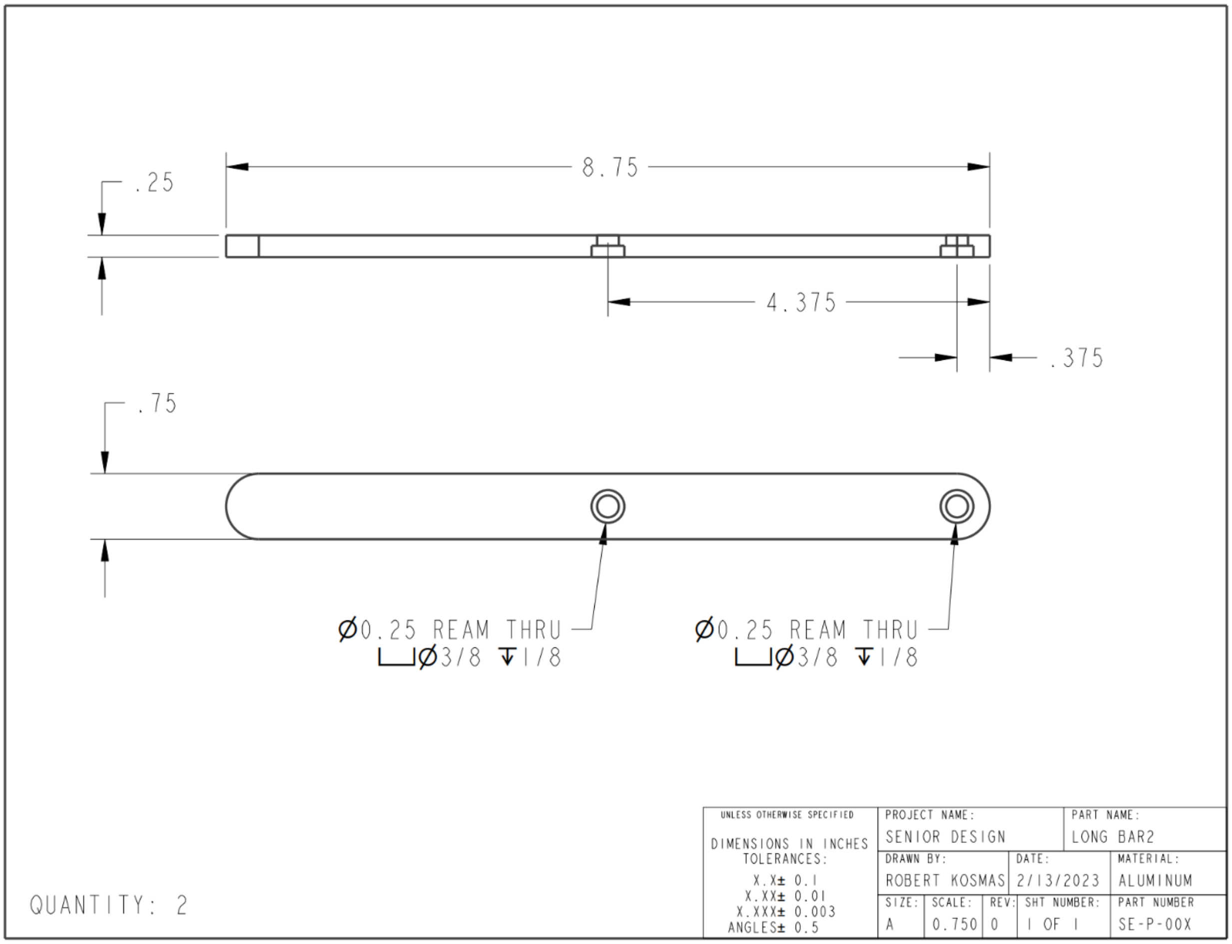
A
SCALE:
0.750
REV:
0
SHT NUMBER:
1 OF 1
PART NUMBER
SE-P-00X


8.75
.25
4.375
.375
.75
Ø0.25 REAM THRU
⌴Ø3/8 ↧1/8
Ø0.25 REAM THRU
⌴Ø3/8 ↧1/8
QUANTITY: 2
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
X.X± 0.1
X.XX± 0.01
X.XXX± 0.003
ANGLES± 0.5
PROJECT NAME:
SENIOR DESIGN
PART NAME:
LONG BAR2
DRAWN BY:
ROBERT KOSMAS
DATE:
2/13/2023
MATERIAL:
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SCALE:
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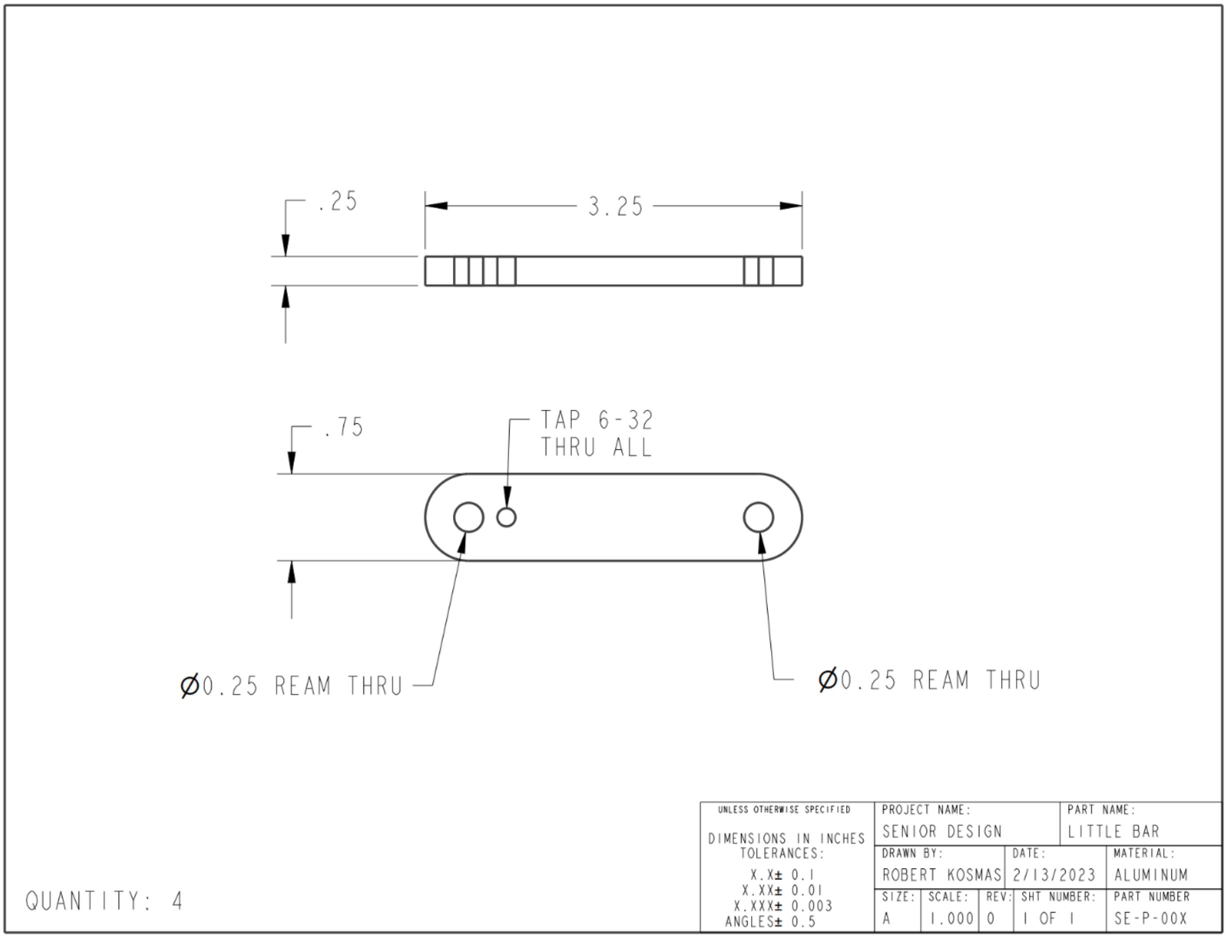
SHT NUMBER:
1 OF 1
PART NUMBER
SE-P-00X


.25
3.25
.75
TAP 6-32
THRU ALL
Ø0.25 REAM THRU
Ø0.25 REAM THRU
QUANTITY: 4
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
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X.XX± 0.01
X.XXX± 0.003
ANGLES± 0.5
PROJECT NAME:
SENIOR DESIGN
PART NAME:
LITTLE BAR
DRAWN BY:
ROBERT KOSMAS
DATE:
2/13/2023
MATERIAL:
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SCALE:
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REV:
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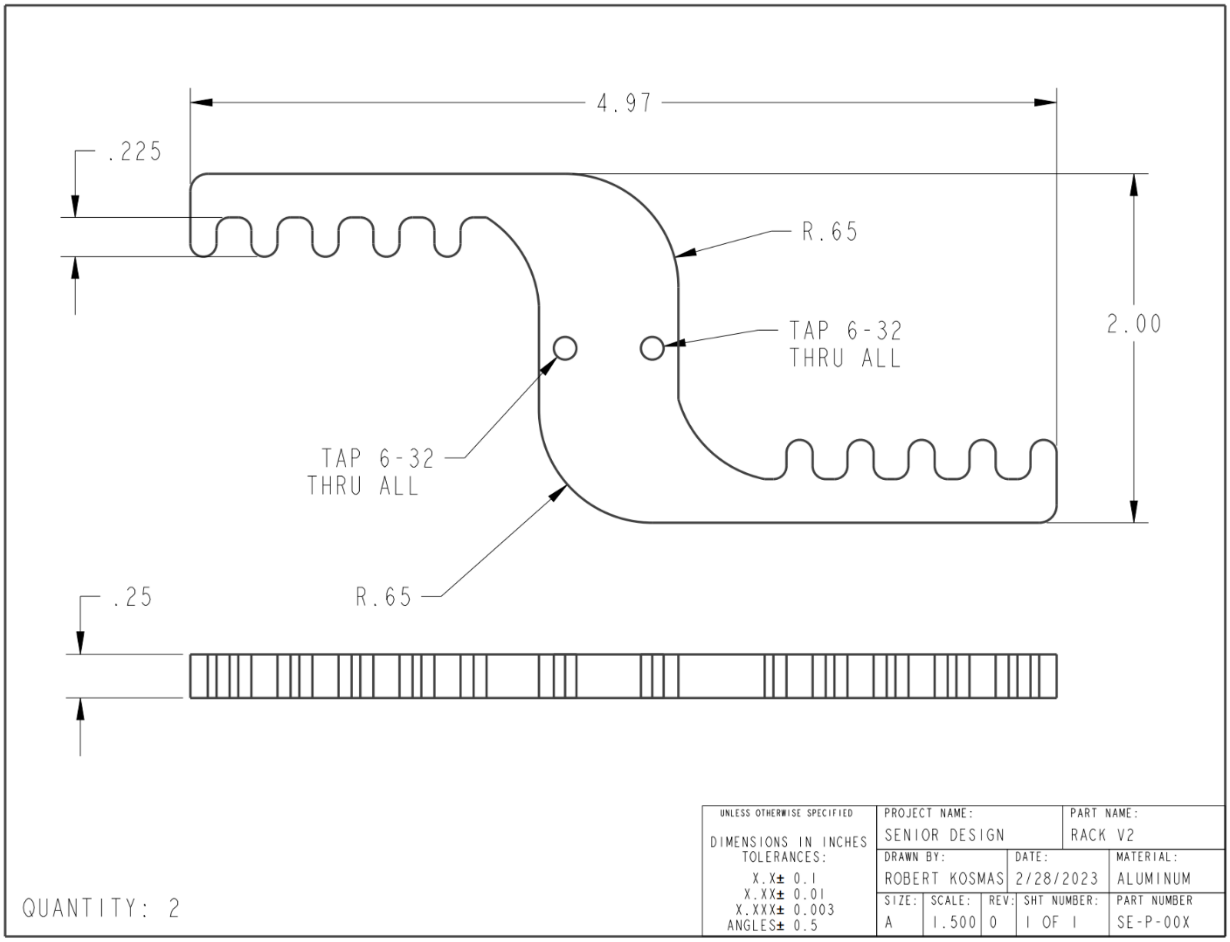
SHT NUMBER:
1 OF 1
PART NUMBER
SE-P-00X



4.97
.225
R.65
TAP 6-32
THRU ALL
2.00
TAP 6-32
THRU ALL
R.65
.25
QUANTITY: 2
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
X.X± 0.1
X.XX± 0.01
X.XXX± 0.003
ANGLES± 0.5
PROJECT NAME:
SENIOR DESIGN
PART NAME:
RACK V2
DRAWN BY:
ROBERT KOSMAS
DATE:
2/28/2023
MATERIAL:
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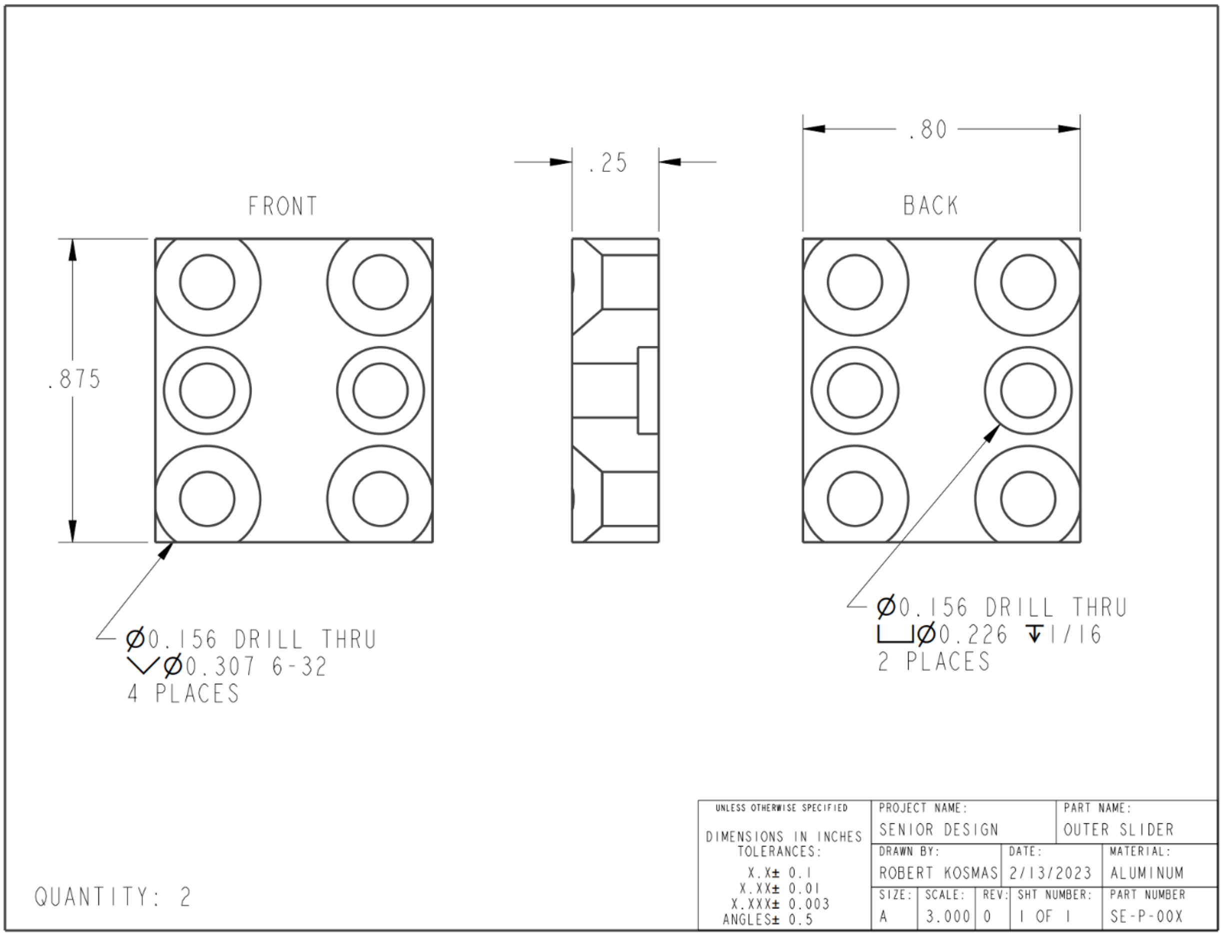
1 OF 1
PART NUMBER
SE-P-00X


.80
.25
FRONT
BACK
.875
Ø0.156 DRILL THRU
⌵Ø0.307 6-32
4 PLACES
Ø0.156 DRILL THRU
⌴Ø0.226 ↧1/16
2 PLACES
QUANTITY: 2
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
X.X± 0.1
X.XX± 0.01
X.XXX± 0.003
ANGLES± 0.5
PROJECT NAME:
SENIOR DESIGN
PART NAME:
OUTER SLIDER
DRAWN BY:
ROBERT KOSMAS
DATE:
2/13/2023
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REV:
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1 OF 1
PART NUMBER
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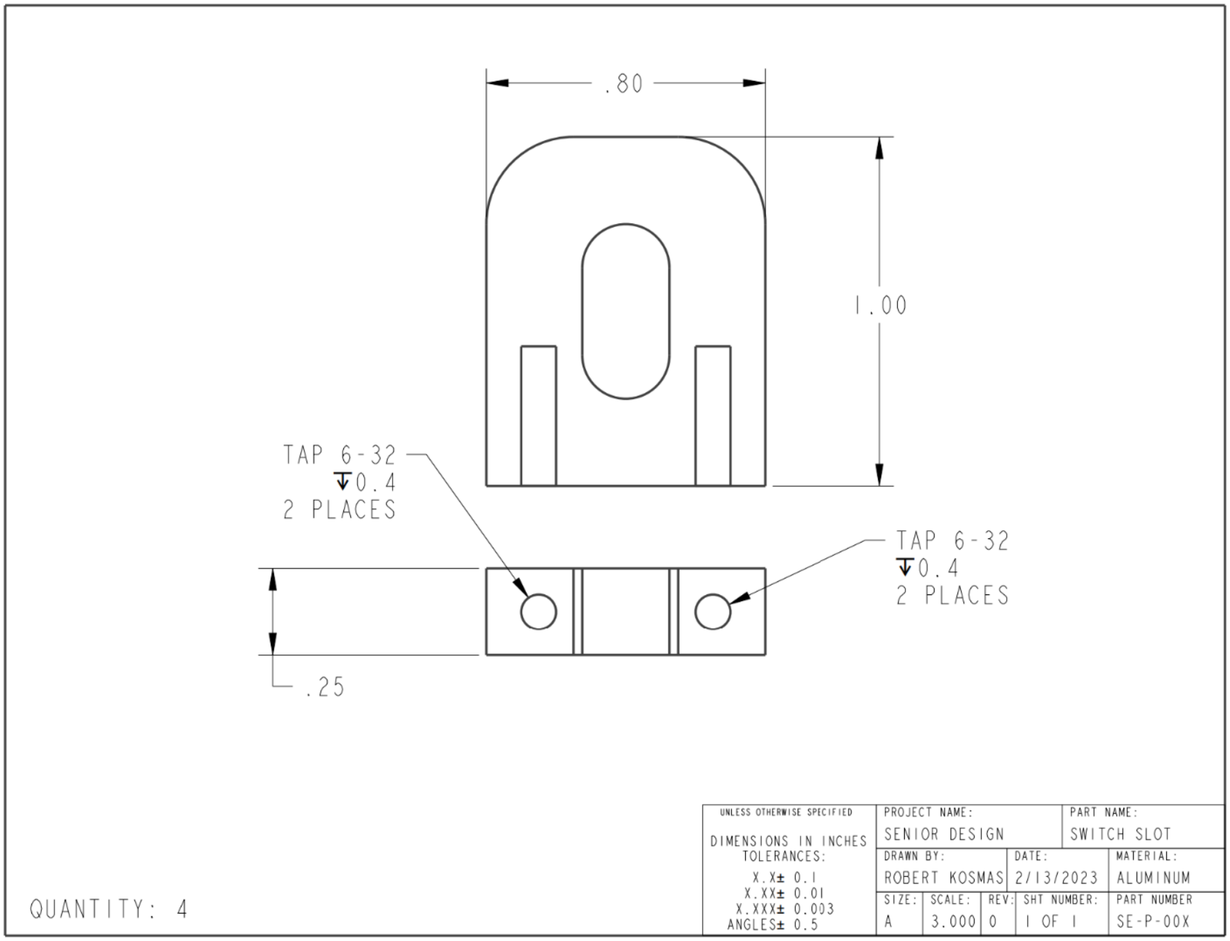
.80
1.00
TAP 6-32
↧0.4
2 PLACES
TAP 6-32
↧0.4
2 PLACES
.25
QUANTITY: 4
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
X.X± 0.1
X.XX± 0.01
X.XXX± 0.003
ANGLES± 0.5
PROJECT NAME:
SENIOR DESIGN
PART NAME:
SWITCH SLOT
DRAWN BY:
ROBERT KOSMAS
DATE:
2/13/2023
MATERIAL:
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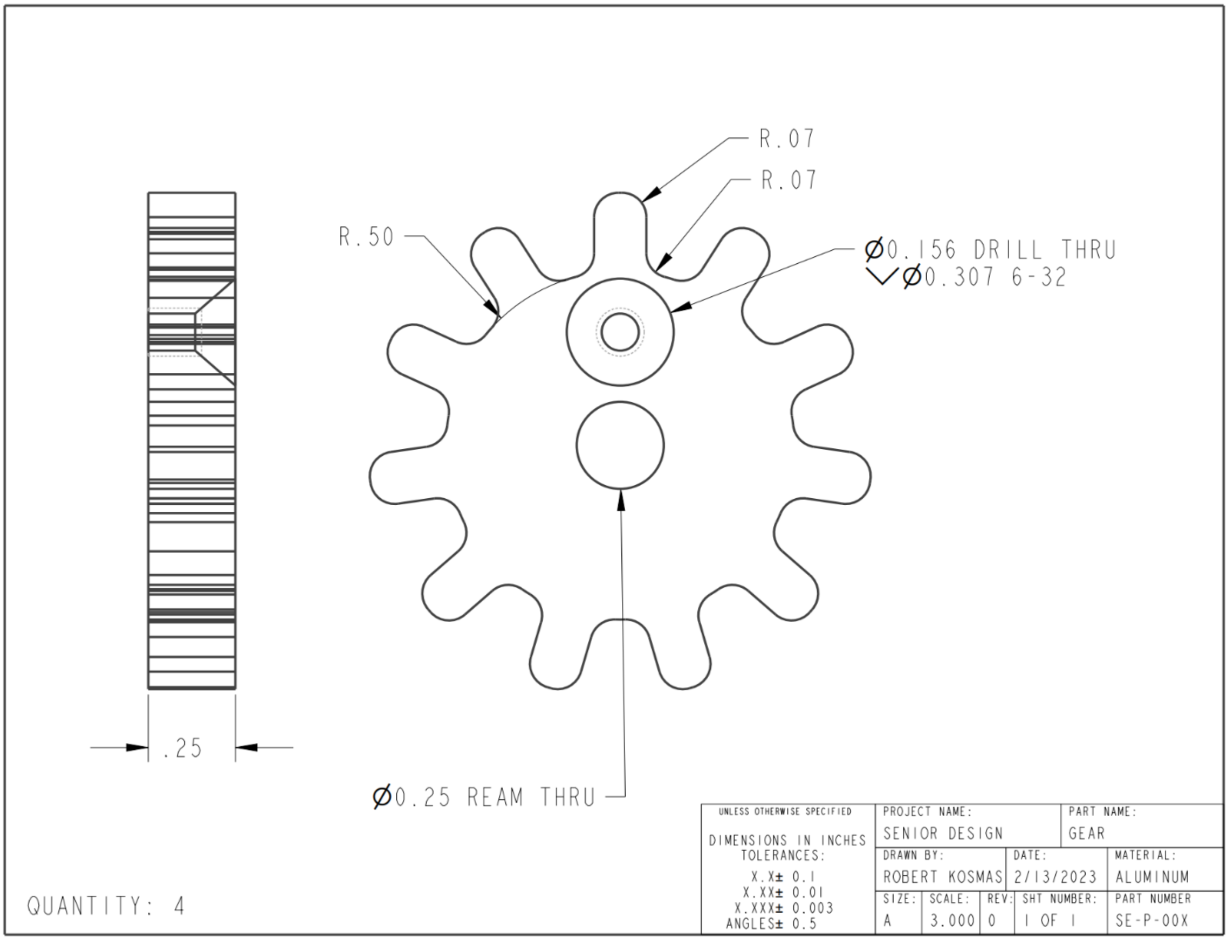
SHT NUMBER:
1 OF 1
PART NUMBER
SE-P-00X


R.07
R.07
R.50
Ø0.156 DRILL THRU
⌵Ø0.307 6-32
.25
Ø0.25 REAM THRU
QUANTITY: 4
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
X.X± 0.1
X.XX± 0.01
X.XXX± 0.003
ANGLES± 0.5
PROJECT NAME:
SENIOR DESIGN
PART NAME:
GEAR
DRAWN BY:
ROBERT KOSMAS
DATE:
2/13/2023
MATERIAL:
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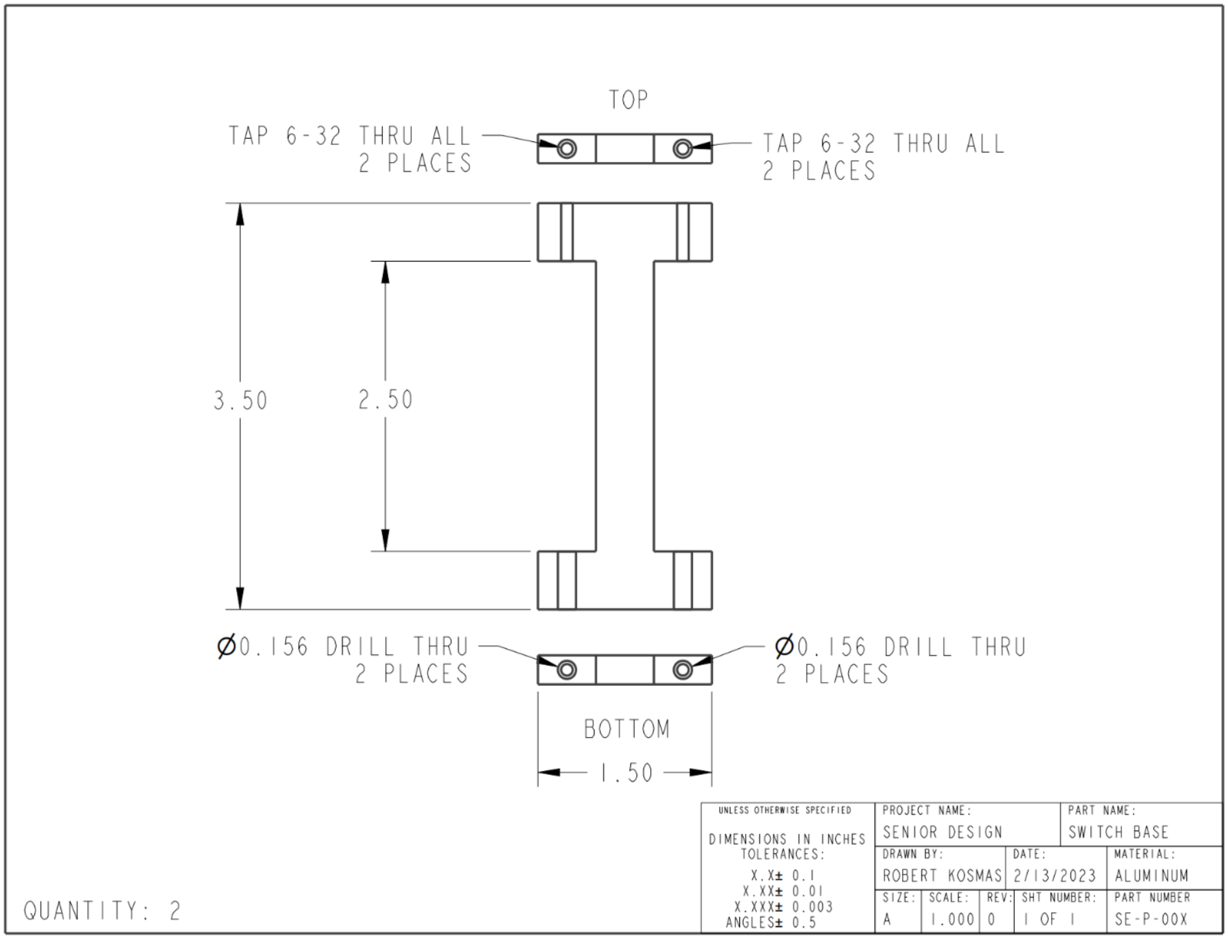
SHT NUMBER:
1 OF 1
PART NUMBER
SE-P-00X


TOP
TAP 6-32 THRU ALL
2 PLACES
TAP 6-32 THRU ALL
2 PLACES
3.50
2.50
Ø0.156 DRILL THRU
2 PLACES
Ø0.156 DRILL THRU
2 PLACES
BOTTOM
1.50
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
X.X± 0.1
X.XX± 0.01
X.XXX± 0.003
ANGLES± 0.5
PROJECT NAME:
SENIOR DESIGN
PART NAME:
SWITCH BASE
DRAWN BY:
ROBERT KOSMAS
DATE:
2/13/2023
MATERIAL:
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REV:
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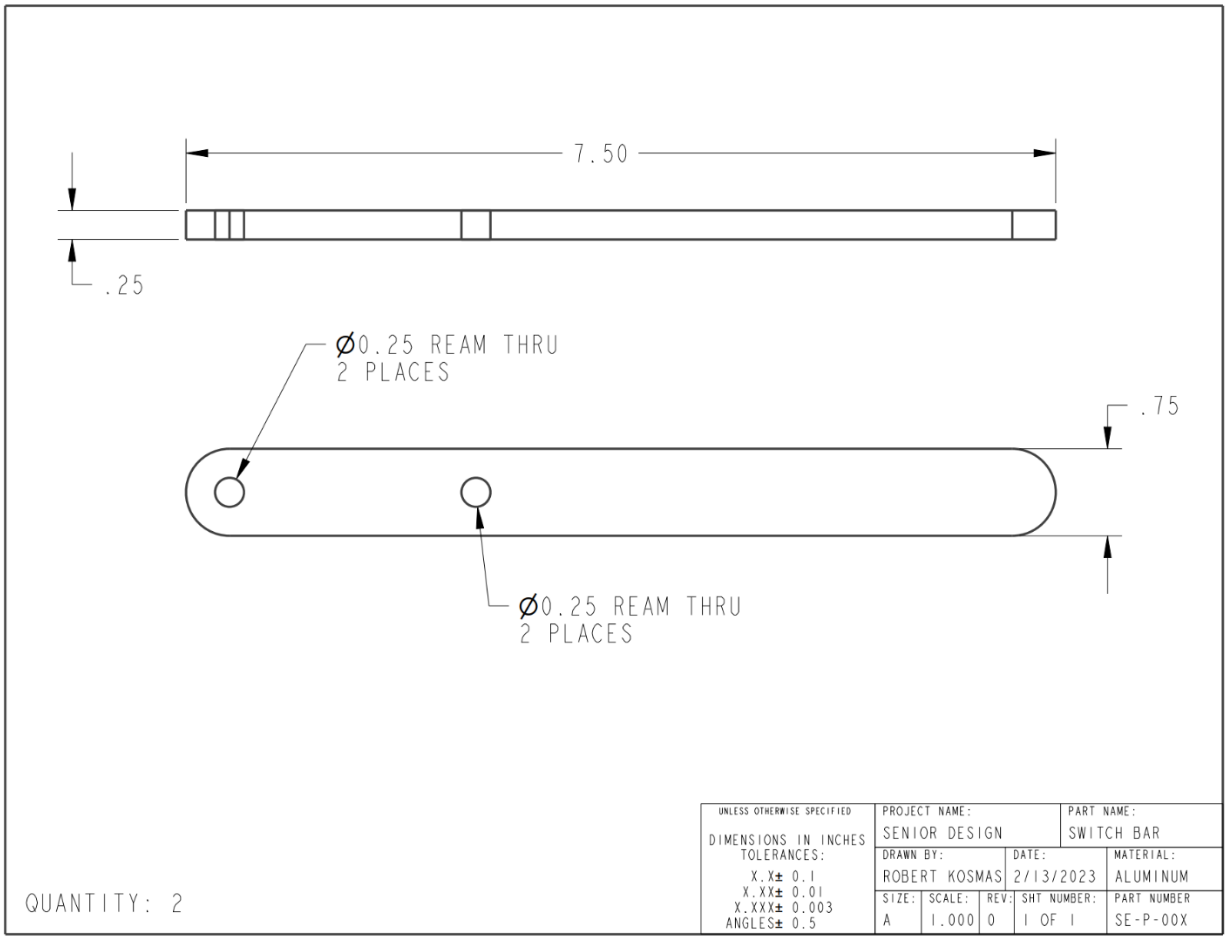
SHT NUMBER:
1 OF 1
PART NUMBER
SE-P-00X
QUANTITY: 2


7.50
.25
Ø0.25 REAM THRU
2 PLACES
.75
Ø0.25 REAM THRU
2 PLACES
QUANTITY: 2
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
X.X± 0.1
X.XX± 0.01
X.XXX± 0.003
ANGLES± 0.5
PROJECT NAME:
SENIOR DESIGN
PART NAME:
SWITCH BAR
DRAWN BY:
ROBERT KOSMAS
DATE:
2/13/2023
MATERIAL:
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SCALE:
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REV:
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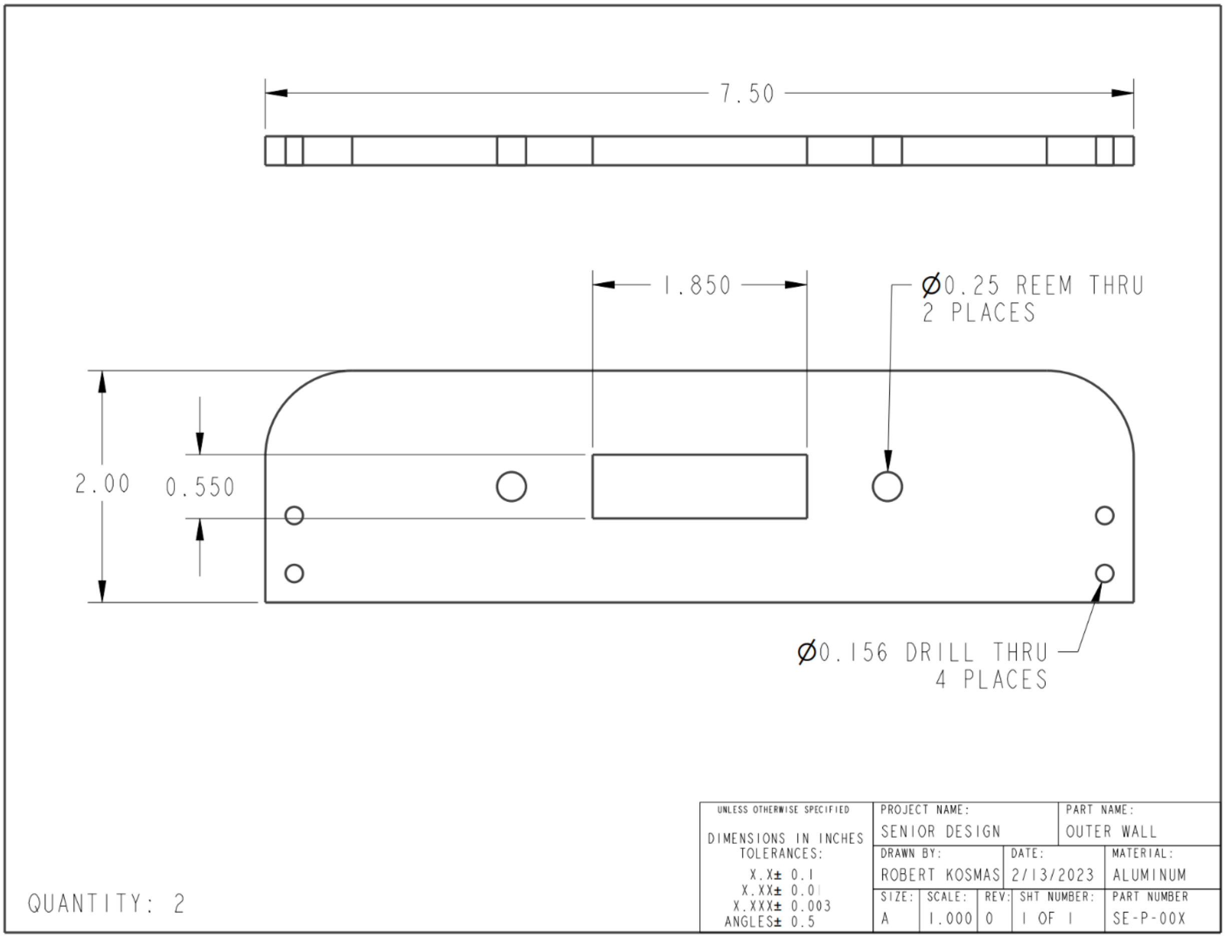
SHT NUMBER:
1 OF 1
PART NUMBER
SE-P-00X


7.50
1.850
Ø0.25 REEM THRU
2 PLACES
2.00
0.550
Ø0.156 DRILL THRU
4 PLACES
QUANTITY: 2
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
X.X± 0.1
X.XX± 0.01
X.XXX± 0.003
ANGLES± 0.5
PROJECT NAME:
SENIOR DESIGN
PART NAME:
OUTER WALL
DRAWN BY:
ROBERT KOSMAS
DATE:
2/13/2023
MATERIAL:
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SIZE:
A
SCALE:
1.000
REV:
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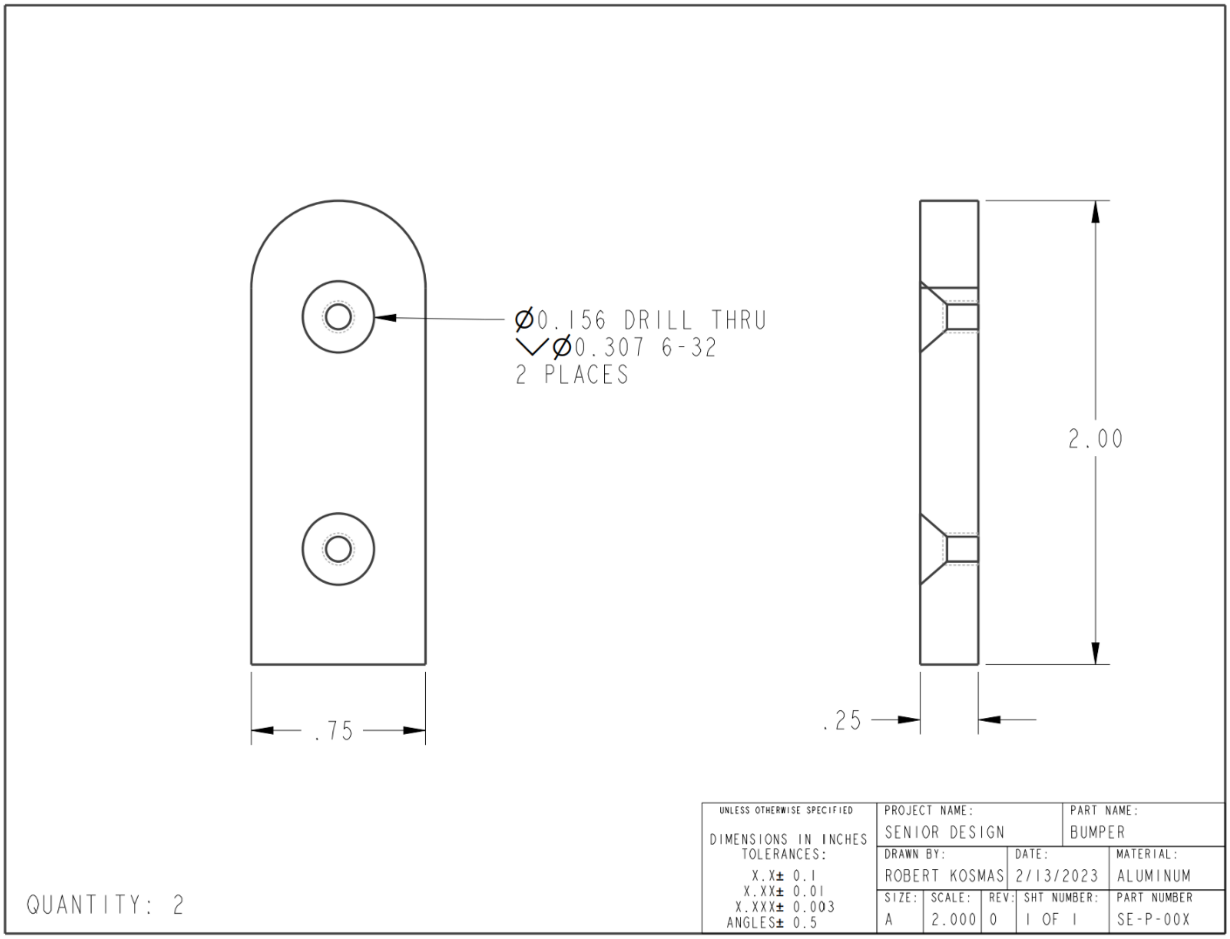
SHT NUMBER:
1 OF 1
PART NUMBER
SE-P-00X



Ø0.156 DRILL THRU
⌵Ø0.307 6-32
2 PLACES
2.00
.75
.25
QUANTITY: 2
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
X.X± 0.1
X.XX± 0.01
X.XXX± 0.003
ANGLES± 0.5
PROJECT NAME:
SENIOR DESIGN
PART NAME:
BUMPER
DRAWN BY:
ROBERT KOSMAS
DATE:
2/13/2023
MATERIAL:
ALUMINUM
SIZE:
A
SCALE:
2.000
REV:
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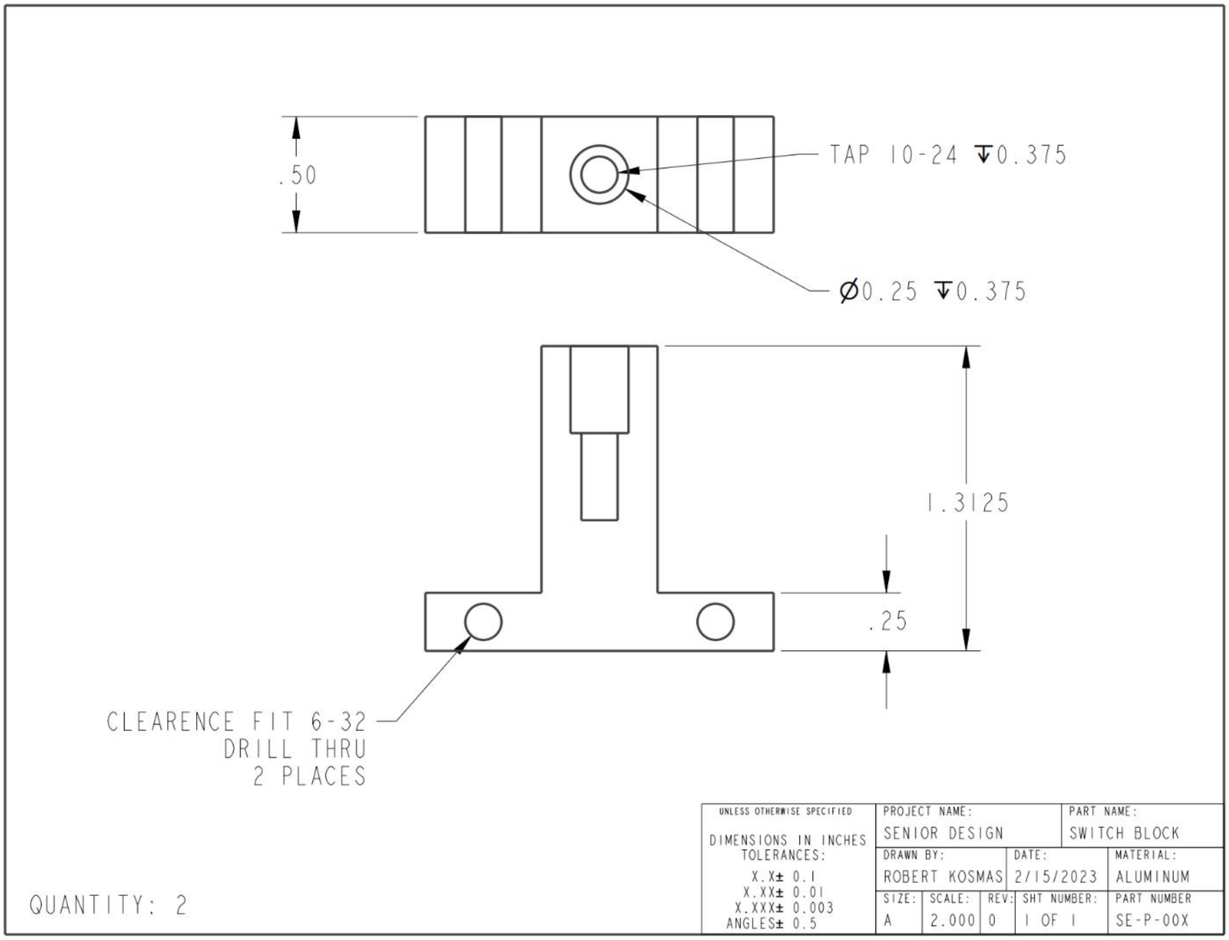
SHT NUMBER:
1 OF 1
PART NUMBER
SE-P-00X


.50
TAP 10-24 ↧0.375
Ø0.25 ↧0.375
1.3125
.25
CLEARENCE FIT 6-32
DRILL THRU
2 PLACES
QUANTITY: 2
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
X.X± 0.1
X.XX± 0.01
X.XXX± 0.003
ANGLES± 0.5
PROJECT NAME:
SENIOR DESIGN
PART NAME:
SWITCH BLOCK
DRAWN BY:
ROBERT KOSMAS
DATE:
2/15/2023
MATERIAL:
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2.000
REV:
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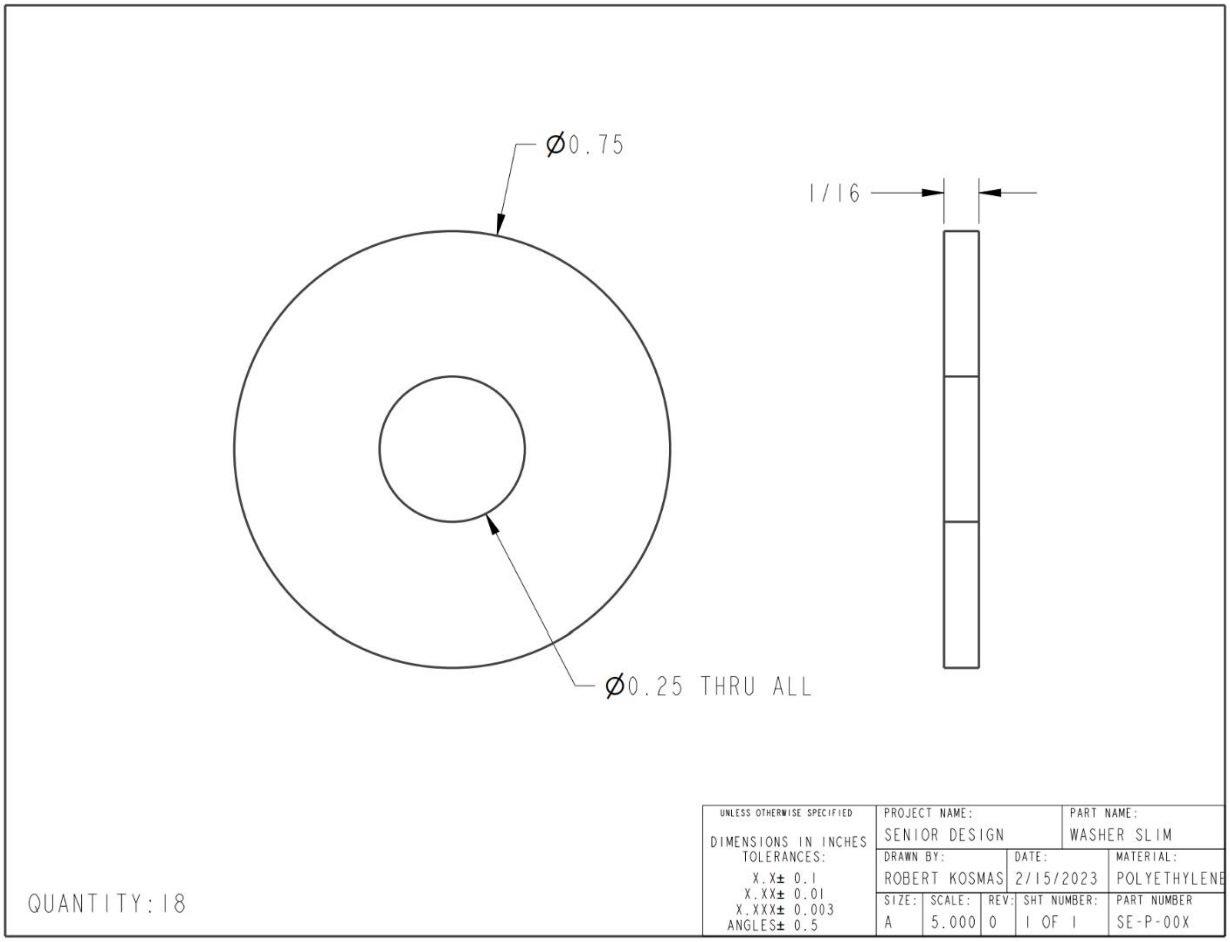
SHT NUMBER:
1 OF 1
PART NUMBER
SE-P-00X


Ø0.75
1/16
Ø0.25 THRU ALL
QUANTITY:18
UNLESS OTHERWISE SPECIFIED
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TOLERANCES:
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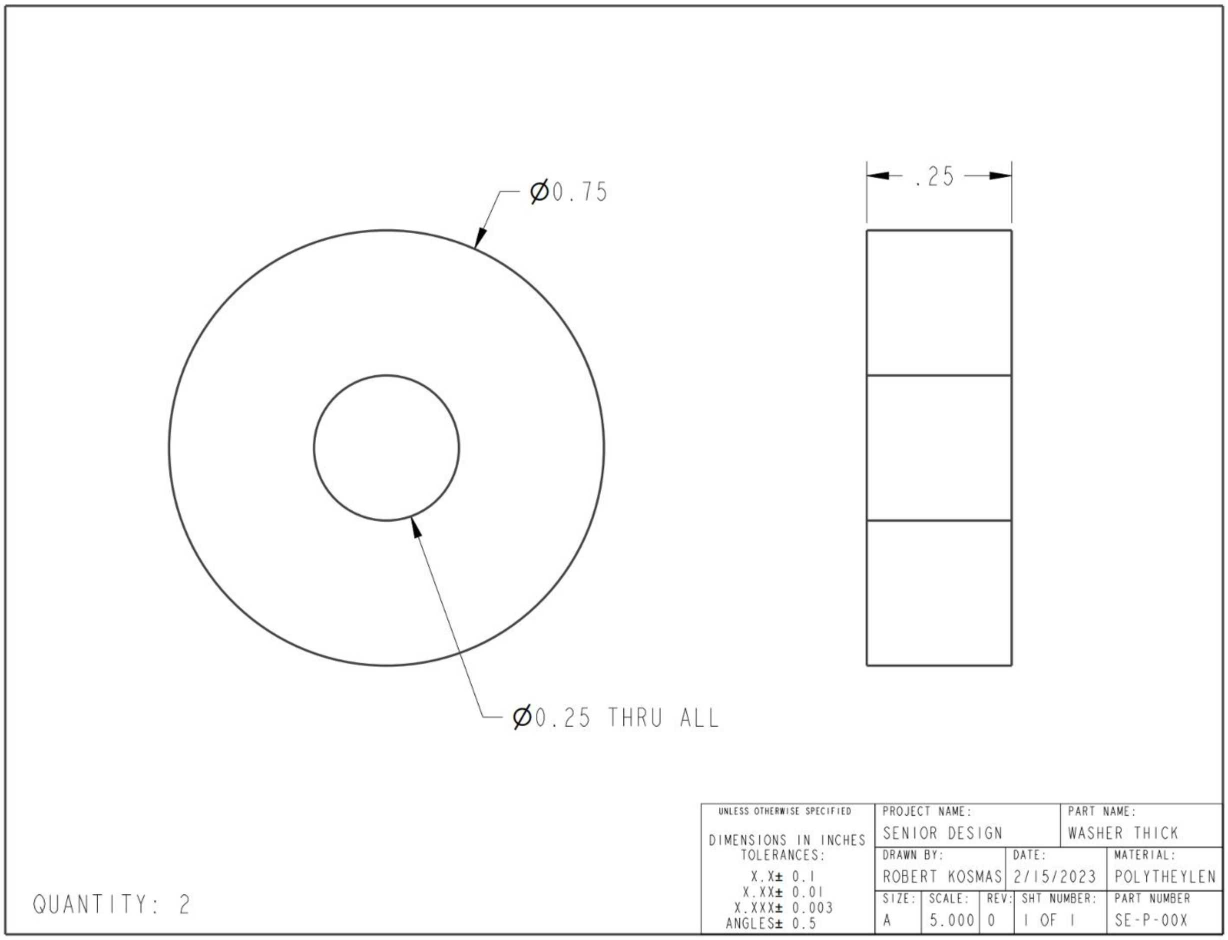
X.XX± 0.01
X.XXX± 0.003
ANGLES± 0.5
PROJECT NAME:
SENIOR DESIGN
PART NAME:
WASHER SLIM
DRAWN BY:
ROBERT KOSMAS
DATE:
2/15/2023
MATERIAL:
POLYETHYLENE
SIZE:
A
SCALE:
5.000
REV:
0
SHT NUMBER:
1 OF 1
PART NUMBER
SE-P-00X


Ø0.75
.25
Ø0.25 THRU ALL
QUANTITY: 2
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
X.X± 0.1
X.XX± 0.01
X.XXX± 0.003
ANGLES± 0.5
PROJECT NAME:
SENIOR DESIGN
PART NAME:
WASHER THICK
DRAWN BY:
ROBERT KOSMAS
DATE:
2/15/2023
MATERIAL:
POLYTHEYLEN
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A
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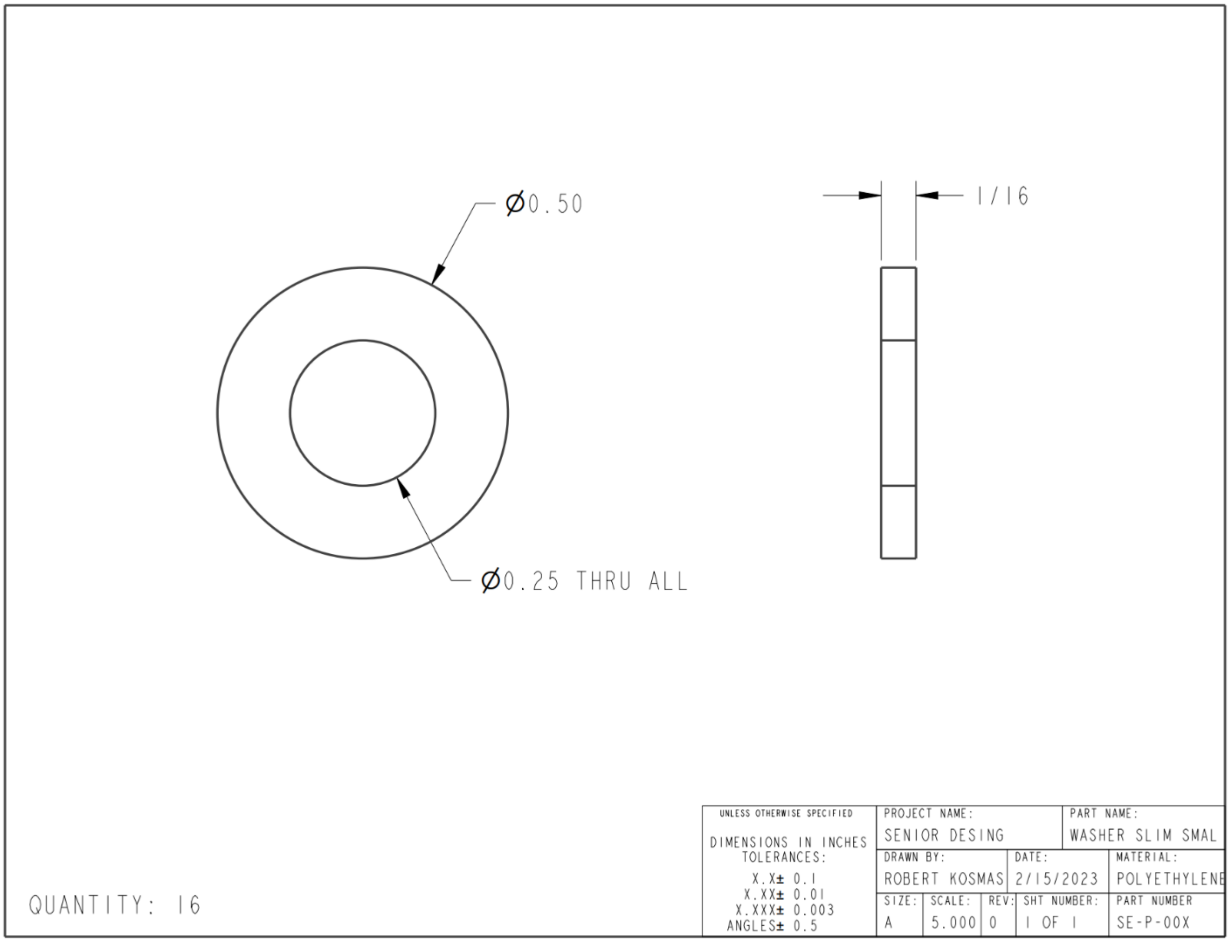
SHT NUMBER:
1 OF 1
PART NUMBER
SE-P-00X



Ø0.50
Ø0.25 THRU ALL
1/16
QUANTITY: 16
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
X.X± 0.1
X.XX± 0.01
X.XXX± 0.003
ANGLES± 0.5
PROJECT NAME:
SENIOR DESING
PART NAME:
WASHER SLIM SMAL
DRAWN BY:
ROBERT KOSMAS
DATE:
2/15/2023
MATERIAL:
POLYETHYLENE
SIZE:
A
SCALE:
5.000
REV:
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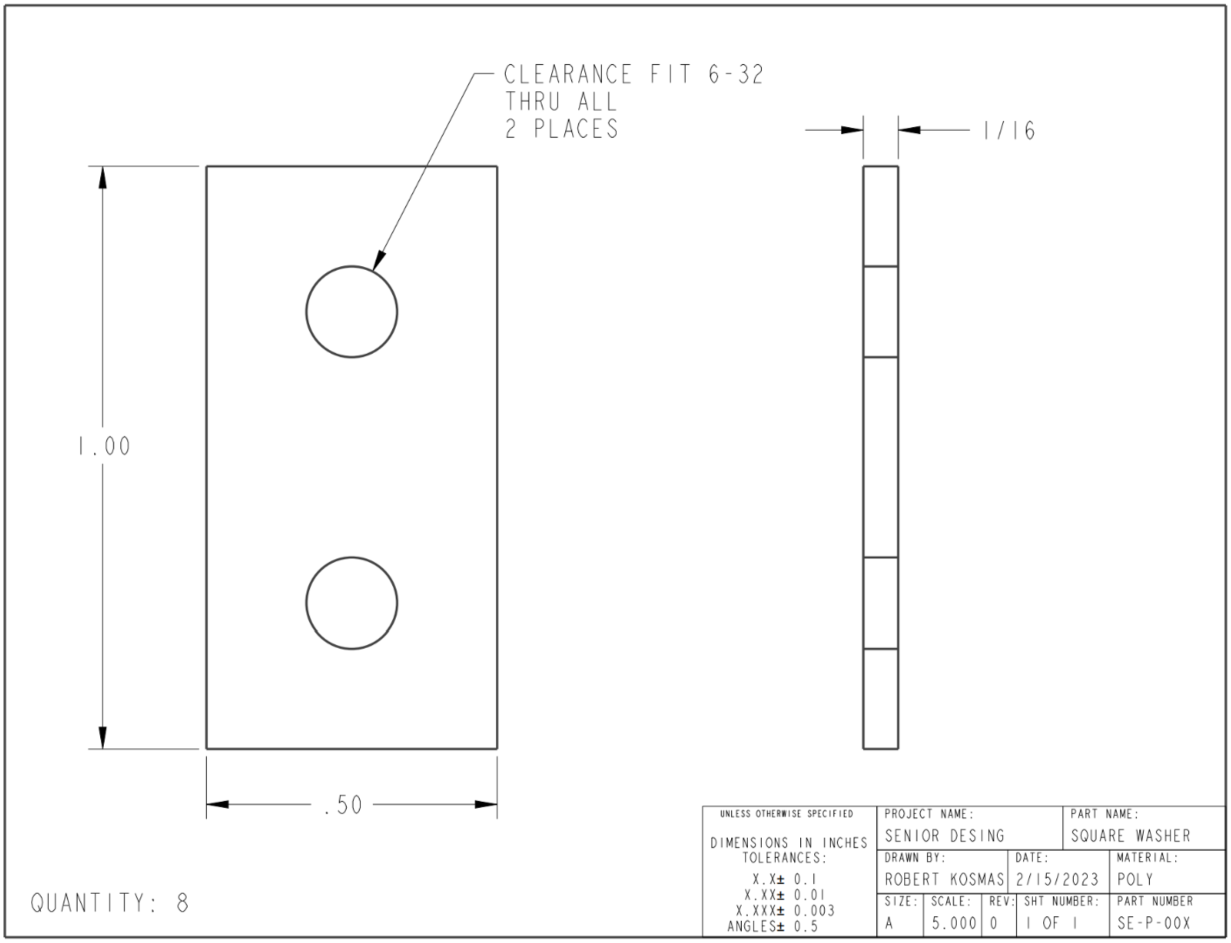
SHT NUMBER:
1 OF 1
PART NUMBER
SE-P-00X


CLEARANCE FIT 6-32
THRU ALL
2 PLACES
1/16
1.00
.50
QUANTITY: 8
UNLESS OTHERWISE SPECIFIED
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TOLERANCES:
X.X± 0.1
X.XX± 0.01
X.XXX± 0.003
ANGLES± 0.5
PROJECT NAME:
SENIOR DESING
PART NAME:
SQUARE WASHER
DRAWN BY:
ROBERT KOSMAS
DATE:
2/15/2023
MATERIAL:
POLY
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SCALE:
5.000
REV:
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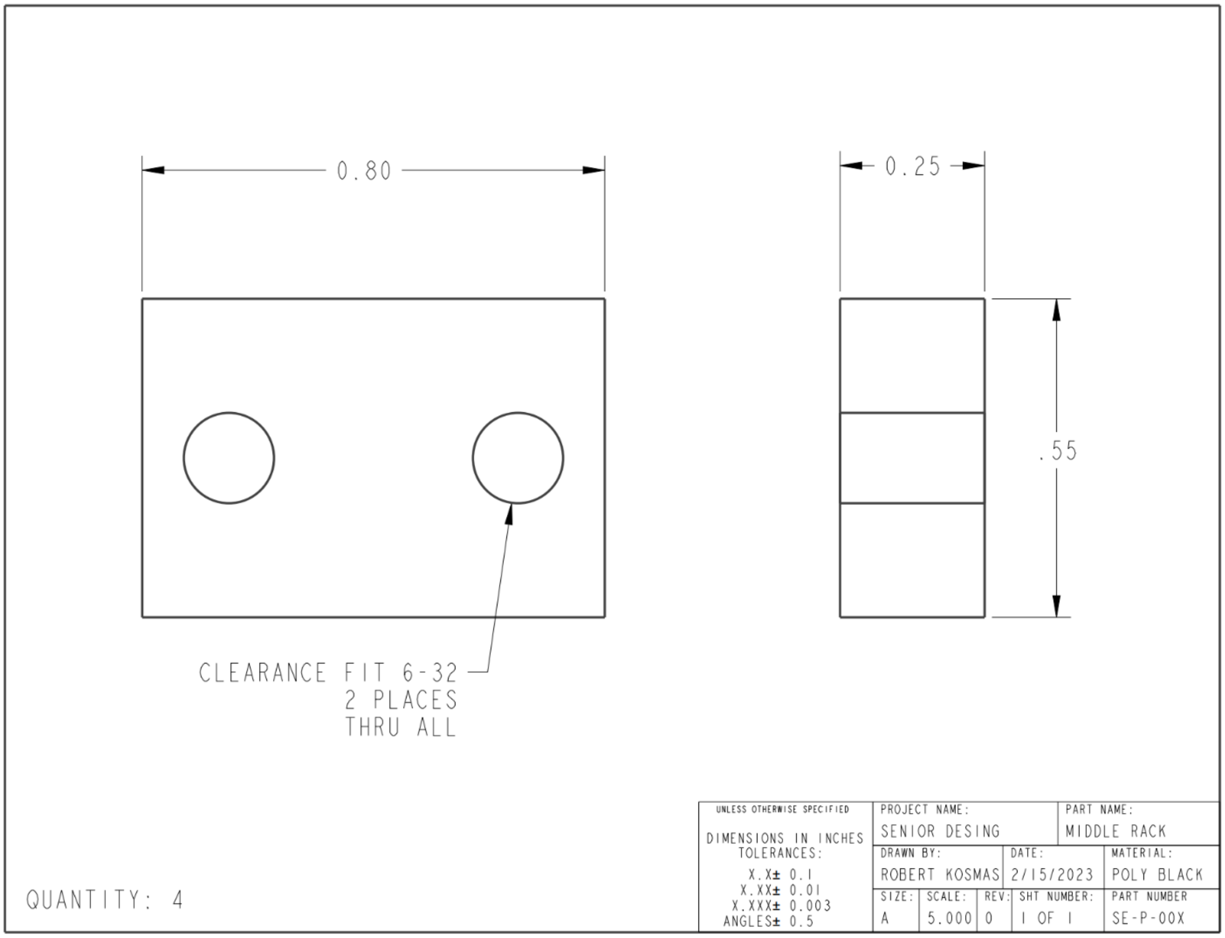
SHT NUMBER:
1 OF 1
PART NUMBER
SE-P-00X


0.80
0.25
.55
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2 PLACES
THRU ALL
QUANTITY: 4
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DIMENSIONS IN INCHES
TOLERANCES:
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X.XX± 0.01
X.XXX± 0.003
ANGLES± 0.5
PROJECT NAME:
SENIOR DESING
PART NAME:
MIDDLE RACK
DRAWN BY:
ROBERT KOSMAS
DATE:
2/15/2023
MATERIAL:
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SCALE:
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REV:
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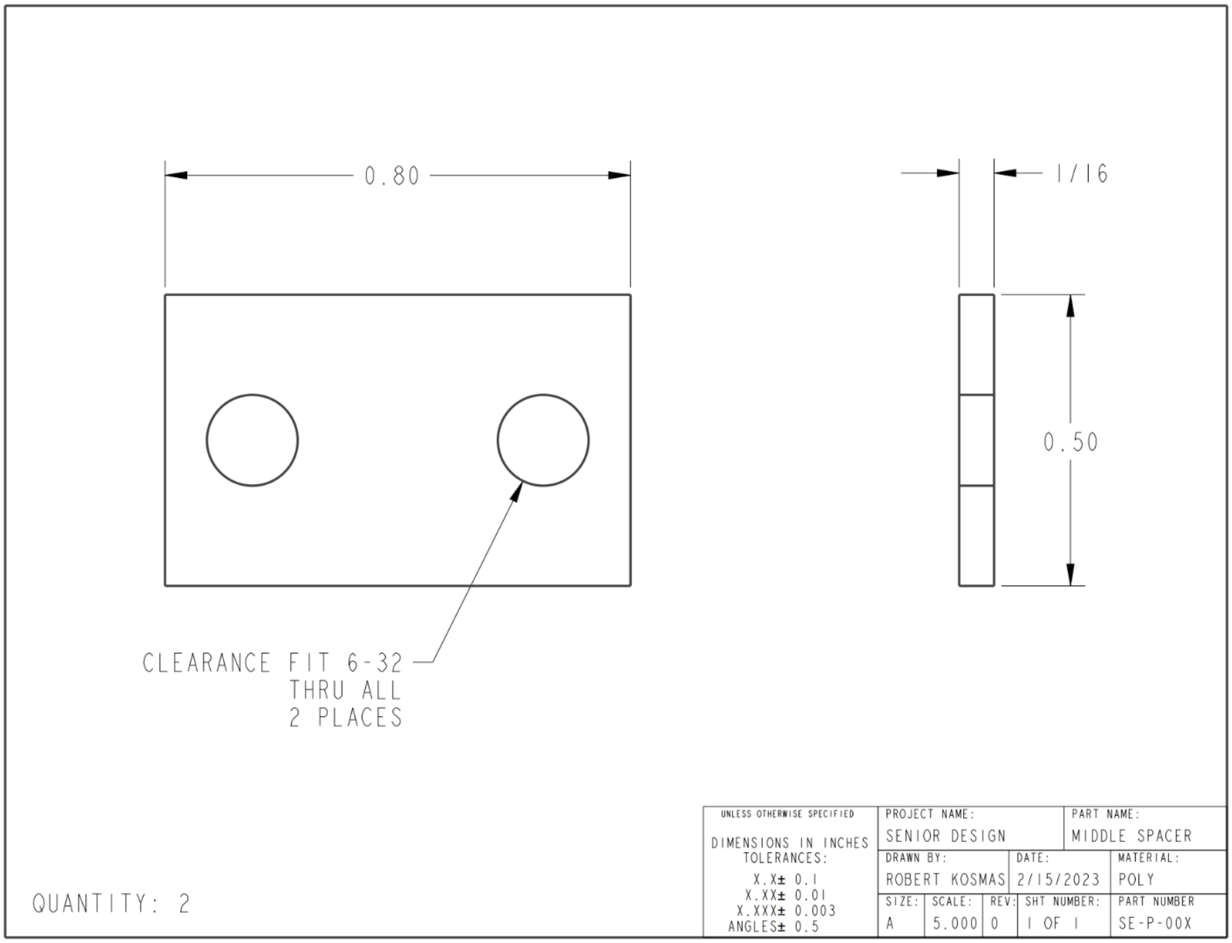
1 OF 1
PART NUMBER
SE-P-00X


0.80
1/16
0.50
CLEARANCE FIT 6-32
THRU ALL
2 PLACES
QUANTITY: 2
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
X.X± 0.1
X.XX± 0.01
X.XXX± 0.003
ANGLES± 0.5
PROJECT NAME:
SENIOR DESIGN
PART NAME:
MIDDLE SPACER
DRAWN BY:
ROBERT KOSMAS
DATE:
2/15/2023
MATERIAL:
POLY
SIZE:
A
SCALE:
5.000
REV:
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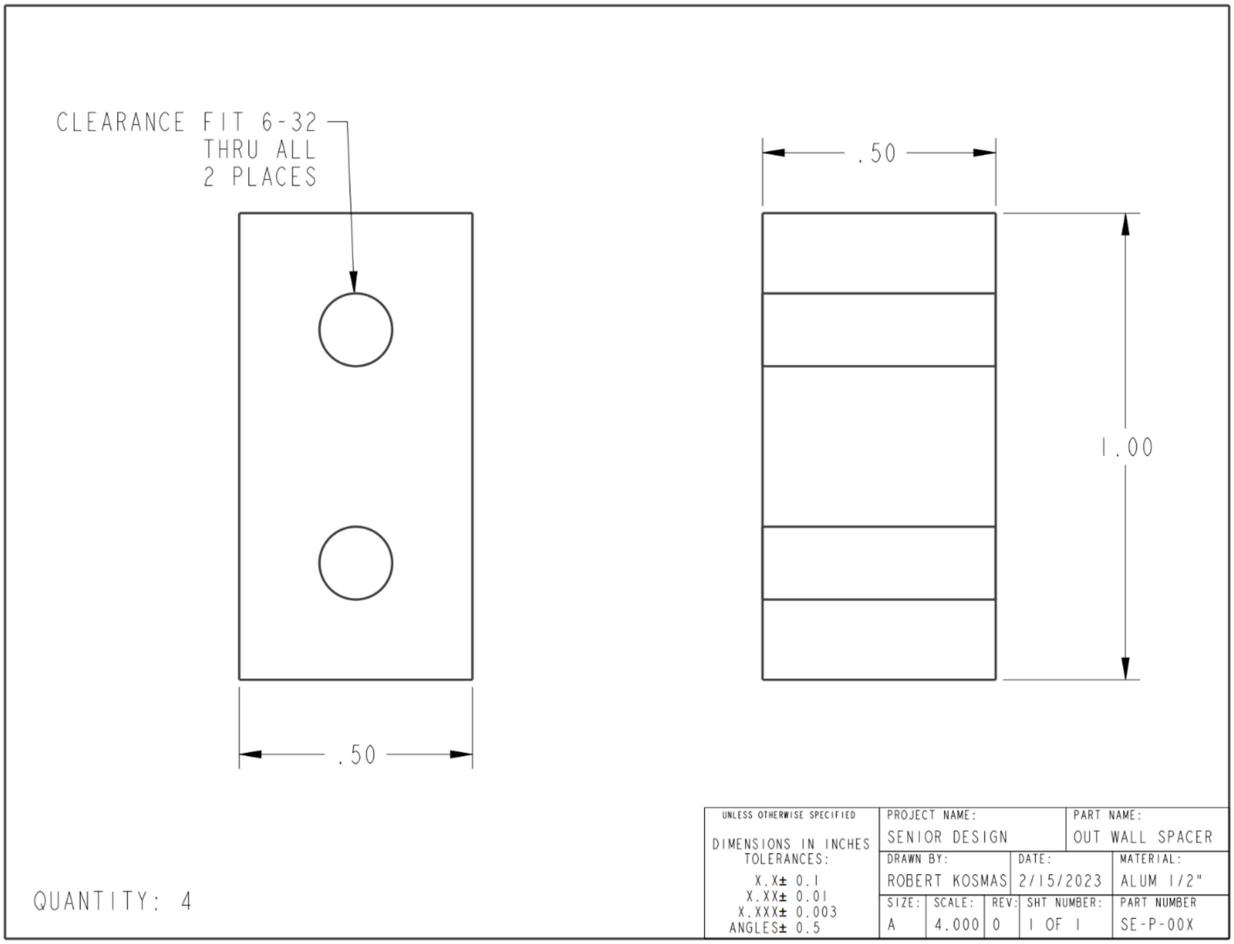
SHT NUMBER:
1 OF 1
PART NUMBER
SE-P-00X


CLEARANCE FIT 6-32
THRU ALL
2 PLACES
.50
.50
1.00
QUANTITY: 4
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
X.X± 0.1
X.XX± 0.01
X.XXX± 0.003
ANGLES± 0.5
PROJECT NAME:
SENIOR DESIGN
PART NAME:
OUT WALL SPACER
DRAWN BY:
ROBERT KOSMAS
DATE:
2/15/2023
MATERIAL:
ALUM 1/2"
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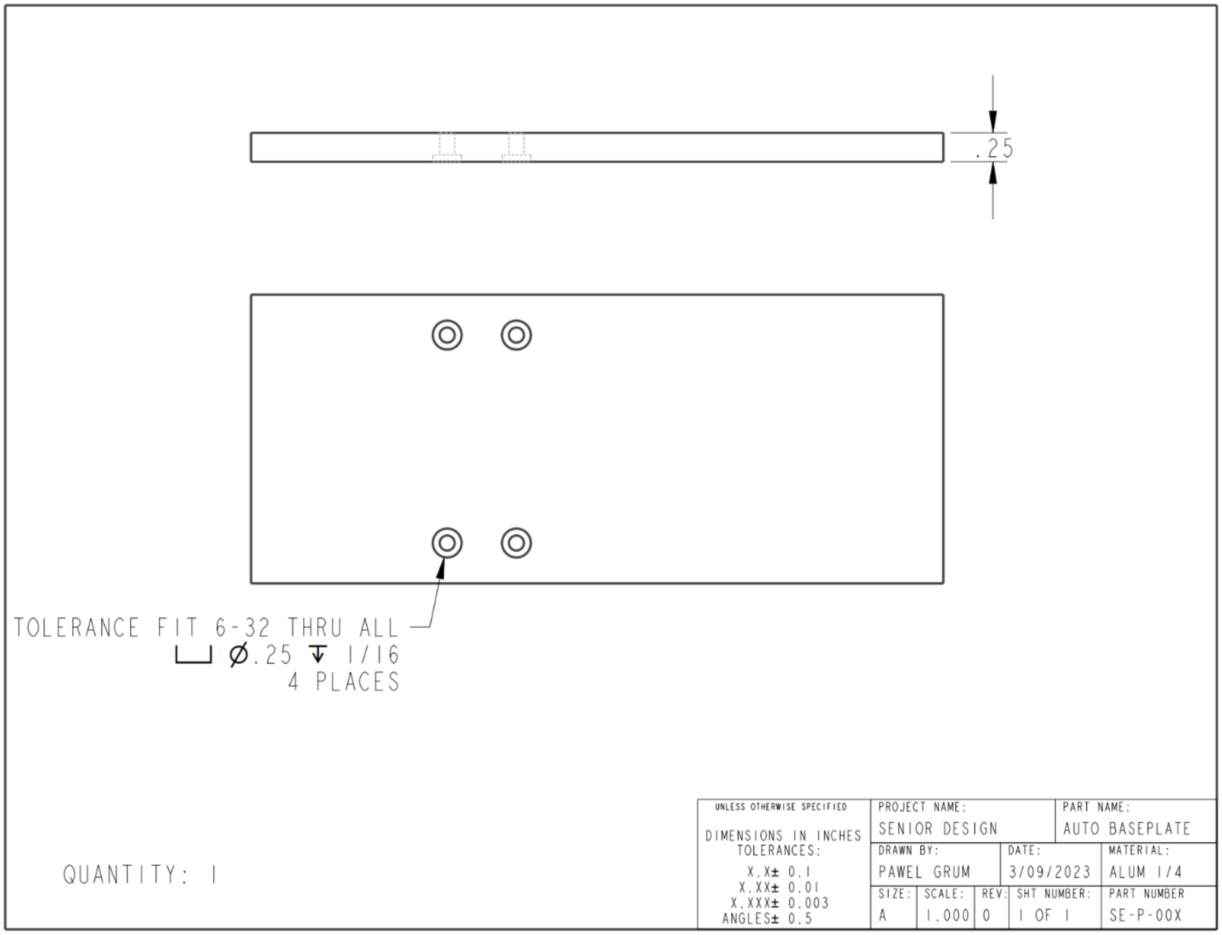
SHT NUMBER:
1 OF 1
PART NUMBER
SE-P-00X



.25
TOLERANCE FIT 6-32 THRU ALL
⌴ Ø.25 ↧ 1/16
4 PLACES
QUANTITY: 1
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
X.X± 0.1
X.XX± 0.01
X.XXX± 0.003
ANGLES± 0.5
PROJECT NAME:
SENIOR DESIGN
PART NAME:
AUTO BASEPLATE
DRAWN BY:
PAWEL GRUM
DATE:
3/09/2023
MATERIAL:
ALUM 1/4
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A
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1.000
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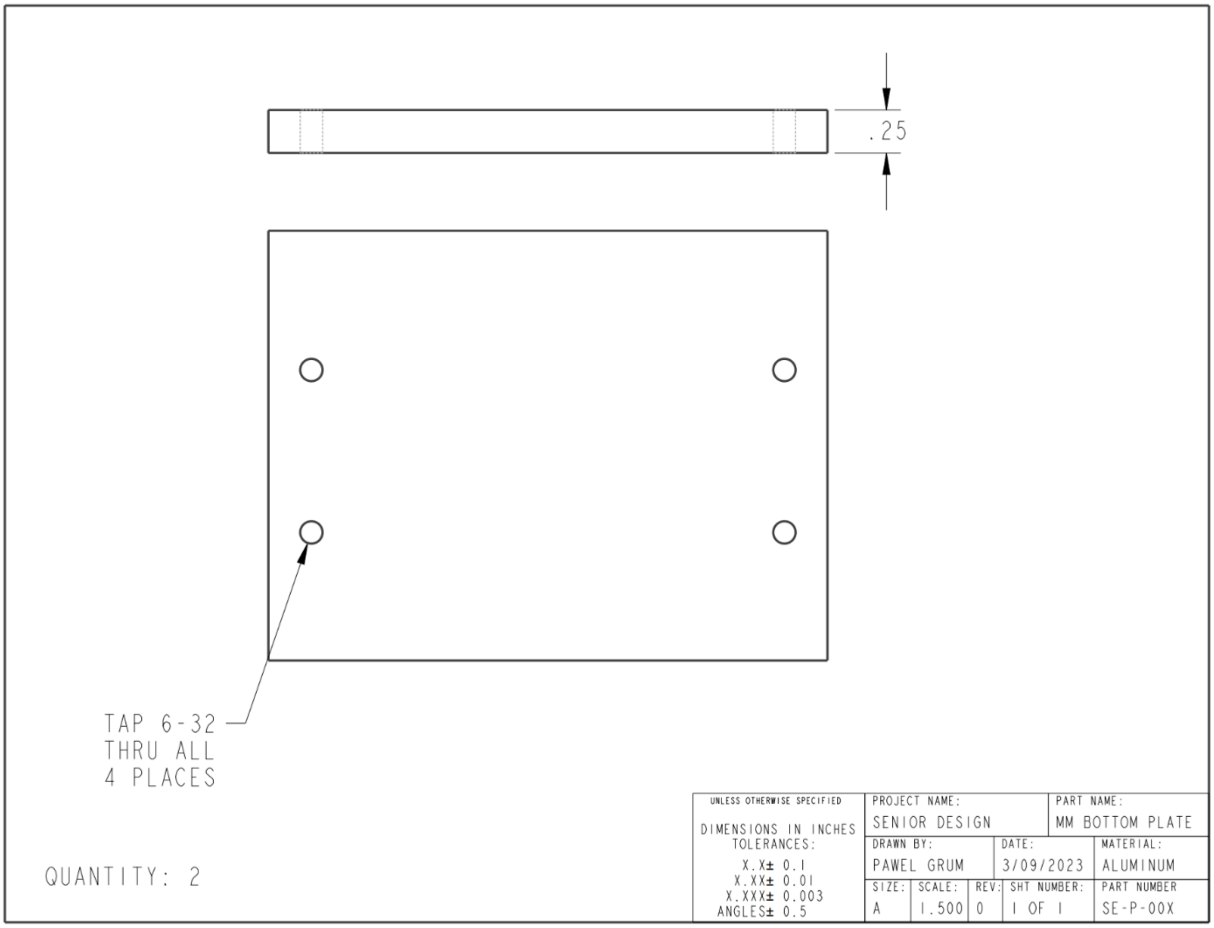
SHT NUMBER:
1 OF 1
PART NUMBER
SE-P-00X



.25
TAP 6-32
THRU ALL
4 PLACES
QUANTITY: 2
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
X.X± 0.1
X.XX± 0.01
X.XXX± 0.003
ANGLES± 0.5
PROJECT NAME:
SENIOR DESIGN
PART NAME:
MM BOTTOM PLATE
DRAWN BY:
PAWEL GRUM
DATE:
3/09/2023
MATERIAL:
ALUMINUM
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REV:
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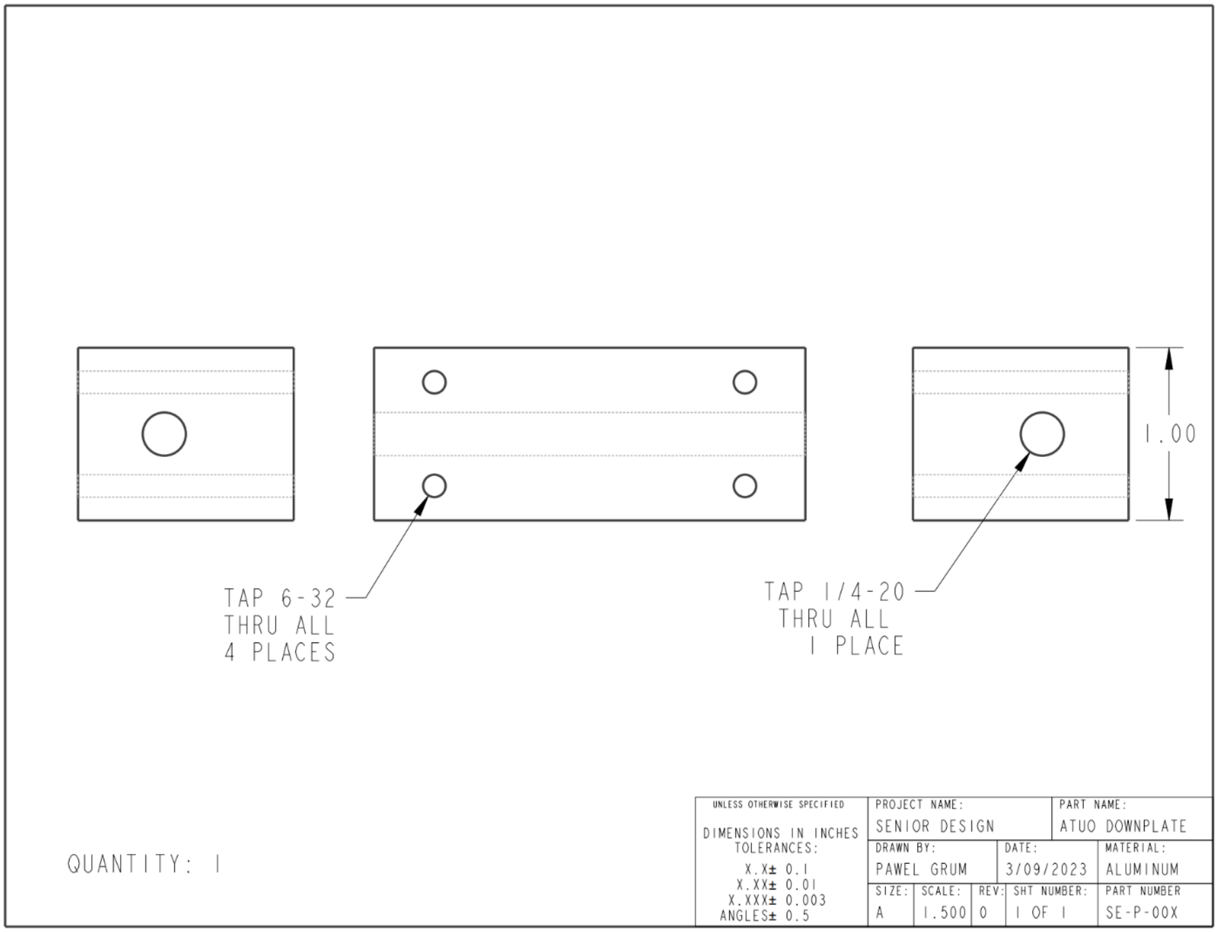
SHT NUMBER:
1 OF 1
PART NUMBER
SE-P-00X


1.00
TAP 6-32
THRU ALL
4 PLACES
TAP 1/4-20
THRU ALL
1 PLACE
QUANTITY: 1
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
X.X± 0.1
X.XX± 0.01
X.XXX± 0.003
ANGLES± 0.5
PROJECT NAME:
SENIOR DESIGN
PART NAME:
ATUO DOWNPLATE
DRAWN BY:
PAWEL GRUM
DATE:
3/09/2023
MATERIAL:
ALUMINUM
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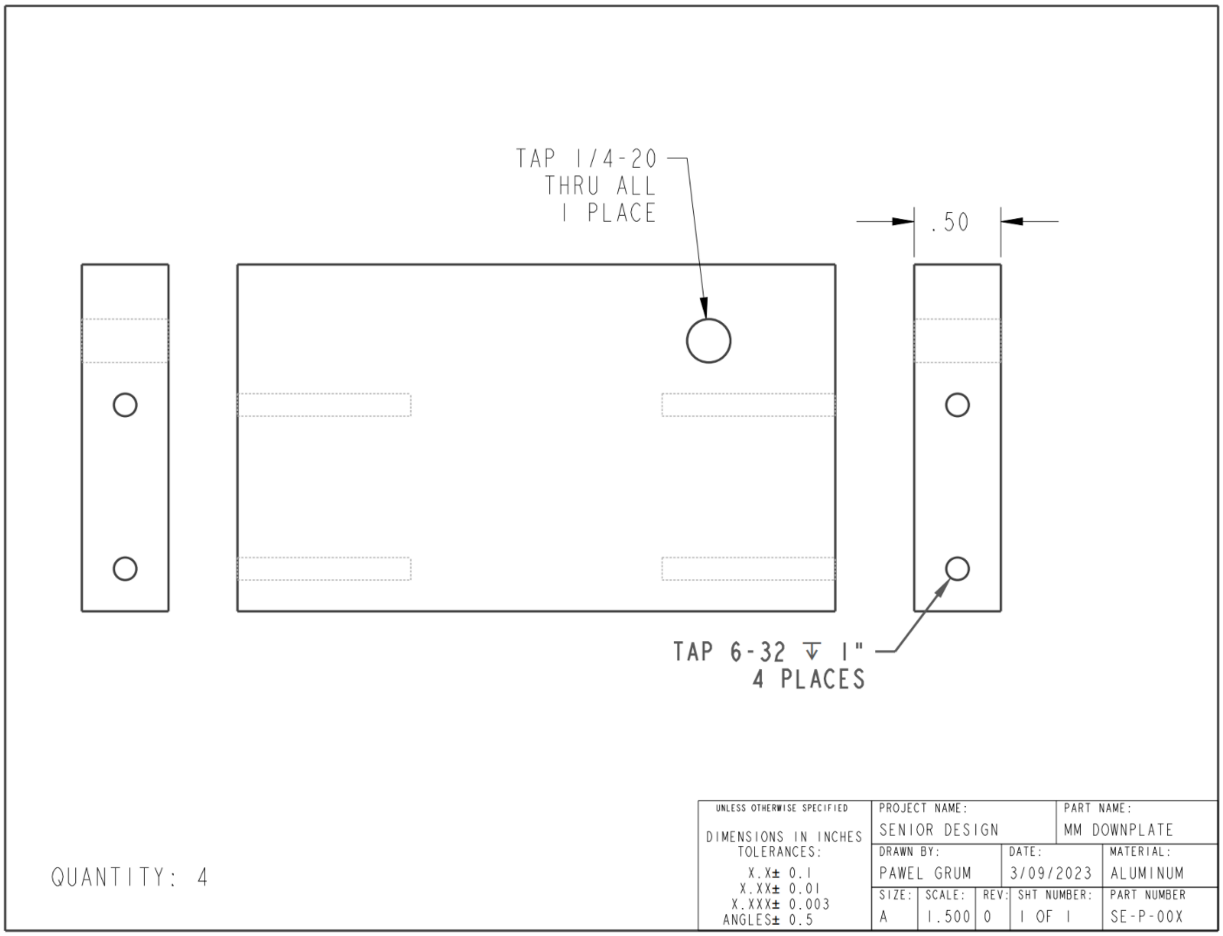
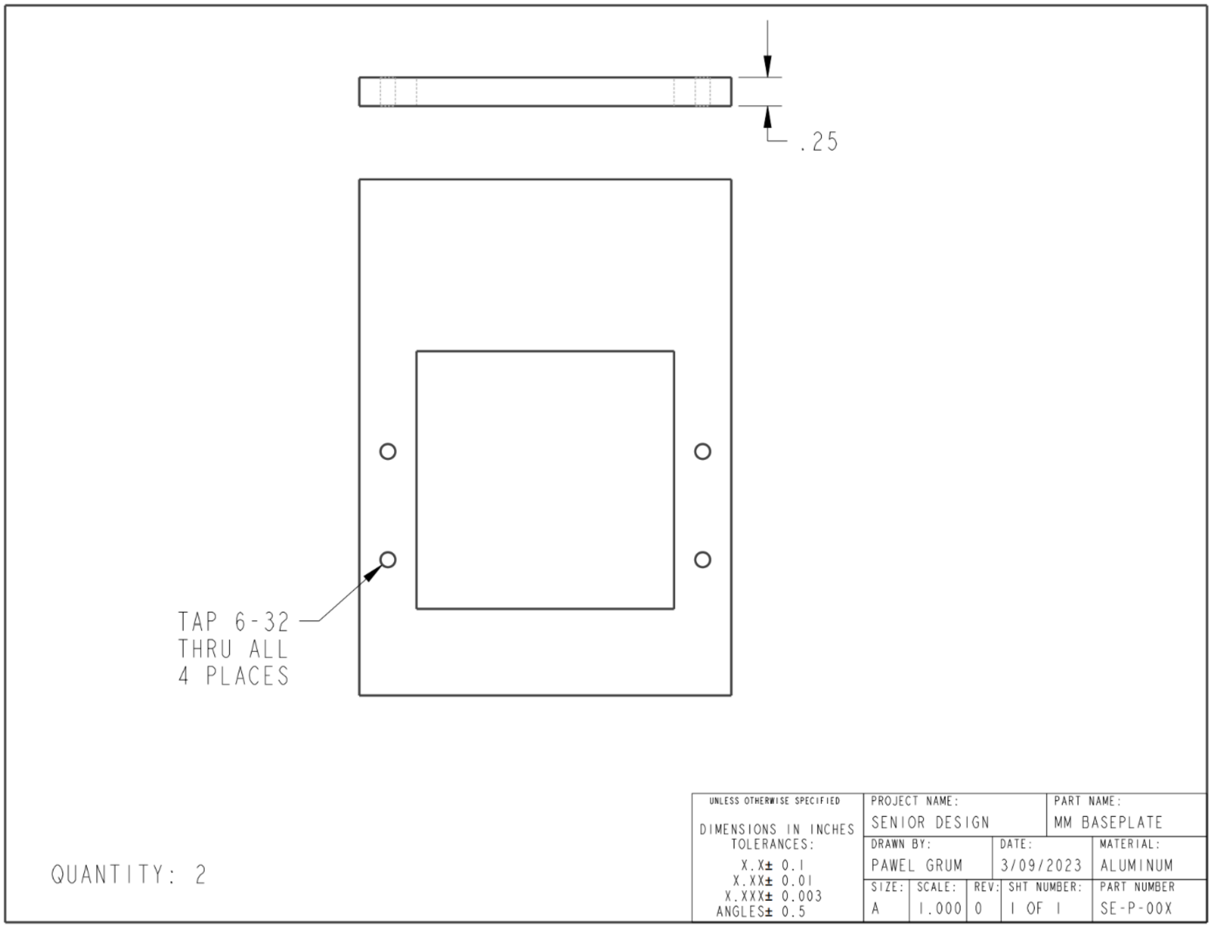
PART NUMBER
SE-P-00X


TAP 1/4-20
THRU ALL
1 PLACE
.50
TAP 6-32 ↧ 1"
4 PLACES
QUANTITY: 4
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
X.X± 0.1
X.XX± 0.01
X.XXX± 0.003
ANGLES± 0.5
PROJECT NAME:
SENIOR DESIGN
PART NAME:
MM DOWNPLATE
DRAWN BY:
PAWEL GRUM
DATE:
3/09/2023
MATERIAL:
ALUMINUM
SIZE:
A
SCALE:
1.500
REV:
0
SHT NUMBER:
1 OF 1
PART NUMBER
SE-P-00X


.25
TAP 6-32
THRU ALL
4 PLACES
QUANTITY: 2
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
X.X± 0.1
X.XX± 0.01
X.XXX± 0.003
ANGLES± 0.5
PROJECT NAME:
SENIOR DESIGN
PART NAME:
MM BASEPLATE
DRAWN BY:
PAWEL GRUM
DATE:
3/09/2023
MATERIAL:
ALUMINUM
SIZE:
A
SCALE:
1.000
REV:
0
SHT NUMBER:
1 OF 1
PART NUMBER
SE-P-00X

Appendix J: Calculations

The following table displays results found throughout testing on the Self-Nesting T.

Test/Calculations	Values
Force to Lift Self Nest T	3 lbs
Time to Raise	4 secs
Time to Lower	1 sec
Load Withstood	Over 10 lbs
People Required	0
Vibrations at Level 7 for 10 Mins	No Falling
Vibration at Level 8 for 10 Mins	No Falling
Vibration at Level 9 for 10 Mins	No Falling
Vibration at Level 10 for 10 Mins	No Falling
Stall Torque of Motor	26.55 lbs in
Force to Stop Pallet	<2 lbs
Cycles Completed without Ceramic Dust	300
Cycles Completed with Ceramic Dust	300

Appendix K: Risk Assessment

FAMU-FSU College of Engineering
Project Hazard Assessment Policy and Procedures

INTRODUCTION

University laboratories are not without safety hazards. Those circumstances or conditions that might go wrong must be predicted and reasonable control methods must be determined to prevent incident and injury. The FAMU-FSU College of Engineering is committed to achieving and maintaining safety in all levels of work activities.

PROJECT HAZARD ASSESSMENT POLICY

Principal investigator (PI)/instructor are responsible and accountable for safety in the research and teaching laboratory. Prior to starting an experiment, laboratory workers must conduct a project hazard assessment (PHA) to identify health, environmental and property hazards and the proper control methods to eliminate, reduce or control those hazards. PI/instructor must review, approve, and sign the written PHA and provide the identified hazard control measures. PI/instructor continually monitor projects to ensure proper controls and safety measures are available, implemented, and followed. PI/instructor are required to reevaluate a project anytime there is a change in scope or scale of a project and at least annually after the initial review.

PROJECT HAZARD ASSESSMENT PROCEDURES

It is FAMU-FSU College of Engineering policy to implement followings:

1. Laboratory workers (i.e. graduate students, undergraduate students, postdoctoral, volunteers, etc.) performing a research in FAMU-FSU College of Engineering are required to conduct PHA prior to commencement of an experiment or any project change in order to identify existing or potential hazards and to determine proper measures to control those hazards.
2. PI/instructor must review, approve and sign the written PHA.
3. PI/instructor must ensure all the control methods identified in PHA are available and implemented in the laboratory.
4. In the event laboratory personnel are not following the safety precautions, PI/instructor must take firm actions (e.g. stop the work, set a meeting to discuss potential hazards and consequences, ask personnel to review the safety rules, etc.) to clarify the safety expectations.
5. PI/instructor must document all the incidents/accidents happened in the laboratory along with the PHA document to ensure that PHA is reviewed/modified to prevent reoccurrence. In the event of PHA modification a revision number should be given to the PHA, so project members know the latest PHA revision they should follow.
6. PI/instructor must ensure that those findings in PHA are communicated with other students working in the same laboratory (affected users).
7. PI/instructor must ensure that approved methods and precautions are being followed by :
    a. Performing periodic laboratory visits to prevent the development of unsafe practice.
    b. Quick reviewing of the safety rules and precautions in the laboratory members meetings.
    c. Assigning a safety representative to assist in implementing the expectations.
    d. Etc.
8. A copy of this PHA must be kept in a binder inside the laboratory or PI/instructor's office (if experiment steps are confidential).

Project Hazard Assessment Worksheet				
PI/instructor: Dr. Shayne McConomy	Phone #: 850-410-6624	Dept.: Mechanical	Start Date: 11/15/2022	Revision number: 1
Project: T506 Corning Plugger Pallet Short Part Stabilization			Location(s): FAMU-FSU College of Engineering (COE)	
Team member(s): Pawel Grum, Taylor Larson, Robert Kosmas, Segundo Sanchez, Jared White			Phone #: 561-768-3722	Email: tml18bg@fsu.edu

Experiment Steps	**Location**	**Person assigned**	**Identify hazards or potential failure points**	**Control method**	**PPE**	**List proper method of hazardous waste disposal, if any.**	**Residual Risk**	**Specific rules based on the residual risk**
Machining Materials	Senior Design Lab	All team members	Slippage while drilling, sharp metal edges, sparks/heat	Difficult metal work will be done by a machine shop. Metal work done by team members will be done in the presence of at least one other member. The room will have ample lighting and will be well ventilated.	Safety Glasses Gloves	Metal shards/scrap swept and thrown away	HAZARD: 2 CONSEQ: Severe Residual: Medium	After approval by the PI, a copy must be sent to the Safety Committee. A written Project Hazard Control is required and must be approved by the PI before proceeding. A copy must be sent to the Safety Committee. A second worker must be in place before work can proceed (buddy system). Limit the number of authorized Workers in the hazard area
CAD	College of Engineering Remote	All Team Members	Eye strain, Carpal Tunnel	Every 30 minutes of computer use, look at something 20-30 feet away for 30 seconds to prevent eye strain. Take a 5 minute break to walk/ stretch for every hour of computer work.	Blue light glasses	N/A	HAZARD: 1 CONSEQ: Negligible Residual: Low	Proper breaks shall be taken. To ensure breaks are taken a timer will be set.
Vibrational Testing	College of Engineering	All Team Members	Fall hazard, Lifting hazard, Pinching due to scissor lift, Potential injury due to motion of device	Appropriate clothing, testing with multiple team members present	Safety glasses, pants, closed-toe shoes, OSHA requires	N/A	HAZARD: 2 CONSEQ: Minor Residual: Low med	Safety controls are planned by both the worker and supervisor. A second worker must be in place before work can proceed (buddy system).

					protective headwear if there is potential for objects to fall on the head			Proceed with supervisor authorization.
Ceramic Dust Testing	College of Engineering	All team Members	Breathing in ceramic dust can be harmful to the lungs. Potential damage to lungs and ability to breathe properly.	Contain the testing within in a box or protected area. Use tarps to contain ceramic dust. Test will also be performed outside	Wear N-95 mask to prevent inhaling dust.	Ceramic dust can be disposed of in standard trash	HAZARD: 3 CONSEQ: Moderate Residual: Medium	PPE must be applied before any testing can be complete. After approval by the PI, a copy must be sent to the Safety Committee. A written Project Hazard Control is required and must be approved by the PI before proceeding. A copy must be sent to the Safety Committee. A second worker must be in place before work can proceed (buddy system). Limit the number of authorized workers in the hazard area.
Assembly of T	College of Engineering	All Team Members	Pinching, Pallet lifting hazard, Potential to get cut due to sharp corners	Pallet at around 50 lbs will be lifted by 2 people	Safety glasses, closed-toe shoes, OSHA requires protective headwear if there is potential for objects to fall on the head	N/A	HAZARD: 1 CONSEQ: Minor Residual: Llow	All PPE must be applied before any machine or equipment is used. Supervisor/PI must be notified before testing begins. If testing must be stopped for any reason, PPE must be reapplied before continuing. There must be more than one team member present when assembly is occurring.
Assembly of Over Hangs	College of Engineering	All Team Members	Pinching, Low voltage electric shock, Potential to	Contain assembly in dry area. Keep the electric components	Safety glasses, closed-toe shoes	Dispose of electronic waste in	HAZARD: 3 CONSEQ :Minor	Safety controls are planned by both the worker and supervisor.

			get cute due to sharp corners	unplugged during assembly.		appropriate bin.	Residual: Low Med	A second worker must be in place before work can proceed. Proceed with supervisor authorization.

Principal investigator(s)/ instructor PHA: I have reviewed and approved the PHA worksheet.

Name	Signature	Date	Name	Signature	Date

Team members: I certify that I have reviewed the PHA worksheet, am aware of the hazards, and will ensure the control measures are followed.

Name	Signature	Date	Name	Signature	Date
Pawel Grum		02/21/2023 ~~11/15/2022~~	Jared White		02/21/2023 ~~11/15/2022~~
Taylor Larson		02/21/2023 ~~11/15/2022~~	Robert Kosmas		02/21/2023 ~~11/15/2022~~
Segundo Sanchez		02/21/2023 ~~11/15/2022~~			

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DEFINITIONS:

Hazard: Any situation, object, or behavior that exists, or that can potentially cause ill health, injury, loss or property damage e.g. electricity, chemicals, biohazard materials, sharp objects, noise, wet floor, etc. OSHA defines hazards as "*any source of potential damage, harm or adverse health effects on something or someone*". A list of hazard types and examples are provided in appendix A.

Hazard control: Hazard control refers to workplace measures to eliminate/minimize adverse health effects, injury, loss, and property damage. Hazard control practices are often categorized into following three groups (priority as listed):

1. **Engineering control:** physical modifications to a process, equipment, or installation of a barrier into a system to minimize worker exposure to a hazard. Examples are ventilation (fume hood, biological safety cabinet), containment (glove box, sealed containers, barriers), substitution/elimination (consider less hazardous alternative materials), process controls (safety valves, gauges, temperature sensor, regulators, alarms, monitors, electrical grounding and bonding), etc.
2. **Administrative control:** changes in work procedures to reduce exposure and mitigate hazards. Examples are reducing scale of process (micro-scale experiments), reducing time of personal exposure to process, providing training on proper techniques, writing safety policies, supervision, requesting experts to perform the task, etc.
3. **Personal protective equipment (PPE):** equipment worn to minimize exposure to hazards. Examples are gloves, safety glasses, goggles, steel toe shoes, earplugs or muffs, hard hats, respirators, vests, full body suits, laboratory coats, etc.

Team member(s): Everyone who works on the project (i.e. grads, undergrads, postdocs, etc.). The primary contact must be listed first and provide phone number and email for contact.

Safety representative: Each laboratory is encouraged to have a safety representative, preferably a graduate student, in order to facilitate the implementation of the safety expectations in the laboratory. Duties include (but are not limited to):

- Act as a point of contact between the laboratory members and the college safety committee members.
- Ensure laboratory members are following the safety rules.
- Conduct periodic safety inspection of the laboratory.
- Schedule laboratory clean up dates with the laboratory members.
- Request for hazardous waste pick up.

Residual risk: Residual Risk Assessment Matrix are used to determine project's risk level. The hazard assessment matrix (table 1) and the residual risk assessment matrix (table2) are used to identify the residual risk category.
The instructions to use hazard assessment matrix (table 1) are listed below:

1. Define the workers familiarity level to perform the task and the complexity of the task.
2. Find the value associated with familiarity/complexity (1 – 5) and enter value next to: HAZARD on the PHA worksheet.

Table 1. Hazard assessment matrix.

		Complexity		
		Simple	Moderate	Difficult
Familiarity Level	Very Familiar	1	2	3
	Somewhat Familiar	2	3	4
	Unfamiliar	3	4	5

The instructions to use residual risk assessment matrix (table 2) are listed below:

1. Identify the row associated with the familiarity/complexity value (1 – 5).
2. Identify the consequences and enter value next to: CONSEQ on the PHA worksheet. Consequences are determined by defining what would happen in a worst case scenario if controls fail.
   a. Negligible: minor injury resulting in basic first aid treatment that can be provided on site.
   b. Minor: minor injury resulting in advanced first aid treatment administered by a physician.
   c. Moderate: injuries that require treatment above first aid but do not require hospitalization.
   d. Significant: severe injuries requiring hospitalization.
   e. Severe: death or permanent disability.
3. Find the residual risk value associated with assessed hazard/consequences: Low –Low Med – Med– Med High – High.
4. Enter value next to: RESIDUAL on the PHA worksheet.

Table 2. Residual risk assessment matrix.

Assessed Hazard Level	**Consequences**				
	Negligible	Minor	Moderate	Significant	Severe
5	Low Med	Medium	Med High	High	High
4	Low	Low Med	Medium	Med High	High
3	Low	Low Med	Medium	Med High	Med High
2	Low	Low Med	Low Med	Medium	Medium

	Long term (chronic) effects such as mutagenic (affects cell structure), carcinogenic (cancer), teratogenic (reproductive effect), dermatitis of the skin, and occupational asthma and lung damage.
Noise	High levels of industrial noise will cause irritation in the short term, and industrial deafness in the long term.
Temperature	Personal comfort is best between temperatures of 16°C and 30°C, better between 21°C and 26°C. Working outside these temperature ranges: may lead to becoming chilled, even hypothermia (deep body cooling) in the colder temperatures, and may lead to dehydration, cramps, heat exhaustion, and hyperthermia (heat stroke) in the warmer temperatures.
Being struck by	This hazard could be a projectile, moving object or material. The health effect could be lacerations, bruising, breaks, eye injuries, and possibly death.
Crushed by	A typical example of this hazard is tractor rollover. Death is usually the result
Entangled by	Becoming entangled in machinery. Effects could be crushing, lacerations, bruising, breaks amputation and death.
High energy sources	Explosions, high pressure gases, liquids and dusts, fires, electricity and sources such as lasers can all have serious effects on the body, even death.
Vibration	Vibration can affect the human body in the hand arm with `white-finger' or Raynaud's Syndrome, and the whole body with motion sickness, giddiness, damage to bones and audits, blood pressure and nervous system problems.
Slips, trips and falls	A very common workplace hazard from tripping on floors, falling off structures or down stairs, and slipping on spills.
Radiation	Radiation can have serious health effects. Skin cancer, other cancers, sterility, birth deformities, blood changes, skin burns and eye damage are examples.
Physical	Excessive effort, poor posture and repetition can all lead to muscular pain, tendon damage and deterioration to bones and related structures
Psychological	Stress, anxiety, tiredness, poor concentration, headaches, back pain and heart disease can be the health effects
Biological	More common in the health, food and agricultural industries. Effects such as infectious disease, rashes and allergic response.

Project Hazard Control- For Projects with Medium and Higher Risks

Name of Project:		Date of submission:
Team member	**Phone number**	**e-mail**
Taylor Larson	850-556-9735	tmlarson@fsu.edu
Robert Kosmas	850-512-0398	rck19a@fsu.edu
Jared White	561-768-3722	jtw18c@fsu.edu
Pawel Grum	331-431-1475	pgrum@fsu.edu
Segundo Sanchez	850-570-2138	sas19x@fsu.edu
Faculty mentor	**Phone number**	**e-mail**
Eric Hellstrom	850-645-7489	hellstrom@eng.famu.fsu.edu

Rewrite the project steps to include all safety measures taken for each step or combination of steps. Be specific (don't just state "be careful").

Machining any metal materials could have significant risk if the proper precautions are not taken. The potential injuries include put are not limited to pinched, punctured, cut, blinded, or removal of limb. To combat these risks, eyeglasses and non-loose clothing will be worn and a second worker or "buddy" must be present for fabrication.

Any CAD that has to be done has a negligible risk. The potential injuries include but are not limited to eye strain and carpal tunnel. To combat these risks proper breaks and stretches will be followed. A timer will be used to ensure that breaks are taken at proper times.

Vibrational testing of the device has a low risk level. The potential injuries include, but are not limited to fall hazard, lifting hazard, and injury due to device motion. To combat these risks, proper lifting techniques will be used a second worker must present for all testing.

Ceramic dust testing has a moderate risk level. The potential injuries include but are not limited to breathing in ceramic dust can be harmful to the lungs. Potential damage to lungs and ability to breathe properly. To combat these risks proper masks and eye protection will be worn.

Assembly of the project device has a low risk. The potential injuries include but are not limited to pinching, pallet lifting hazard, potential to get cut due to sharp corners. To combat these risks proper assembly method will be evaulted and discussed prior to assembling parts, proper techniques will be used, and used a second worker must present for all testing.

Assembly of the overhangs has a low med risk. The potential injuries include but are not limited to pinching, small shocks, potential to get cut due to sharp corners. To combat these risks proper assembly method will be evaulted and discussed prior to assembling parts, proper techniques will be used, and parts will remain disconnected from power while building.

Thinking about the accidents that have occurred or that you have identified as a risk, describe emergency response procedures to use.

If there are any injuries, fires, or an emergency, the first step to be taken is to call 911. If there are any problems that may concern the facility, we have to contact our department representative.

- Remove the injured person from hazard location of accident if safe to do so.
- Call the appropriate authority (supervisor, FSUPD, 911, Poison Control dependent on severity and injury).
- Call emergency contact of injured person and inform them of incident.
- Shut down/close off source of injury, if possible, in a safe and controlled manner.

- Isolate scene until the responding authority arrives.
- Ensure responding authority has all necessary information on the situation and assist them however they may need.
- Call 911 for injuries, fires or other emergency situations.
- Call your department representative to report a facility concern.

List emergency response contact information:

- Call 911 for injuries, fires or other emergency situations
- Call your department representative to report a facility concern

Name	Phone number	Faculty or other COE emergency contact	Phone number
Dana Larson	850-556-8531	Keith Larson	850-410-6108
Joseph Kosmas	850-529-5993	Keith Larson	850-410-6108
Lesley White	561-339-1575	Keith Larson	850-410-6108
Katarzyna Mika	352-777-3724	Keith Larson	850-410-6108
Edwardo Sanchez	850-570-0985	Keith Larson	850-410-6108

Safety review signatures

Team member	Date	Faculty mentor	Date

Report all accidents and near misses to the faculty mentor.