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Dry Ingredient Dispenser, Group S, 2017

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Executive Summary

The purpose of this Project Report is to discuss the design process and construction of an automated dry ingredient dispenser intended for home bakers. Manually measuring dry ingredients can be time-consuming, inaccurate, and plain messy. The dry ingredient dispenser is a kitchen appliance that fits onto a standard countertop and at the touch of a button dispenses the requested amount of ingredient even in several different unit systems, allowing for a clean and seamless round of holiday baking and for ease of use by the consumer. Once the user inputs the type, amount, and unit system of the ingredient they need and uploads the sketch to the Arduino, a linear actuator pushes the grate back and forth across a hole in the bottom of a food-grade bin, sifting the flour out. A load cell attached to a converter reads accurately reads weight values and sends a command back to the Arduino to retract the linear actuator when the requested amount has been dispensed. The grate is designed to sit against the bin so that several different bins can be interchanged for different ingredients. This report outlines several major stepping stones to the final prototype design, including but not limited to Engineering Analysis performed in SolidWorks, project constraints, concept generation and selection, customer interviews, and risk identification.

MEMS 411: Senior Design Project

Dry Ingredient Dispenser

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1 INTRODUCTION AND BACKGROUND INFORMATION

1.1 INITIAL PROJECT DESCRIPTION

Our idea is an automatic dry ingredient dispensing system. This product will accurately and consistently dispense dry ingredients prior to the mixing process. The product can be easily stored and fit on a standard kitchen counter to allow for ease of use. It will also have a user-friendly interface that allows for multiple unit inputs. The product will be geared toward residential use and not commercial use.

1.2 EXISTING PRODUCTS

Existing Product #1

Figure 1: Ingredient Masters's Large-scale dry ingredient dispensers (material specific)

Link: http://www.ingredientmasters.com/dry-ingredient-dispensers/

These ingredient dispensers are industrial scale but use a special polyethylene material so that the contents of each container don't "sweat" with temperature fluctuations. This would be a useful product to determine what kind of food-grade material we should use for our containers.

Existing Product #2

Figure 2: PantryChic Store and Dispense System

Link: http://www.pantrychic.com/product-overview/

The PantryChic Store and Dispense System uses separate plastic containers that are mounted onto the base when ready to measure and obtain that specific ingredient. The user can type in the amount they need in five different unit systems and the ingredient is dispensed into the bowl.

Existing Product #3

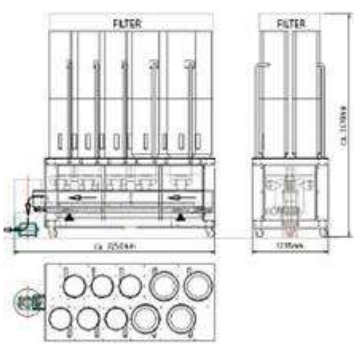


Figure 3: Hb Technik Ingredient Dispenser Compo 800

Link: http://www.hb-technik.at/en/products/ingredient-dispenser/automatic-ingredient-dispenser/ingredient-dispenser-compo-800.html

The ingredients in this product are stored in containers side-by-side and weighed and dosed simultaneously before being extracted to a location of the user’s choice. This is another large-scale example that we could alter and shrink down to table-top size.

1.3 RELEVANT PATENTS

Patent #1

Patent #US 5460209A

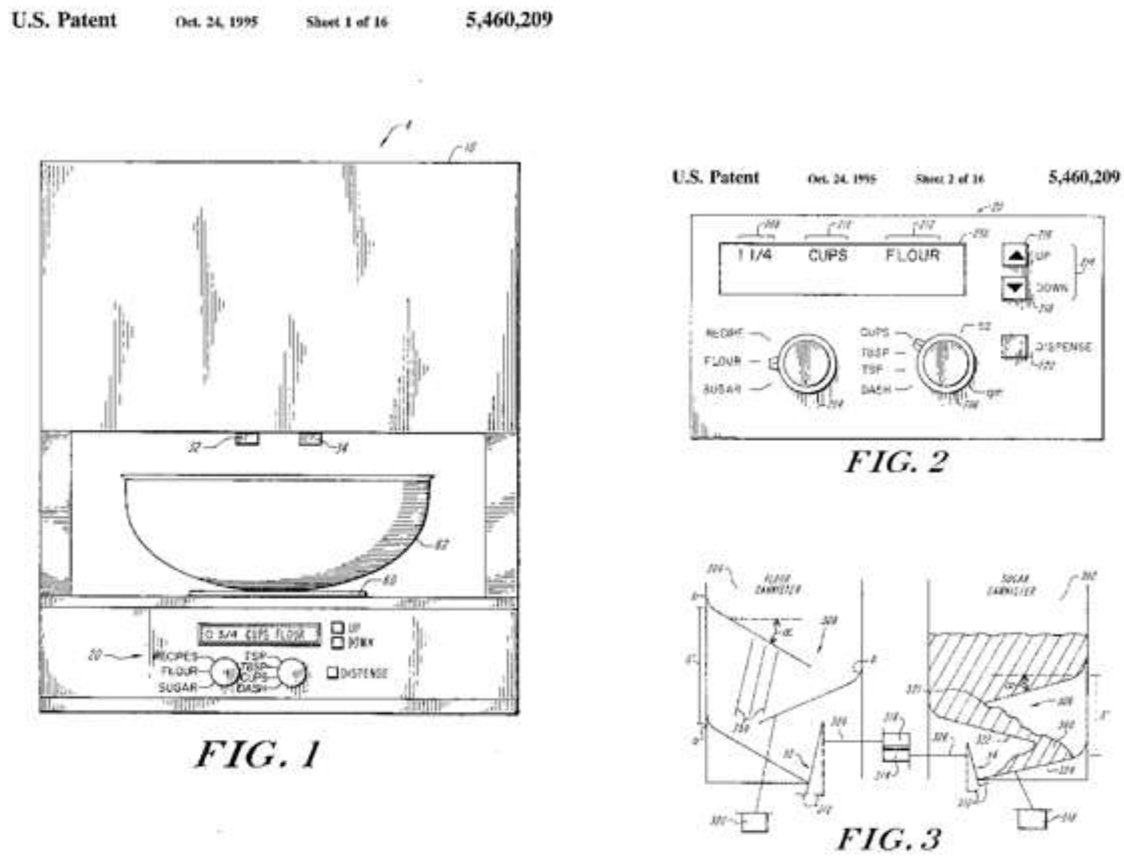


Figure 4: Patent #US 5460209A Images

This patent consists of a dry ingredient dispenser with different ingredients inside, a vibrating element to coax the ingredients out onto a collection stage, and rather than a weigh scale, a calculator to determine the amount of ingredient on the collection stage based on the constant volumetric flow rate out of the spouts.

Patent #2

Patent #US 9010585 B1

No Images Available

This dry ingredient dispensing unit includes containers attached to a sliding rail that can then be attached to a stable wall or cupboard. Each container is inside a hopper which a dry ingredient is loaded into. Sliding dispensing plates, also in the hopper, are stacked and have an aperture that dispenses a requested amount of the ingredient. The plate then slides out.

1.4 CODES & STANDARDS

Standard #1: NSF/ANSI 18-2016 Manual Food and Beverage Dispensing Equipment

Standard #2: NSF/ANSI 8-2012 Commercial Powered Food Preparation Equipment

1.5 PROJECT SCOPE

1. The purpose of the dry ingredient dispenser is to provide consistent and precise measurement and dispensing of dry ingredients for culinary purposes.

2. Our ideal customers are home bakers and culinary enthusiasts.

3. This product will eliminate the need for measuring cups and messy tabletops. It will also lead to better consistency from one batch of a recipe to another. This product will also provide storage for dry ingredients and eliminate the need for complex conversions.

4. We want to design and construct a product that will precisely and consistently measure and distribute dry, culinary ingredients. We want to be able to store up to one cubic foot of each ingredient and measure and dispense each ingredient within an accuracy of 5grams. We also want to be able to store these ingredients in a manner that allows them to be used easily and not take up a lot of space (the space allowed on a standard countertop). This product will also be easy to clean and to use.

5. This project will create a product that precisely and consistently measures and distributes dry, culinary ingredients.

6. This project will not create a product that mixes dry ingredients or cooks the ingredient into a final dish.

7. Keys to success
   a. A connected system that allows for multiple ingredients at once
   b. Accurate distribution and measurement of the ingredients on a consistent basis
   c. Familiarity with a Raspberry Pie and its programming
   d. Physical dates set for stages of the project to be completed
   e. Good communication between project departments

8. Project Assumptions

a. We can convert the mass of an ingredient to a volume of an ingredient accurately and consistently
b. We can account for multiple measurement types
c. We can easily and accurately control the mass flow of an ingredient

9. Project Constraints
   a. Limited budget
   b. Space (Standard countertop)
   c. Time (One semester)
   d. Manufacturing Methods (Limited to campus resources)
   e. Materials (Food grade and budget)

10. Key Deliverables
   a. Physical Prototype
   b. The Code
   c. The Final Report

1.6 PROJECT PLANNING

A Gantt chart was created and updated throughout the course of the project.

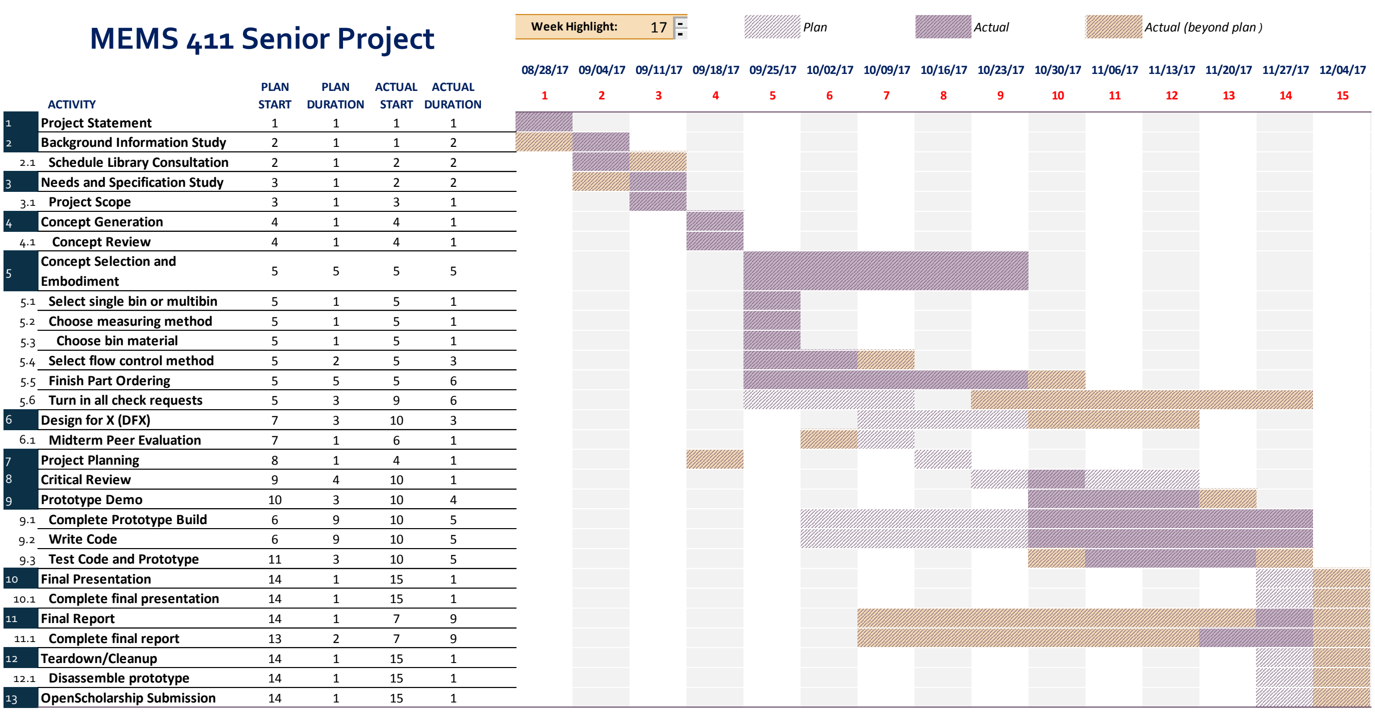


Figure 5: Project Gantt Chart

1.7 REALISTIC CONSTRAINTS

In the design phase of our project, we had to consider several constraints in varying categories that could potentially affect the success of our product.

1.7.1 Functional

There are many functional constraints pertaining to our project because of its mechanical nature. Because it's a countertop kitchen appliance, we had to keep the size down to what would fit underneath and inside a standard cabinet. Material was a major consideration as the food container had to be food-grade to comply with our standards, and the dispensing base and mounting rails had to be strong and easy to put together with screws, which is why we chose wood and aluminum, respectively. We also have to control motion of parts so that the forces applied are not large enough to damage any of the expensive components in the design, such as the linear actuator. Information flow is another difficulty our project faces. It must accept user data and accurately translate that into an amount dispensed, requiring a lot of background processes and coding through the microcontroller.

1.7.2 Safety

Safety is not a huge concern for our product, considering it will only be used by adults and is out of reach of small children. A warning label would be placed in the manufacturing process to deter hand placement anywhere near the dispensing unit, and a user manual would be included to avoid any unsafe use. We have considered the weight of our product as well as risk of tipping, but have determined that if operated normally it will not tip or fall off of a counter.

1.7.3 Quality

Two potential concerns for the quality and life of our product are the amount of cycles it can survive without malfunctioning and adhering to the two standards we have used. Currently there are fasteners in the food zone, forbidden by the standard for manual food and beverage dispensing equipment. To make this product adhere to that standard we would need to find an alternative or cover up the fasteners with food-safe material. In addition, we have no way to test for life of the product, but hope that because of its solid construction and strong epoxy that the unit will function normally for at least 100 cycles.

1.7.4 Manufacturing

If our product ever went on to be manufactured in a large-scale setting, we believe the design would change drastically. The bin would most likely remain a food-grade plastic but the dispensing base and unit that holds the electrical components would all be done through injection molding. This would reduce the weight and increase the manufacturability of our product. We would also upgrade to a touch panel for user input and would need to find a quality supplier of those. Another major hurdle would be deciding how to package it simply and securely into a single box with minimal parts to assemble on the customer side. Currently, our prototype would have to go a long way to meet the needs for good manufacturability and that is a constraint that didn't go into our design process for the prototype.

1.7.5 Timing

Timing constraints were very real for our project. Since we only had a semester, we were scrambling to complete the prototype in a way that wasn't in line with our vision for the project at the beginning of the semester. There were things we wanted to accomplish, like using more than one ingredient at a time on the dispensing base, but were not able to because of lack of time. We also had to improvise certain mechanisms and redesign as we went because we discovered that our original ideas were not feasible in a semester.

1.7.6 Economic

Most of our design constraints reside in this category. Our budget was only 230 dollars and we ended up going over that a little bit. The components necessary for a fully functional and user-friendly Dry Ingredient Dispenser would exceed that budget. In addition, we were a bit stretched for resources because the machine shop was not always open when we were able to get in.

1.7.7 Ergonomic

Ergonomics form the main purpose of our product- people interacting with the device to receive a certain output. Therefore, it’s very important that our device is easy to interact with and to use. Ideally, the user is prompted to input their type and amount of ingredient in any unit system and just press start. Everything else should be automatic. It should also be clear when the machine is done dispensing. However, since this all takes a lot of extra coding, it is a constraint.

1.7.8 Ecological

Our device won’t really have major implications for politics or the world, but we are taking into consideration the resources we have used. Most of the wood we used was recycled from things we found in the Engineering building. However, some materials we used, such as the epoxy, may be damaging to the environment if not disposed of properly. If the polyester plastic used in the food-grade bin is also thrown away, it would sit in a landfill for years.

1.7.9 Aesthetic

Aesthetics was one of our lowest concerns when designing our product although in the design for manufacturing phase it would be important. The unit will most likely be sitting on people’s kitchen countertops, so it would be desirable to have it look good. The sleeker the design, the more attractive it will be to potential consumers.

1.7.10 Life Cycle

The Dry Ingredient Dispenser is not very quiet as the linear actuator makes around 55 dB of noise, about the level of conversational speech [1]. We are unsure of potential wear over its lifetime because we cannot test through its entire life, but we believe it’s built to last quite a while, considering the low forces and strains present in the device. Cleaning is something we designed for; the bin is removable so that the unit can be cleaned with a vacuum or a paper towel.

1.7.11 Legal

For our product to make it to production it would need to meet all of the standards for manual food and beverage dispensing equipment. This could have legal implications if not done properly. We would also need to patent our idea for the spring-grate system. We also need to double check and ensure we are not infringing on any other patents of similar products.

1.8 REVISED PROJECT DESCRIPTION

The dry ingredient dispenser, intended for household use, is a kitchen appliance which will accept user input via a computer interface and automatically dispense the amount of dry ingredient requested prior to mixing by hand. The bins are designed to be interchangeable such that several different dry ingredients can be dispensed into the same bowl, reducing inaccuracy of measurements and making baking less messy. The user will be able to enter input using different unit systems and the appliance will fit on a standard countertop.

CUSTOMER NEEDS & PRODUCT SPECIFICATIONS

1.9 CUSTOMER INTERVIEWS

Table 1: Customer Data Obtained from Customer Interview

Customer Data: Dry Ingredient Dispenser (DID) II
Customer: Cassie Davis (BME Student)

Address: Washington University in St. Louis
Date: 9/16/17

Question	Customer Statement	Interpreted Need	Importance
What is the most labor intensive part of baking for you?	Waiting for the item to bake; washing out measuring cups; having a mess; liquid and dry ingredient in same measuring cup	DID removes the need for measuring cups	5
Do you spend any time on converting units from a recipe to another set of units?	She doesn't spend time converting; uses recipes that have cups and ounces; not a problem for her; but helpful to have both units	DID accepts all input unit possibilities and converts them	4
Is spilling dry ingredients an issue while you are baking?	Sometimes, it's a typical problem she is used to; opening the flour bag creates a mess	DID requires less clean-up than manual measuring	5
Approximately how much space do you use to store your baking dry ingredients?	Medium-large space; she keeps it all in one place; not an issue because she has space; It's a problem at her family's home	DID bins take up minimal space/DID base is compact	3
How important is the appearance of items you place on your counter?	Needs to match other appliances; neutral; blend into counter; so pretty important	DID has a sleek, attractive look	2

How precise do you think you are when you manually measure ingredients? Is it important to you to be precise every time?	"It's close enough" attitude sometimes; she knows it is important since it is for baking; She prefers to be precise	DID dispenses ingredients to a high degree of accuracy	4
What is more important to you- saving counter space or saving time when dispensing dry ingredients?	Depends on how much space you have; she has canisters to hold dry ingredients so if she had an option to replace them with a device that also stores the same things she would take that option; would want it to fit into a standard cupboard and be lightweight to place into the cupboard; would be cool to be placed on the wall	DID replaces standard storage bins for dry ingredients DID fits into or underneath a standard cabinet DID is lightweight	2 4 3

1.10 INTERPRETED CUSTOMER NEEDS

Table 2: Interpreted Customer Needs

Need Number	Need	Importance
2	DID accepts all input unit possibilities and converts them	4
3	DID requires less clean-up	5
4	DID bins take up minimal space	3
5	DID has a sleek, attractive look	2
6	DID dispenses ingredients to a high degree of accuracy	4
7	DID replaces standard storage bins for dry ingredients	2
8	DID fits into or underneath a standard cabinet	4
9	DID is lightweight	3
10	DID has sealed and smooth corners [2]	4
11	DID Bin covers will overlap and be sloped [3]	4

1.11 TARGET SPECIFICATIONS

Table 3: Target Specifications Sheet

Metric Number	Associated Needs	Metric	Units	Acceptable	Ideal
1	1	% improvement in satisfaction over measuring cups	Percent	80	100
2	2	# of user input options	Integer	>3	>5
3	3	Time it takes to clean up after use	Minutes	<5	<2
4	4	Total Ingredient Volume	Cubic inches	<350	<250
5	5	Level of aesthetic	Rating 1-5	>1	>3
6	6	Error in ingredient measurement	Percentage	<15	<10
7	7	Height of entire unit	Inches	<18	<17.5
8	8	Weight	Pounds	<15	<10
9 [2]	10	Passes external corners test	Boolean	T	T
10 [3]	11	Passes covers test	Boolean	T	T

2 CONCEPT GENERATION

2.1 FUNCTIONAL DECOMPOSITION

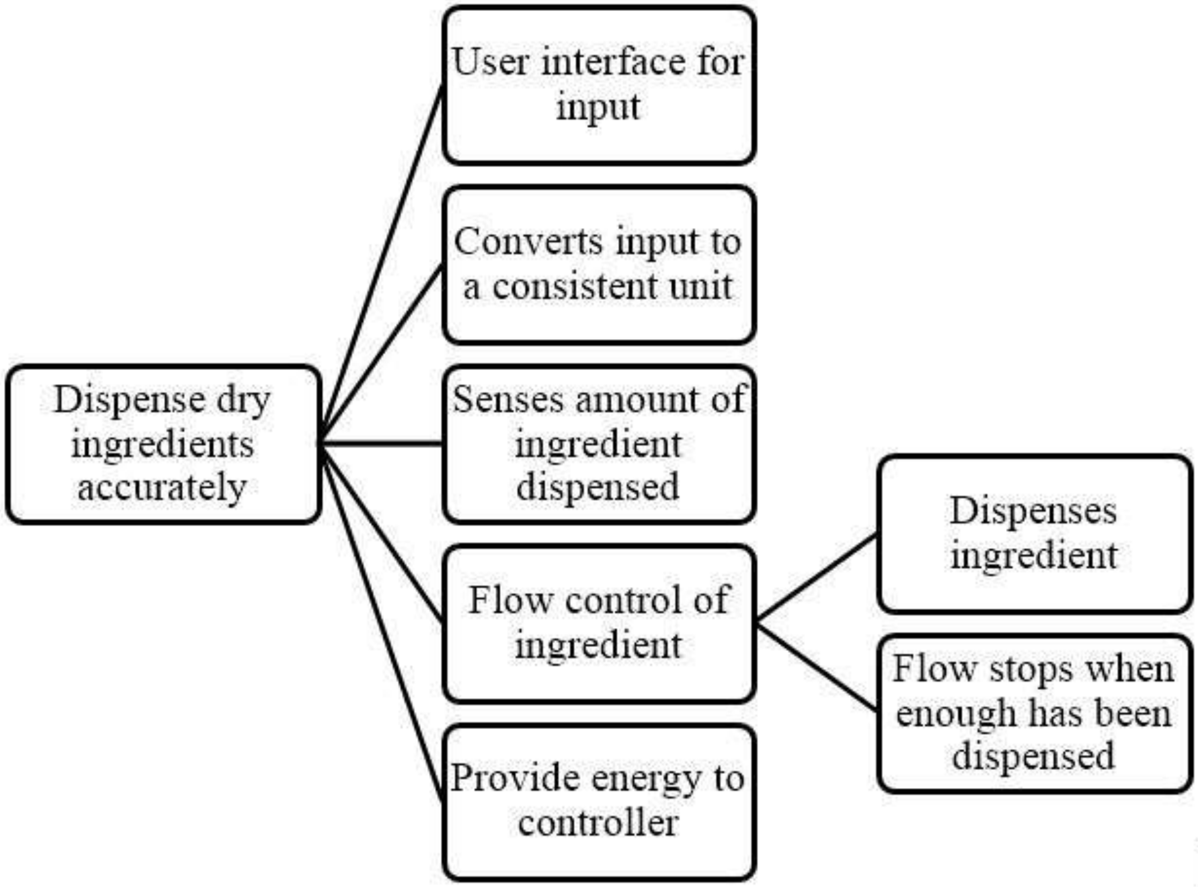
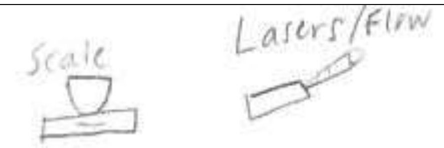
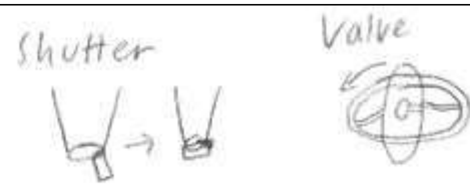


Figure 6: Functional Decomposition Chart

2.2 MORPHOLOGICAL CHART

Table 4: Morphological Chart

User interface for input	GUI on PC 	Dials 	Touch Pad 
Converts input to a consistent unit	Computer 	Microprocessor 	

Senses amount of ingredient dispensed	
Flow control of ingredient	
Provide energy to controller	

2.3 CONCEPT #1 – "MULTIBIN WEIGHT-CONTROLLED"

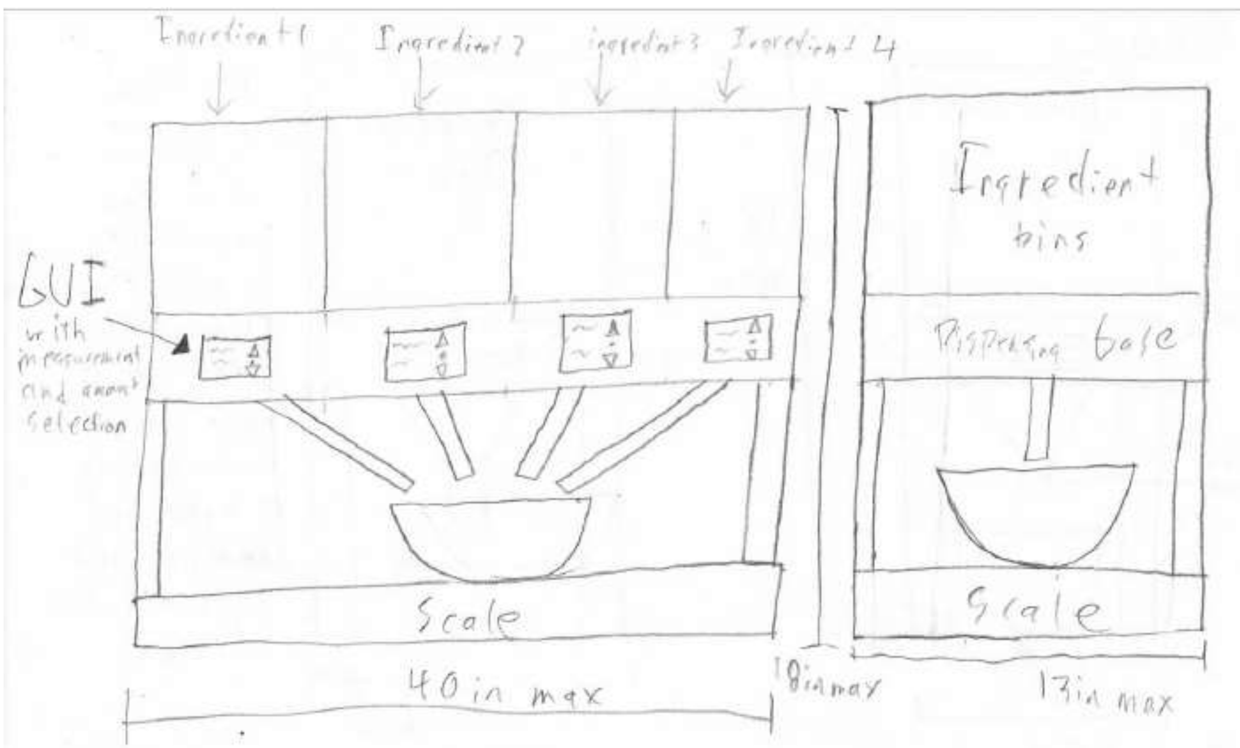


Figure 7: Concept Drawing of Design #1

Concept Name: "Multi-bin Weight Controlled Design"

Description: The dry ingredient dispenser has multiple bins that are controlled independently but part of the same apparatus. The different bins are for each different dry ingredient, such as flour, sugar, baking powder, and baking soda. Tubes leading from each bin all lead to the bowl. A scale below reads the weight change in the bowl which is then converted to the amount of ingredients desired. When the amount desired is reached the scale sends a signal to the controller to shut off flow of that ingredient.

Solutions:

1. User input through a GUI
2. Code converts the units
3. Scale weighs the bowl
4. Valve
5. Computer

2.4 CONCEPT #2 – "LASER-SENSING MEASURING CUP"

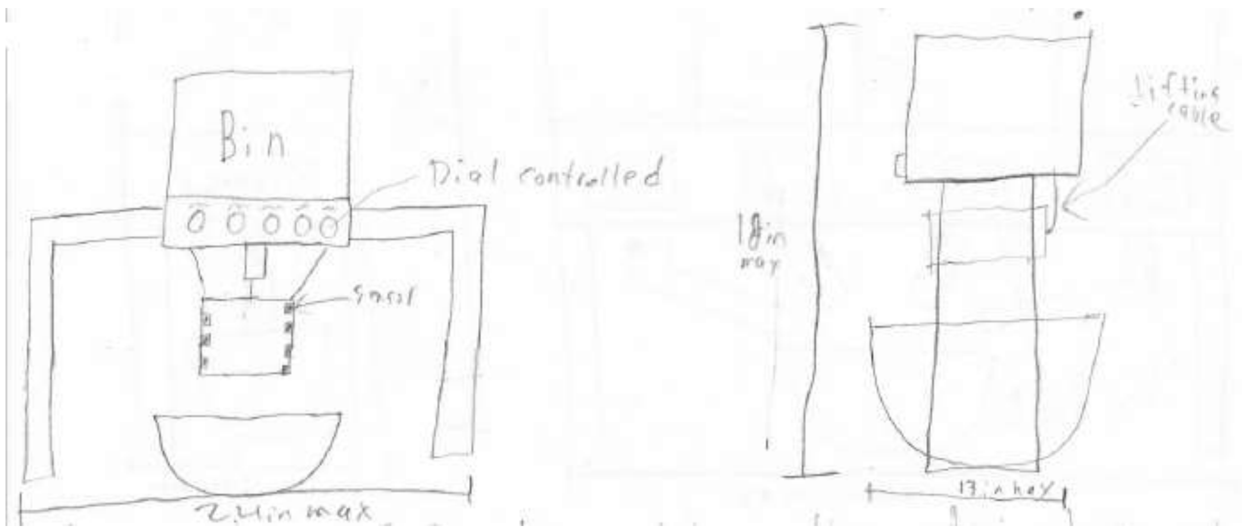


Figure 8: Concept Drawing of Design #2

Concept Name: "Laser Sensing Measuring Cup"

Description: The dry ingredient bin sits on top of the dispensing unit, which dispenses onto a measuring cup with laser sensors inside. The laser sensors detect when the measuring cup is at the desired amount and triggers a hinge which dumps the ingredient from the measuring cup into the bowl.

Solutions:

1. User input through dials
2. Code converts the units

3. Lasers detect the amount
4. Rotating platform
5. Computer

2.5 CONCEPT #3 – "SINGLE BIN LASER-CONTROLLED"

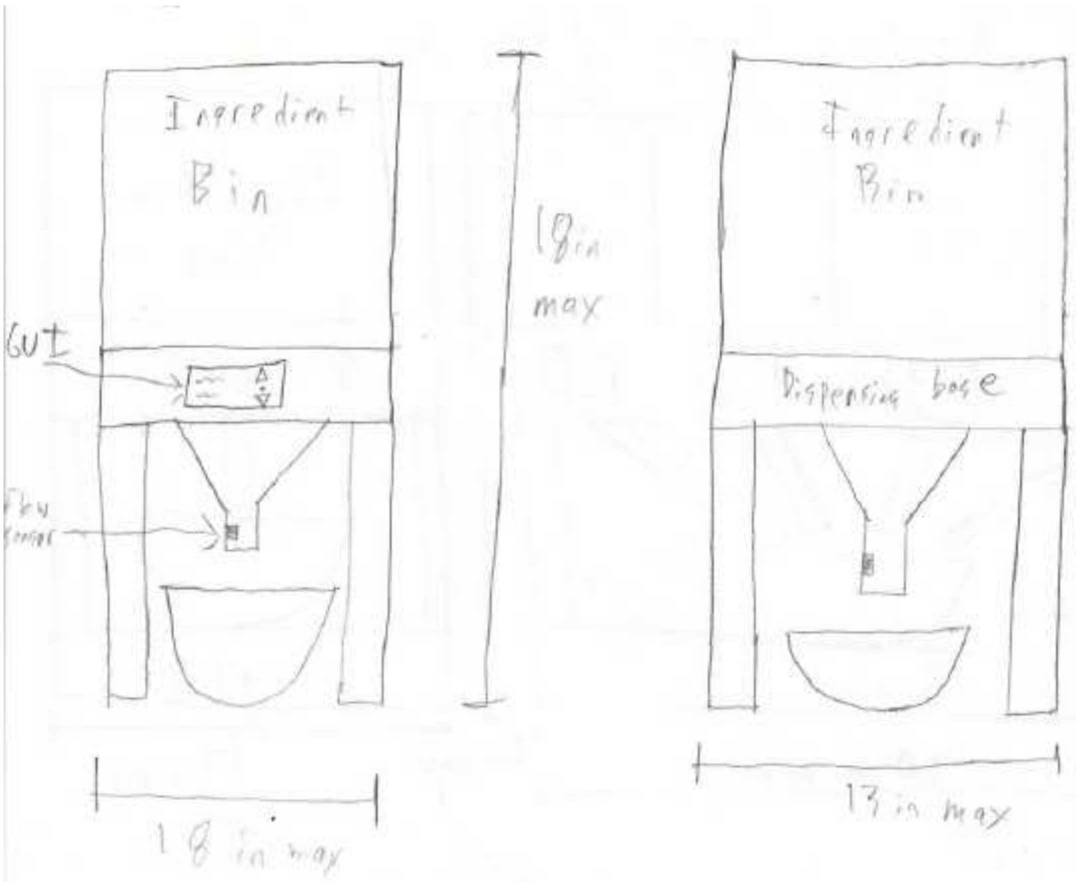


Figure 9: Concept Drawing of Design #3

Concept Name: "Single Bin Laser Flow Controlled"

Description: A single bin mounted on top of a dispensing unit contains the ingredient the user needs. The input is done through a GUI interface on the computer and when the ingredient is dispensed lasers detect the amount that has been released.

Solutions:

1. Input through touchpad
2. Microprocessor
3. Laser detects amount

4. Shutter mechanism
5. Plugs into wall

2.6 CONCEPT #4 – "MULTIBIN LASER-CONTROLLED"

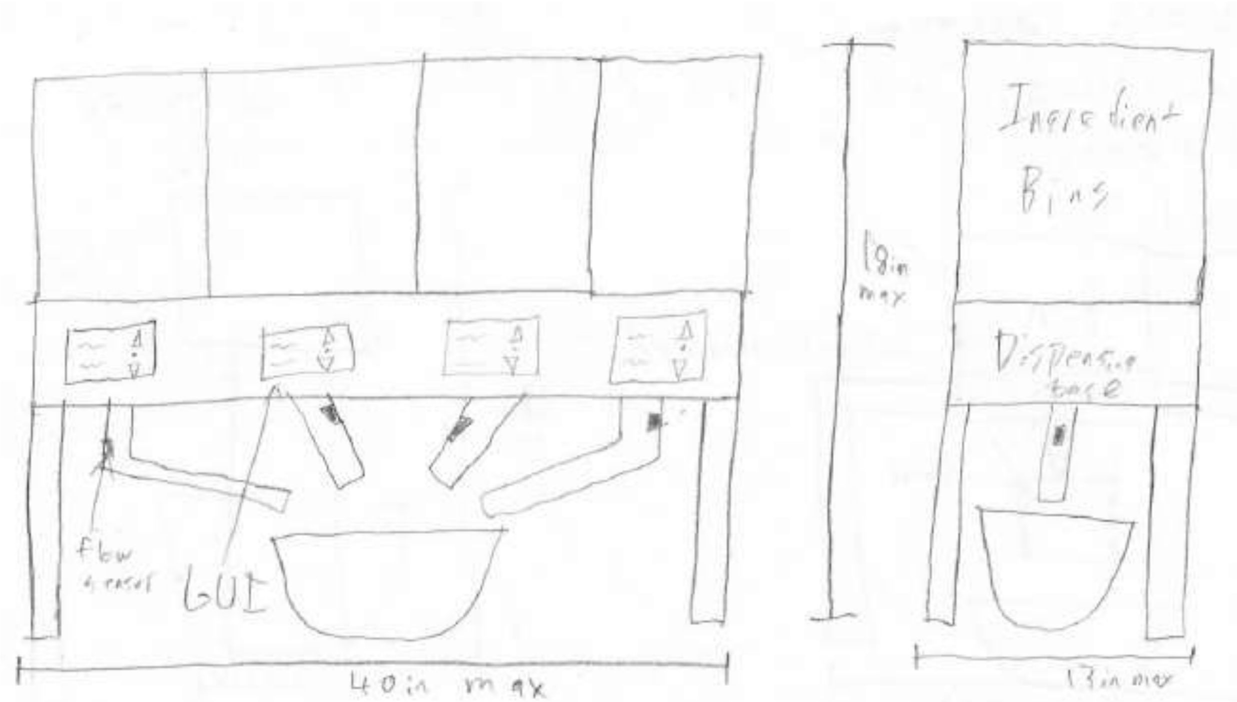


Figure 10: Concept Drawing of Design #4

Concept Name: "Multi-Bin Laser Flow Controlled"

Description: Multi-Bin system that dispenses multiple ingredients to one location. Each bin will have a laser flow sensor that will send a signal to a controller to control the flow of each ingredient.

Solutions:

1. User input through GUI
2. Code converts the units
3. Lasers detect the amount
4. Valve
5. Computer

2.7 CONCEPT #5 – "ROBOT ARMS"

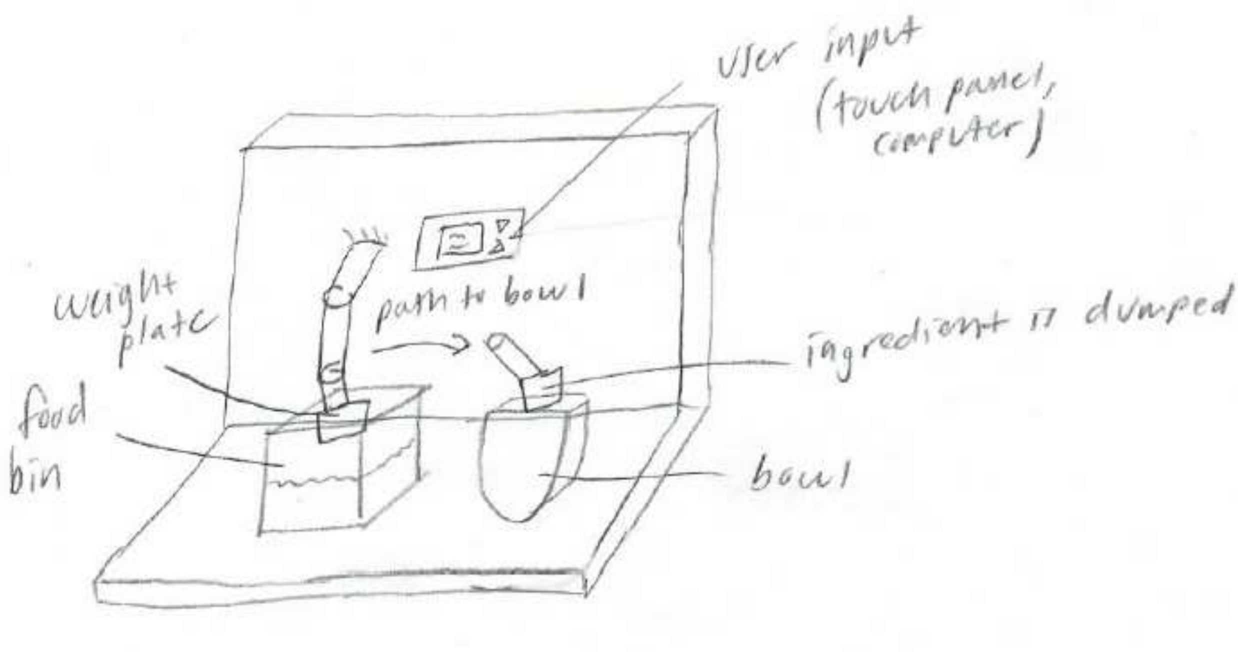


Figure 11: Concept Drawing of Design #5

Concept Name: "Robot Arms"

Description: Robot arms that detect where a bin of ingredients is placed. The arms then scoop out of the bin into a laser sensing measuring cup. When the desired amount is met the arms then dump the ingredients into the mixing bowl.

Solutions:

1. User input through GUI
2. Code converts the units
3. Lasers detect the amount
4. Rotating platform
5. Computer

2.8 CONCEPT #6 – "SINGLE BIN WEIGHT-CONTROLLED"

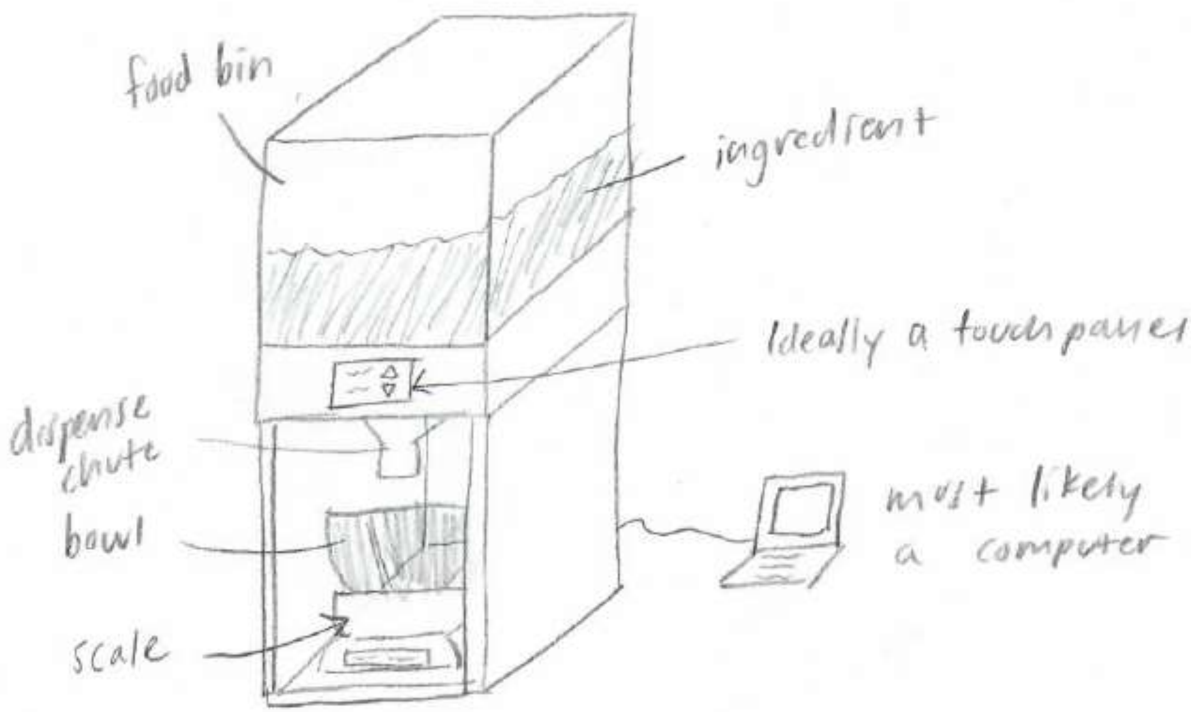


Figure 12: Concept Drawing of Design #6

Concept Name: "Single Bin Weight Controlled"

Description: Single bin system that dispenses ingredients onto a mixing bowl onto a scale. The scale converts weight into measuring units for the ingredient on the dispensing unit. The scale then sends a signal to the controller to stop the flow.

Solutions:

1. User input through GUI
2. Code converts the units
3. Weight converts units
4. Shutter
5. Computer

3 CONCEPT SELECTION

3.1 CONCEPT SCORING MATRIX

	Cleanliness	Cost of components	Ease of use	Portability	Ease of storage	Accuracy	Aesthetics	Feasibility	Fail Safe (clumping)	Row Total	Weight Value	Weight (%)
Cleanliness	1.00	1.00	3.00	5.00	1.00	0.20	7.00	0.33	0.20	18.73	0.10	10.02%
Cost of components	1.00	1.00	0.33	5.00	0.33	0.14	3.00	0.20	0.33	11.34	0.06	6.07%
Ease of use	0.33	3.00	1.00	5.00	5.00	0.33	7.00	0.33	0.20	22.20	0.12	11.88%
Portability	0.20	0.20	0.20	1.00	0.20	0.14	1.00	0.14	0.14	3.23	0.02	1.73%
Ease of storage	1.00	3.00	0.20	5.00	1.00	0.20	5.00	0.33	0.14	15.88	0.08	8.50%
Accuracy	5.00	7.00	3.00	7.00	5.00	1.00	9.00	0.33	1.00	38.33	0.21	20.51%
Aesthetics	0.14	0.33	0.14	1.00	0.20	0.11	1.00	0.11	0.11	3.15	0.02	1.69%
Feasibility	3.00	5.00	3.00	7.00	3.00	3.00	9.00	1.00	1.00	35.00	0.19	18.73%
Fail Safe (clumping)	5.00	3.00	5.00	7.00	7.00	1.00	9.00	1.00	1.00	39.00	0.21	20.87%
									Column Total:	186.87	1.00	100%

Figure 13: Analytic Hierarchy Process

		Multibin Laser		Multibin Weight		Single Bin Laser		Single Bin Weight		Robot Arms		Laser Measuring Cup	
Selection Criterion	Weight (%)	Rating	Weighted	Rating	Weighted	Rating	Weighted	Rating	Weighted	Rating	Weighted	Rating	Weighted
Cleanliness	10.025	3	0.30	3	0.30	4	0.40	4	0.40	1	0.10	2	0.20
Cost of components	6.07	1	0.06	2	0.12	3	0.18	4	0.24	1	0.06	2	0.12
Ease of use	11.88	4	0.48	4	0.48	3	0.36	3	0.36	5	0.59	3	0.36
Portability	1.73	1	0.02	1	0.02	3	0.05	3	0.05	1	0.02	2	0.03
Ease of storage	8.5	1	0.09	1	0.09	4	0.34	4	0.34	1	0.09	2	0.17
Accuracy	20.51	3	0.62	4	0.82	3	0.62	4	0.82	4	0.82	3	0.62
Aesthetics	1.7	2	0.03	2	0.03	3	0.05	3	0.05	5	0.09	2	0.03
Feasibility	18.73	2	0.37	3	0.56	3	0.56	4	0.75	1	0.19	2	0.37
Fail Safe (clumping)	20.87	1	0.21	1	0.21	4	0.83	4	0.83	3	0.63	3	0.63
	Total score	2.172		2.625		3.394		3.848		2.576		2.533	
	Rank	**6**		**3**		**2**		**1**		**4**		**5**	

Figure 14: Concept Scoring Matrix

3.2 EXPLANATION OF WINNING CONCEPT SCORES

The single bin weight design uses a single bin with attached scale to accurately dispense the amount of ingredient specified. This concept ranked first mainly because it contains features necessary for all of the user needs and is more feasible than the other concepts in terms of cost and product weight and portability. It ranked first for cost of components mainly because it is only a single bin and doesn't require a laser but rather an inexpensive scale hooked up to a computer. It ranked average for portability and ease of use, similar to much of the other concepts, but outscored in ease of storage compared to the multibin designs, because it will be smaller and more lightweight. One of the main reasons the single bin design won is due to fail safe conditions. Having multiple bins with tubes leading to one place can result in ingredient clumping in the tube because of humidity and other factors. However, the interchangeable single bin will avoid this problem.

3.3 EXPLANATION OF SECOND-PLACE CONCEPT SCORES

The single bin dry ingredient dispenser with laser sensing technology came in second place using the scoring matrix. The laser measures the dry ingredient as it is dispensed, assuming a constant volumetric flow rate. The concept scored well in the cleanliness and the fail-safe category because of its single bin design, but scored poorly in cost of components and feasibility compared to the scale design. A laser would be more expensive to purchase and possibly more difficult to set up. Additionally, accuracy may be affected as we would be assuming a constant flow rate of ingredient. The single bin laser design would have been very close to the single bin weight design had it not been for the cost of components and feasibility categories. These two categories were given a lot of weight because if we cannot afford to buy the parts and complete the project, the other categories would not matter.

3.4 EXPLANATION OF THIRD-PLACE CONCEPT SCORES

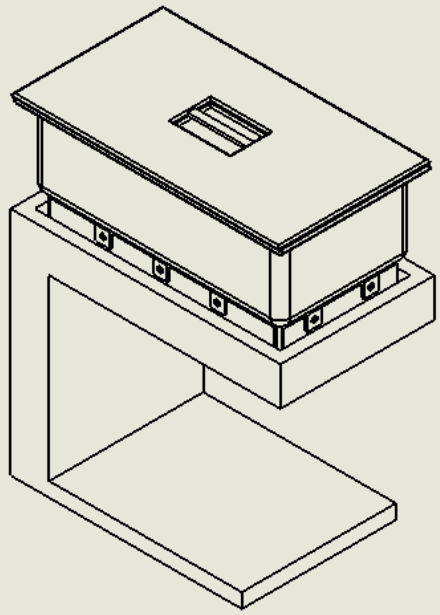
The multibin weight design came in third place using the scoring matrix. The main issue in using this design would be avoiding humidity effects in the dispensing unit, clumping, etc. Cleanliness was given a poor rating because these tubes cannot be cleaned as effectively since they would need to run so long to the mixing bowl. Cost of components would increase due to the increase in material we would need for the ingredient bins. The aesthetics, ease of storage and portability would also be negatively affected because the product would be larger and heavier, due to the multiple bins. The only category from the scoring matrix that improved in this concept was ease of use. Having multiple bins with all ingredients at hand, the customer would not need to manually switch bins every time they needed a different ingredient.

3.5 SUMMARY OF EVALUATION RESULTS

We believe the winning concept is our simplest, most feasible choice. We are going with the weight controlled, single bin design as a result of doing the analytical hierarchy chart and the weighted scoring matrix. It does not involve the problem of clumping through tubes which we gave the most weight, and it will be feasible, which we gave the second highest weight to. A scale will be an inexpensive option and having a single bin will allow us to focus on how the unit will dispense the ingredient accurately and mechanically. The unit will also be the best for storage and portability. The second and third-place concepts did not win due to cost constraints and fail safe issues.

4 EMBODIMENT & FABRICATION PLAN

4.1 ISOMETRIC DRAWING WITH BILL OF MATERIALS



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Dispensing Base		1
2	L12-I Actuator	30mmStroke; 50:1	1
3	Bin		1
4	Mounting L Bracket		10
5	Track and Shaft Mounting Bracket		2
6	Support Shaft		1
7	Long Mounting Rail		2
8	Short Mounting Rail		2
9	Grate		1
10	9657K414	Compression Spring	1
11	Lid		1

Figure 15: Isometric View with Bill of Materials

4.2 EXPLODED VIEW

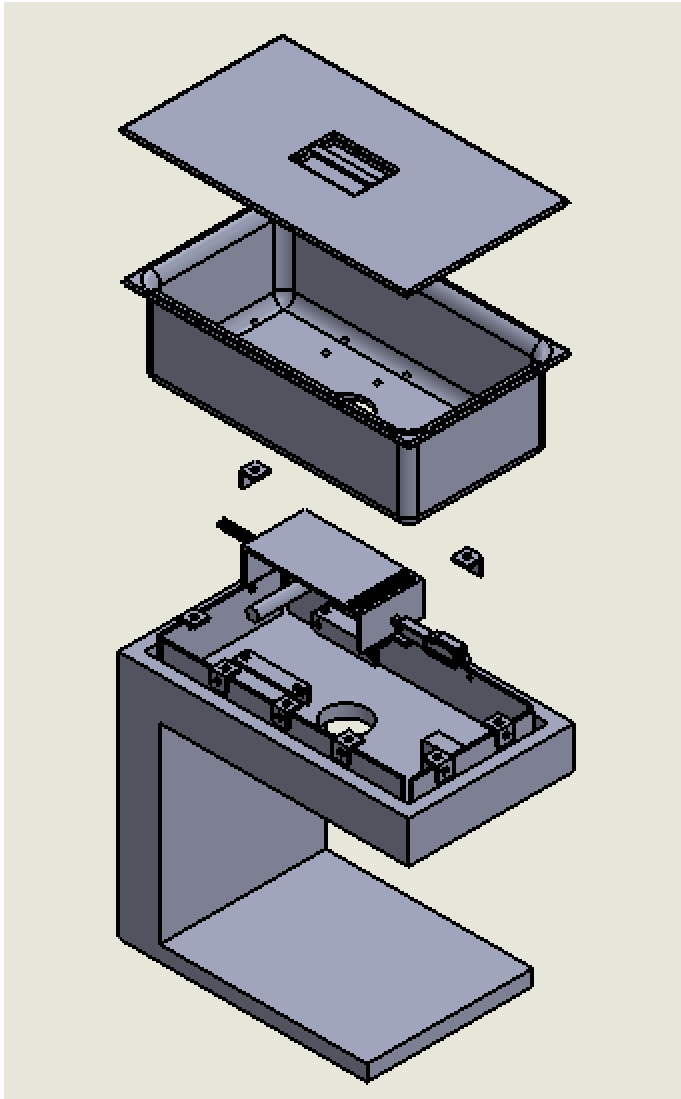


Figure 16: Exploded View

4.3 ADDITIONAL VIEWS

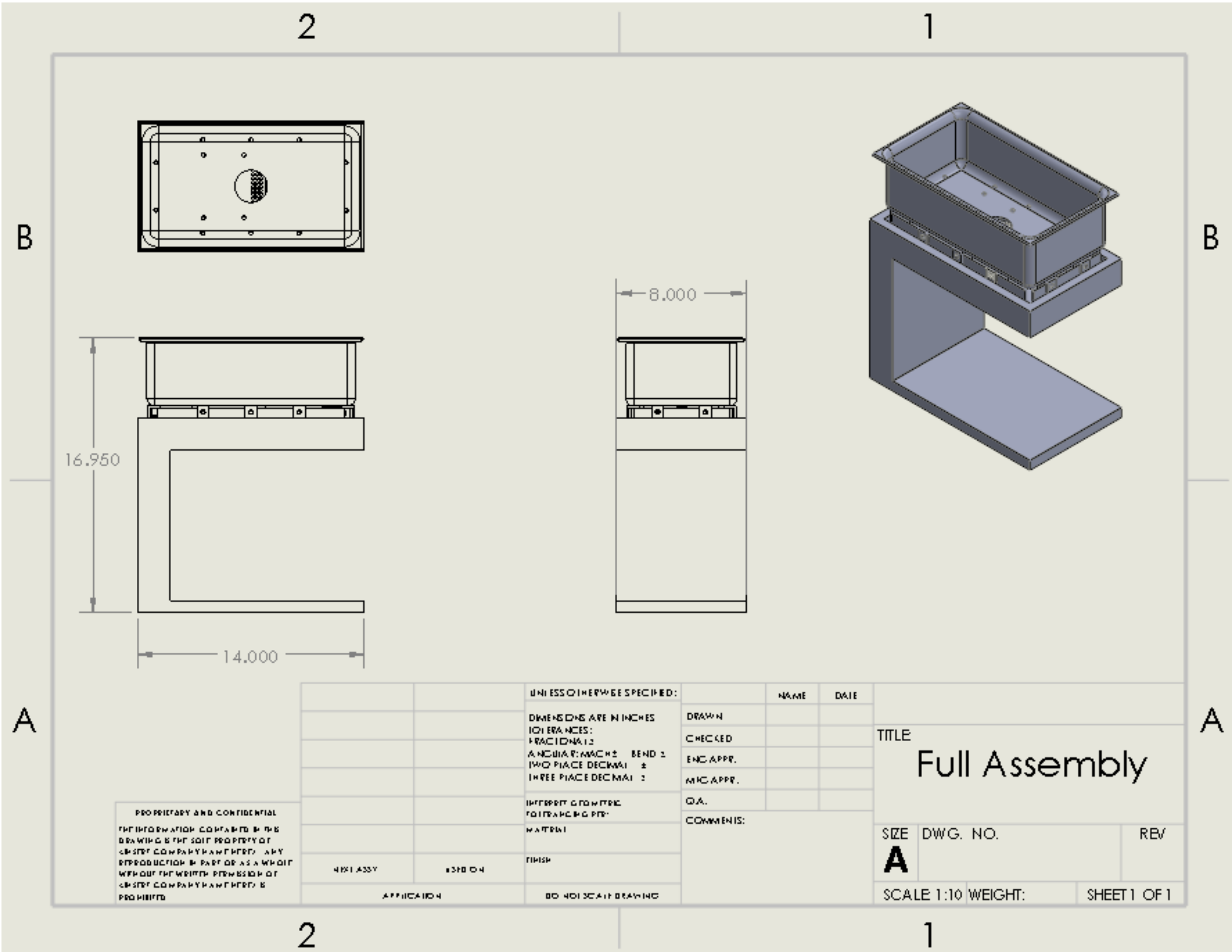


Figure 17: Full Assembly

CAD Drawings for each fabricated part may be referenced in Appendix B.

5 ENGINEERING ANALYSIS

5.1 ENGINEERING ANALYSIS RESULTS

5.1.1 Motivation

The two main standards used in the design process of the Dry Ingredient Dispenser are NSF/ANSI Manual Food and Beverage Dispensing Equipment and NSF/ANSI 8-2012 Commercial Powered Food Preparation Equipment. The standards outline the minimum food protection and sanitation requirements for the materials, design, construction and performance of manual and commercial powered food equipment. The requirements for internal angles and corners in the food zone were taken into consideration when we purchased the bin. For instance, any edge less than 135 degrees is required to be smooth, or having a radius of at least 0.125 inches. The information contained in the standards resulted in our purchasing a food-grade, polyester plastic container that met the criteria. Because of the smooth edges on the bin, we are not concerned with the stresses in the food zone due to the weight of the ingredient.

However, the wooden dispensing base will sustain a load of a 5-lb bag of flour, so a stress analysis will be performed to ensure it does not tip and the stress does not concentrate too much at the corners. A stress analysis will also be performed using SolidWorks on the grate itself. We hope to obtain a result that confirms our design will succeed; however, poor stress results may require us to change the design entirely.

5.1.2 Summary Statement of the Analysis

The engineering analysis performed on the Dry Ingredient dispenser consisted mainly of a SolidWorks Von Mises stress analysis on the grate and determination of the force required from the actuator to move it against the opposing spring force for the springs we chose. A SolidWorks analysis was also performed to determine if the forces and moments put on the dispensing base may cause it to sag or to tip, or cause concentrations of stresses to form in the corners.

5.1.3 Methodology

To carry out the Grate analysis, an assembly was created with just one of the short mounting rails and the grate, and a simulated spring was placed between two parallel faces of spring constant 2.71 lbs./inch. A simulated force of 5 lbs. (the maximum possible produced by the actuator) was placed on the other end of the grate closer to the dispensing holes. The material was set as 5086 Aluminum. A Von Mises stress analysis was performed as well as an animation to determine how well the force compressed the spring. To analyze the stress on the dispensing base, a distributed force of 5 lbs. was placed at the top where the plastic bin would sit and the bottom piece of wood was fixed in place. A Von Mises stress analysis was performed and an animation also played.

5.1.4 Results

The results of the Grate analysis indicated the only increased values of Von Mises stress occurred around the small dispensing holes and not on the actual grate. The maximum stress value as shown is about 1.27×10^7 N/m^2, not large enough to be concerning for easy-to-form marine-grade aluminum. A screenshot of the stress results is shown below.

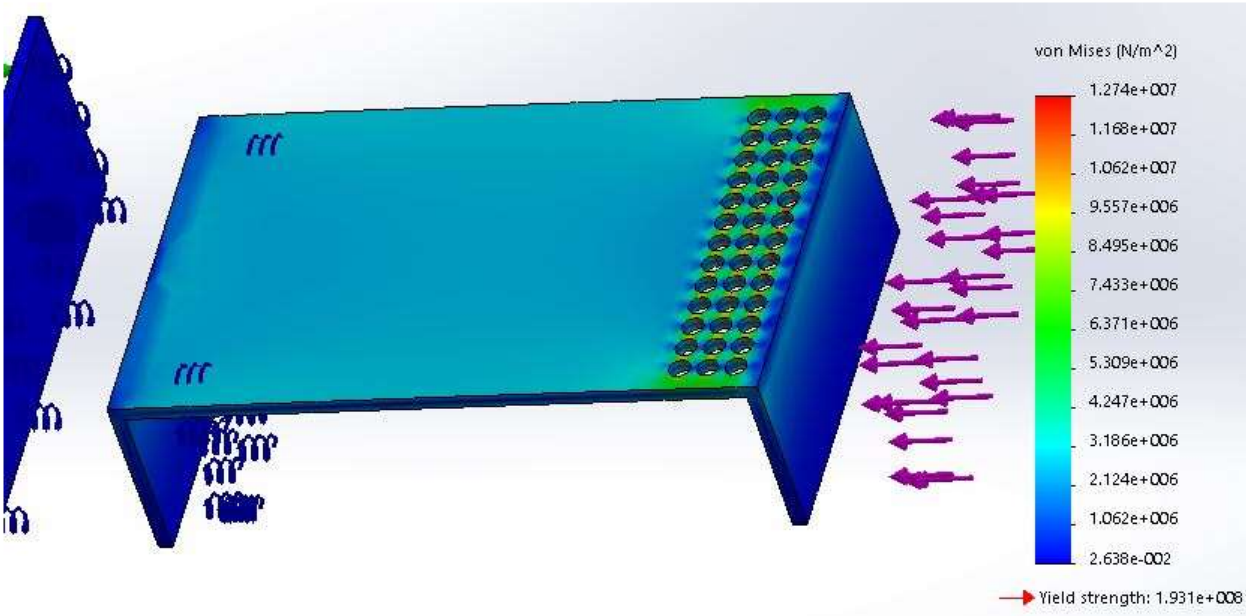


Figure 18: Grate Analysis

The results of the stress analysis performed on the dispensing base indicate that the maximum Von Mises stress occurs along the bottom of the unit as well as at some of the corners. The maximum stress was found to be $1.5x10^5$ N/m^2. However, due to the stiffness of the wood we are using for the base, we do not expect considerable sag due to the 5 lb. bag of flour. The stress map is shown in Fig. 2.

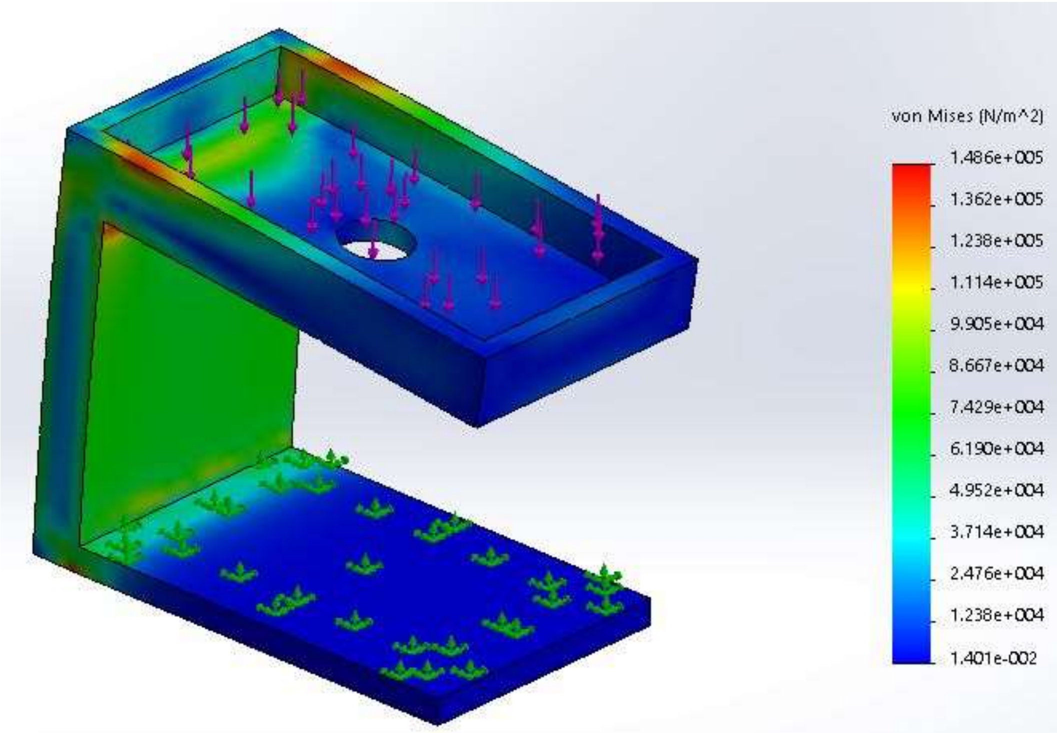


Figure 19: Dispensing Base Analysis

5.1.5 Significance

The result of the Grate analysis may cause us to change the dispensing holes into dispensing rails, so that there will be more surface area of hole and more surface area between rails, reducing the stress concentration in that area while also aiding in dispensing of the flour. The results of the Grate analysis also confirmed to us that we selected the correct Actuonix Linear Actuator, with 22 N (5 lb.) maximum force capability, for the spring chosen.

The only part which was changed following the stress analysis was the base of the unit. The very bottom of the dispensing base was originally 10 inches long from the end of the back side. However, when we took into account the weight in the food zone, we increased the length to 12 inches to further avoid tipping.

5.2 PRODUCT RISK ASSESSMENT

5.2.1 Risk Identification

Risk Name: Finger Caught

Description: Having a spring, actuator, and aluminum grate system presents the risk of someone getting their fingers caught. If someone puts their fingers in the hole trying to clear a clog or speed up the rate of dispensing while the device is running, they could injure their finger. This has a better likelihood of occurring if our device is not working properly; however, most people will have enough common sense not to reach into the device while it has power. Since most devices have a similar safety issue, it is not catastrophic if it occurs.

Impact: 3

Likelihood: 2

Risk Name: The device falling off the counter and hitting a person

Description: Tipping of the device falls into this category. Similar to Ikea furniture, there is always a risk of tipping associated with having a top-heavy unit. For safety purposes, the device can likely be attached to the backsplash. Since it is unlikely that most people will do this, the risk is mainly that the unit can be pulled off the countertop by its cords by a small child or an adult by accident. This is still unlikely, since it is meant to be tucked away underneath the cabinets, but is a liability issue, so it is assigned an impact of three.

Impact: 3

Likelihood: 2

Risk Name: Electrical Fire

Description: Because the Dry Ingredient dispenser consists of several different electrical components including an Arduino, actuator, and load cell, and is made of flammable wood, there is a risk of fire associated with the device. This would most likely occur from a spark produced by the electrical outlet that it’s plugged into, so is rare, but would be catastrophic for the unit.

Impact: 5

Likelihood: 1

Risk Name: Ingredient Contamination

Description: Because of the ingredient’s exposure to the aluminum grate and holes which may be exposed to fasteners, there is a possibility for the ingredient to be contaminated. Oil and dust may get into the system such that regular cleaning of the bin is encouraged. Since the standard outlines that no fasteners are allowed in the food zone, steps will be taken to ensure the fasteners are adequately covered. This is a more likely event because of the grate’s proximity, and would have a large impact because it is a sanitization issue, directly conflicting with the NSF/ANSI manual food dispensing equipment standard.

Impact: 4

Likelihood: 3

Risk Name: Structural Failure

Description: Structural failure may occur if the wooden 2x4 boards we use are not structurally sound or if the dispensing base falls over or buckles when the weight of the flour is placed into the bin. This is not likely to happen since we are screwing two 2x4s to the bottom piece for extra support. If the top of the dispensing base cracks or sags too much, we would need to introduce more support possibly with two more wooden posts at the front end. If structural failure occurs, it will be catastrophic for obvious reasons.

Impact: 5

Likelihood: 2

Risk Name: Spillage

Description: Spillage of ingredients is a more likely but very mild risk associated with the device. The point of the automated Dry Ingredient Dispenser is to reduce clean up, so we are doing our best to minimize any spillage during the process. However, we are expecting some spillage, especially over several uses. This may also depend on how carefully the user uses the device. If it is banged around, it is likely components within the device will shift and cause more spillage.

Impact: 1

Likelihood: 5

5.2.2 Risk Heat Map

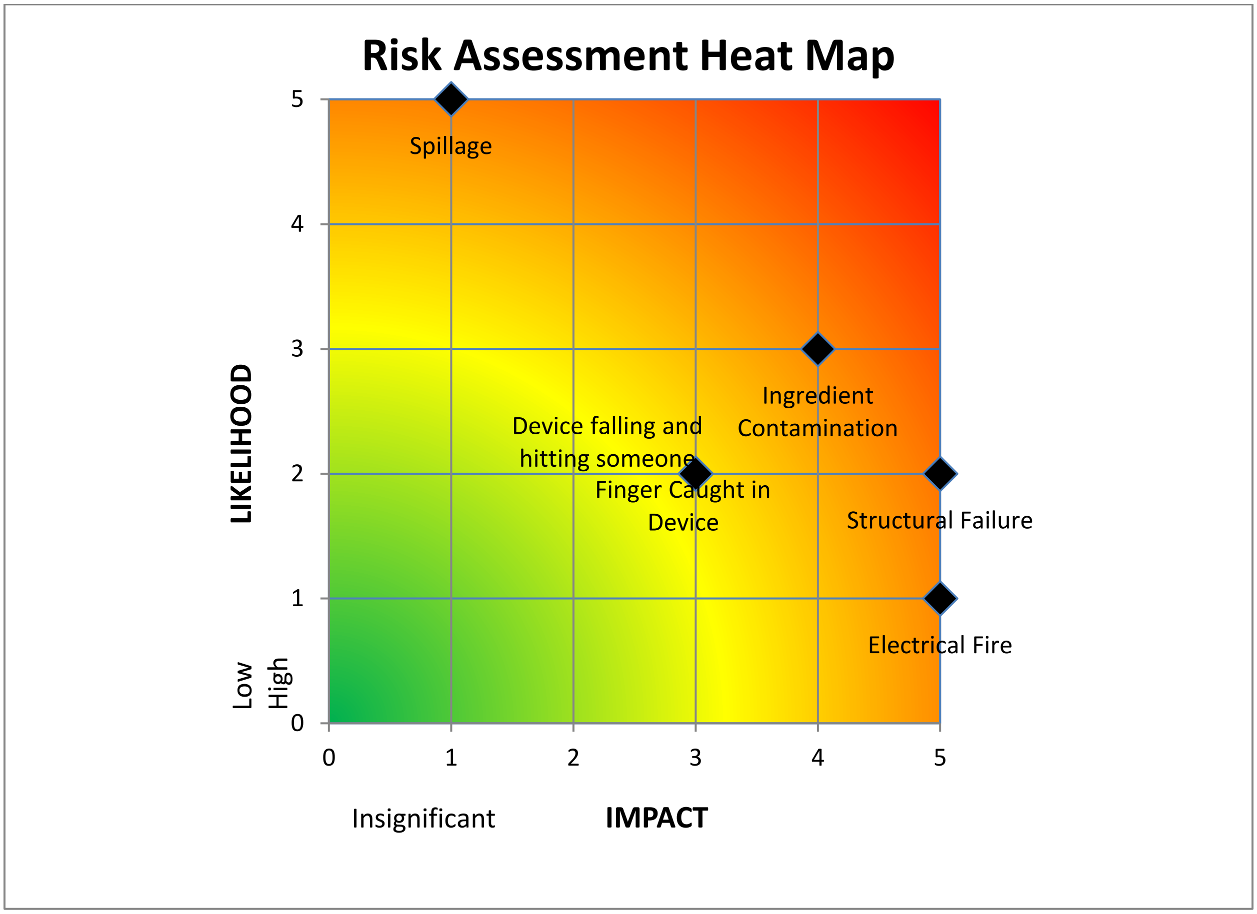


Figure 20: Risk Assessment

5.2.3 Risk Prioritization

According to the heat map generated, ingredient contamination, spillage, structural failure, and electrical fire fall into the orange and are the risks we should prioritize. Electrical fire is something we cannot completely control, unless we find a way to fireproof the device by using a non-flammable material, especially if we were to develop a more advanced prototype down the road. Since structural failure is not as likely to occur if the device is used properly, it does not need to be prioritized as much as ingredient contamination and spillage.

6 DESIGN DOCUMENTATION

6.1 PERFORMANCE GOALS

- It will dispense the amount of ingredient to 10-20 grams degree of accuracy.
- It will convert between unit systems within 1 percent of accuracy.
- It takes less than 15 seconds to interchange bins.
- It fits on a typical countertop under a cabinet: less than 18 inches tall, less than 24 inches wide, and less than 12 inches deep.
- It completes the dispense cycle within 1 minute from when "start" is pressed.

6.2 WORKING PROTOTYPE DEMONSTRATION

6.2.1 Performance Evaluation

We were not able to meet all of our five performance goals. We met three of them and part of a fourth. Our device was not always accurate and it was difficult to test for accuracy, because the dispense cycle took much longer than 1 minute to complete. It took several minutes to get just a little bit of flour, because we did not have enough vibration or agitation to get the flour to come out quickly. When we did test it, it was not within 10-20 grams degree of accuracy, but more around 40 grams off. However, it does convert between unit systems in the code, it takes 8 seconds to interchange the bin, and we met the volume requirement for the unit itself. The depth was a bit longer than 12 inches but overall it would fit well in or under a standard cabinet.

6.2.2 Working Prototype – Video Link

https://www.youtube.com/watch?v=-opSTAzo4mA&t=3s

6.2.3 Working Prototype – Additional Photos

Figure 21: Additional Prototype Photos

7 DISCUSSION

7.1 DESIGN FOR MANUFACTURING – PART REDESIGN FOR INJECTION MOLDING

7.1.1 Draft Analysis Results

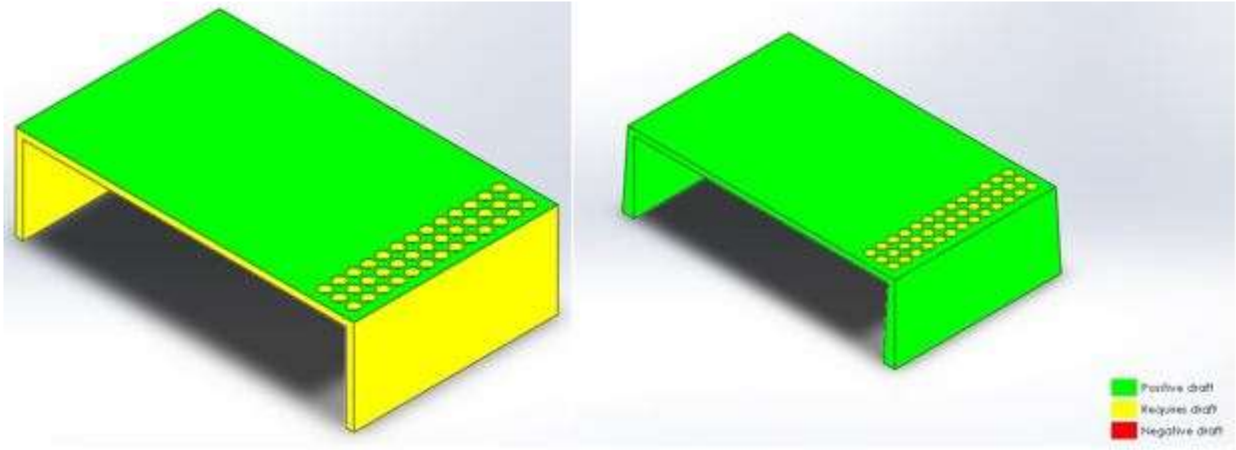


Figure 22: Draft Analysis Results

7.1.2 Explanation of Design Changes

The Grate was chosen for the draft analysis because it is a rather simple part that, if this device were to be mass produced, would be injected molded. A 2 degree draft was chosen. The top face of the Grate was chosen to be the face that was pulled from. This was because it allowed for minimal changes to the part for the 2 degree draft to be implemented. Then each vertical face from that pulling reference was made to have 2 degrees of draft.

7.2 DESIGN FOR USABILITY – EFFECT OF IMPAIRMENTS ON USABILITY

7.2.1 Vision

The use of colors is not of the upmost importance in using the Dry Ingredient Dispenser. There will be no colors involved in obtaining user input to allow for usability by color-blind people. However, a lack of vision will be problematic as the input cannot be done by voice-command.

7.2.2 Hearing

Hearing plays no role in using our device, despite listening for when the device is finished dispensing. However, this can be done by sight. Someone with no hearing ability can use the device to its full capacity.

7.2.3 Physical

A steady hand may be beneficial to our device for inputting the information, and for general baking purposes. However, arthritis won’t negatively impact the use of our device as completely steady hands aren’t necessary. A person who has no limbs will be unable to use the device without assistance.

7.2.4 Language

A non-English speaker would have trouble inputting values into the device, as they are only in English. However, our Dry Ingredient Dispenser could be coded to have multiple languages available for the instructions and prompting for user input.

7.2 OVERALL EXPERIENCE

7.2.1 Does your final project result align with the initial project description?

We accomplished the overarching concept in our initial project description. Our device fits the volume requirement we set and converts between unit systems. It dispenses ingredients and stops when a requested value is reached. The only objectives we didn't reach consistently are the accuracy as well as the user-friendly interface. Constraints due to time and money prevented us from finding a viable solution to both of these problems.

7.2.2 Was the project more or less difficult than you had expected?

The project was much more difficult than originally expected. Although we found certain ways to do things easier, such as using the load cell instead of the scale, we did run into a lot of problems throughout the project. These included getting the grate to seal against the bin and prevent leakage, finding time to get into the machine shop to machine all of our parts, and getting the code to handle processing the Linear Actuator and the load cell simultaneously.

7.2.3 In what ways do you wish your final prototype would have performed better?

We had hoped that the ingredient would dispense much faster. It took several minutes to get enough flour so we did not meet that performance goal. We also hoped that the grate would hold a better seal against the bin. We tried to remedy that several different ways but still had some leaking when using more dense ingredients, like sugar.

7.2.4 Was your group missing any critical information when you evaluated concepts?

We definitely overestimated when coming up with our performance goals. We believed we could achieve a level of accuracy comparable to an industrial scale dry ingredient dispenser, about 5 grams of accuracy. Because we were using cheaper parts and did not have a lot of coding knowledge, we should have given more room for error.

7.2.5 Were there additional engineering analyses that could have helped guide your design?

Additional analysis on the flow rate of the different ingredients could have helped our design. If we could have tested the amount of agitation needed to keep ingredients flowing or the amount per unit area of exposure that would fall, we could have had a better idea on the hole size and the grate hole size.

7.2.6 How did you identify your most relevant codes and standards and how they influence revision of the design?

Lauren Todd helped us find the standards that best applied to our project: manual food dispensing equipment and commercial powered food dispensing equipment. These standards caused us to keep sanitation in mind and to purchase food-grade plastic for the components that would be in contact with the food.

7.2.7 What ethical considerations (from the Engineering Ethics and Design for Environment seminar) are relevant to your device? How could these considerations be addressed?

The main environment ethics considerations for our device is material. For our prototype we were able to use mainly environmental friendlier material like wood. However if a device were to be manufactured it would be made out of plastic. If this device was made out of a recyclable plastic that would help keep its environmental impact to a minimum.

7.2.8 On which part(s) of the design process should your group have spent more time? Which parts required less time?

If we were to start this design process over we would most likely spend more time working on the material selection and dimensioning. When we ordered the material the first time we discovered it was not capable of a few things that we had planned (i.e. the stock aluminum was too thick to bend in our machine shop). Also some of the dimensions were not aligned correctly between components that seemed obvious after we started the building part of our project. If we has spent more time on these aspects before we started building the building process could have went much smoother. Also relating to the material selection would be the selection of our micro controller. We found out after starting the coding that our original selection of using a Raspberry Pi micro controller did not supply enough voltage through its pins to control the linear actuator. Therefore we had to switch to an Arduino and a new coding language part way through our building process that also increased the difficulty of our project.

7.2.9 Was there a task on your Gantt chart that was much harder than expected? Were there any that were much easier?

Testing the code was much harder than expected. We discovered only after testing code on the Raspberry Pi that we had to change microcontrollers completely, to get enough digital output voltage to move the actuator. Then after changing to an Arduino, the python GUI had to be scratched entirely and we had to figure out user input in C instead of Python, which we already had some experience in. It was also difficult to get the processor to handle both the actuator and the load cell simultaneously. Machining our parts also took much longer than expected, especially because of the limited machine shop hours in the final week of building the prototype. Once we had all of our parts, assembling the prototype was easier than expected.

7.2.10 Was there a component of your prototype that was significantly easier or harder to make/assemble than you expected?

Once component of our prototype that was much harder to build than expected was the grate. As stated before, the aluminum stock ordered was not bendable with the machinery we had at our disposal and so we had to improvise. We tried to attach the grate together using threaded L brackets but were unsuccessful because of space constraints in our design. We then tried epoxy and found that to be unsuccessful as well. We were able 3-D print a great but could not get the 3-D printed grate to print flat and not curl. This caused the seal of our grate against the ingredient bin to less than ideal. If we could start over we would order thinner aluminum and bend it which would allow the grate to be straight and have less machining.

7.2.11 If your budget were increased to 10x its original amount, would your approach have changed? If so, in what specific ways?

If our budget was 10x bigger we would have considered actually injecting molding our design. If a mold was within budget we could then have injected molded our entire dispensing base and a more ideally shaped ingredient bin. This would allowed us to simply fit components in rather than machining components to all fit together. Another thing we could have looked into would be a user input device. If we had a bigger budget we could have looked into a touch screen GUI that could have controlled the micro controller and avoided the pc to micro controller connection we needed for our prototype.

7.2.12 If you were able to take the course again with the same project and group, what would you have done differently the second time around?

We would have spent more time on the initial designing phases so that when build time came the project would have went smoother. We would have consulted the machine shop more in order to know what capabilities we had before ordering material and assuming our capabilities.

7.2.13 Were your team member's skills complementary?

Our skills were very complementary. Noelle had a little more programming background while Nick had more machining and CAD experience. We called Noelle the "software engineer" and Nick the "structural engineer." We could have benefitted greatly from a third team member with experience in either of these things but we did the best we could with a team of two.

7.2.14 Was any needed skill missing from the group?

The extensive coding experience needed for the project was not there. We had to teach ourselves how to program the Arduino properly along the way. Given more experience, the coding could have been done in a day; however, the process involved trial and error several times. Tutorials found online also helped to determine wiring and when we wrote the actual code.

7.2.15 Has the project enhanced your design skills?

This project has enhanced our design skills. Mainly by showing us to think of the capabilities that are at our disposal and not just the capabilities that we think we have or think are common.

7.2.16 Would you now feel more comfortable accepting a design project assignment at a job?

We believe that we do have a better idea of what a design project job would entail. This allows us to feel more comfortable accepting a position related to design.

7.2.17 Are there projects you would attempt now that you would not have attempted before?

We do feel more apt to try DIY projects at home that seem complicated. It has shown us that it is fun to "tinker" and projects can be rewarding and fun.

8 APPENDIX A - PARTS LIST

Table 5: Final Parts List

	Part	Source Link	Supplier Part Number	Color, TPI, other part IDs	Unit price	Tax ($0.00 if tax exemption applied)	Shipping	Quantity	Total price
1	Food-Grade Plastic Storage Container	McMaster	6686T64		$12.28	$0.00	$7.82	1	$20.10
2	Food-Grade Plastic Storage Container Lid	McMaster	6686T53		$6.72	$0.00	$0.00	1	$6.72
3	Aluminum Stock	McMaster	5865T73	4"x24"	$10.38	$0.00	$0.00	2	$20.76
4	Springs	McMaster	9657K419		$6.36	$0.00	$0.00	1	$6.36
5	New springs	McMaster	9657K414		$6.12	$0.00	$5.77	1	$11.89
6	Load cell with HX711	Amazon	B075317R45		$12.99	$0.00	$0.00	1	$12.99
7	Pi Cables	Amazon	B01GK2Q4ZQ		$6.59	$0.00	$0.00	1	$6.59
8	Breadboard	Amazon	B0135IQ0ZC		$5.69	$0.00	$0.00	1	$5.69
9	Screws, Spacers, and wood	Home Depot			$12.31	$1.24	$0.00	1	$13.55
10	Linear Actuator	Actuonix	L-12I		$90.00	$0.00	$19.66	1	$109.66
12	Linear Actuator Power Supply	Actuonix	DCPOWERSUPPLY		$10.00	$0.00	$19.71	1	$29.71
13	Screws, Epoxy	Home Depot			$8.59	$0.87	$0.00	1	$9.46
14	Electrical Components	Micro Center			$4.97	$0.50	$0.00	1	$5.47
15	Steel Rod	McMaster	89905K12		$4.85	$0.00	$6.19	1	$11.04
16	Second Load Cell with HX711	Amazon			$8.90	$0.00	$8.99	1	$17.89
Total:									**$287.88**

9 APPENDIX B - CAD MODELS

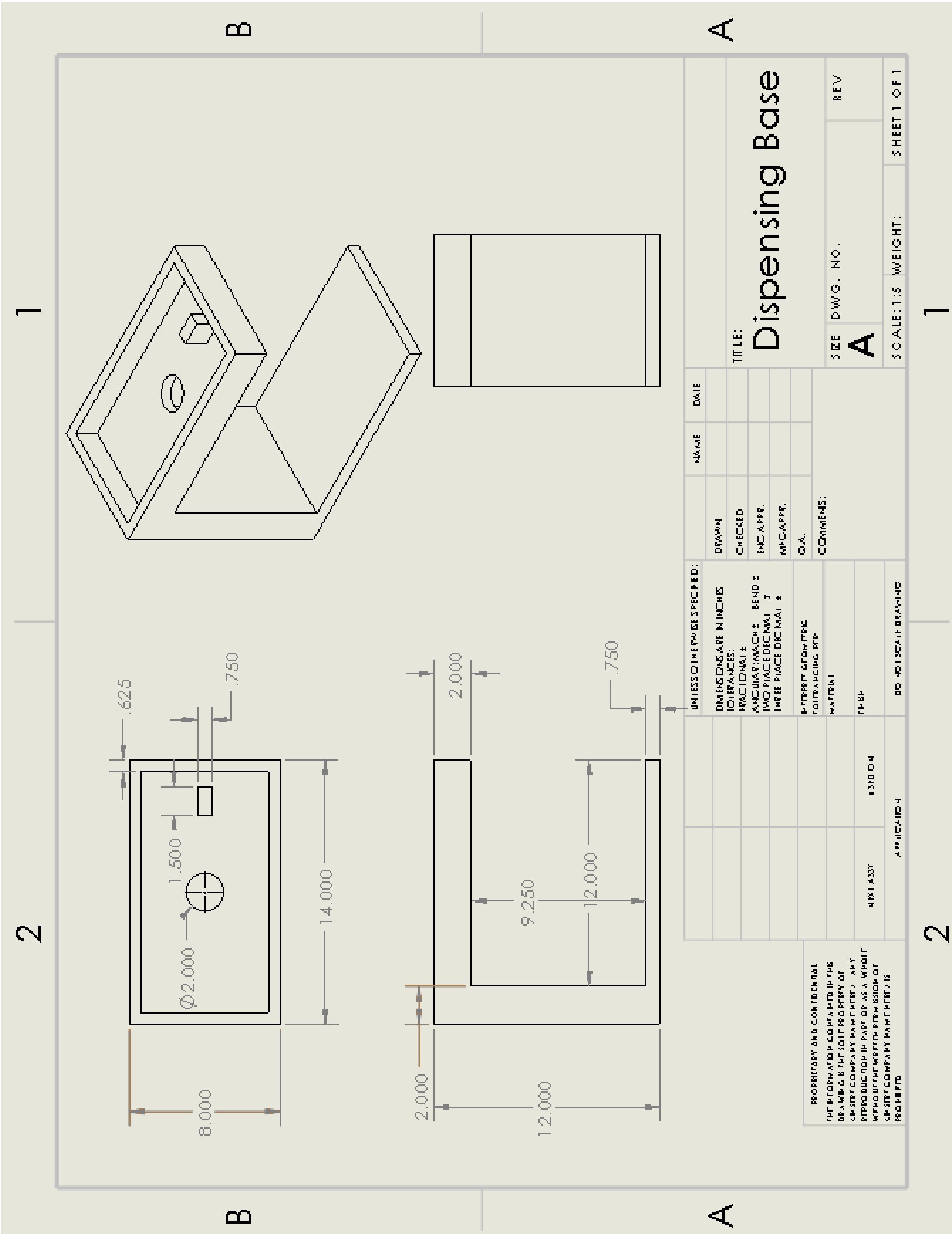


Figure 23: Dispensing Base

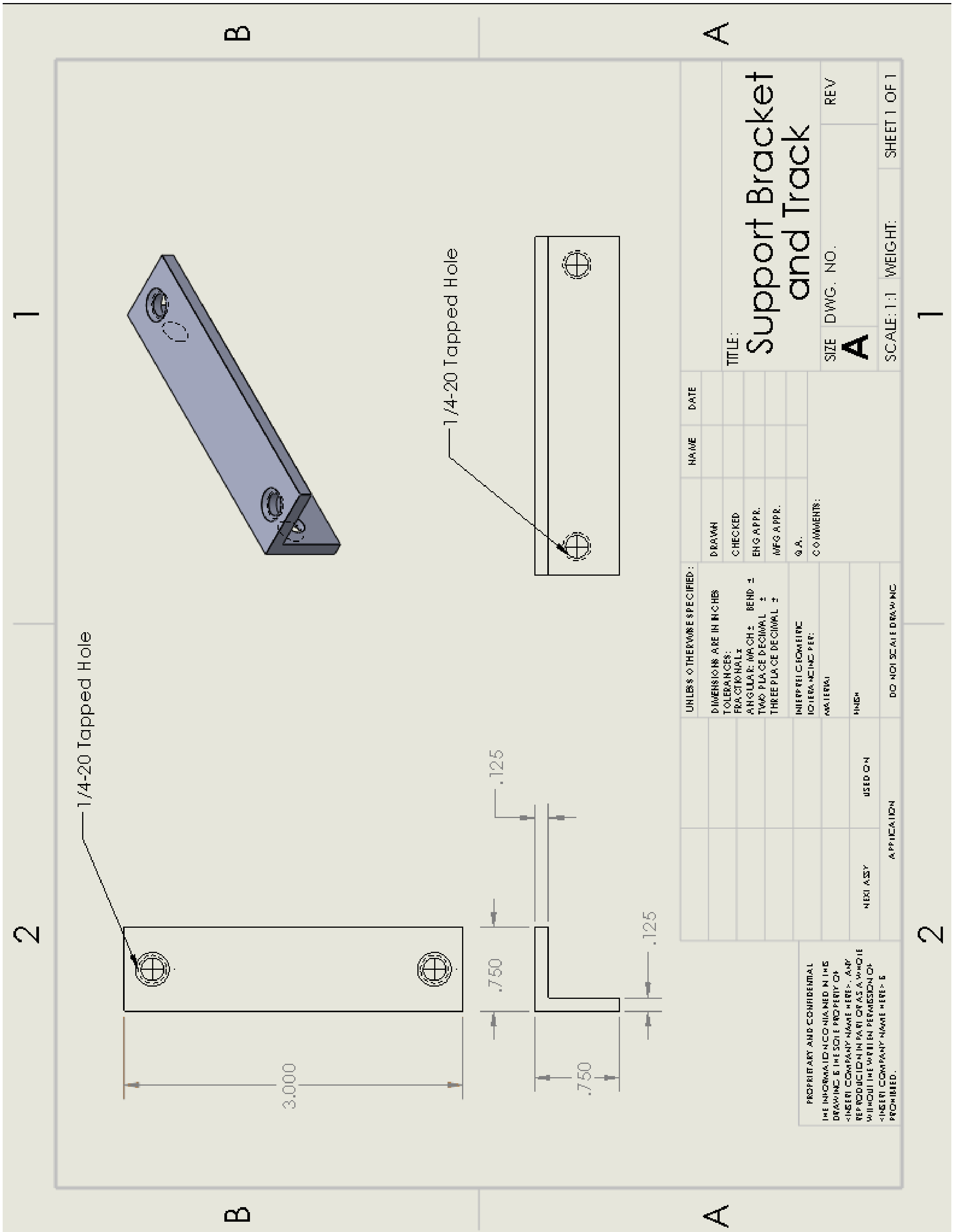


Figure 24: Support Bracket and Track

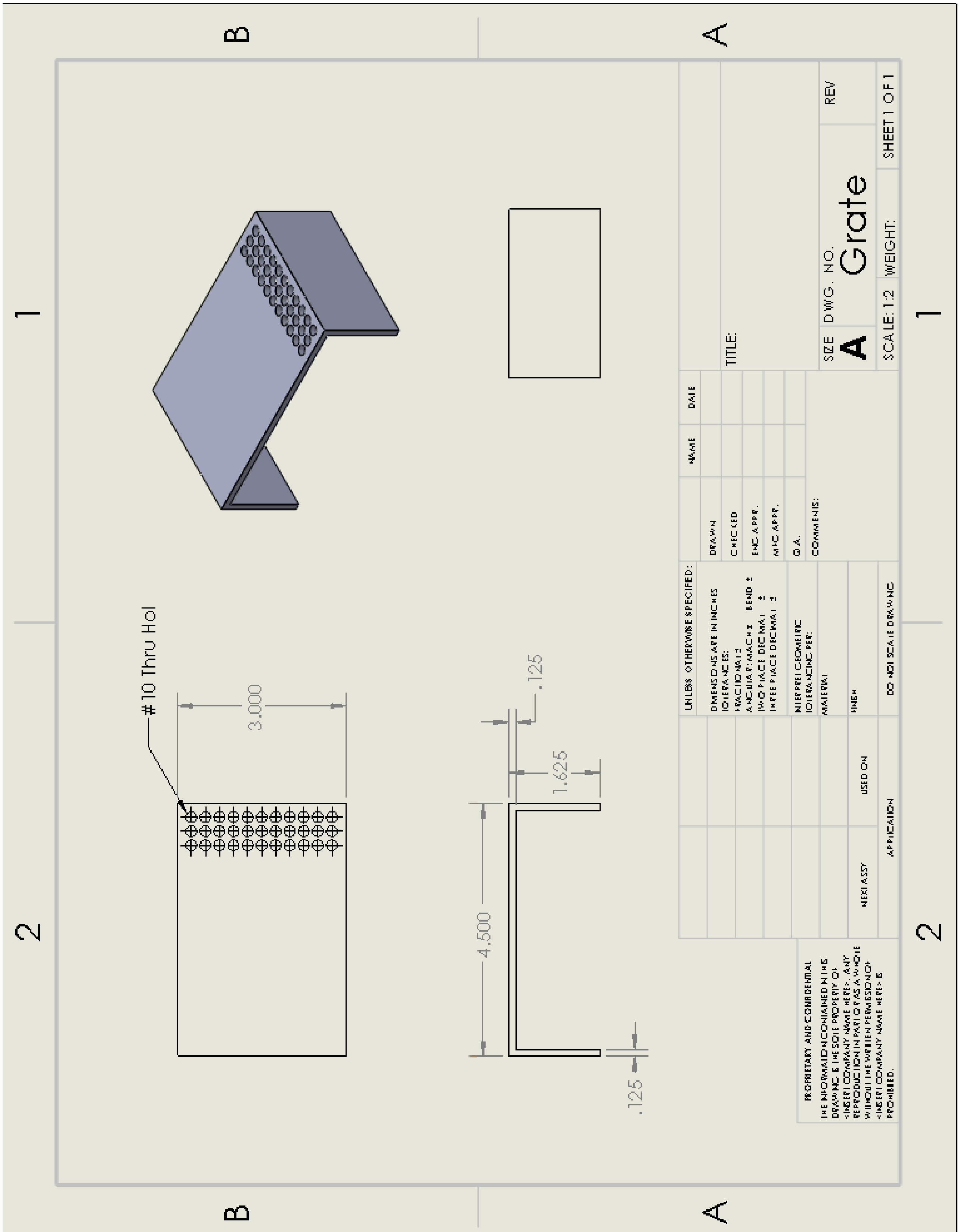


Figure 25: Grate

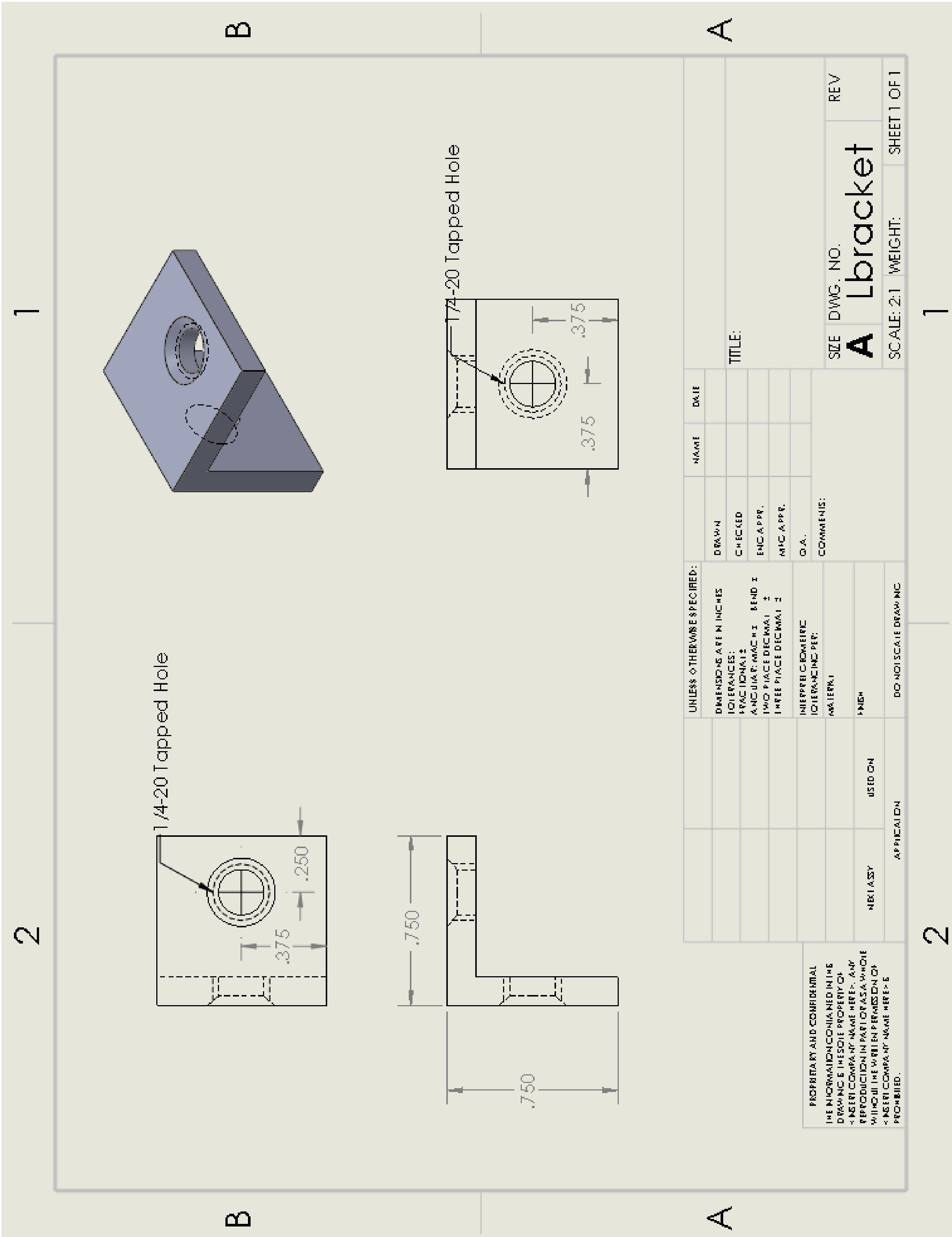


Figure 26: L Bracket

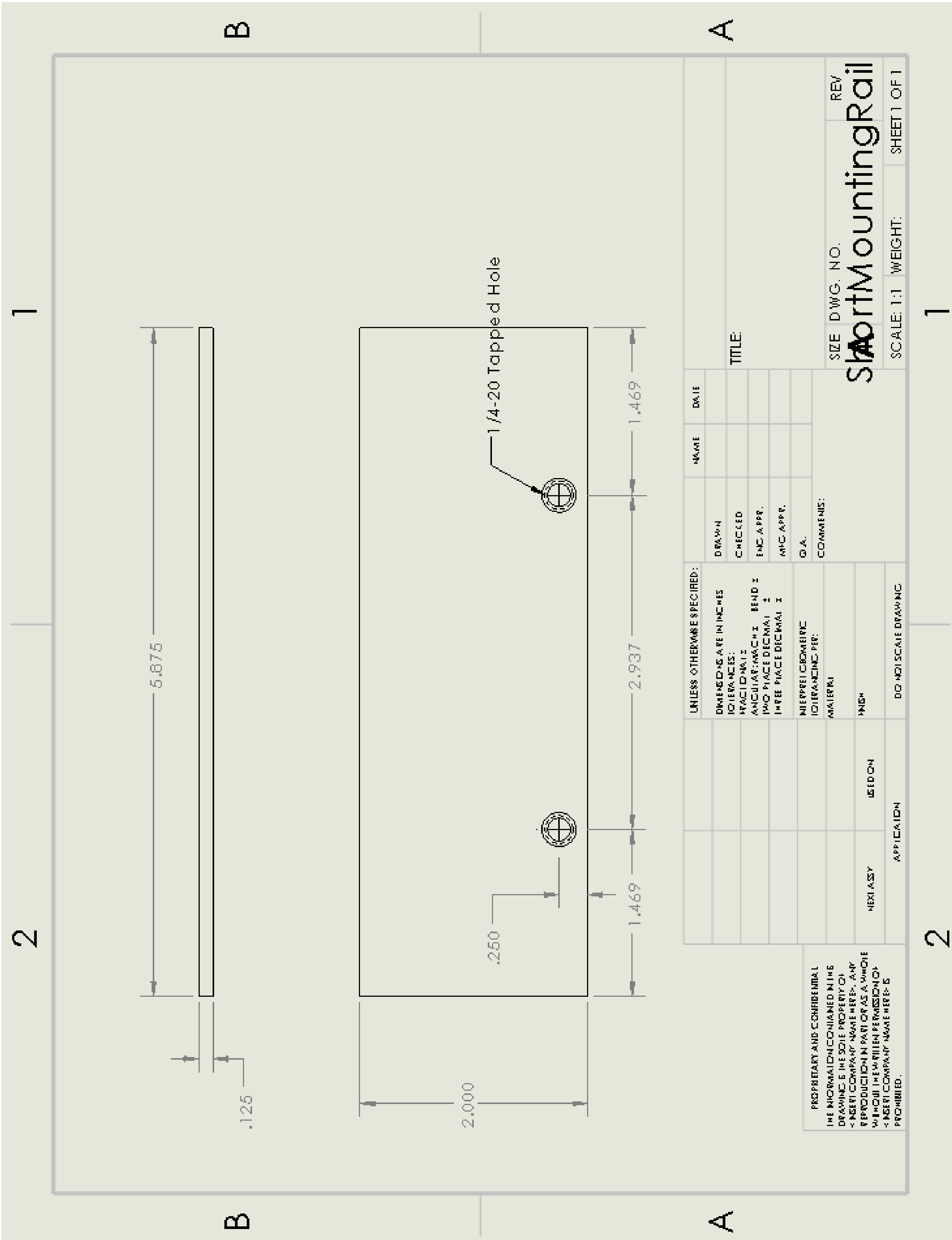


Figure 27: Short Mountng Rail

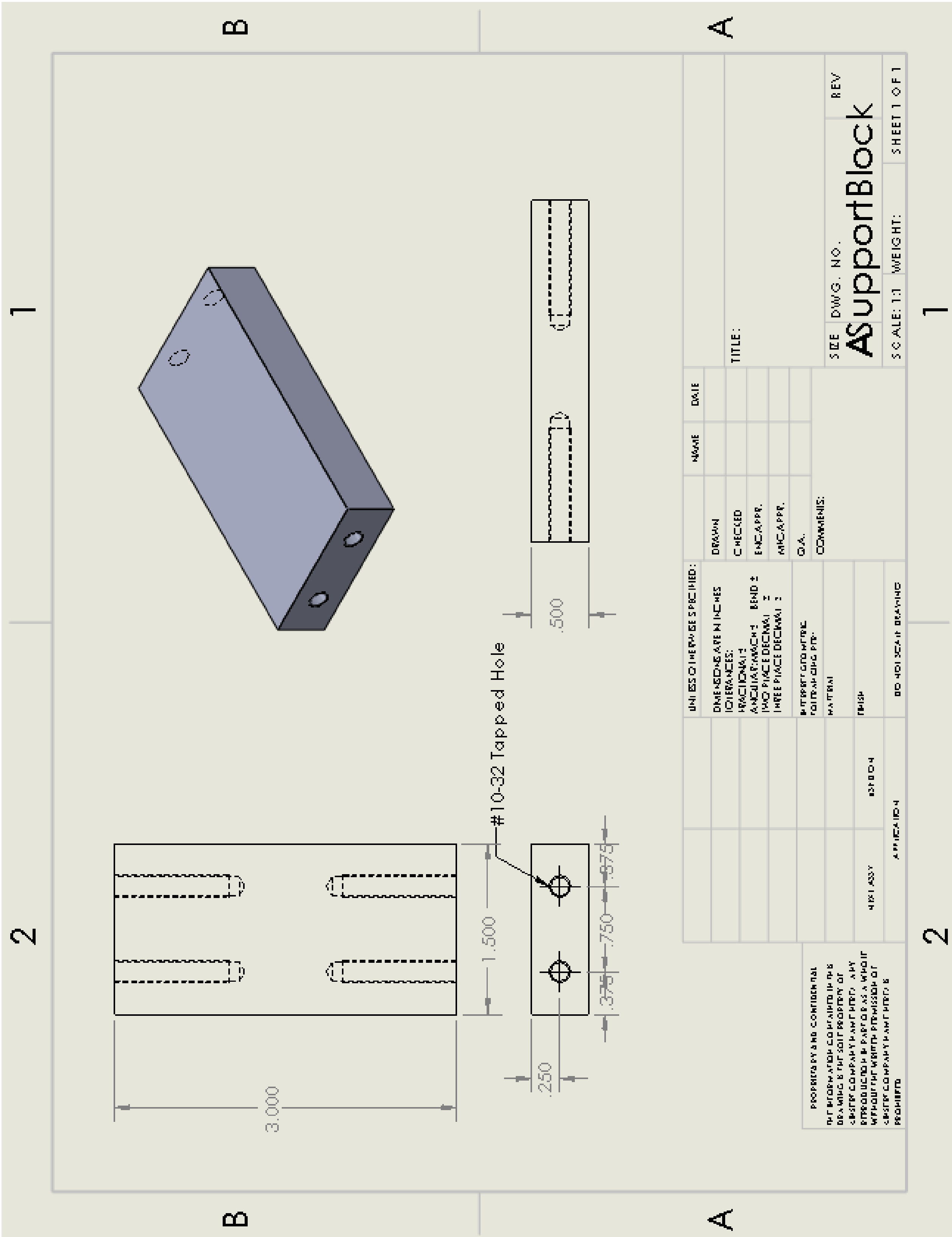


Figure 28: Support Block

10 ANNOTATED BIBLIOGRAPHY

[1] http://www.noisehelp.com/noise-level-chart.html

[2] NSF/ANS Commercial Powered Food Preparation Equipment, 8-2012: Section 5.3 "External Corners"

[3] NSF/ANS Manual Food and Beverage Dispensing Equipment, 18-2012: Section 5.12.1 "Covers"