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WeighstEd

Vince Heyman

Tatianna Schluep

Timothy Jaworski

SANTA CLARA UNIVERSITY

Department of Mechanical Engineering

I HEREBY RECOMMEND THAT THE THESIS PREPARED
UNDER MY SUPERVISION BY

Vince Heyman, Tatianna Schluep, Timothy Jaworski

ENTITLED:

WeighstEd

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Department Chair:	Dr. Drazen Fabris	6/13/19 date

WeighstEd

By

Vince Heyman, Tatianna Schluep, Timothy Jaworski

SENIOR DESIGN PROJECT REPORT

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Abstract

The purpose of this design thesis is to outline and describe the design project; WeighstEd. *WeighstEd,* is a data collection, storage, and analysis system for food waste to help Santa Clara University's Sustainability Center reach a quantifiable food waste reduction goal of 10% by 2020 by using data to make informed cafeteria changes. The report will outline the entire engineering design process from ideation to manufacture including analysis techniques and benchmark testing. This report will serve as a written documentation of three mechanical engineers Senior Design Project completed at Santa Clara University. WeighstEd will be implemented at on campus events and in the university cafeteria beginning in the 2019-2020 school year.

Acknowledgements

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Chapter 1

INTRODUCTION

Our planet has finite resources and as one of the many inhabitants of this planet it is our responsibility not to deplete them. Although the consumption of many of these resources are necessary for human survival and wellbeing, much of the resources we extract from the environment goes to waste. This is especially true in regards to food waste.

In the United States, 40% of all food goes to waste.[1] This amounts to seventy-million tons of food wasted and two-hundred and twenty billion dollars spent on food that is never eaten[2]. Wasted food translates to wasted resources. In a 2017 report, The Natural Resources Defense Council disclosed that 2.6% of greenhouse gas emissions, 21% of freshwater and 18% of cropland in the United States was used to grow wasted food.[3] Individuals and organizations around the globe can come together in order to solve this complex issue. One such organization that has made a commitment to reducing food waste is Santa Clara University.

Figure 1. Resource depiction

Background

Santa Clara University has enacted a comprehensive food waste reduction goal of 10% by 2020 and needs to collect data on a quarterly basis in order to track and analyze progress and execute new policy to reduce food waste. Sustainability SCU currently estimates food waste on campus by having volunteers manually record food waste data over four days for 3 hours each day. They extrapolate this data to make generalizations about the *entire* quarter. The volunteers count how many people use the compost bin over this time, weigh the bin, and divide weight by people to find the average amount of waste that is collected. The volunteers also ask questions regarding why people did not finish their meal. Tables of data collected during the spring quarter of 2018, which demonstrates this process, can be found in the customer needs section. These tables highlight the inefficiency, lack of valuable information and lack of volume needed for consistent,

[1] Gustavsson, Jenny, et al. "Global Food Losses and Food Waste." *Food and Agricultural Organization of the United Nations*, United Nations, 2011, www.fao.org/3/mb060e/mb060e.pdf.
[2] ibid.
[3] Gunders, Dana. "Wasted: How America Is Losing Up to 40 Percent of Its Food from Farm to Fork to Landfill ." *NRDC*, 2012, Wasted: How America Is Losing Up to 40 Percent of Its Food from Farm to Fork to Landfill .

useful data. This process required many student volunteers and meticulous data entry, yet still produced unreliable and inconsistent data.

Motivation of Subject Matter

Santa Clara University has stated that it wants to reduce food waste on campus by 10% by 2020. One method of addressing this problem is by systematically determining portion sizes for meals so that the average food waste per meal (lbs. /meal) reaches a target level. Our senior design team's goal is to design a machine that will gain information needed to determine food waste reduction initiatives based on portion sizes and other methods.

The current method that SCU uses, although functional, has ample room for improvement. First, the current method involves a high level of man hours to collect a relatively small amount of data. Last quarter, data was collected over 12.5 hours, in which two volunteers were needed each hour to be stationed at the main dish return and at the Bronco[4]. 25 hours of human labor were used for a process that can be fully automated. These are 25 volunteer hours that Sustainability SCU could put to other uses.

Second, the body of data is insufficiently large to make an accurate assessment of overarching trends in food waste at SCU. Data is collected for two lunches and two dinners. Analysis of the first lunch data showed that on average, 0.316 lbs. of food was wasted per person, while results of the second lunch showed that .50 lbs. of food was wasted per person. This is a 36% increase. The first dinner had 0.146 lbs. of food wasted on average per person while the second dinner had 0.219 lbs. of food wasted on average per person. This is a 33% increase. Sustainability SCU stated that the average food waste per person through the Spring quarter of 2018 was 0.22 pounds based on the data obtained through four meals during the quarter[5]. However, the wide variations in food waste over two meals suggests that the data is insufficient to accurately determine the average food wasted per person each quarter in order to create a quarterly trend line or be used to educate policy.

One aspect of the current method of collecting data that is successful is that volunteers ask why students do not eat a particular meal and are able to make qualitative observations on what meals were most wasted. They were able to identify that the Bistro special, the Bronco fries, and sides from La Parilla were more wasted than other items. The SCU Sustainability report gives a vague recommendation that Bon Appetit reassess the portion sizes but does not give quantitative suggestions using collected data. The current method does not categorize the food waste data by meal and does not set a target for average food waste per meal. Therefore the study cannot be

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[4] Eason, Amanda, and Henry Ferguson. *Scrape Your Plate Spring 2018 Results Log*. Santa Clara University, 2018, pp. 1–5, *Scrape Your Plate Spring 2018 Results Log*.

[5] Ibid.,

used to make a quantitative statement about how much each meal should be reduced. The current method for food waste analysis at SCU is a good start, but there is plenty of room for improvement in *accuracy, consistency, and efficiency* in regards to data collection.

Problem Statement

Santa Clara University has made a commitment to reducing food waste. However, there is no system in place for collecting data pertaining to the quantity of food wasted and what meals have the highest volume of waste. Thus, there is insufficient information to educate policy that may alleviate the issue of food waste at the university. The Sustainability Center is looking for an efficient method to collect, analyze, and monitor this valuable information.

Project Description, Objectives, and Goals

Aligning with the problem we had identified, we decided that our goals would be to weigh and collect food waste, to store and analyze the relevant meal data, and to educate students about food waste trends. These goals are quite broad but after exploring the needs of the Santa Clara University Sustainability Center and the needs of the end users, or the students who are going to be using the product we identified some constraints that guided the design. The main goal of our project then, was to fulfill the Sustainability Center's request for a product that can track the food waste per menu item as well as collecting individual meal data which can be used to find the average food waste trends in portable device that provides a fast, easy, and informative experience to the user without the need for a volunteer or staff member to supervise it while in use.

Review of Field

In order to benchmark our product and define the scope, research about the field of food waste analysis in schools was necessary. The research revealed a lack of product and an undeveloped field, although there were a few companies who are attempting to attack the problem. Food waste is an issue which, on its own, is popular in conversation amongst scholars, students, politicians and more. Alleviating and mitigating food waste is also a topic that has begun to receive some attention as a data collection issue. The company, ReFED has made it their mission to "provid[e] restaurants and food service providers with data on wasteful practices to inform behavioral and operational changes," but all they offer is trajectory data without the technology or methodology to collect data.[6]

Companies, namely restaurants and food service providers, are beginning to apply the adage "what is measured is managed" to food waste and there are a small number of businesses who have led short term programs to gather and track food waste data in universities and senior homes.[7] However, the most common form of data collection is done by "plac[ing] all food

[6] "Rethink Food Waste." *ReFED*, www.refed.com/solutions/waste-tracking-and-analytics.
[7] ibid.

trimmings into marked containers," a laborious and time consuming process.[8] This process does yield trackable, accurate food waste data but does so in a way that is slow, cumbersome, annoying to users, and requires many volunteer or worker hours to transport, weigh, and record the data. This process is no different than the current process used at Santa Clara University by the Sustainability Center. The Sustainability Center identified flaws in this process because they were unable to collect enough data, accurate data, and often did not have volunteers to work at all.

Figure 2. Food waste sorting process

One company, Leanpath, is on a "mission to make food waste prevention and measurement everyday practice in the world's kitchens."[9] They have created and implemented a semi-automated system for tracking food waste in *commercial* kitchens and they urge companies to take control of their waste.[10] With the combination of a tablet, proprietary software, a scale, and a camera, Leanpath integrates their food waste data collection system in the backend, requiring food service provider staff members to separate the food waste into categories and log the weights in 10-15 step deep menus that define the foot type, specific item, reason for waste, and much more. They do track food waste data and offer instant feedback about waste weights.

[8] "Trim Trax." *Trim Trax - Sustainability - Stony Brook University*, Application Support for Administration, www.stonybrook.edu/sustainability/green-map/details/trim-trax.shtml.
[9] "Leanpath Food Waste Prevention Technology and Solutions." *Prevent Food Waste with Leanpath Technology*, www.leanpath.com/.
[10]ibid.

Figure 3. Leanpath's semi-automated food waste tracking system

Even though businesses, namely Leanpath, are beginning to acknowledge the importance of tracking food waste data, the market still lacks a *consistent, convenient, and accurate* method for collecting, storing, and analyzing food waste data on college campuses with students specifically. There is no product made specifically for students who make up the largest wasting demographic in the nation.[11] Leanpath systems still require a sorting step before the data collection, a step that WeighstEd negates. This step requires staff members to sort and bin waste before Leanpath weighs, identifies, and takes pictures of the waste. Furthermore, Leanpath Zap, 360, and Online are platforms which require training to use because of the complex software and detailed tablet processes. The experience is not automated and the 360 model is not a standalone product, meaning it needs outside sources to operate and control.

Chapter 2

SYSTEM LEVEL

Customer Needs

Objective

The purpose of this section is to identify potential customers and their needs with respect to collecting food waste data at Santa Clara University. Information was collected through interviews and surveys. This information was analyzed to draw conclusions and form patterns in customer needs and user preferences.

[11] University of Illinois College of Agricultural, Consumer and Environmental Sciences. "Why are young adults wasting so much food? Study looks at perceptions and food behaviors." ScienceDaily. ScienceDaily, 22 August 2018. <www.sciencedaily.com/releases/2018/08/180822122832.htm>.

Current and Potential Users

Customer

Our primary customer and sponsor of our product is the Santa Clara University Center for Sustainability. However, the future target clients will include environmentally-minded organizations seeking to educate its members on food waste as well as any food providers seeking to optimize portion sizing in order to improve profit margins.

User

The user of our product differs from our customer. Although we will get contracted out by organizations such as Santa Clara University or Bon Appetit, it is the members of that organization or that company's clientele that must interact with the product. The user does not have a stake in the product and may not be interested in the information being collected. Therefore, it is imperative that the method of collecting information be low impact on the user or some incentive program be used.

Client Interview

The WeighstEd team has interviewed Lindsey Kalkbrenner, the director for the SCU Center of Sustainability. During the interview, she stated that one of the primary sustainability objectives of Santa Clara University was to cut down on food waste. Specifically, the university wants to reduce food waste by 10% by 2020 from 2018 levels. The Center for Sustainability wants a standalone device that would replace the current method of obtaining food waste data which involves volunteers who manually weigh and write down qualitative observations of the food wasted by individuals in Benson. This device must also be portable so that it may be used at tradeshows and school events and the data must automatically propagate a database.

Demographic Information on the Customers

SCU students are mainly between the ages of 18-22 and there are approximately an equal amount of male and female students. About 62 percent of undergraduates are from California, with the others coming from throughout the United States and 44 countries. Of these students a majority are white with a strong Hispanic and Asian presence. More than half (53 percent) of the undergraduate population live in University housing, with 90 percent of first-year students and 70 percent of sophomores living on campus.[12] Researchers at the University of Illinois found that "18- to 24-year-olds, especially college students, have a higher tendency to waste food," which fits the demographic at SCU.[13]

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[12] Data USA. "Santa Clara University." *Data USA*, datausa.io/profile/university/santa-clara-university/.

[13] University of Illinois College of Agricultural, Consumer and Environmental Sciences. "Why are young adults wasting so much food? Study looks at perceptions and food behaviors."

End User Questions

Our team has designed a questionnaire to determine the end users preference in how food waste information would be collected. The purpose of this questionnaire was to get user feedback into the most effective method of collecting data from the users. The questionnaire was handed out to randomly selected students dining in the cafeteria and a total of 25 student responses were collected. The questionnaire and questionnaire data tabulations can be found in Appendix G.

Interpretation of Data

The results showed that 44% of students believe that food waste is somewhat important and 36% believe that food waste is important. From this data, we can deduce that the majority of students do care about food waste, but tend away from the extremes of being very passionate about the issue or not caring at all. Only 12% of respondents thought that food waste was a very important issue and only one respondent did not care about the issue. This begins to make a case that SCU students would spend time to help SCU collect food waste data.

The next questions were aimed at understanding what method would be most effective in collecting food waste data from the student body. The results showed that 20% of students would spend as much as 30-60 seconds interacting with some type of device to collect their food waste data, 48% of students responded that they would spend 20-30 seconds, 20% of students responded that they would spend 10 seconds, and only 12% of students responded that they would not spend any time at all with the device. This data suggests that a majority of students would be willing to interact with a device that collects food waste data after meals. The final question was used to see if we could invoke more participation through the use of an incentive. Out of the 3 respondents who originally answered that they would not participate in the study, 2 of the respondents answered that they would participate if some sort of incentive program was implemented such as entries into a raffle or reward points for snacks or SCU Swag. All other respondents said they would not need an incentive to use the device.

Table of Customer Needs

The client interview and the survey results were used to produce a list of customer needs. These needs encompass both *product specifications*, as discussed with Lindsey from the SCU Sustainability Center, as well as *user preferences*, collected from a small sample of Santa Clara University students who regularly eat in the Benson cafeteria. These results have been organized by need based on priority and importance specified by the customer, users, and project team. The need specifications highlighted denote needs that were emphasized by both the client and users.

Table 1. Client and user needs organized by priority and specification.

	Specification	**Description**	**Target**	**Priority**	**Priority Rationale**
1	**Portable**			HIGH	Client needs
1a	Accessibility	ADA accessible height	36 in	MEDIUM	Client needs
1b	Maximum weight of the product	Light enough to roll or be lifted onto transportation	< 50 lbs.	MEDIUM	Client needs
1c	Method of Transport	Lockable wheels or external transportation (cart, truck...)	flat, small bumps	HIGH	Client needs
2	**Scale Accuracy**	Measurements must be able to provide food waste trends to specified accuracy	< .002 lbs.	HIGH	Must perform to specified accuracy
3	**Opening Time**	Must be able to provide sufficient torque to open sliding door in specified time	< 1.5 s	MEDIUM	User needs
4	**Ease of Use / Impact on User**	Must be self-explanatory to the user and provide user w/ valuable information	Very Satisfactory	HIGH	User needs
5	**User Interaction Time**	Average user interaction time	< 30 s	HIGH	User needs
6	**Waste Accumulation**	Hold up to 50 lbs. of waste	50 lbs.	LOW	Minimize maintenance
7	**LCD Display & Touchscreen Tablet**			MEDIUM	
7a	Readability of Displays	Distance from which comfortable reading is possible for user	LCD: 15 ft., Tablet: 3ft	MEDIUM	Communicate results, raise awareness, attract users
7b	Quality of Content Displayed	Educational, straightforward, and simple content for user	Very Satisfactory	MEDIUM	Educate passerby's
8	**Aesthetics**	Draws positive attention; sleek environmentally conscious vibes	Very Satisfactory	MEDIUM	Attractive product incentivizes use
9	**Data Collection**			HIGH	Client needs
9a	Per Person	Individual waste data collected per meal eaten by user		HIGH	Client needs
9b	Per Dish	Average waste data collected for all dishes served in Benson		HIGH	Client needs
9c	Types of Food Wasted Most	Meals or restaurants with the highest average waste	meal, location	HIGH	Client needs

<u>High Priority Goals</u>

Based on table 1 a list outlining only the high priority needs was generated. There are 4 high priority goals that the final system must satisfy.

1. Device is able to be transported to and from various locations around campus with ease
2. Device weighs food waste to an accuracy of +/- .002 lbs.
3. User-friendly interface with a user process time < 30 seconds
4. Data analysis must be effective in determining trends in per person food waste for each dish served in Benson

Reflection and Detailed Summary of Customer Needs Results

The information collected on the product users and the client indicate that the issue of food waste is a present concern in their minds. The most important issues that our product should address based on the information gathered from the customers are the accurate and detailed gathering of food waste data based on a portable system that is easy and quick to use in order to incentivize the use of the machine.

The previous data collection techniques don't allow for large amounts of data to be collected easily which can skew the data. The widespread the use of the machine will enable the gathering of large enough samples of data which can then be processed to extrapolate the actual total food waste. From the user's perspective the aspect of the machine that matters the most is the ease of use. A majority of the students that were interviewed already scrape their food waste into a compost bin and are willing to spend an additional 20-30 seconds inputting information about their food waste in order to help SCU reach achieve its food waste initiatives. Using this information about our customer we will be able to hone in on designing features that will ensure *WeighstEd* is a powerful tool in fighting food waste on campus.

System Sketch with User Interaction

Figure 4 depicts the entire system with main components pointed out. The user interaction is also described below which identifies how customers and students in Benson interact with WeighstEd.

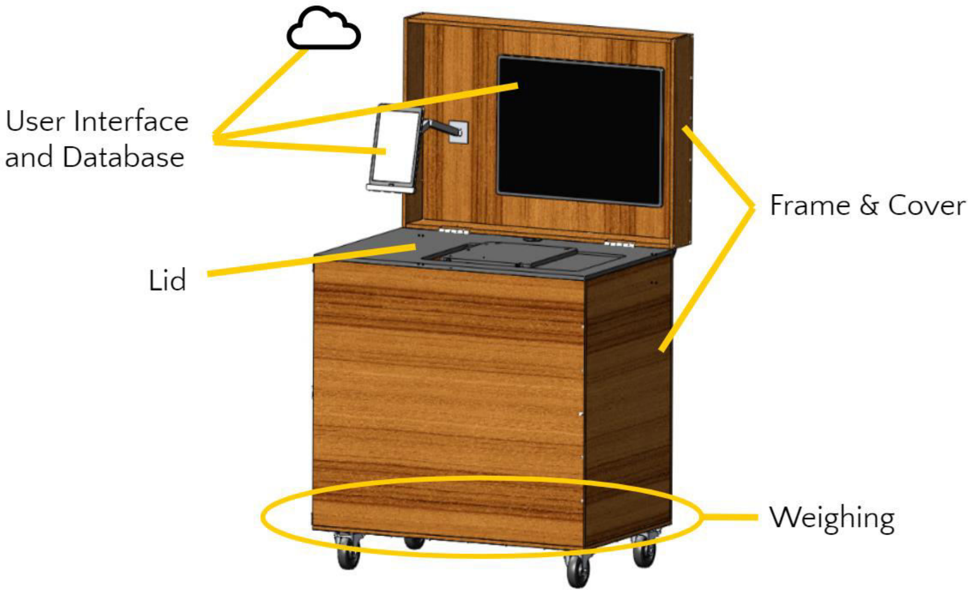

Figure 4. System sketch identifying major components

Functional Analysis & Decomposition

This section outlines the functional decomposition, specifically showing the inputs, outputs, and dependencies. To further understand the flow and interconnectivity of WeighstEd, a functional analysis was performed by combining the front end and back end steps to produce the following decomposition. The flowchart below describes the decision making process of WeighstEd as well as the product of each decision. In the following diagram, the rectangles represent a subsystem, the ovals represent the human interactions, and the rounded rectangles represent an action that the user is required to take before continuing the process.

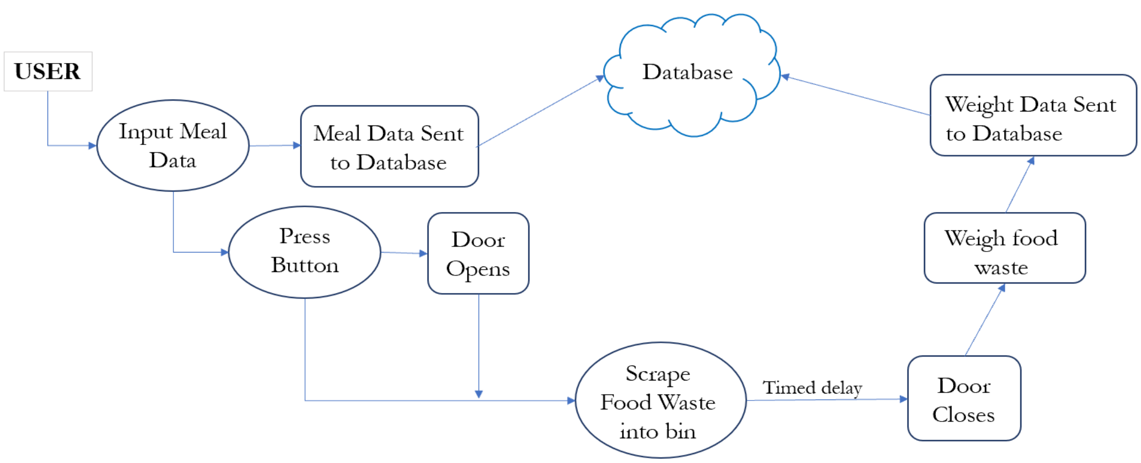

Figure 5. System Functional Diagram

1. User Interface
    a. Input: User specifies the meal that was eaten on a touchscreen tablet.
    b. Output: Records meal identification
2. Opening mechanism
    a. Input: Actuate the lid when the Google form has been submitted
    b. Output: Open lid
    c. Input: Actuate lid when the user has finished disposing of food
    d. Output: Close lid
3. Weighing
    a. Input: Record weight data once lid has closed
    b. Output: Records weight data information
    c. Constraints: Accuracy of measurement
4. Database
    a. Input: User interface meal identification, picture of plate, weight data
    b. Output: Processed data in a useful format for analysis

User Interaction Description

The WeighstEd process consists of the six steps outlined below:

1. Student identifies meal via the touchscreen tablet
2. The automatic door opens to reveal the waste bin
3. Student scrapes plate and weight data is taken via the load cell beneath the waste bin
4. The automatic door closes to conceal the waste bin
5. The weight data is categorically stored in the database for analysis
6. Real time food waste weight data is displayed to the student via the TV screen

Students interact with WeighstEd in three ways; 1) to identify their meal 2) to dispose of their food waste by scraping their plates 3) to get educated about their school's food waste trends via the TV screen and real time data. 1 and 2 are active interactions while 3 is passive and optional for users.

Table 2. Inputs, Outputs, and Constraints

Inputs	Outputs	Constraints
● User specified ○ Meal location ○ Meal ● Scraped single meal food waste ● Button pressed	● Weight reading per meal ● Quarterly waste trends ● Door open/close	● One meal scraped at a time ● Scale tares post use ● Meal must be pre-identified ● Button pressed after form submission

Inputs

The inputs for this project are both informational and physical. The user specified information; meal location and specific meal, are inputs identified through the UI and are processed via the touchscreen tablet. Scraped food waste is a physical input from the users. The button is both a physical and informational input. Users press a button to signify that they have completed the Google form and input their meal data. This input triggers other functionality in the WeighstEd process.

Outputs

The outputs are all triggered actions or quantities. The data from the weighed food scraps is an output stored in Google sheets. Quarterly waste trends are then formed from this continuous waste data and stored for the client also in Google sheets. The door opening and closing is a triggered output action initiated by the button and weight readings.

Constraints

The constraints for this project limit and determine the functionality of the overall system. All of the constraints must be met for the WeighstEd system to successfully run and complete all of its objectives. One meal must be scraped at a time so that its weight can be properly matched to the meal and location identified prior to the acceptance of the waste. The scale must tare after each reading to ensure the next reading is accurate. The meals must be pre-identified to trigger the lid to open and to properly match the waste with its weight. And lastly, the button must be pressed after the Google form submission to actuate the opening of the lid for the disposal and weighing of the meal waste.

Benchmarking Results & Market Survey

Research revealed no current product that closely resembles the WeighstEd. Although there are many programs which are designed to reduce food waste, there is a lack of technologies which facilitate in the collection of food waste data. Studies show that Americans waste about 40% of their food and college campuses are no different (Gunders 1). Universities are taking action to reduce their waste and many have committed to sustainability efforts campus wide. A few of the waste reduction techniques are outlined below.

Food Recovery Network

One organization that fights against food waste is the Food Recovery Network. This non-profit organizes students from universities across the United States to donate excess food from their cafeterias to soup kitchens. Although this organization is effective at donating foodstuffs that have not been consumed, it is not a solution for reducing the food that gets wasted by students not finishing meals.

Starting a Student Run Compost Initiative
Taking example from UC Davis, schools are educating their students about the power of compost as well as collecting compostable, organic matter. UC Davis' full Compost Initiative Report can be found in Appendix G.

Raising Awareness
Whether through clubs, administration, or programs, starting the conversation about student waste can go a long way. Studies have shown that students are less inclined to overfill their plate after seeing postage about food waste efforts. Specifically, students throw out 15% less food when dining halls post anti-waste messages and slogans.

Connecting with a Food-Waste Reduction Network or Organics Recycler
Many facilities have found alternatives related to converting food waste into useful products. For example, food waste can be converted into potting soil, livestock feed, and even biodiesel fuel.

Meal Serving
The traditional service of buffet-style in dining halls is more susceptible to food waste as students often "eat with their eyes" and are more likely to overestimate how much food they will actually finish. Furthermore, the school must estimate how much food they think will be consumed so to avoid running out, they too overestimate.

Meal serving is also a psychology game. Universities experiment with the way the food is presented, the order, and other physical factors like these. Schools also experiment with serving sizes.

Summary
Research and analysis of the market and into potential customer inclinations, wants, and needs revealed many informative results. Based on the information gathered from the Sustainability Center, the product must be portable, standalone, and collect average, per-use, food waste data for each dish served in the cafeteria. The product must also be user-friendly and take less than 30 seconds to complete the user interaction in order to incentivize the use of the product. Potential customers did not specify that they would need a tangible incentive to use WeighstEd.

The Center for Sustainability's current data collection method does not allow for large amounts of data to be collected and does not collect food waste data organized by dish served. A standalone device will enable the gathering of large samples of data which can then be processed to obtain more accurate results. From the user's perspective, the aspect of the machine that matters the most is the ease of use. A majority of the students that were interviewed already scrape their food waste into a compost bin and are willing to spend an additional 20-30 seconds inputting information about their food waste in order to help SCU reach achieve its food waste initiatives. The customer needs information has been used to design features that ensure *WeighstEd* is a powerful tool in fighting food waste.

Team and Project Management

The following section serves to address and describe team related aspects of the project with respect to planning and organization.

Challenges & Constraints

Since taking on the project of using technology to analyze food waste, our team has realized that similar endeavors have not been attempted. As mentioned in the benchmarking section, reducing food waste is an issue that is being addressed but there are no devices which track and analyze food waste. Although this suggests a market opening as organizations become increasingly environmentally conscious, it also creates a challenge in that there are no similar projects to take inspiration from. This challenge only exists when looking at the product from a big picture perspective. To deal with this challenge we broke down our product into its functions-- weighing, collecting waste, identification of data, storing information in a database. There are many products in existence which can perform each necessary function and it has become our task to synthesize each function to serve our overarching purpose.

One challenge has been communication with the Center for Sustainability. The director was often busy and arranging meetings time was sometimes difficult. Therefore, through the year our team made sure to write down all important questions before the meeting in order to ensure that all of our design concerns were addressed. Our team would draw from the feedback received in previous meetings when design decisions had to be made when the Center for Sustainability was unable to meet for consultation.

Design Process

The beginning of the design process included heavy brainstorming where all ideas were considered and no ideas were thrown away. Our team received suggestions from our advisors, professors, and peers throughout this phase. We listed, sketched, and discussed each idea, even if some were far-fetched. At the end of the initial brainstorming phase we had several system level ideas. To narrow down the pool of ideas, we relied heavily on client input, customer needs, and user specifications to develop sketches, make design decisions, and finalize goals. We initially believed that the user interaction would be the highest priority because we were afraid that users might not have any interest in helping SCU collect food waste data. After the client and customer needs had been obtained, it became clear that our design focus should be on *accuracy, consistency, and process time*. We then narrowed our system level ideas and broke each system into subsystems. The brainstorming process was then repeated for the subsystems.

At the subsystem level, we looked at complex concept generation matrices to compare the remaining ideas. Several iterations of matrices were created until we finalized the ideal balance of priorities. These matrices are discussed more heavily in the Subsystem section and can be found in Appendix C. As we began to solidify a single idea, it became clear we needed to begin prototyping to prove concepts. We decided to initiate a proof of concept for each subsystem to be confident that the overall product would achieve each of our objectives. The goals and objectives we wished to achieve were dependent on individual components of subsystems as well as how well a subsystem could integrate with the other subsystems.

Risks & Mitigation

When our team chose this project we knew that our biggest risk was that the project involved a considerable amount of mechatronics and networking, and all of our team members have had limited exposure in both of these fields. Our first attempt at mitigating this risk was to recruit computer and electrical engineering majors. Our team consists entirely of mechanical engineering majors and although each team member has reached out to his or her computer engineering and electrical engineering contacts, none were available to join our team. Moving forward from this setback our team decided that we would break down the mechatronics aspects evenly among all three team members to simplify the process. Our Fall quarter proof of concept conveniently involved three mechatronics components--camera, load cell, and touch screen. Each team member was assigned one component to find relevant libraries, understand the commands, hook up the electronics, and write the code for his or her component. In the end, the mechatronics and networking components were successful by splitting up the work and devoting time to learn what was needed to be learned.

Conflicts between team members is a risk which must be mitigated in any team. On one hand, differing perspectives is healthy by reducing groupthink. However, when these disagreements turn into personal disputes problems arise. Therefore, we have discussed the proper perspective to have when voicing and listening to an opinion. We have decided that we may voice our perspectives and critiques about the project freely while understanding that a critique about one’s idea is not a personal attack. For each assignment we agree upon how to divvy up the work so that we feel like everyone is contributing an equal amount while also playing to our strengths.

Team Management

Our approach to team management has been with an emphasis on collaboration. Our team has assigned a team leader but the leadership style is informal. The team leader generally begins the process of breaking down and assigning tasks for each assignment but a team discussion occurs before tasks are finalized. All disputes are settled democratically--fortunately, our team has an odd number of members. One such issue occurred when choosing the process by which to identify meals. Although the team leader wanted to use an NIR sensor to identify meals in order to save time for the users and create more buzz for the project, the other members convinced the team leader that using a touch screen interface would have a greater chance of success because of the teams limited exposure to mechatronics and because reviews of the NIR sensor that was within budget suggested that the sensor was not fully reliable. Team rules created during the formation of the team are enforced by all team members. For example, our team decided that any member who misses a team meeting will bring pizza to a team meeting in the future. We all held the team member accountable and had a team bonding experience during the process of finishing an extra-large pizza shared only among the three team members. A strong leadership style makes sense when one team member has significantly more experience in a field than the others. However, our team has implemented a successful democratic approach to team management because we are student peers with relatively balanced strengths and weaknesses.

Budget

Our team of three had a budget of $1500 dollars through the School of Engineering. The full budget can be found in Appendix A. but our final budget came out to $1300.58 for the entire project which accounts for initial prototyping, sunk costs in parts that were taken out of the design, and building of the product. The major costs were associated with the electronics, including the TV, the tablet, the scale; and sourcing acrylic for the door assembly.

Table 3. Budget summary by subsystem

Subsystem	Meal Identification	Frame and Cover	Weighing	Power and Database	Lid
Budget	$ 159.41	$ 451.98	$ 179.28	$ 217.05	$ 293.16

Timeline

Our team started working on this project at the beginning of the 2018-2019 school year. We spent the Fall 2018 quarter defining our project scope and goals, along with creating the first iteration of the design. In the Winter 2019 quarter we finalized the design and analysis, and began sourcing materials and parts for the manufacturing stage. In the Spring 2019 quarter we finished the construction, which required minimal modifications from the final design due to some manufacturing issues and the wishes of the Sustainability Center. At the end of the quarter we tested the product, as well as refining some aspects of the user interface and the frame and lid in preparation for handing off the project to the Center for Sustainability at Santa Clara University. For a more thorough breakdown of our project timeline refer to Appendix B.

Chapter 3

SUBSYSTEM LEVEL

In the following section the product is broken down into its four essential subsystems to analyze the individual components in greater detail.

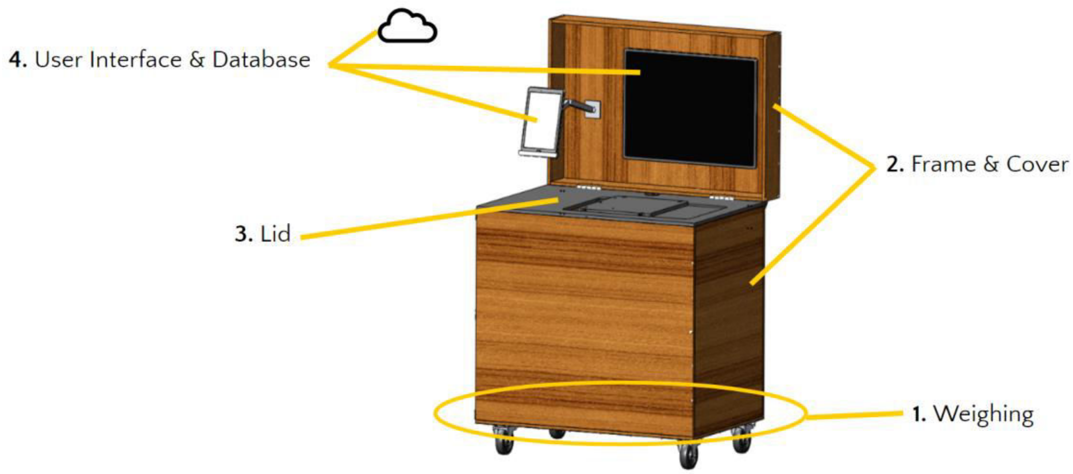

Figure 6. Depiction of the location of each subsystem

Weighing Subsystem

The weighing subsystem is designed to weigh the food waste and send the data to the microcontroller for processing. This subsystem must be accurate and consistent in order to ensure the processing of useful data. The weighing subsystem consists mostly of two wooden boards with a bending beam load cell in between. As shown in Figure 6, the load is applied at one end of the load cell and it is supported at the other. The load cell then measures the amount of bending using a strain gage to calculate the weight applied. The load cell purchased was Omega Bending Beam Load Cell model number, which has a specification of up to 66 pounds (30kg).

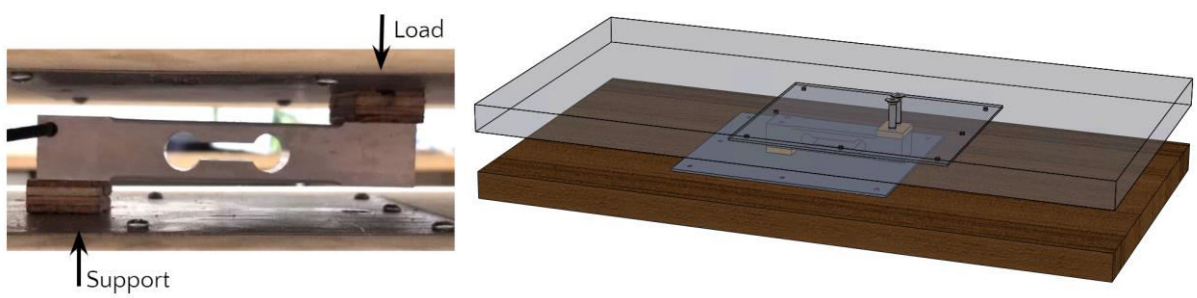

Figure 7: (a) Bending beam load cell scale design with supports and spacers
(b) SolidWorks model of the scale designed for the weighing subsystem

<u>Design Constraints and Considerations</u>

The weighing subsystem we designed must:

- Weigh to an accuracy of within 0.002 lbs.
- Have the ability to weigh up to 55 lbs.
- Have the ability to coordinate with a microcontroller
- Have the ability to zero after each use
- Price
- Be of “reasonable” size *relative* to the lid and frame

Rationale

The most important requirement of the weighing subsystem is that the scale can obtain measurements accurate to within 0.002 pounds. The rationale behind this level of accuracy is derived from the Santa Clara University's food waste reduction goals. SCU has stated that it desires to reduce food waste by 10% by 2020. Although it has been determined that SCU sustainability's current methodology for collecting and analyzing food waste data is flawed, we have used their current estimate for average food waste per meal of .22 lbs. as a baseline. Therefore, if we were to reduce the current level of food waste per meal of 0.2 grams by 10%, the average food waste per meal would drop to 0.18 pounds. Based on our assumption, 0.002 pounds of accuracy ensures that our data has an error that is within 1% of 0.02 pounds.

In our system the scale has been designed to sit below the rubbish bin and zero after each measurement. In order to function in this manner the load cell must be able to hold up to 55 pounds before requiring the waste bin to be emptied. The load cell must also be able to communicate with a microcontroller in order to be able to read the data and automatically update the database with the weight data as well as to associate each measurement with a particular meal.

Material Selection

We chose 0.75 inch thick plywood cut in a rectangle shape to be the main surfaces of the weighing mechanism since the material is cheap and easy to machine. The wooden panels were reinforced with steel sheet metal in order to reduce the bending without the need for adding much material as well as being easy to machine.

Concept Selection and Design Iteration

The decision to use a bending beam load cell for the weighing subsystem was made early on in the design process. Placing the scale beneath the waste bin allows for cleaner, faster weighing; eliminating the need for any major cleaning method for the load cell and the need to remove the waste from the scale. Instead of placing the weighing mechanism on top and wiping the food off after weighing, our system can accumulate more food scraps before the waste bin needs to be emptied without sacrificing accuracy. Additionally, prior to final assembly sheet metal supports and wooden spacers were added to reduce bending of the wood and to add stability to the scale.

Frame Subsystem

The purpose of the frame is two-fold. It must provide structure while also being user-friendly. The frame is constructed of plywood and steel angle brackets for reinforcement.

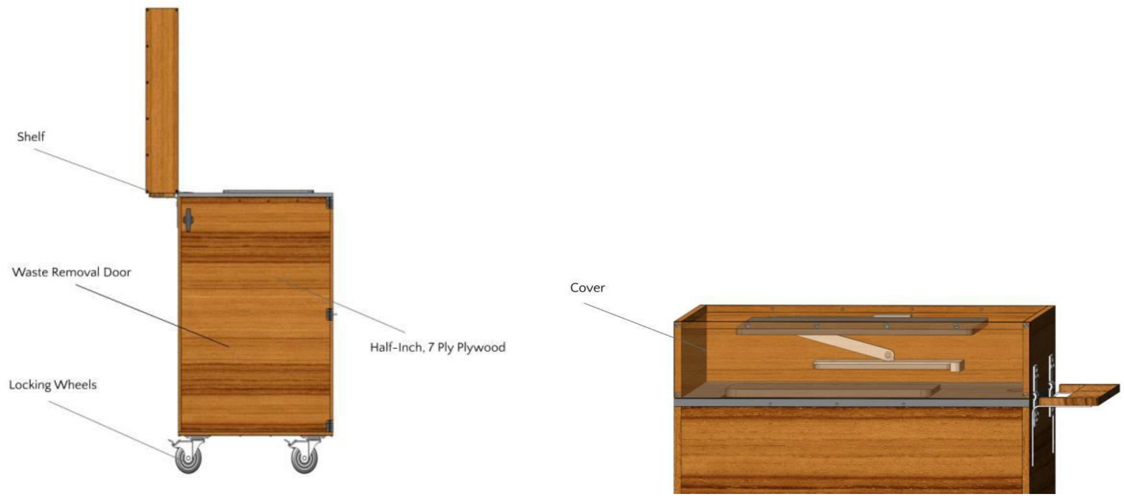

Figure 8. Notable Frame Parts

Design Constraints and Considerations

- Give structural integrity to all components of the device
    - Securely fasten backend hardware and lid subsystem
    - Hold up to 50 lbs. of food waste without failure
- Portable
- Meet All Safety Requirements
    - Tipping
    - Electrocution
- Ensure ease of removal of food waste
- Aesthetically pleasing exterior
- Food-Resistant

Rationale

Material Selection

In the design of the frame subsystem a primary material needed to be selected for use. The criteria for material selection was strength, weight, cost, manufacturability, and aesthetics. Aluminum sheet, acrylic, and plywood were the three candidates for the primary frame material.

The primary functionality of the material is that it must provide strength to withstand the weight of the entire system along with a minimum of 50 lbs. of food waste. All materials were capable of providing this level of strength with minimal reinforcement. It was also determined that the weight and manufacturability of all three materials were relatively similar. However, both aluminum sheets and acrylic were both more costly and did not fit the desired aesthetic profile as successfully as plywood with a stained finish. Therefore, seven-ply plywood was chosen in order to provide the necessary structural integrity to the system while optimizing expenses and aesthetics.

~Structural Integrity~
The structural integrity of the frame is derived from half-inch, seven-ply plywood held together using wood glue and angle brackets along the corners. The shelf is constructed of half-inch, seven ply plywood and two angle brackets in order to hold the cover up in the open position. The wheels lock to hold the system in place while in use. The cover fastens the backend hardware (tablet and smart TV) to the frame and when the cover closes the tablet and smart TV are able to be stored.

Figure 9. Angle Bracket Supporting Lid Subsystem

Figure 10. Cover Supported by Shelf

~Portability~
The device is able to be transported along relatively smooth surfaces by means of five-inch locking caster wheels. However, transportation across bumpy surfaces such as brick walkways would prove difficult and may necessitate the use of a vehicle.

Figure 11. Locking Caster Wheels

~Safety Requirements~

The first safety concern stems from uneven weight distribution due to the cover extending off the back of the base when in the open position. However, initial calculations showed that the offset weight of the cover would not cause the device to tip, which has been validated by the prototype. The tipping calculations can be found in Appendix H. It can be clearly seen in the side view of the product shown in figure 12 that the product does not tip.

Figure 12. Stable Weight Distribution of System

The second safety concern is electricity. The tablet and smart TV are both powered by wall outlets and the motor is powered by a 24V 1.8A power supply. These electronic components have the potential to be dangerous if not contained. In order to mitigate this risk, all electronic components are spaced between rubber insulation, which doubles as vibration damping. Also the components are stored in a box located halfway up the side of the frame and 12 inches away from the rubbish bin so that any liquid from the food waste has no chance of causing a short circuit. As a final safety measure, all power from the wall outlet goes through a power strip with over-current and electrical short circuit protection before powering any electrical components.

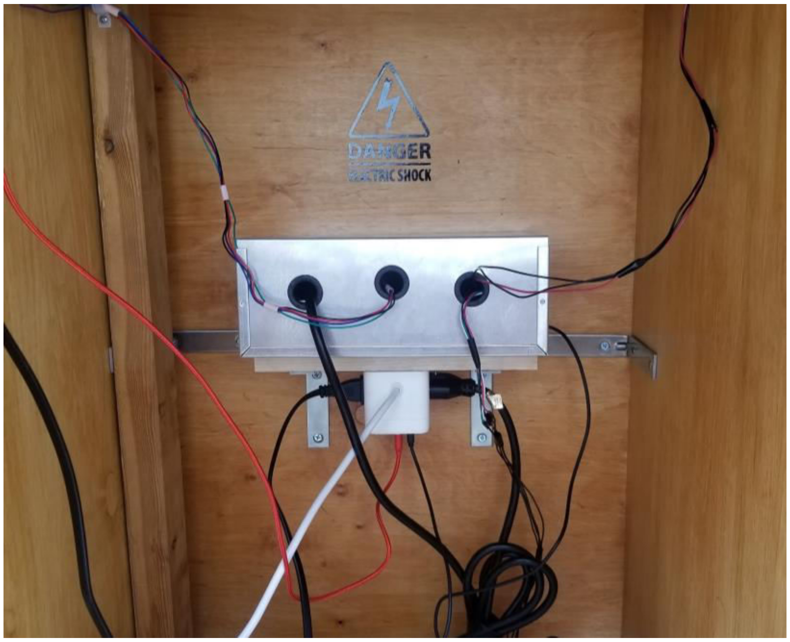

Figure 13. Electrical Components

~Aesthetics~

The aesthetic of the device was chosen to be natural and professional in order to match the theme of sustainability and foster user interest in the device. This requirement was met by giving the plywood a golden pecan stain with a satin finish. Plywood edges were cut and connected to the adjacent piece of plywood at 45^{o} in order to have a clean, professional appearance.

Figure 14. Team Members Staining Cover

~Food-Resistant~
Design decisions have been made to reduce the likelihood of food coming into contact with the frame. Nevertheless, the possibility still exists that an accident, or perhaps sabotage, would cause food and liquid to get on the frame. The plywood has been given layers of waterproofing in order to be able to clean food scraps and liquid off of the frame without leaving any permanent markings.

Concept Selection and Design Iteration
There was one design iteration of the frame subassembly. It was observed that the first prototype of the frame was too large to be easily transported and stored. The frame and cover dimensions (X in x Y in) were reduced from 36 in x 24 in to 30 in x 20 in as illustrated in figures 15 and 16. Note that the horizontal plane of the frame and the vertical plane of the cover have matching dimensions.

Figure 15. Frame Dimension Description

Figure 16. Cover Iteration

Lid Subsystem

The lid subsystem consists of an automatic open/close acrylic door actuated by a rack gear and pinion transmission assembly. The lid subsystem was designed to ensure methodical collection of data by providing a visual and physical pass/no pass gate via an automatic door. Methodical collection of data was necessary to prohibit premature collection of waste; that is waste being collected and weighed *before* identification.

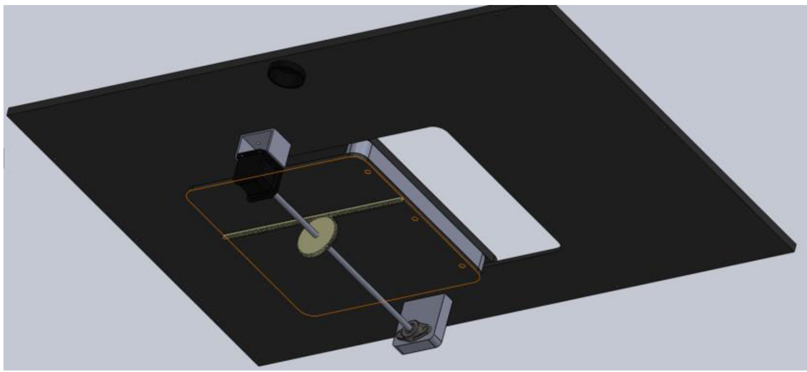

Figure 17. SolidWorks model of Lid Subsystem, bottom isometric view

The lid subsystem is made up of three components; the door subassembly, transmission subassembly, and lid base subassembly. The door subassembly is a layered acrylic component which includes the acrylic plate that slides open and closed over the lid base as well as rack gear which interfaces with the transmission. The transmission subassembly actuated and controls the movement of the door subassembly. It is composed of a steel, keyed shaft secured between a mounted bearing and stepper motor shaft. Through the use of a coupling shaft, the motor shaft and keyed shaft rotate together when the motor is powered. A 60-tooth gear is secured on the shaft with a key and two shaft collars to prevent wander. Lastly, the lid base subassembly is a two layer acrylic, laser cut frame whose main purpose is to support the other components of the lid (transmission and door) and shield the inner components of the frame (electronics and waste). These three subassemblies can be seen in the figures 18 through 20.

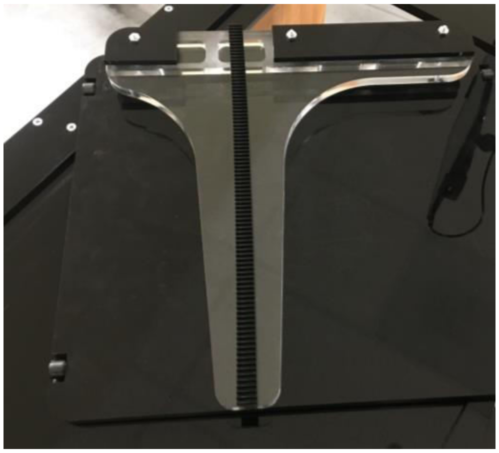

Figure 18. Door subassembly, bottom view of rack gear

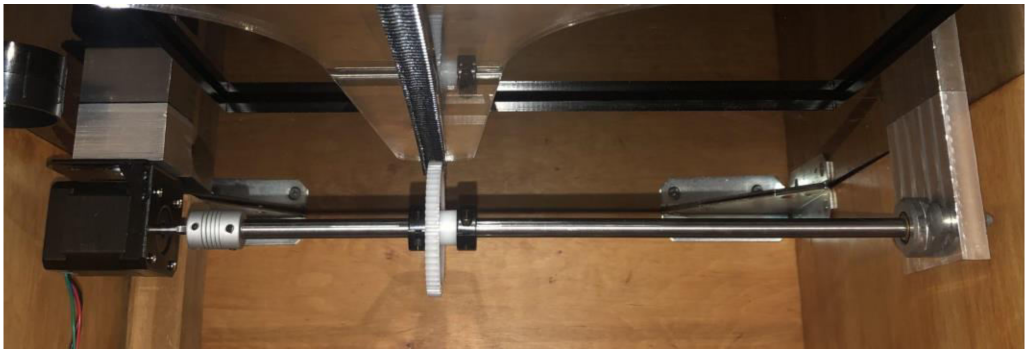

Figure 19. Transmission subassembly, side view of gear interface

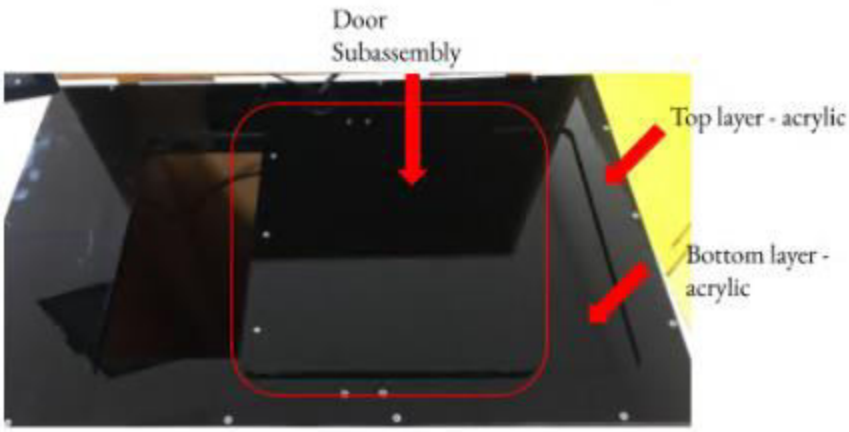

Figure 20. Lid base subassembly, top view of door interface

Design Constraints and Considerations

The specifications for the lid subsystem functionality were outlined as follows:

- Lid door must open in less than or equal to 1.5 seconds
- Lid door must close in less than or equal to 1.5 seconds
- Subsystem must improve user composting experience
- Subsystem must be aesthetically pleasing
- Subsystem must be robust

Rationale

Material Selection

The materials for each component were methodically chosen, tested, and confirmed based on function and needs. Most parts required high strength to weight ratios, easy manufacturability, and long life. A detailed look at each part material and rationale can be found in the table below and in the following sections.

Table 4. Lid Subassembly material selection

Part	Material	Rationale
Lid Base	Black Acrylic	Strength to weight, aesthetic
Door Layers	Black, Clear Acrylic	Strength to weight, aesthetic
Rack Gear	Acetal Plastic	Strength, accuracy, Life
Pinion	Acetal Plastic	Strength, accuracy, Life
Keyed Shaft	1045 Carbon Steel	Strength, accuracy, Life
Custom Mounts (x2)	6061 Aluminum	Weight, machinability

The following sections describe the rationale behind each design constraint and the considerations that were made.

~Lid Door Open/Close Time~

WeighstEd is a product designed for student interaction, specifically college students. College students were surveyed at SCU about their commitment to food waste and willingness to participate in food waste analysis tactics. From these surveys, which are outlined in detail in the Customer Needs section of this report on page X. The results showed that 70% of students at Santa Clara University, specifically first and second year students (the primary audience for WeighstEd), would be willing to spend between 20 and 60 seconds interacting with a product after their meals which would aid SCU in its food waste reductions goals. This was the primary motivation to reduce the entire process time of one iteration of getting WeighstEd.

The lid door open and close times combine to make up a portion of the overall process time. In order to meet the goals the survey results revealed, the 1.5 second time caps were defined. These two would lead to an overall process time of 3 seconds for the door functions, leaving between 17 and 57 seconds for the rest of the processes (i.e. meal identification, plate scraping, transition time, and displayed data).

~Improve Customer Experience ~

Currently at SCU, surveys revealed that 80% of students compost their wasted food after most meals. This equates to about 2,200 students composting food each meal. That is 6,600 students trafficking the composting stations per day. The current composting experience is extremely messy and uninformative. Students attempt to scrape their plates into circular holes about 6” in diameter. The average platter size in Benson is 8.5”. Students are not made aware of any of the food waste data collected by the sustainability center and barely know which items are compostable or not.

Figure 21. SCU’s current compost area as of 2019

There was a large opportunity to improve the user experience due to the current situation explained and shown above. Therefore, it was designated as a design constraint for this subsystem. To improve this experience, the lid shape and size were altered to allow for easier scraping. The shape went from a circle to a rectangle and increased in size by 80%. Additionally, the door open/close process was automated to provide a hands-free, technologically advanced, exciting feel for students. To benchmark whether WeighstEd improved the composting experience, surveys were given out to students who have used both products.

~Aesthetically Pleasing~
The materials chosen for the lid subassembly were acrylic, acetal plastic, and aluminum. 75% of the components were laser cut out of acrylic sheets for ease of manufacturability, high strength to weight ratios, and aesthetics. The colors were chosen to compliment the sustainable and smart tones of the rest of the product. Acrylic is affordable, weather resistant, impact-resistance, and can operate in a large range of temperatures. For the custom components, aluminum 6061 was used for its light weight and machinability.

~Robust~
The purpose of WeighstEd is to replace student volunteers, in addition to collecting, storing, analyzing, and displaying food waste data. In order to alleviate the time and stress of supplying and maintaining volunteer hours, the product needs to be robust so it can withstand student abuse as well as the effects of outside forces. The lid door open and close process was fatigue tested with computer software to ensure wear and tear would not affect the overall functionality of the product.

<u>Concept Selection and Design Iteration</u>
Door and Lid
The purpose of the lid subsystem is to methodically collect food waste and act as a visual and physical barrier to the internal components and waste. Methodical collection of food waste must occur so that the weight of the food waste and the meal identification data be accurately sorted in the database without the data being contaminated by multiple meals. Initially, several different concepts were designed for this subsystem. There was ideation around automatic cleaning mechanisms that could wipe away leftover or forgotten waste, Doors that could weight and dump the waste themselves, and even a hanging scale/door combination. A few of these initial designs and sketches can be seen below.

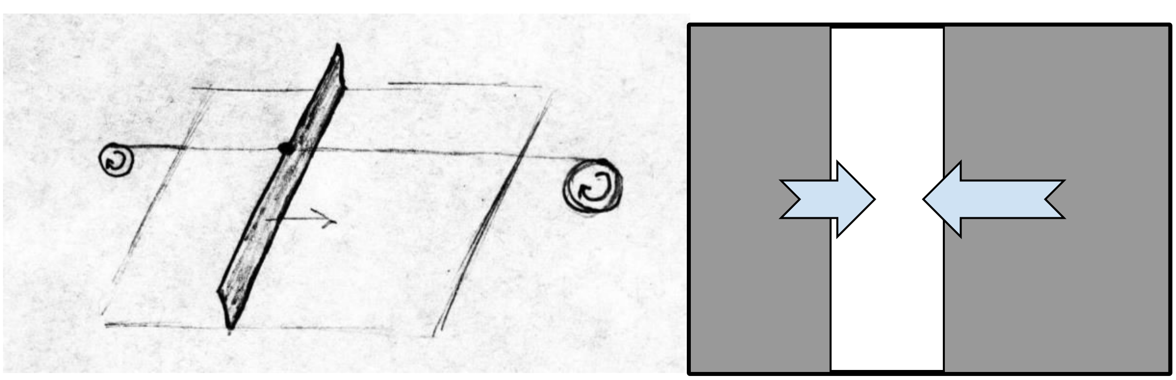
Figure 22. Initial lid design sketches

Three lid design ideas were produced and developed. The first idea was an opening mechanism modeled after the iris of a camera, the second idea was an inward folding flap, and the third idea was a sliding door. A scoring matrix, which can be found in Appendix C, was used in order to determine which opening mechanism would serve the predefined list of requirements and desirable criteria best. The automatic sliding door had the highest rating because of its manufacturability, and cost-effectiveness. However, the iris lid was chosen because of its aesthetics and because it involved a more mechanical engineering design challenges. Specifically, it involved involute gear design, mechanism design, and motor torque. This design was fleshed out, fully designed, modeled and tested in SolidWorks.

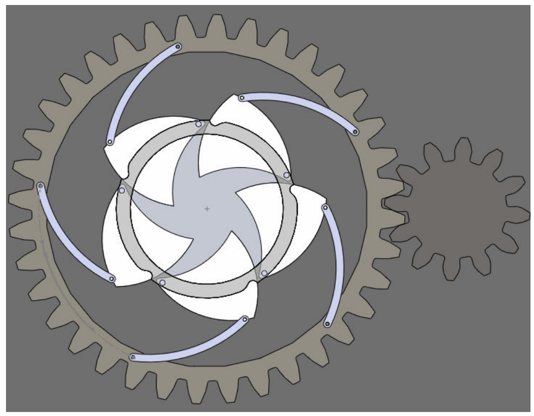

Figure 23. Bottom view of iris lid design SolidWorks

Ultimately this design was not manufactured because it had complicated geometries, irrational size ratios, and was difficult to assemble. A full report of this design and its analysis can be found in Appendix E. The automatic sliding door proved to be the outstanding idea because of its simplicity.

Opening Mechanism

Once the sliding door idea was chosen, iterations began to select the actuation method. Between a pulley mechanism, rollers, and gears, a combination of track rollers and gears were chosen. The track rollers provide ease of sliding for the door and the rack gear and pinion acted as the transmission for the motion.

To implement track rollers into the door, hubs were designed on the sides of the door to minimize dust and debris build-up and food waste scrap interference. This detail can be seen in figure 24. Due to the thin features created at both the top flange of the hub and bottom thickness below the hole for the track roller and base of the door, analysis was done on this component. The original design failed during manufacture. After finite element analysis on new hole locations, the hub design was successfully completed. A full report of the hub analysis can be found in Appendix F.

Figure 24. Track roller hub design showing thin features

Backend Subsystem

The backend subsystem is responsible for collecting and analyzing food waste data, as well as educating the user and the client about food waste. It must collect average food waste on a per meal basis for desired items served at Benson and food waste trends must be tracked from quarter to quarter in order to determine if SCU is meeting its food waste reduction commitment. Lastly, it must provide educational food waste information to the user.

The backend software is composed of Google Forms, Google Sheets, and Arduino IDE. The backend hardware is composed of a tablet, a microcontroller, a smart TV, and a button.

Step 1: User-Interface Interaction

The first step of the process is to obtain the user input. The user accesses the Google Form on the tablet and answers two questions from dropdown menus. First, the user selects the location from which the meal was purchased. Second, the user selects his or her meal from the list of meal options served at that specific meal location. Google apps scripts, a process for writing custom functions in JavaScript for Google Applications, is implemented to run a code every time the Google Form is submitted. This code is programmed to send the user input from the Google Form to the Google Sheet.

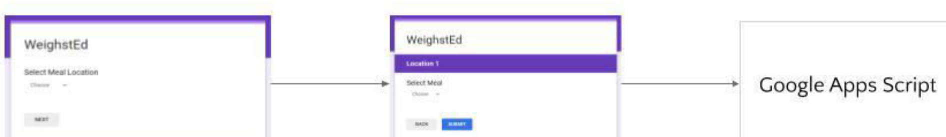

Figure 25. Meal identification through Google forms

Step 2: Button Press
The user is then prompted to press a button in order to communicate to the microcontroller to run the mechatronics processes.

Step 3: Mechatronics
The Arduino first opens the lid via the stepper motor and then takes a weight reading with the load cell once the food waste has been collected in the rubbish bin.

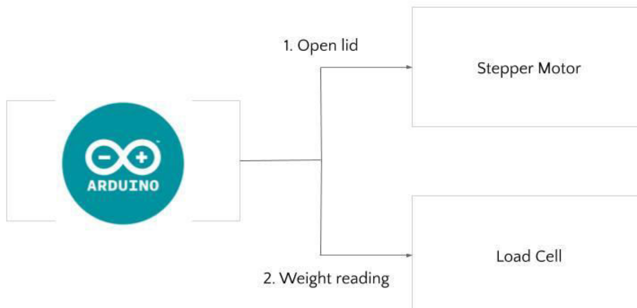

Figure 26. Arduino commands

Step 4: Microcontroller Send Weight Reading to Google Sheets
The weight reading is then sent back to Google Sheets through Pushing Box as an HTTP GET Request.

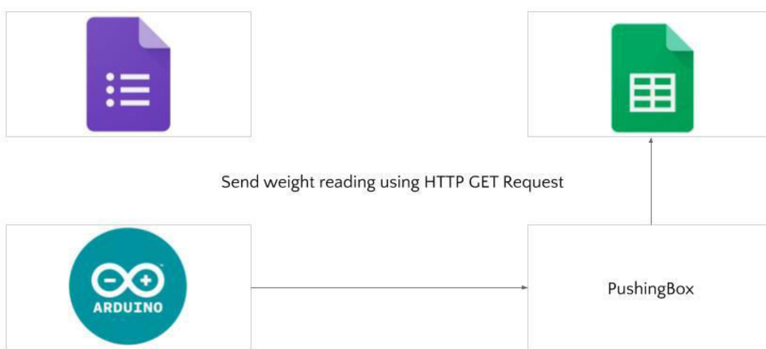

Figure 27. Arduino – Google Sheet communication

Step 5: Sort Weight Reading in Database
The user input is then used to sort the weight reading by meal location and menu item in the database. The Google script has a safety measure implemented so that the weight reading is only sorted if the Google form was submitted before the button was pressed. The button pressing alone does not trigger a weight reading to be added anywhere in the database.

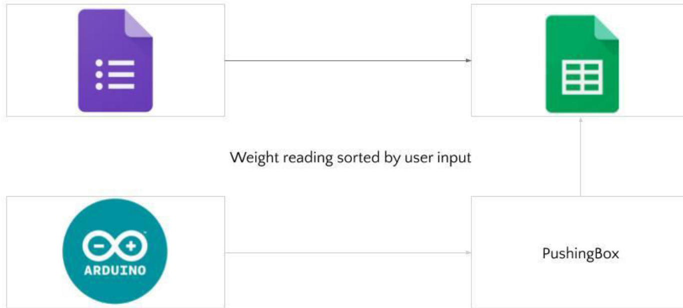

Figure 28. Database sorting using meal identification

Step 6: Update Quarter-to-Quarter Food Waste Trends

The weight reading is sorted into the correct single quarter sheet and the average weight of each item of food waste is tracked quarter to quarter in the quarter-to-quarter sheet. An example of a single quarter sheet is shown on the left and the quarter-to-quarter sheet is shown on the right.

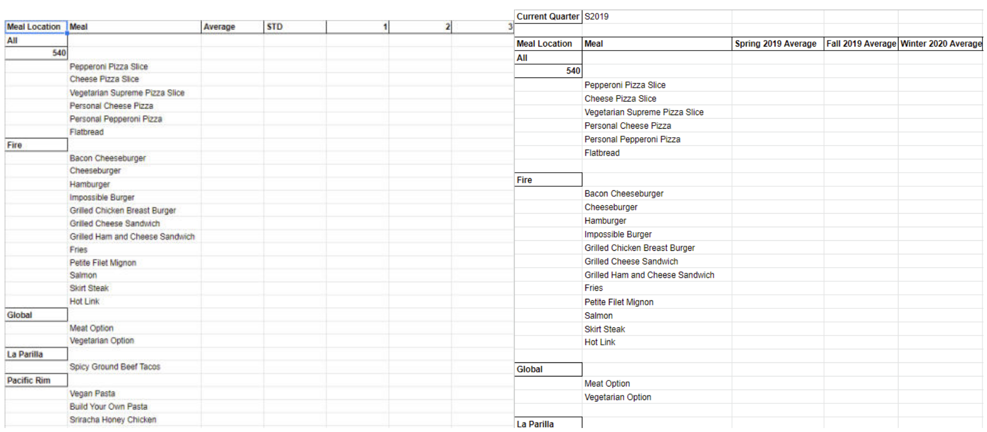

Figure 29. Example Google Sheet single quarter (left), multi-quarter (right)

Step 7: Educate Student Body Using Trends

Finally, the trends are displayed on the smart TV in order to educate the student body.

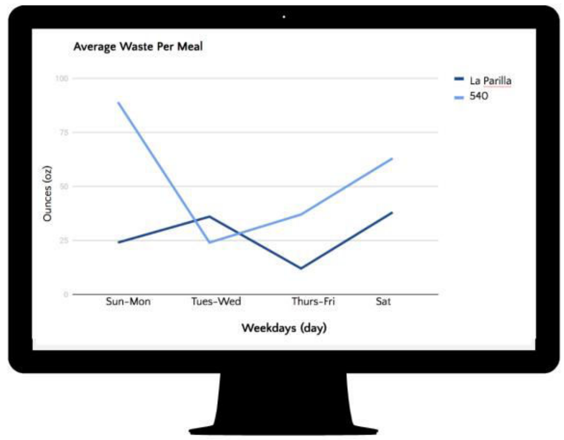

Figure 30. Example LCD display – student education

Design Constraints and Considerations

- Collects average food waste per meal
- Correctly identifies desired food items
- Analyze food waste trends on a per quarter basis
- minimal end-user impact
  - Process time < 30 s
  - <= 3 User Prompts
- User-friendly database for client
- Present education food waste information to the user
  - Quarterly trends
  - Food waste impact
  - Food waste reduction tips

Rationale

The type of data that our device collects, as stated in the design constraints and considerations, was specifically requested by the Center for Sustainability. Our definition of *minimal user impact* derives from an anonymous survey that our team issued to Benson diners. The survey revealed that 68% of students who frequent Benson would be willing to spend 20-30 seconds performing some task such as inputting meal data into a tablet in order to help SCU collect relevant food waste data. However, this percentage may be lower because there is social pressure to be environmentally conscious on campus. For prototyping design purposes it has been assumed that 20-30 seconds is a reasonable amount of time for students to interact with our device.

Concept Selection and Design Iteration

User Interface
The criteria for the user interface was that it must properly identify desired food items and collect the average food waste per meal for each item, have minimal user impact, and be easy for the Center for Sustainability to adapt to menu changes. The three options for the user interface was to build an Android Application, use Intuiface, a non-coding user-interface building program, or use Google Forms. Although all options had the potential to collect the desired information efficiently and with minimal user impact, the Center for Sustainability requested the use of Google Forms because it was the application most familiar to the Center.

Database
The criteria for the database was that it could analyze the desired food waste trends, integrate with the other backend components, and be easy for the Center for Sustainability to use and edit. The two options were to use SQL or Google Sheets. Again, both options could have provided the same functionality, however, Google Sheets was selected because of the Center's affinity with Google Applications.

Chapter 4

SYSTEM INTEGRATION, TESTING AND RESULTS

This section outlines the three most significant tests performed. These tests monitored the functionality and efficiency of the product. The weighing accuracy, door process time, and system process time were each tested. Each section describes the purpose and importance of the testing, the experimental protocol, and the results and discussion. The results are compared to the desired results outlined in table 4.

Table 5. Desired Results

Test	***Desired Result***
Weighing Accuracy	$\mp$ 0.002 lbs.
Door Process Time (Open/Close)	<1.5 seconds each
System Process Time	<30 seconds

Weighing Accuracy

Purpose
In order to test the accuracy of the scale that we had built, we performed a short series of tests and compared the values obtained from the load cell to that of a commercially available scale

with greater accuracy than our load cell. We added a weight, then zeroed the scale, added an additional 0.2 lb. weight and collected the weight measurement. Using this test our load cell was able to read the correct weight to within 1% of the 0.02 lb. weight, as desired.

Experimental Protocol

The load cell works using a Wheatstone bridge to measure the bending of a beam, which deforms linearly at small loads according to Hooke's Law. Some of the issues in the weighing subsystem that could be problematic are changes in temperature, and hysteresis. However the zeroing of the load cell prior to each measurement helps reduce the possibility of either of these preventing accurate readings.

Results

The experiment showed unequivocally that the scale was within an acceptable range of accuracy, as shown in table 5 where the error between the weight measured by a baseline scale and the weight measured on the weighing subsystem were less than 1% of 0.02 lbs.

Table 6. Error Results for the weighing accuracy test

Weight added prior to zeroing scale (lbs)	% Error
0	0.45%
1	0.25%
5	0.35%
10	0.75%
25	0.45%
50	0.05%

Door Process Time

Purpose

To incentivize students to use WeighstEd to help SCU collect food waste data, the interactive process needed to be minimal in time (seconds). One of the components of the process time is the opening and closing of the lid to monitor the acceptance of food waste scraps. The main purpose of this test was to ensure that the process time remained in an acceptable range.

Experimental Protocol

In order to test the process time of the door open and close, hand timers were used to measure from start to stop time. Three hand timers were used and the average from the three was recorded as the time for that specific test. The open time and close time were tested separately to provide a more specific body of data. The timers were started when motion was registered and stopped when there was no more motion from the lid (signifying that the lid was fully opened). 10 tests were performed for each scenario. More tests were planned, but the data became consistent enough for the accuracy of the time data. The design specification for the door process time was 1.5 seconds or less to open and 1.5 seconds or less to close. The testing results are shown below.

Results & Discussion

The table below shows the raw data from the opening and closing door process time tests. The averages were calculated and are also shown in table 6. The times are in seconds.

Table 7. Door open and close process times

Trial	*Opening Time*		*Trial*	*Closing Time*
Trial 1	3.1		Trial 1	2.7
Trial 2	2.8		Trial 2	2.9
Trial 3	2.9		Trial 3	2.6
Trial 4	2.6		Trial 4	2.6
Trial 5	2.8		Trial 5	3
Trial 6	3.1		Trial 6	3
Trial 7	2.6		Trial 7	2.7
Trial 8	2.82		Trial 8	2.9
Trial 9	3.1		Trial 9	2.7
Trial 10	3		Trial 10	2.9
Average:	2.882		**Average:**	2.8

The tables show that the average achieved door open time was 2.9 seconds and the average achieved door close time was 2.8 seconds. Statistical analysis was run on these testing results with 95% confidence. The standard deviations, true range, and the percent difference between target and experimental for each test (open and close) are shown in the table below.

Table 8. Statistical Analysis for lid open and close process time test

Opening Time						
Average:	2.88	**N:**	10		**Target:**	1.5
STD:	0.1924000462	**t9,95**	2.262		**Percent Differenc**	-92.13
Range:	0.14					
Closing Time						
Average:	2.80	**N:**	10		**Target:**	1.5
STD:	0.156347192	**t9,95**	2.262		**Percent Differenc**	-86.67
Range:	0.11					

The average experimental time for the lid opening process was 2.9 seconds which was about 92% different (more) than the desired time. Additionally, the average lid closing process was 2.8 seconds which was about 87% different. Although the average times are much slower than the desired specifications, the results were deemed acceptable because the overall process time remained within the given constraint of 20-30 seconds. Visual inspection of the open time also confirmed that these results were acceptable. A faster open or close time may have been a safety hazard and would have compromised the overall integrity of the design.

System Process Time

Purpose

The system process time experiment was done in order to determine if the system process could achieve an average user interaction time of under 30 seconds.

Experiment Protocol

Ten random users of the device participated in this experiment at a Forge Garden sustainability event. The iPhone timer application was used to measure the process. The timer began when the user first touched the tablet and the timer was stopped when the user had finished scraping his or her food waste into the rubbish bin. The average of the ten trials were taken and statistical analysis was done, as shown in equations 1-3 below, to find the true mean range with 95% confidence and the percent difference between the target process time and the experimental process time.

The following equation was used to solve for the standard deviation of a sample population where N is the number of samples and xi is an individual sample.

$$S_x = 1/N \, \Sigma x_i \tag{1}$$

Equation 2 used the mean and the sample standard deviation to find a range of the true mean to 95% confidence where x' is the true mean, Sx is the standard deviation of a sample population, and t is the student t distribution.

$$x' = S_x \,+/-\, t_{\nu,P}\, S_x^{.5} \tag{2}$$

Equation 3 was used to find the percent error between the target process times and the experimental process times.

$$e = (x' - x) / x \tag{3}$$

where *x'* is the experimental sample value and *x* is the predicted or expected value.

Results & Discussion

Table 9. Process Time Results

Target Process Time (x)	**Experimental Process Time (x')**	**Percent Difference (e)**
30 s	*25.76 +/- 2.02 s*	*-14.15%*

The results showed that the experimental process time took 25.76 seconds, which was 14% lower than our target. Therefore, the process time specification was met and exceeded.

Chapter 5

COSTING ANALYSIS

To define the allocation of funds as well as the budget breakdown, it is important to consider a costing analysis. In a costing analysis, one must first identify the purpose, the perspective, the time period, and then all of the costs both direct, indirect, and overhead. The purpose of this costing analysis is to determine the importance and priority of our budgeting including prototyping, manufacturing, and out-sourced parts with respect to a defined timeline. The perspective is from the designers, manufacturers, and sellers putting budgeting as a high priority. The time period is the course of one school year that is about nine months. In this time, the project must come as close to completion as possible and the funds will be held accountable during every phase.

Table 9 shows the allocation of funds given to the proof of concept generated at the end of Fall 2018. This proof of concept can otherwise be known as the first prototype. The table can be organized by subsystem as four separate proof of concepts were completed to show the overall functionality of the project by component. These four subsystems were the weighing (showing that weight data could be collected from a load cell or scale and stored), the frame and lid (showing that the mechanical component of our project can open and close with actuation and interface with a frame), the meal identification (showing that an image could be captured and a category selected from a touchscreen tablet), and data processing (showing that the captured images and food categories could be matched and collected into a single database). We had originally allocated $200 for prototyping and proof of concept so after Fall 2018, we were on track to stay under budget. Therefore, ordering plans were kept consistent.

Table 10. Proof of Concept Budget Fall 2018

Proof of Concept Budget				
Component	**Cost ($)**	**Supplier**	**Status**	**Subsystem**
Load Cell - Scale w/ HX-711 Breakout Board	11.49	Amazon	Prototype version purchased	Weighing
Iris Lid Fins - Raw Material	Overestimated 10	SCU Maker Lab	To laser cut	Frame & Lid
Iris Lid Base & Connectors - Raw Materials	Overestimated 10	SCU Maker Lab	To laser cut	Frame & Lid
LCD Screen - Touchscreen LCD 2 w/ ILI9341	12.99	Amazon	Prototype version purchased	Meal ID
Camera & Board	25.99	Amazon	Prototype version purchased	Meal ID
Microcontroller - Arduino Mega Board w USB Connector Cable	14.86	Amazon	Prototype version Purchased	Data Processing
Wires & Cables - Starter Kit with wires, resistors, breadboard	12.49	Amazon	Prototype version purchased	Data Processing
TOTAL	$97.82			
Remaining Funds	$1,402.18			

Table 10 outlines the plans that were made for ordering the remaining parts in Winter 2019. Some of the parts in the table have were prototyped but needed fresh, correctly sized hardware for the final product. Some of the costs were intentionally overestimated.

Table 11. Remaining Part Acquisition Table Winter 2019

Component	**Cost**	**Supplier**	**Timeline**	**Subsystem**
Waste Bin - Rubbermaid Commercial FG263256GRAY Brute Plastic Trash Can without Lid, 32-gallon, Gray	36.00	Amazon	Winter 2019	Weighing
Iris Lid Fasteners	20.00	Home Depot	Winter 2019	Frame & Lid
Metal Frame Support/Connection	300.00	TBD	Winter/Spring 2019	Frame & Lid
Wheels (x4)	25.00 x 4 = 100.00	Amazon/Home Depot	Winter/Spring 2019	Frame & Lid
Fasteners	20.00	Home Depot	Winter 2019	Frame & Lid
Servo Motor	150.00	Amazon	Winter 2019	Frame & Lid
Proof of Concept Parts				
Load Cell - Scale	300.00	Amazon	Winter 2019	Weighing
Touchscreen Tablet	100.00	Amazon	Winter 2019	Meal ID
LCD Display	250.00	Amazon	Spring 2019	ALL
Miscellaneous	100.00		Winter 2019	ALL
TOTAL	$1,376.00			

Following the close of Winter 2019, we were still on track to remain under budget by about $215. Therefore, plans were continued. A full outline of the budget, broken down by subsystem, can be found in the Budget section of this report. Production costs estimates and evaluations can be found in the following section which outlines the tentative business plan for WeighstEd including full costing analysis and manufacturing costs.

Chapter 6

BUSINESS PLAN

Introduction

Currently, meal service providers and caterers are in the dark about food waste trends. They are completely unaware of what foods are being wasted, when they are being wasted, and why they are being wasted. The lack of feedback here is a huge business opportunity. Any information stream is extremely useful data because information streams allow management to optimize processes which can save money, time, resources, and more.

The main customers of food waste data are big university catering companies like Bon Appetit. These companies deal with hundreds of thousands of dollars of food nationally, and currently do not use waste tracking techniques. The main issue is the opportunity lost with on-site restaurant, catering, and meal service companies. Most of these food facilities have no existing data to analyze waste and they have not invested in food waste analysis as a solution because they do not understand the potential cost savings. Current methods of collecting food waste data are extremely time consuming and cumbersome. These current methods consist of sorting bins and non-specific weight data. Further, this current method of food waste analysis is typically done by student volunteers with university sustainability centers. The information is less valuable to students and campus organizations because it is unsustainable, therefore it does not consist of a large enough body of data to yield meaningful results. Furthermore, the information is neither specific nor specialized.

Objective of Company

The main goal of WeighstEd Inc. is to provide catering services, on-site restaurant services, and meal service providers with analytical and accurate food waste information about the food they are delivering to students at campus dining locations. This data will take the form of charts, graphs, and raw data on Google Sheets.

Description of Product

WeighstEd opens a new information feedback loop that does not yet exist between meal service providers and their food. It provides the potential to optimize the food distribution process and as a result will save meal service providers time and money, reduce waste, and help the environment.

Potential Markets

Currently, to our knowledge, there are ZERO university catering companies who have implemented any type of automated food waste analysis tracking and monitoring. The market is massive. There are roughly 5,300 colleges and universities in America, most of which hire on-site restaurant services to control students' on-campus dining experience. There are several forms of college dining, ranging from all-you-can-eat buffet style to cafe pay-per-meal style. Nevertheless, WeighstEd is versatile and can be effective for all university dining styles since the user interface is customizable for each school's cafeteria needs.

Competition

The competition for an automated food waste collection and analysis product is slim to none. Currently there are no products on the market geared toward student interaction. However, the students are the primary consumers of the wasted product so it is careless not to consider the trends of students. These trends will differ from campus to campus and WeighstEd can customize for each cafeteria. Current methods still include a sorting process which requires a worker or volunteer to hand gather and categorize all the food waste so that data can be tracked accurately. WeighstEd eliminates this sorting step, easing the process and making it efficient and accurate.

Manufacturing Plans

We plan to build approximately 10 for the first round of manufacturing within 2 months in order to have products to show, sell, and perform additional testing. And as demand picks up we would be able to begin manufacturing more, with the objective of having 200 products in the first 6 months, and 500 products after the first 12 months. Hiring two temporary contract builders, one salesman, one technician and one manager for a year will cost approximately $900,000. Leasing a small office in the Silicon Valley will cost an estimated $250,000 and purchasing a company vehicle will that will aid in manufacturing will cost $40,000 including an allowance for gasoline. The cost of the machining tools necessary to produce the part will be passed onto the builder that we hire as a contractor. The cost of parts for producing the first 10 products will be approximately $10,000 and the other 490 are estimated to cost approximately $450,000. This means that we would need $1,500,000 to get the company started and keep it going for 1 year. After that, the cost of maintaining the company would be approximately $600,000 per year after the two builders finish their contract. Additionally, the cost to produce 100 additional units per year would raise the costs to $690,000.

Product Cost & Price

According to our budget we have spent $1300.58. Finding better suppliers and perhaps replacing some custom parts with commercially available parts we are hoping to reduce the price per device to down to approximately $900. This would allow us to sell them at $1250 as standalone machines. However the main source of revenue will be to lease them at $175 per month of use without including insurance. Catering companies and commercial eateries could use our product to optimize portion sizing and potentially save thousands of dollars on food that is wasted. The lease would include a subscription to the technician staff member of WeighstEd Inc. that would be able to fix any issues that might arise.

Financial Plan and ROI

If we can gain traction with the first customers quickly, we would be able to start making sales after the first 2 months of manufacturing and start bringing in revenue. The expected sales are 100 leases at the end of the first 6 months and an additional 300 leases by the end of the year for a total of 400 leases, with an outright sales predicted to be 50 for the year. This would mean that the company would have a revenue of $17500 per month at month 6, growing to $70000 per month by the end of the year, with $62500 from sales. At a constant rate for the years after with a total of 500 leases per month and 50 sales per year it would take 4 years to turn a profit since after the first year there would be a net loss of $1,082,500 with a yearly net profit of $402,500 per year from the second year onwards.

At this rate, the company would be able to pay back its investors within 10 years, breaking even after 8 and a half years.

Table 12. Financial projections for minimal long term expansion

Year	Costs	Leasing Option Revenue	Unit Wholesale Revenue	Total Revenue	Net Yearly Profit
1	1,500,000	400,000	62,500	462,500	-1,037,500
2+	690,000	750,000	62,500	812,500	122,500

Warranty and Servicing

The expected lifetime of this product is seven years and the warranty policy and servicing are based on this estimate.

<u>Warranty</u>

There is a warranty policy in which damaged product will be fixed free of charge in the first year, including shipping!

<u>Servicing</u>

In the infancy stage of the company, the servicing will be combined with the manufacturing division. Therefore, broken products will have to be shipped to the manufacturing warehouse in order to be repaired. The product will be fixed and shipped back within two weeks of receiving it. Shipping and repair will be free for the first year under the warranty, however, the customer will have to pay for shipping after the first year and pricing will vary between $50 and $300 depending on the necessary repair/replacement.

Insurance

WeighstEd will give customers the option to purchase a $28 yearly insurance policy. The insurance policy will cover all costs associated with repairs, replacements, and shipping for that year. After the product has reached the age of eight years the insurance policy will no longer be offered. This age limit is in place because the product was designed to live for only seven years.

Chapter 7

ENGINEERING STANDARDS AND REALISTIC CONSTRAINTS

As engineers, it is important to consider the implications of design decisions and product functionality. To facilitate good engineering practices and design with Santa Clara University Jesuit values, each of the following categories were considered in the design and production of WeighstEd; social sustainability, health and safety, environmental, and ethical. The design constraints as well as the implications in each category due to this project are outlined below.

Social

Our product can make a significant social impact by creating environmentally-conscious communities. WeighstEd aspires to educate users in order for them to be more conscious about the decisions they make with every meal purchase. In turn, this may help individuals connect through their consciousness about food waste and find a deeper connection to the natural world.

Sustainability

Our project focuses on the need to educate the public, specifically the students at SCU, about how the amount of food that is wasted on an individual level can impact the environment. It also focuses on reaching finite goals at the university level for food waste reduction by providing facts that provide a clear picture of the current situation and what issues create the biggest burden on the environment so that our impact on the environment is diminished.

Health & Safety

To reduce the risk of accidental harm coming to anyone who uses our product the final design must consider the ease of use and the possibility of injury, for example due to pinch points. During use, most of the moving parts will be enclosed within the frame providing a physical barrier. The exception is the opening mechanism which all users must interact with. To reduce the possibility of injury the lid does not fully close or open so that it cannot pinch the user. No smart safety measures such as an infrared sensor were implemented.

Environmental

Our project, which focuses on reducing the environmental impact of food waste by providing facts to encourage conversation about sustainability, must also take into account the environmental impact that our design has. For this purpose the choice of materials used in the design was made to meet the technical specifications while minimizing the ecological footprint that the manufacturing of the project entails. It was also important to take into account the process of disposing of the project once the product has reached the end of its life cycle, particularly the electronic components since they contain toxic elements.

Ethical

As inhabitants of the planet Earth, it is humans ethical duty to serve and protect nature, it's given resources, and its creatures. To do so, it is imperative that waste be mitigated. Food waste accounts for extremely large percentages of resource allocation (which are discussed in depth in the introduction section of this report) and the production, consumption, and subsequent waste of these resources and the foods they create release harmful toxins into the environment. Additionally, 795 million people in the world "do not have enough food to lead a healthy active life" and this equates to about 1 in every 9 people on Earth.[14] Decreasing food waste can save resources, save money, and help re-allocate to areas in need.

[14] "World Hunger Statistics." *Food Aid Foundation*, www.foodaidfoundation.org/world-hunger-statistics.html.

Chapter 8

SUMMARY AND CONCLUSIONS

The purpose of this senior design project was to design and build a data collection system for food waste in order to help meet food waste reduction goals, optimize portion sizes, and educate individuals about their own impact when it comes to food waste. A very exciting aspect of this particular project is that we will be passing on our product to the Sustainability Center at Santa Clara University in order to help the university in its commitment to reducing food waste.

Our design was broken down into the following subsystems to address the particular design requirements: weighing, lid, frame, and backend. Each of these subsystems contributes to the overall functionality of WeighstEd.

Our team had to grow as engineers along our journey of designing WeighstEd. Our project involved mechatronics as well as backend data processing, actuation, and coding--which each team member had little experience with before taking. Each of the team members gained valuable skills in these areas as well as in manufacturing, ideation, troubleshooting, and written and oral communication. The interdisciplinary nature of this project proved to be the most difficult component as implementing these sections had a very steep learning curve.

The most fulfilling part of this project was the connection to Santa Clara University, specifically the Sustainability Center. Creating something that has the potential to create a long and lasting impact on SCU and its students is an extremely special reward. Furthermore, creating a functional product that is ready for immediate use is a great accomplishment.

We are passionate about reducing food waste on campus and we are confident that our project will be a useful tool for the Sustainability Center to enact meaningful food waste reduction policies.

Figure 31. WeighstEd

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Appendix A: Budget

Table A1: Budget broken down by subsystem

Component Description	# of items	Cost /part	Cost Total
LID			
Top Plate, Door	1	$128.42	$128.42
Stepper Motor Mounting Bracket	1	$8.99	$8.99
Base	1	$5.00	$5.00
Motor	1	$13.99	$13.99
Connector Tab	1	$2.00	$2.00
Keyed Shaft	1	$22.12	$22.12
Motor Mount	1	$0.00	$0.00
Shaft Mount	1	$0.00	$0.00
Shaft Collars	2	$4.11	$8.22
Shaft Collar Key	1	$0.00	$0.00
Shaft Coupler Motor Connector	1	$7.66	$7.66
Track Rollers	4	$18.47	$73.88
Gear	1	$8.62	$8.62
Rack	1	$3.27	$3.27
Acrylic Glue	1	$10.99	$10.99
Stepper Motor Driver Module	1	$10.99	$10.99
Plastic Cord Grommet	1	$4.14	$4.14
Sleeve Bearing	1	$9.73	$9.73
Lid Assembly	1	$233.64	$293.16
Subsystem Totals		$233.64	$293.16

Component Description	# of items	Cost /part	Cost Total
POWER AND DATABASE			
Starter Kit (Wires, Resistors, Etc.)	1	$12.49	$12.49
Miscellaneous Electronics	1	$37.93	$37.93
Enclosure	1	$30.35	$30.35
ESP8266	1	$12.99	$12.99
Arduino Mega	1	$12.49	$12.49
Arduino Yun	1	$69.99	$69.99
HX711 Amplifier	1	$13.95	$13.95
External Power Supply	1	$26.86	$26.86
Subsystem Totals		$190.19	$217.05

Component Description	# of items	Cost /part	Cost Total
MEAL IDENTIFICATION			
LCD Touchscreen	1	$132.43	$132.43
LCD Touchscreen Security Case	1	$9.99	$9.99
Tablet Wall Mount	1	$16.99	$16.99
Subsystem Totals		$159.41	$159.41

Component Description	# of items	Cost /part	Cost Total
FRAME & COVER			
Waste Bin	1	$12.97	$12.97
Home Depot Plywood - 2ft x 4ft	4	$21.72	$86.88
Lumber Yard Plywood - 5ft x 5ft	2	$25.00	$50.00
Waterproofing	1		
Stain	1	$8.98	$8.98
Pre-Conditioner	1	$12.68	$12.68
Stain Brush	1	$9.41	$9.41
Caster Wheels (lockable)	4	$13.30	$53.21
Steel Hinge For Cover	2	$7.40	$14.80
Plastic Hinge For Trash Door	3	$1.44	$4.32
Wooden Beam 1x1x36	1	$3.28	$3.28
Fasteners	1	$34.68	$34.68
Solid Square Bar 1x1x12 in	1	$8.29	$8.29
Hollow Square Bar 1x1x12 in (1/16 thick	1	$3.36	$3.36
Hollow Square Bar 1x1x36 in (1/16 thick	1	$8.31	$8.31
TV Wall Mount	1	$10.97	$10.97
TV	1	$90.00	$90.00
Tablet Mount	1	$25.00	$25.00
Loctite Threadlocker OPTION 1	1	$6.47	$6.47
Loctite Epoxy OPTION 2	1	$8.37	$8.37
Subsystem Totals		$311.63	$451.98

Component Description	# of items	Cost /part	Cost Total
WEIGHING			
Load Cell (30kg)	1	$135.00	$135
Load Cell Amplifier	1	$13.95	$14
Load Cell Frame Plywood	1	$22.99	$22.99
Washers	1	$0.78	$0.78
Nuts	2	$0.64	$1.28
Bolts (M6)	1	$5.28	$5.28
Metal Support	1		
#6 1/2 inch wood screws	16		
Subsystem Totals		$178.64	$179.28

Appendix B: Timeline

This Appendix show the workflow carried out through the project in the form of a series of Gantt charts, first for the project as a whole, and followed by the individual subsystems.

Table B1. System level Gantt chart by month

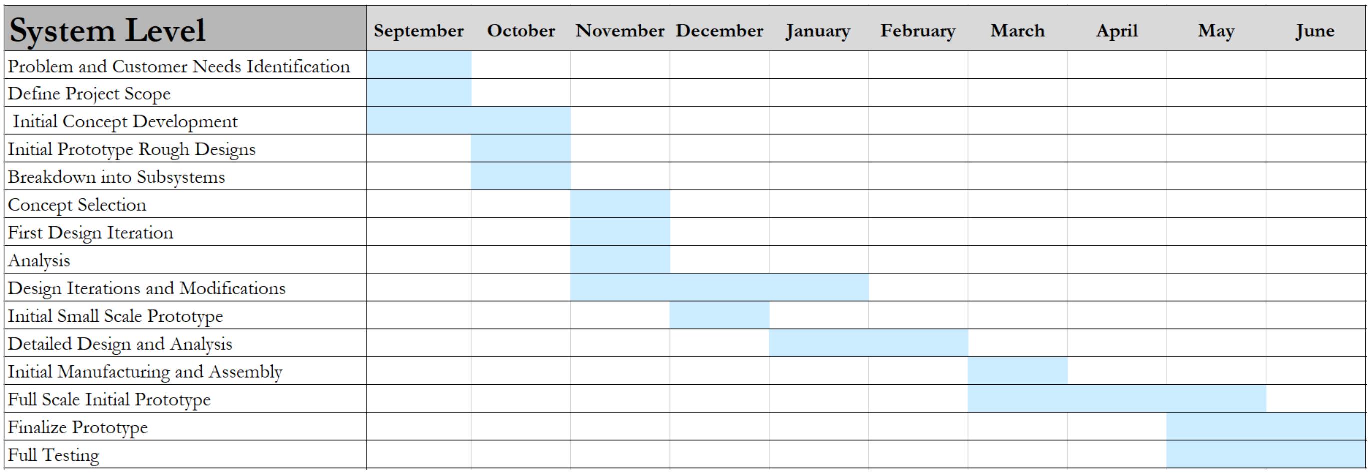


Table B2. Frame Gantt chart by month

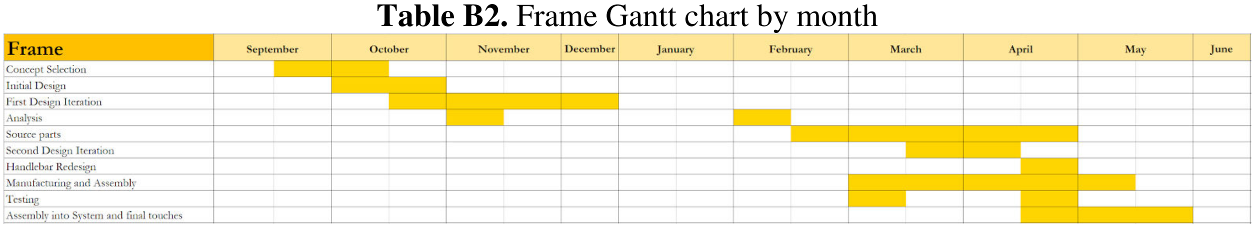


Table B3. Lid Gantt chart by month

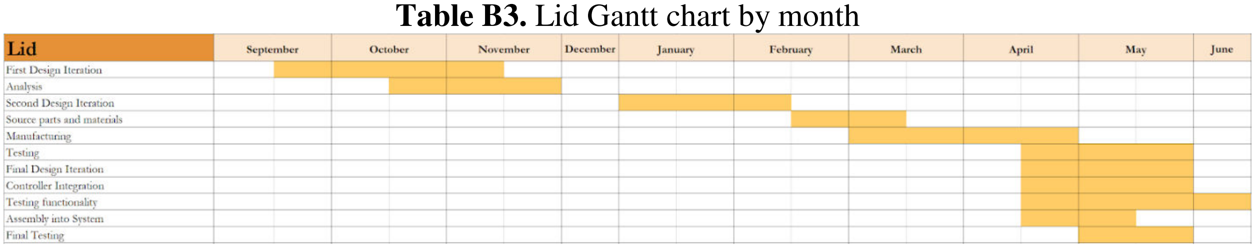


Table B4. Weighing Gantt chart by month

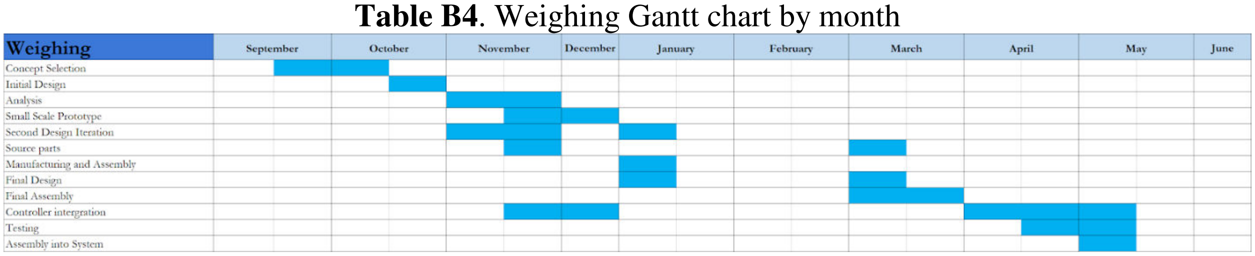


Table B5. Meal Identification Gantt chart by month

Table B6. Power/Database Gantt chart by month

Appendix C: Scoring Matrices

WEIGHING SUBSYSTEM							
Criteria	**Weight**	**Hanging Scale w/ Loading Cell**	**Weighted Score**	**Digital Scale Above Bin**	**Weighted Score**	**Digital Scale Below Bin**	**Weighted Score**
Accuracy	0.25	5	1.25	5	1.25	5	1.25
Ease of Use	0.2	3	0.6	4	0.8	5	1
Ease of Manufacture/Assembly	0.125	2	0.25	4	0.5	5	0.625
Cost	0.15	4	0.6	4	0.6	4	0.6
Durability	0.1	4	0.4	4	0.4	5	0.5
Aesthetics (eye-catching)	0.05	4	0.2	3	0.15	3	0.15
Portability	0.125	1	0.125	3	0.375	5	0.625
Totals	**1**	23	**3.425**	27	**4.075**	32	**4.75**
NOTES	**Ranking (High-Low)**						
Weighted score out of 5	1. Digital Scale Below Bin						
Non-weighted score out of 35	2. Digital Scale Above Bin						
	3. Hanging Scale w/ Loading Cell						

AUTO LID OPENING							
Criteria	**Weight**	**Iris**	**Weighted Score**	**Folding Flaps**	**Weighted Score**	**Sliding Door**	**Weighted Score**
Process Time	0.15	5	0.75	5	0.75	5	0.75
Visual Barrier	0.1	4	0.4	4	0.4	5	0.5
Ease of Manufacture/Assembly	0.15	2	0.3	4	0.6	4	0.6
Cost	0.1	3	0.3	4	0.4	4	0.4
Durability	0.2	3	0.6	4	0.8	5	1
Aesthetics (eye-catching)	0.3	5	1.5	2	0.6	3	0.9
Totals	**1**	22	**3.85**	23	**3.55**	26	**4.15**
NOTES	**Weighted Ranking (High-Low)**						
Weighted score out of 5	1. Sliding Door						
Non-weighted score out of 35	2. Iris						
	3. Folding Flaps						

MEAL IDENTIFICATION							
Criteria	**Weight**	**Tablet**	**Weighted Score**	**Image Recognition**	**Weighted Score**	**Molecular Spectroscopy**	**Weighted Score**
Accuracy/Consistency	0.25	3.5	0.875	4	1	4	1
Time For Identification	0.25	3.5	0.875	5	1.25	5	1.25
Ease of Manufacture/Assembly	0.15	4	0.6	2.5	0.375	4	0.6
Cost	0.075	4	0.3	4	0.3	4	0.3
Durability	0.1	5	0.5	3	0.3	5	0.5
Aesthetics	0.05	4.5	0.225	4.5	0.225	4.5	0.225
Portability	0.125	5	0.625	3	0.375	4	0.5
TOTALS	**1**	**29.5**	**4**	**26**	**3.825**	**30.5**	**4.375**
NOTES	**Weighted Ranking (High-Low)**						
Weighted score out of 5	1. Molecular Spectroscopy						
Non-weighted score out of 35	2. Tablet						
	3. Image Recognition						

CLEANING SUBSYSTEM							
Criteria	**Weight**	**Rolling Wiper Arm**	**Weighted Score**	**Squeegee and Bristles Uni-Directional**	**Weighted Score**	**Mechanical Arm**	**Weighted Score**
Level of Cleanliness	0.2	2.5	0.5	3.5	0.7	2	0.4
Process Time	0.2	5	1	4	0.8	5	1
Ease of Manufacture/Assembly	0.1	5	0.5	4	0.4	5	0.5
Cost	0.1	5	0.5	5	0.5	3.5	0.35
Durability	0.15	4	0.6	3.5	0.525	4	0.6
Aesthetics/Disgustingness	0.15	2	0.3	3.5	0.525	3.5	0.525
Portability	0.1	4	0.4	4	0.4	4.5	0.45

TOTALS	**1**	**27.5**	**3.8**	**27.5**	**3.85**	**27.5**	**3.825**
NOTES	**Weighted Ranking (High-Low)**						
Weighted score out of 5	1. Squeegee and Bristles						
Non-weighted score out of 35	2. Mechanical Arm						
	3. Rolling Wiper						
SECOND ITERATION							
Criteria	**Weight**	**Rolling Wiper Arm + Mechanical Arm**	**Weighted Score**	**Squeegee and Bristles + Mechanical Arm**	**Weighted Score**	**Wiper Arm + Squeegee and Bristles**	**Weighted Score**
Level of Cleanliness	0.2	3.5	0.7	4.5	0.9	4.5	0.9
Process Time	0.2	4	0.8	4	0.8	4	0.8
Ease of Manufacturing	0.1	4.5	0.45	4.5	0.45	4.5	0.45
Cost	0.1	3.5	0.35	3.5	0.35	4.5	0.45
Durability	0.15	4	0.6	3.5	0.525	3.5	0.525
Aesthetics	0.15	3	0.45	3.5	0.525	3	0.45
Portability	0.1	4	0.4	4	0.4	4	0.4
TOTALS	1	26.5	3.75	27.5	3.95	28	3.975
	Weighted Ranking (High-Low)						
	1. Wiper Arm + Squeegee and Bristles						
	2. Squeegee and Bristles + Mech Arm						
	3. Rolling Wiper Arm + Mech Arm						

Appendix D: AGMA Bending of Gears | MatLab Code

```
% AGMA Method for Spur Gears (English Units)

% AGMA bending (english units)
dg = 27; % Gear Pitch Diameter
dp = 9; % Pinion Pitch Diameter

% Ko - Overload Factor
Ko = 1; % No Shock

% Kv - Dynamic Factor
V = 30; %Velocity (ft/min)
Qv = 7; %Quality: (commercial is 3-7) (precision is 8-12)

B = .25*(12 - Qv)^(2/3);
A = 50 + 56*(1 - B);
Kv = (A + sqrt(V)/A)^B;

% Ks (neglect)
Ks = 1;

% Pd - Diametral Pitch
N = 12; % Number of Teeth around gear
Pd = N/dp; %teeth per inch around circumference

% F - Face Width
F = .25;

% Km - Load Distribution Factor
Cmc = 1;

a = F/(10*dp);
if a < .05
        a = .05;
end
Cpf = a - .025;

Cpm = 1;

%Open Gearing
A = .247;
B = .0167;
C = -.765*10^(-4);
Cma = A + B*F + C*F^2;
Ce = 1;

Km = 1 + Cmc*(Cpf*Cpm + Cma*Ce);

% Kb - Rim Thickness Factor
%tr = % rim thickness
%ht = 2% tooth height
```

```
%mb = tr/ht
%Kb = 1.6*log(2.242/mb)
Kb = 1;

% J - Geometry Factor
J = .21; % Use figure 14-6 pg. 745 f(N(desired gear),N(mating gear))

Wt = 2; % Tangential Force
Sy = 6500; % Acrylic Yield Strength

Sb = Wt*Ko*Kv*Ks*(Pd/F)*(Km*Kb/J) % Bending Stress
FS_B = Sy/Sb % Factor of Safety for Bending Stress

%Wtb = Sb/(Ko*Kv*Ks*(Pd/F)*(Km*Kb/J))

%r = dp/2
%w = % angular velocity of gear

%Tb = Wtb*r
%Pb = Tb*w

% AGMA Pitting

Cf = 1;
I = .25*(cos(.349) + sin(.349));
Sp = sqrt(Wt*Ko*Kv*Ks*Km*Cf/(dp*F*I)) % Pitting Stress
FS_P = Sy/Sp % Factor of Safety for Pitting

% Wtp = Sb^2/(Ko*Kv*Ks*Km*Cf/(dp*F*I))
%
% Tp = Wtp*r
% Pb = Tp*w
```

```
Sb =
  1.3731e+03
FS_B =
    4.7340
Sp =
    8.6597
FS_P =
  750.6013
```

Published with MATLAB® R2017a

Appendix E: Prototype Lid Finite Element Analysis

Introduction

The subsystem we will analyze is the iris opening mechanism since it will experience the most stress of the entire system due to the most moving parts it contains. First we will examine how one of the five leaves which make up the lid will react to a load applied to the corner of a leaf closest to the center of the opening. This is important to understand what would happen if a small load was applied on the opening which could cause it to fail. And secondly, we will analyze the forces which act on the leading gear of the opening mechanism.

For both analyses the material was modeled as Acrylic (Medium-High impact) from the Solidworks library. Acrylic has a yield strength of 6527 psi, an elastic modulus of 435113 psi, and a Poisson's ratio of 0.35.

Analysis

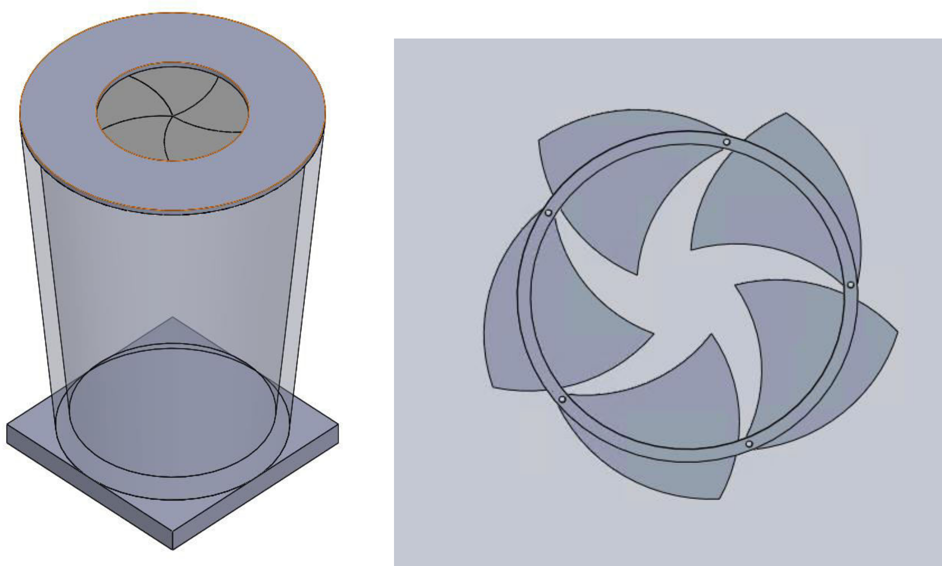


Figure E1: Opening Mechanism subsystem and its location in overall system

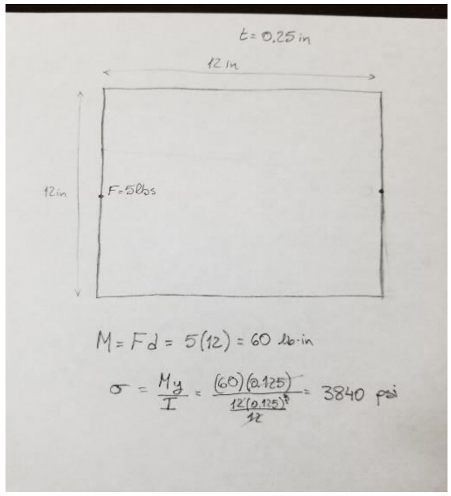


Figure E2: Simplified model and hand calculations for a point force applied to an end of a rectangular flat plate and restrained at the opposite end.

For the preliminary calculations, the plate was simplified as a rectangular thin plate of dimensions 12x12x0.25 inches with a load of 5 lbs. applied to one end and restrained at the opposite end as is shown in Figure E2. The stress was calculated using the equations shown in Figure E2 [1] where M is the bending moment, d is the distance between the force and the calculated moment, I is the cross-sectional moment of inertia and y is the midpoint of the thickness of the plate, where the stress is highest.

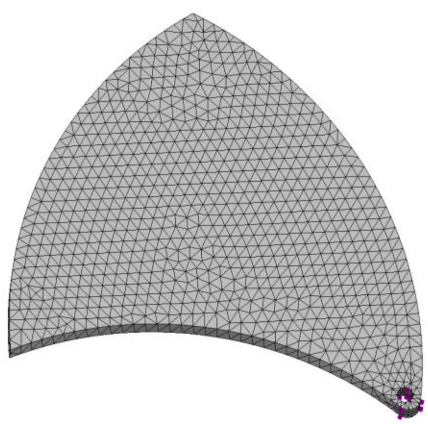


Figure E3: Mesh used for the model of the leaf

For the simulation, a mesh with 9449 elements was used, including a mesh control applied at the hole with the fixed geometry to refine the mesh where the stress concentration was greatest.

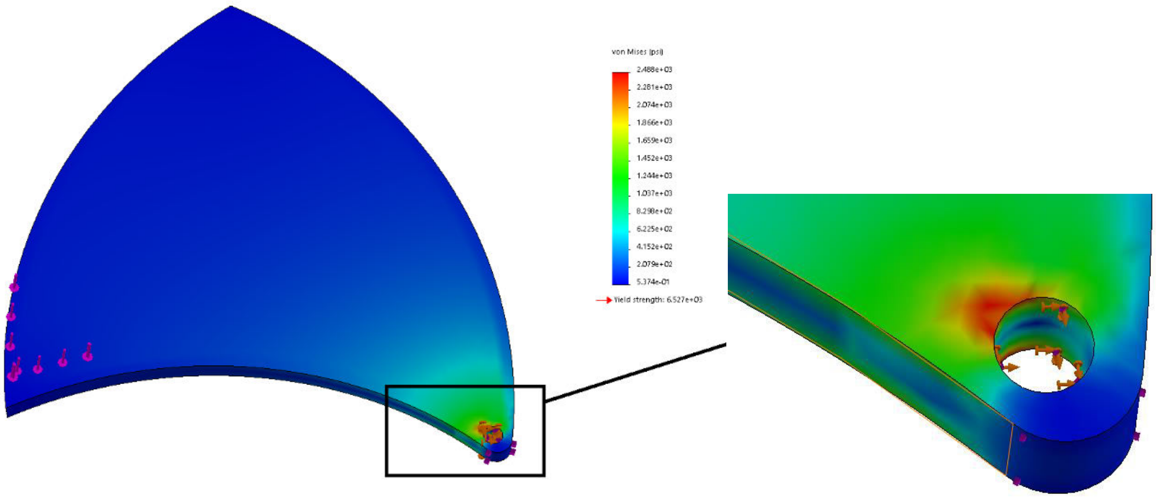


Figure E4: Stress Distribution showing the stress concentration on the acrylic leaf with stress ranges from 2.4884e+03 to 5.374e+01 psi.

A load of 5 lbs. was applied to a region on the tip of the leaf. It was expected to deform without reaching critical stress since the yield strength of acrylic used for the model is 6527 psi and the expected stress was 3840 psi. After simulating the more complex geometry of the true dimensions and shape of the model in Solidworks the highest stress was found around the hole which will be pinned to restrict movement in the vertical direction when the plate is parallel to the ground. The value of the stress found from the Solidworks simulation was lower than the expected value and had a magnitude of 2488 psi as shown in Figure E4.

The main issues that arose when using the model were establishing the correct restraints and fixed geometry for the simulation to run smoothly. This problem was worked around by assuming that the pinned connection would be treated as a fixed geometry when the load was applied for this simulation. In reality, however, the connection will allow for the leaf to rotate in order to open and close the iris mechanism.

Our second possible mode of failure would occur at the gears. We determined that if the gears could withstand loading while in the locked position they would not fail during normal operation when they are free to rotate. Our gears should be able to withstand this test as a safety and quality precaution. Pinions have higher stress than gears so our analysis has been done on the pinion.

In the Solidworks model the acrylic pinion is fixed around the hinge and a two pound force is applied at one of the teeth. 5896 elements are used and mesh refinement was done at the tooth of interest.

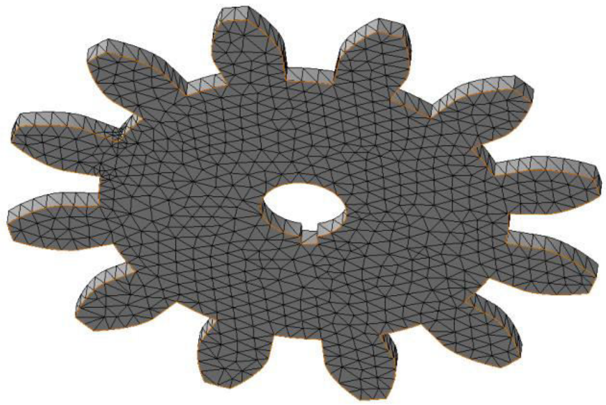


Figure E5: Pinion Mesh

The simulation showed that the maximum Von Mises stress was 29 psi at the tooth transition. In order to check our simulation we made a Matlab code for AGMA method pitting, in which the maximum stress was 10 psi. We believe this discrepancy is because the pinion is moving at 1 ft/s in the code while in our model the pinion is fixed. In both cases the pinion does not fail by a couple of orders of magnitude.

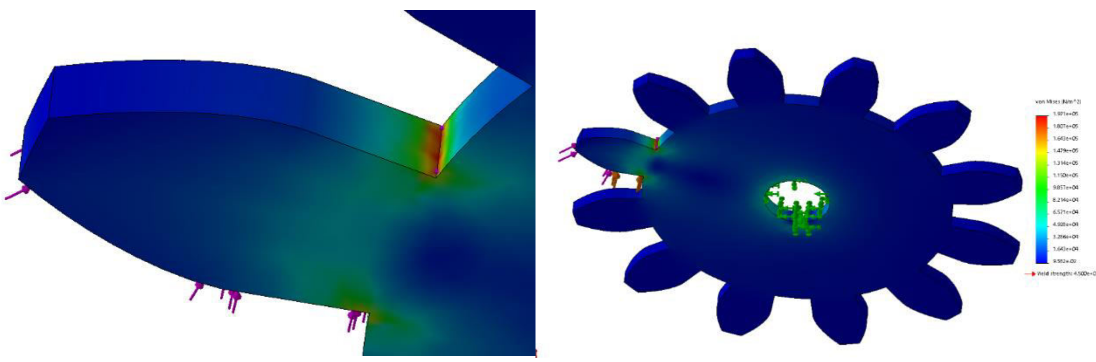


Figure E6: Von Mises Stress Distribution of Pinion Tooth under Loading ranging from 1.901e+05 to 9.582e+02 N/m^2.

Conclusion

The analysis undertaken for this report served to analyze whether the geometry of the lid mechanism and material selected for the lid would withstand operational loading with some factor of safety. Due to the relatively low loading experienced by the parts, the Solidworks models passed with enough room for error to give us confidence that our design is feasible and adequate for the loading conditions. Much more in depth modeling must be done on these parts and the system as a whole, along with real world testing to verify the final design.

Appendix F: Door Hub Finite Element Analysis

The track roller locations became a critical feature after failure during manufacture occurred. Finite element analysis was completed to determine the ideal location of the track roller hole while prioritizing the thin feature below the threads and maintaining the hub cover to shield the rollers from dust, debris, food, and water. The wheel hub and thin features can be seen below.

Figure F1. Track roller in door showing hub and thin features

To analyze the stresses, FEA was completed on a simplified version of the door and modeled as a distributed load over a surface with the hole held fixed. A load of 10 lbs. was tested for different hole locations. The lid assembly and FEA simplification can be seen below.

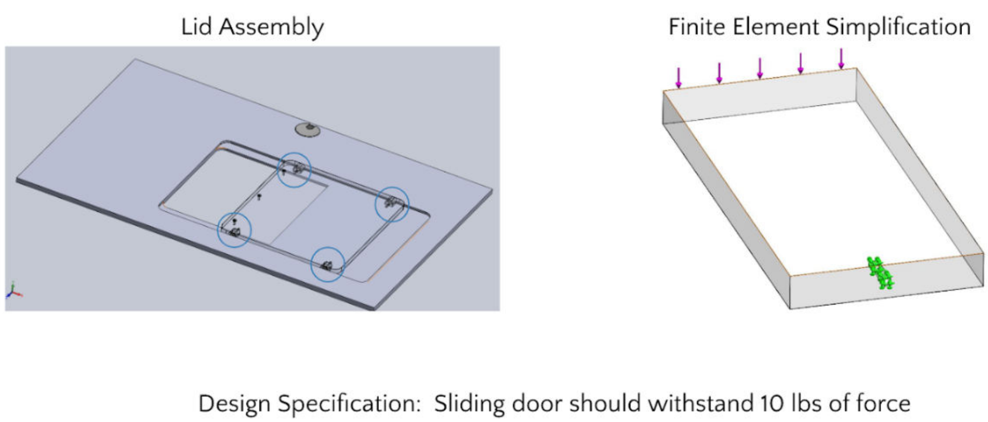


Figure F2. Lid assembly and FEA simplification

From this analysis, shear and normal stresses were created at and along the hole and threads. These two main stresses can be seen in the figures below.

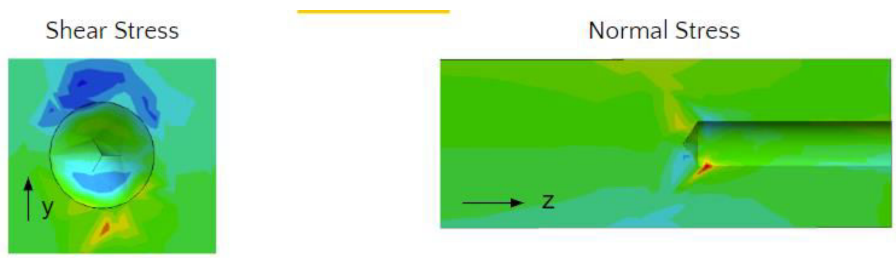


Figure F3. Shear and normal stresses at and along hub hole and threads

To determine whether different whole locations were safe, a failure criterion was necessary. Due to the brittle characteristics of Acrylic and because acrylic is stronger in compression than in tension, Mohr's Failure Criterion was used. To use this failure criterion the shear and normal stresses were used to calculate the principal stresses occurring in each simulation. Theses stresses were then plotted on Mohr's failure criterion graph to determine whether each location would pass and if so with what factor of safety. The following figures show the principal stresses and Mohr Criterion Failure Plot for the accepted hole location.

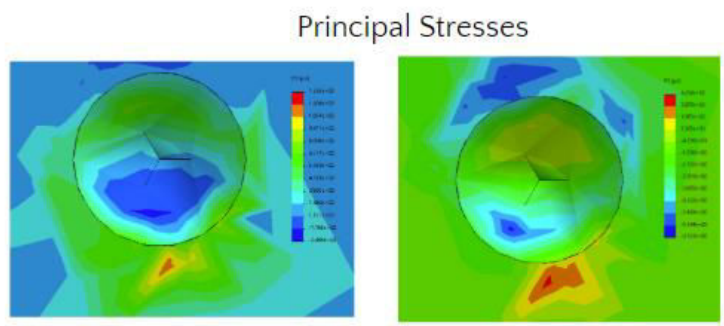


Figure F4. Principal stresses from accepted hub hole location ranging from 1.338e+03 to -2.488e+02 (left) psi and 4.236e+02 and -9.761e+02 psi (right)

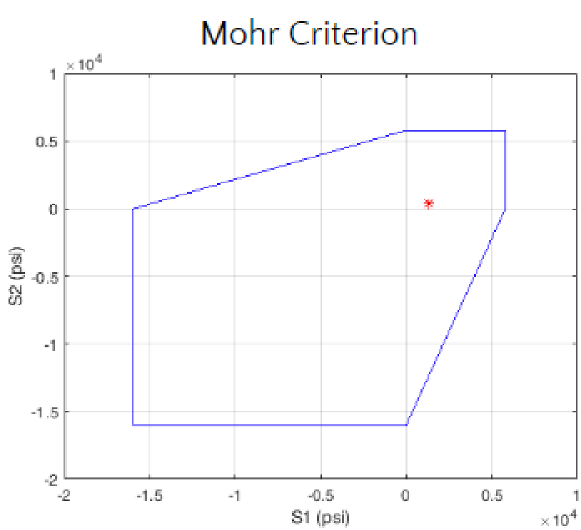


Figure F5. Mohr's Criterion plot showing accepted point

The hole location was accepted with a factor of safety of 4.33.

Appendix G: Food Waste Questionnaire & Raw Data

Food Waste Questionnaire

1. Is food waste an important issue to you?

(Not Important Somewhat Important Important Very Important)

2. How frequently do you eat in Benson?

(Never Rarely Some Meals Most Meals All Meals)

3. What year are you?

(Freshman Sophomore Junior Senior)

4. What gender are you?

(Male Female)

5. How often do you scrape your leftover food into composting?

(Never Rarely Some Meals Most Meals All Meals)

6. How much time would you spend interacting with a food waste collection kiosk after meals in order to help SCU collect information about food waste?

(None 10 seconds 20-30 seconds 30-60 seconds A couple Minutes)

7. Would you need an incentive (ex. reward credits for meal points after certain amount of uses) to interact with a food waste collection kiosk?

(Yes No No Interest in Participation)

Rank the following Incentives (1-4, 1 being most desired):

a. Entries into a raffle ______
b. Reward points that can be redeemed for snacks (cookies, chips, soda, etc.) ______
c. Reward points that can be redeemed for SCU swag (lanyard, sticker, T-shirt) ______
d. Reward points that can be redeemed for discounts at bookstore ______

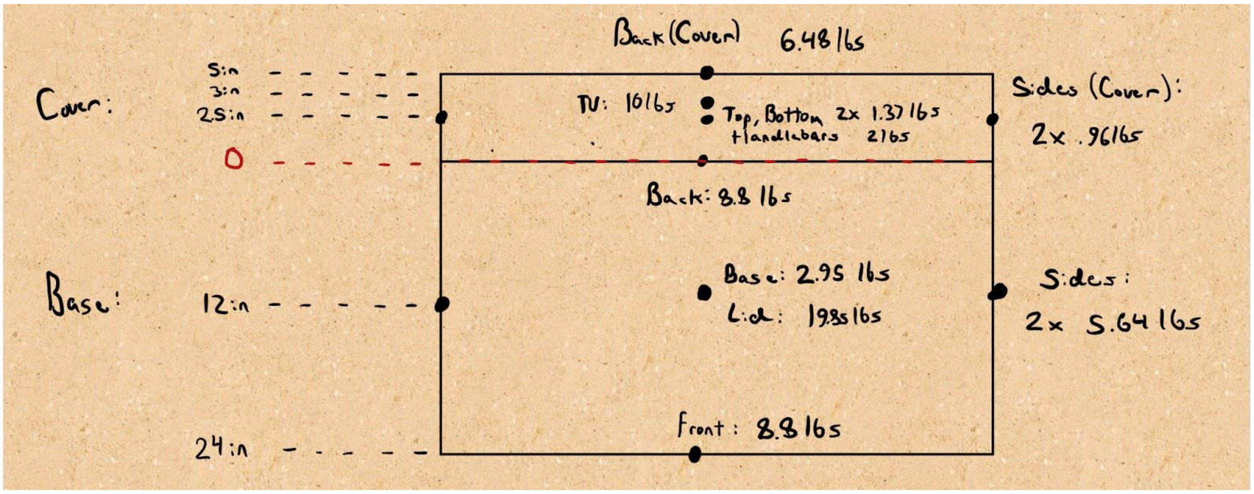
Table G1. *Raw Tabulated Data*

Subject	1	2	4	3	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Question 1	3	3	2	2	2	2	4	2	2	3	4	3	3	4	1	3	2	3	3	2	5	3	2	2	2
Question 2	5	2	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5
Question 3	1	3	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1	1	2	1	1	2	1	1
Question 4	1	2	1	2	2	2	2	1	1	1	2	1	1	2	1	1	1	2	2	2	1	1	1	1	2
Question 5	5	5	5	3	4	5	4	5	2	5	1	2	5	5	5	5	5	5	5	3	2	5	4	5	2
Question 6	1	3	2	2	1	3	3	3	3	4	4	3	3	4	1	4	3	3	3	3	3	4	2	2	2
Question 7	1	2	1	1	2	2	2	2	2	2	2	2	2	1	1	2	1	2	1	1	1	2	2	1	2
a	4	4	4	4	1	4	1	4	4	4	4	4	4	3	2	4	4	4	4	1	2	3	4	4	3
b	1	2	2	1	3	2	4	2	2	1	2	3	3	2	4	3	3	3	1	4	4	2	1	1	4
c	2	1	3	3	2	1	4	3	1	3	1	1	1	4	1	1	1	1	2	3	1	1	2	3	1
d	3	3	1	2	4	3	4	1	3	2	2	2	2	1	3	2	2	2	3	2	3	4	3	2	2

Table G2. Organized data summarizing the results of the SCU student surveys.

Question					
1	**Not Important**	**Somewhat Important**	**Important**	**Very Important**	
	1	11	9	3	
2	**Never**	**Rarely**	**Some Meals**	**Most Meals**	**All Meals**
	0	1	4	18	2
3	**Freshman**	**Sophomore**	**Junior**	**Senior**	
	20	4	1	0	
4	**Male**	**Female**	N/A		
	14	11	N/A		
5	**Never**	**Rarely**	**Some Meals**	**Most Meals**	**All Meals**
	1	4	2	3	15
6	**None**	**10 Seconds**	**20-30 Seconds**	**30-60 Seconds**	**A Couple Minutes**
	3	5	12	5	0
7	**Yes**	**No**	N/A		
	10	15	N/A		

Appendix H: Tipping Calculations



ΣM:

$M_{Cover} = (6.48 \text{ x } 5) + (10 \text{ x } 3) + 2.5 \text{ x } (0.96 \text{ x } 2 + 1.37 \text{ x } 2) = 223.9$ lb x in

$M_{Base} = 12 \text{ x } (5.64 \text{ x } 2 + 19.85 + 2.95) + 24 \text{ x } 8.8 = 2780.16$ lb x in

$M_{Base} >> M_{Cover}$

We can conclude from this calculation that the assembly will not tip over.

Appendix I: Bill of Materials

Component Description	Part #
Frame Subsystem	
Waste Bin	F001
Plywood Sections	F002
Wheels (lockable)	F005
Steel Hinges For Cover	F006
Hinges For Door	F007
2x4 Support Beams	F008
Fasteners	F009
Angle Brackets	F010
Corner Brackets	F011
Door Handle	F012
Cover Handle	F013
TV Wall Mount	FB04
TV	FB05
Handle Assembly	FA2
Frame Assembly	**FA1**
Weighing Subsystem	
Load Cell (30kg)	W001
Load Cell Amplifier	W008
Plywood - Load Cell Frame	W002
Washers	W003
Nuts	W004
Bolts (M6)	W005
Metal Support	W006
#6 1/2 inch wood screws	W007
Spacers	W008
Scale assembly	**WA1**
Meal ID Subsystem	
LCD Touchscreen	M001
LCD Touchscreen Security Case	M002
Tablet Wall Mount	M003
Meal Identification Assembly	**MA1**

Component Description	Part #
Lid Subsystem	
Top Plate, Door	L001
Stepper Motor Mounting Bracket	L003
Base	L004
Motor	L005
Connector Tab	L006
Keyed Shaft	L007
Motor Mount	L008
Shaft Mount	L009
Shaft Collars	L010
Shaft Collar Key	L011
Shaft Coupler Motor Connector	L012
Track Rollers	L013
Gear	L014
Rack	L015
Acrylic Glue	L016
Stepper Motor Driver Module	L017
Plastic Cord Grommet	L018
Sleeve Bearing	L019
Lid Assembly	**LA1**
Power and Database Subsystem	
Miscellaneous Electronics	E008
Enclosure	E007
Starter Kit (Wires, Resistors, Etc.)	E001
ESP8266	E002
Arduino Yun	E003
HX711 Amplifier	E004
Database	E005
External Power Supply	E006
Power and Database Assembly	**EA1**

Appendix J: Testing Tables

Table J1: Weighing Accuracy Test

	0 lbs before tare		*1 lb Before Tare*		*5 lbs Before Tare*	
	True (lbs)	Measured (lbs)	True (lbs)	Measured (lbs)	True (lbs)	Measured (lbs)
	0.1987	0.198	0.1987	0.198	0.1987	0.199
	0.1987	0.198	0.1987	0.198	0.1987	0.198
	0.1987	0.198	0.1987	0.199	0.1987	0.197
	0.1987	0.198	0.1987	0.198	0.1987	0.198
	0.1987	0.197	0.1987	0.198	0.1987	0.198
Average:		0.1978		0.1982		0.198
Standard Deviation:		4.47E-04		4.47E-04		7.07E-04
Percent Error:		0.45%		0.25%		0.35%

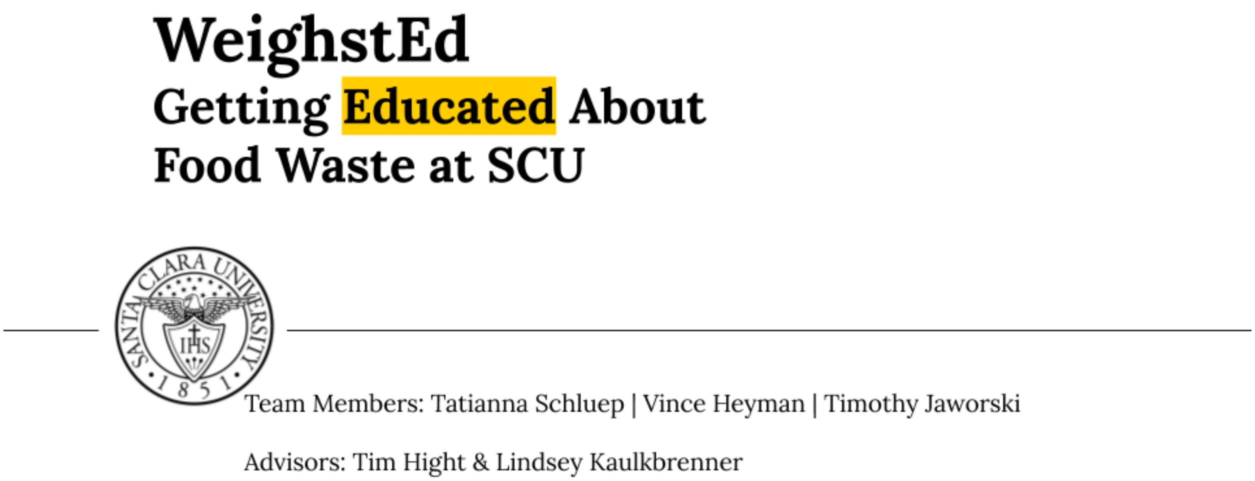
	10 lbs Before Tare		*25 lbs Before Tare*		*50 lbs Before Tare*	
	True (lbs)	Measured (lbs)	True (lbs)	Measured (lbs)	True (lbs)	Measured (lbs)
	0.1987	0.197	0.1987	0.2	0.1987	0.199
	0.1987	0.197	0.1987	0.2	0.1987	0.197
	0.1987	0.197	0.1987	0.2	0.1987	0.198
	0.1987	0.197	0.1987	0.199	0.1987	0.2
	0.1987	0.198	0.1987	0.199	0.1987	0.199
Average:		0.1972		0.1996		0.1986
Standard Deviation:		4.47E-04		5.48E-04		1.14E-03
Percent Error:		0.75%		0.45%		0.05%

Table J2: Process Time Test Data

Trial	*Opening Time*
Trial 1	24.91
Trial 2	23.62
Trial 3	22.56
Trial 4	23.92
Trial 5	26.54
Trial 6	22.93
Trial 7	31.38
Trial 8	28.93
Trial 9	25.47
Trial 10	27.30
Average:	25.76
STD:	2.82
Range:	2.02
N:	10
t9,95	2.262
Target:	30
Percent Difference:	14.15

Appendix K: Senior Design Conference Presentation Slides

This appendix consists of the slides used for the Senior Design Conference Final Presentation of WeighstEd.



1

Problem Identification
Food Waste

A problem in need of more than just a waste bin...

3

Every year in the US . . .

~40%

of all food goes to landfills

70,000,000 tons

of *food wasted*

220,000,000,000$

spent on *food* never eaten

[1]

4

Wasted Resources [2]

Freshwater
21%

Fertilizer
19%

Cropland
18%

Landfill Volume
21%

5

PROBLEM STATEMENT

SCU has made a commitment to reducing its food waste by 10% by 2020.

~ However ~

The school lacks an accurate method for collecting and analyzing food waste data

“

6

2 Project Goals

Driven by Sustainability Center, SCU Student needs and SCU School of Engineering Resources

7

Project Goals

1. Weigh and collect food waste
2. Store and analyze relevant data
3. Educate students about food waste trends

Client Needs

- Collect average food waste
  - Per menu item
  - Tracked quarter to quarter
- No volunteer
- Portable

End User (Student) Needs

- Informative experience
- Fast and Easy

8

3 System Level Run Through

An introduction to WeighstEd

9

System Level Breakdown

- Mobile
- Self Contained
- Educational
- Collects waste data
- Stores waste data
- Analyzes waste data

4 Subsystems

10

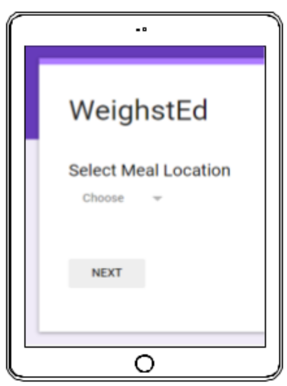
System Level Breakdown

11

Simple 6 Step Process

1

User identifies meal (via tablet)



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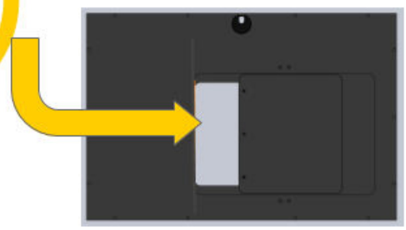
Simple 6 Step Process

1. User identifies meal (via tablet)
2. Door Opens



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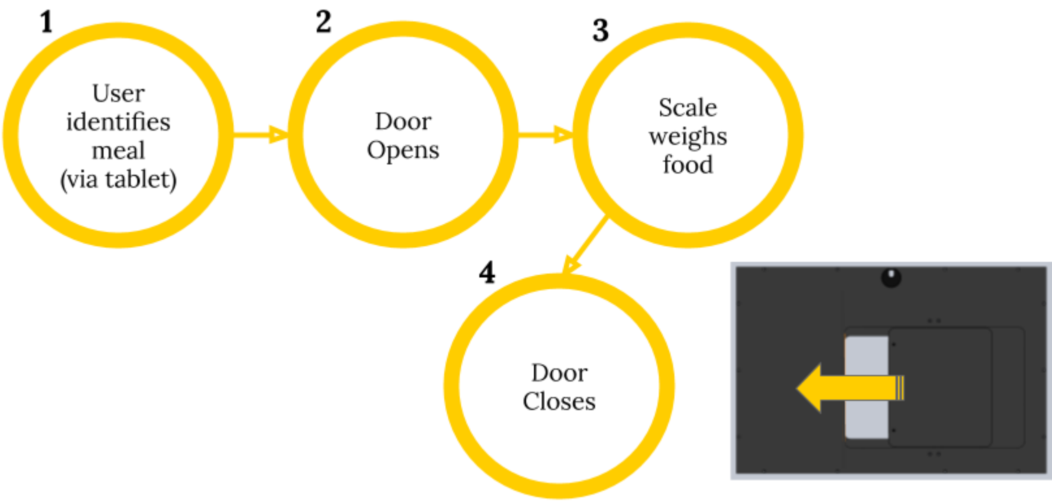
Simple 6 Step Process

1. User identifies meal (via tablet)
2. Door Opens
3. Scale weighs food

14

Simple 6 Step Process



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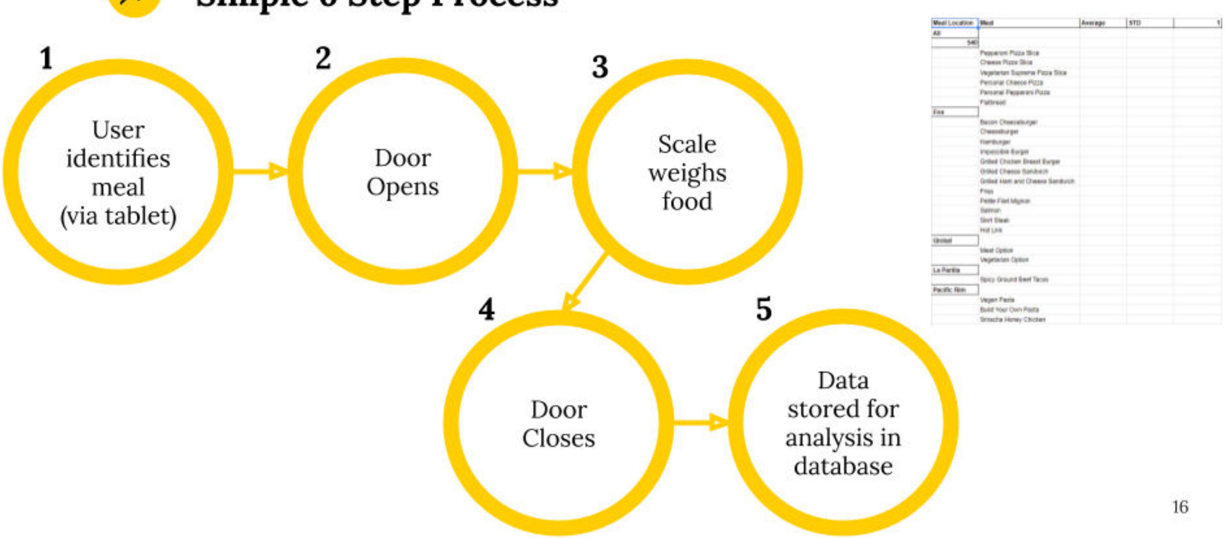
Simple 6 Step Process



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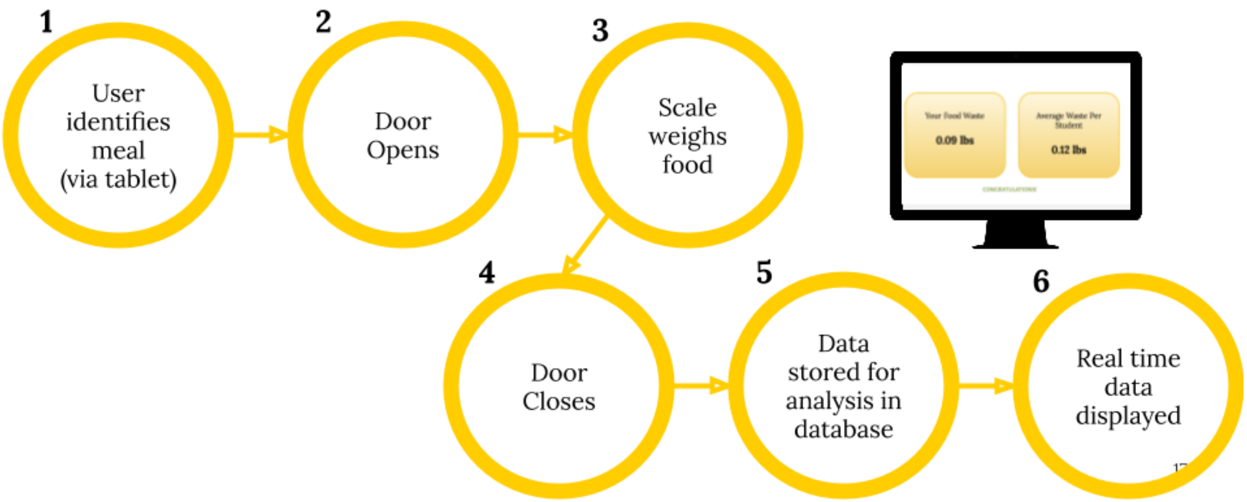
Simple 6 Step Process



4 Subsystem Breakdown

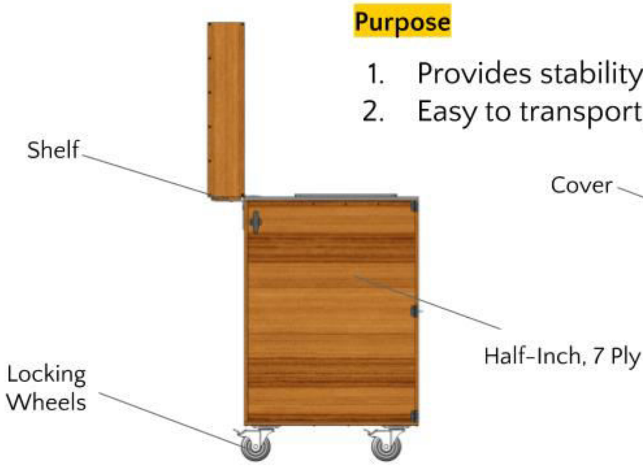
Description, Challenges, Analysis, Improvements

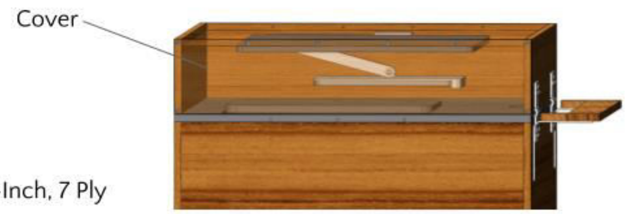
18

Frame & Cover Subsystem

Purpose

1. Provides stability and structural integrity
2. Easy to transport, store, and maintain





19

Design Iteration

- Size Reduction

Weighing Subsystem

Final Scale Design

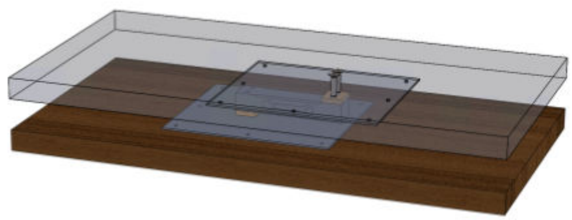
Bending Beam Load Cell

Design Constraints

- Collect accurate weight data of food waste
- Each interaction allows for collection of individual meal information
- Send weight data to microcontroller

21

Weighing Subsystem



Specifications

Up to 55 lb (25 kg) of food waste

±0.002 lb of accuracy

Ensures accuracy without having to unload the waste often

Improvements and Challenges

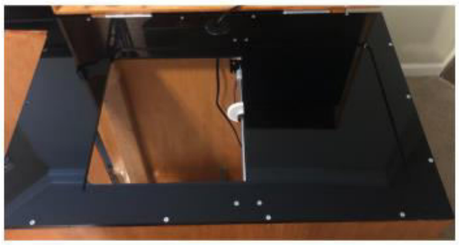
- Added sheet metal supports and wooden spacers
- Reduce bending and add stability

22

Lid Subsystem

Description

Automatic open/close acrylic sliding door actuated by a rack gear and pinion transmission assembly.



Purpose

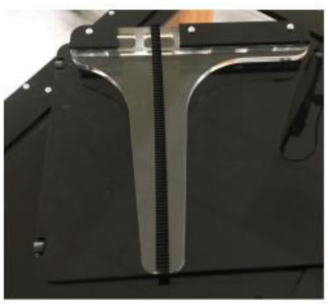
- ensure *methodical* collection of food waste data
- visual/physical barrier to internal components and waste

Specifications

- Door open <1.5 sec
- Improve user composting experience
- Aesthetically pleasing

23

Lid Components

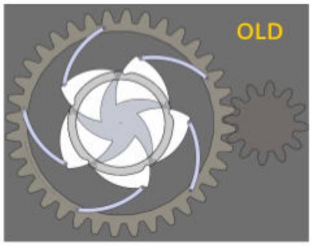


Door Subassembly

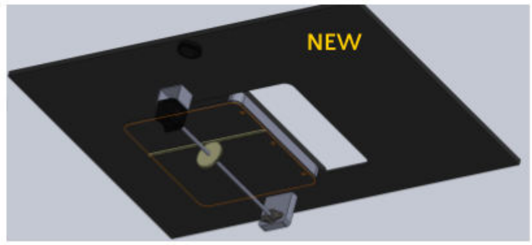
Lid Base

Transmission

Challenges & Improvements | Initial Design



- Difficult manufacturability
  - Custom parts
  - Difficult assembly
- Proportion issues
- Complicated geometry
- Poor user interaction



- Simplified layer assembly
  - Single point connection
- Improved proportion
  - 15% hole increase, 78% less space
- Straightforward geometry
- Enhanced user interaction

Challenges & Improvements | Door Manufacture

Challenges

- Door wheel hub broke when manufactured
- Thread location was prioritized over hub thickness

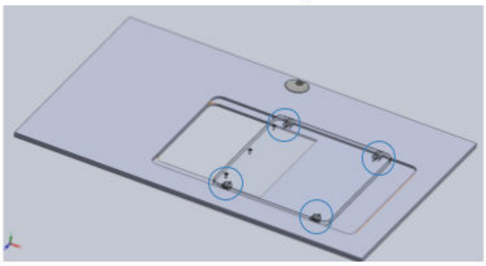
Improvements

- Test and design for thinnest feature with highest factor of safety

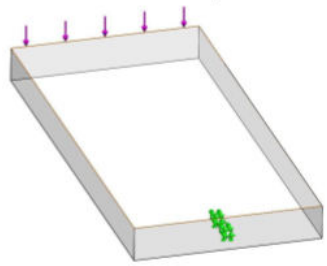
Door Analysis

Finite Element Analysis of Lid at Wheel Threads

Lid Assembly



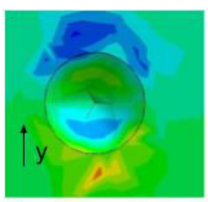
Finite Element Simplification



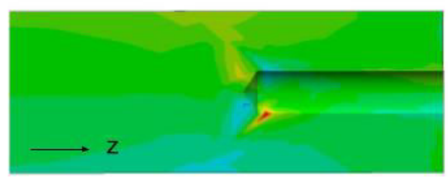
Design Specification: Sliding door should withstand 10 lbs of force

Results

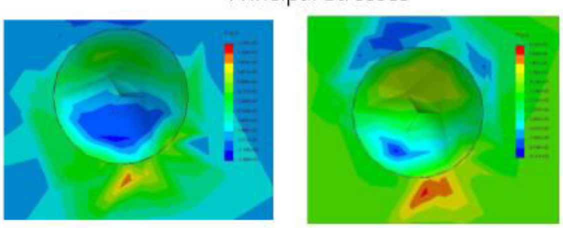
Shear Stress



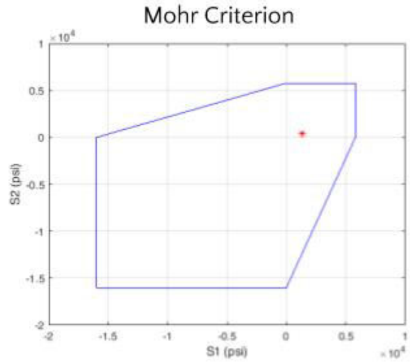
Normal Stress



Principal Stresses

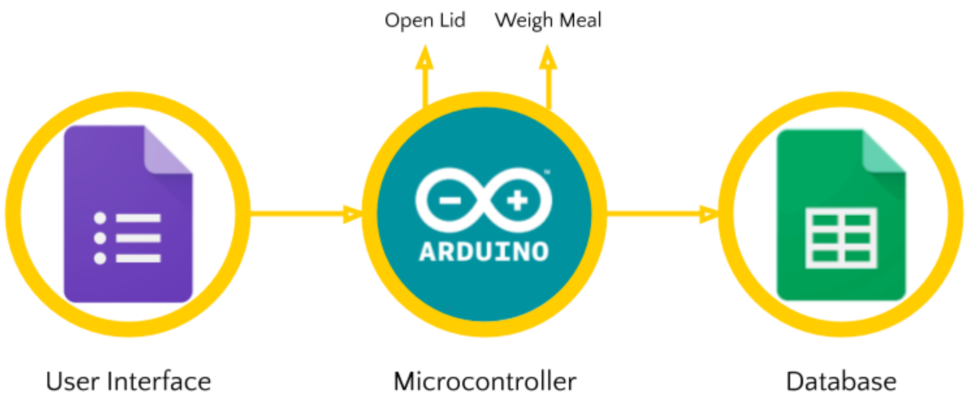


Mohr Criterion



Factor of Safety of 4.33

Backend Subsystem
Data Collection & Processing



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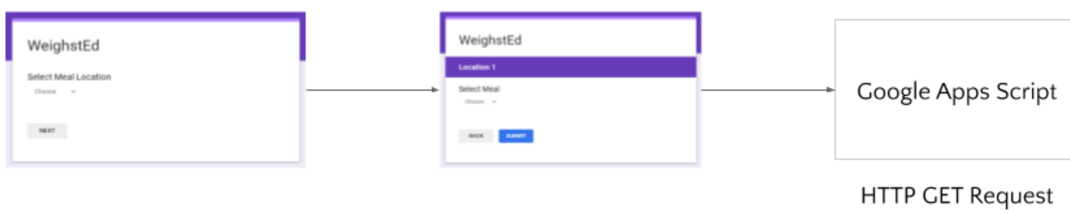
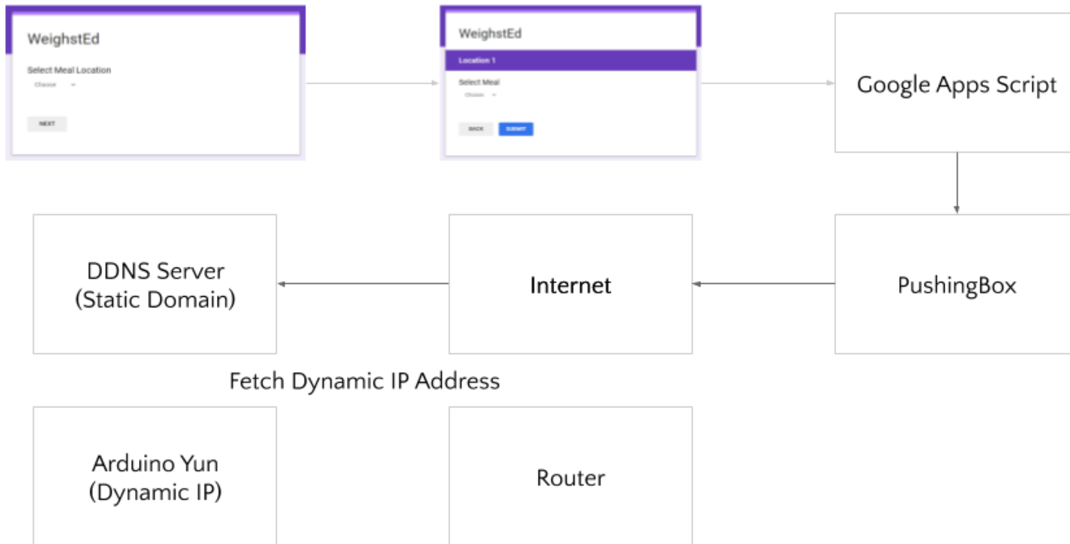
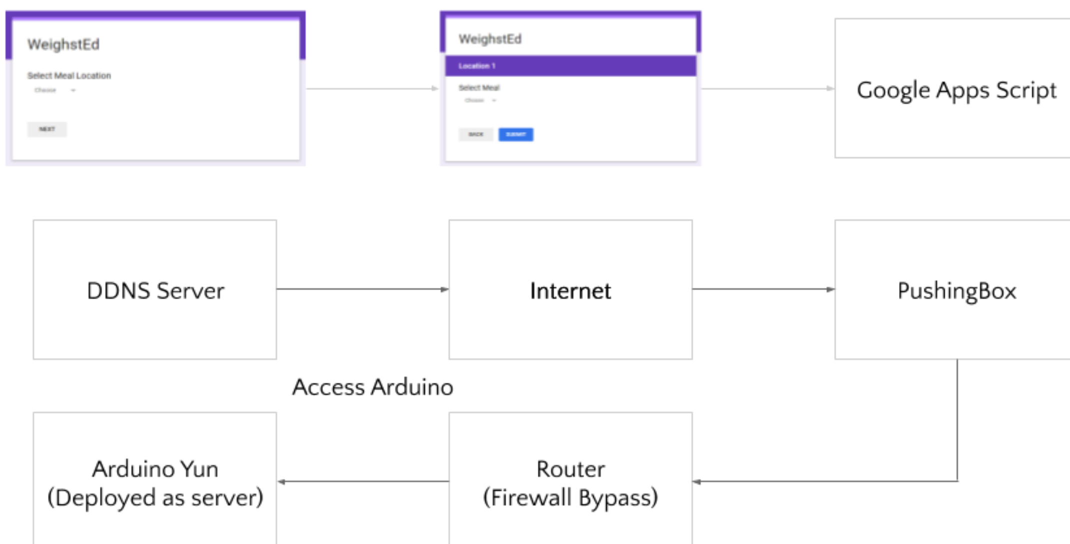
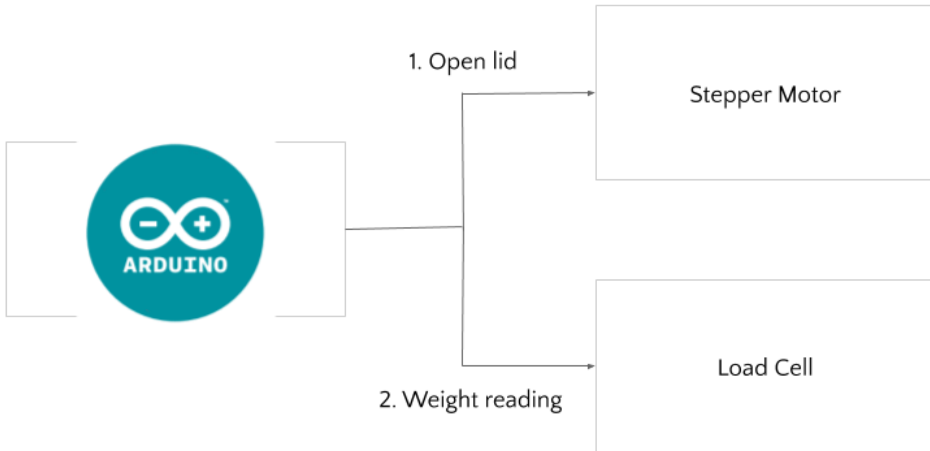
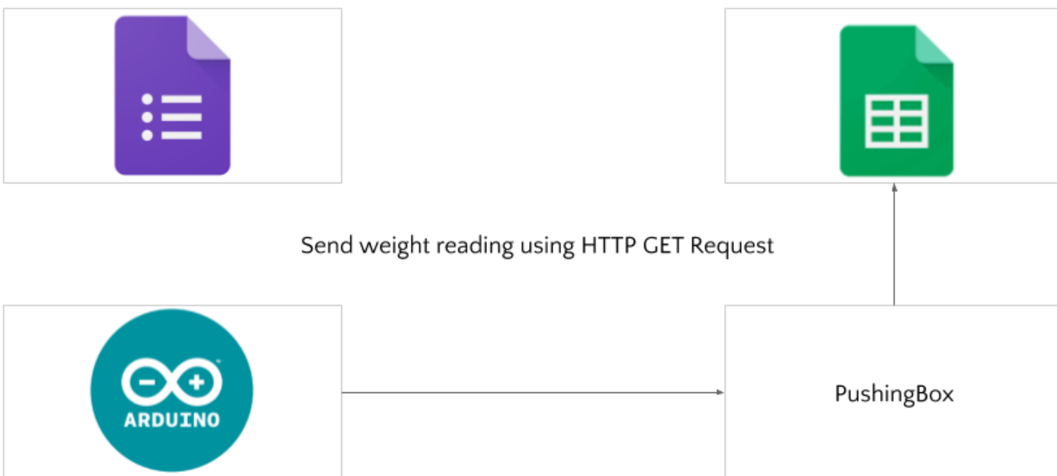



WeighstEd
Select Meal Location
WeighstEd
Select Meal
Google Apps Script
DDNS Server
(Static Domain)
Internet
PushingBox
Fetch Dynamic IP Address
Arduino Yun
(Dynamic IP)
Router

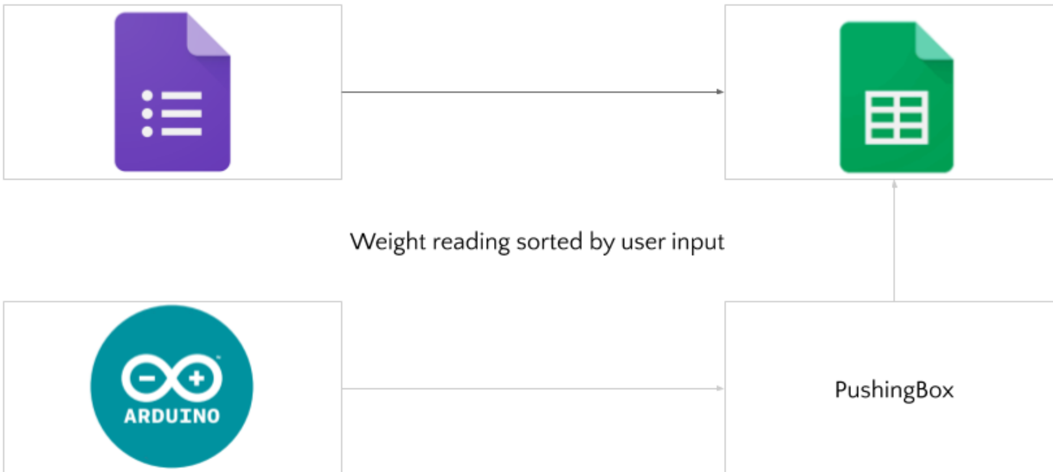

WeighstEd
Select Meal Location
WeighstEd
Select Meal
Google Apps Script
DDNS Server
Internet
PushingBox
Access Arduino
Arduino Yun
(Deployed as server)
Router
(Firewall Bypass)



1. Open lid
Stepper Motor
ARDUINO
Load Cell
2. Weight reading



Send weight reading using HTTP GET Request
ARDUINO
PushingBox



Database

Single Quarter

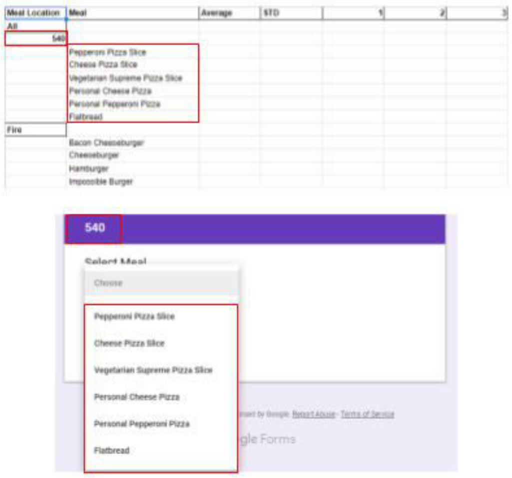
Meal Location	Meal	Average	STD	1	2	3
All						
540						
	Pepperoni Pizza Slice					
	Cheese Pizza Slice					
	Vegetarian Supreme Pizza Slice					
	Personal Cheese Pizza					
	Personal Pepperoni Pizza					
	Flatbread					
Fire						
	Bacon Cheeseburger					
	Cheeseburger					
	Hamburger					
	Impossible Burger					
	Grilled Chicken Breast Burger					
	Grilled Cheese Sandwich					
	Grilled Ham and Cheese Sandwich					
	Fries					
	Petite Filet Mignon					
	Salmon					
	Skirt Steak					
	Hot Link					
Global						
	Meat Option					
	Vegetarian Option					
La Parilla						
	Spicy Ground Beef Tacos					
Pacific Rim						
	Vegan Pasta					
	Build Your Own Pasta					
	Sriracha Honey Chicken					

Quarter-to-Quarter

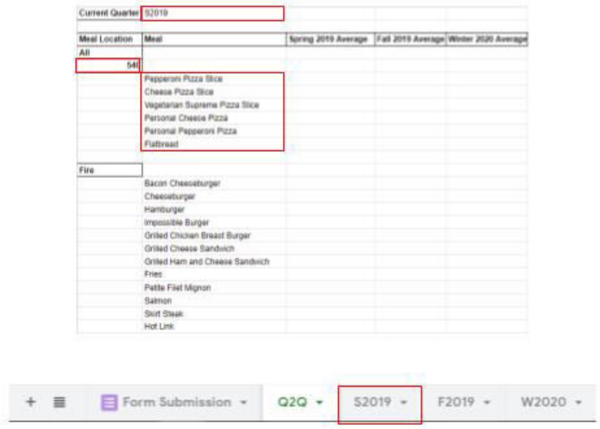
Current Quarter	S2019			
Meal Location	Meal	Spring 2019 Average	Fall 2019 Average	Winter 2020 Average
All				
540				
	Pepperoni Pizza Slice			
	Cheese Pizza Slice			
	Vegetarian Supreme Pizza Slice			
	Personal Cheese Pizza			
	Personal Pepperoni Pizza			
	Flatbread			
Fire				
	Bacon Cheeseburger			
	Cheeseburger			
	Hamburger			
	Impossible Burger			
	Grilled Chicken Breast Burger			
	Grilled Cheese Sandwich			
	Grilled Ham and Cheese Sandwich			
	Fries			
	Petite Filet Mignon			
	Salmon			
	Skirt Steak			
	Hot Link			
Global				
	Meat Option			
	Vegetarian Option			
La Parilla				

Database

Single Quarter



Quarter-to-Quarter



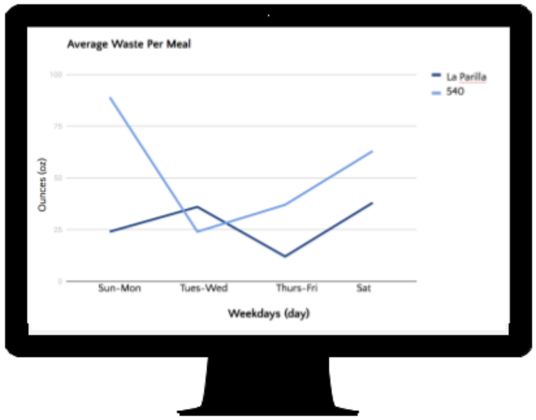
TV Signage

Educate the users about their impact on SCU Sustainability goals...

38

TV Signage

Educate the users about their impact on SCU Sustainability goals…



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Challenges

- Communication between Google Applications and Arduino
- Last minute issues with Pushingbox

40

5

Testing -

Design & Analysis

41

Testing

Scale

Accuracy of weight measurements.

Want: ±0.002 lb

(1% of avg meal waste from initial data)

Weight added prior to zeroing scale (lbs)	% Error
0	0.45%
1	0.25%
5	0.35%
10	0.75%
25	0.45%
50	0.05%

Adding 0.2 lb weight → always less than 1% error

Compared weights with higher accuracy scales

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Testing

Lid open/closing Time

Opening/Closing Time:

Wanted: <1.5 sec

Achieved: ~2.5 sec

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Testing

Future Testing

User Satisfaction Survey

Market Testing

Process time

Goal: <30 seconds

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8 Budget and Costs

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Budget

$1500 granted - $1300.88 used

Final Product	Prototyping	Sunk Costs
~$1100	~$150	~$50
Hardware, Software	Wood, Electronics POC	Handlebars, Fasteners

Frame/Cover	Weighing	Power/Database	Meal ID	Lid
$ 451.98	$ 178.64	$ 217.05	$159.41	$294.16

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6 Safety

Considerations & Implementations

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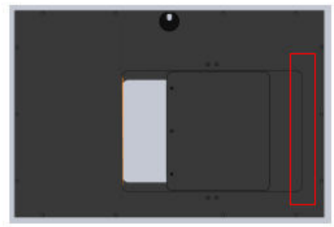
Safety Considerations

1. Lid Pinch Point
2. Tipping
3. Electricity

48

Safety Considerations

1. Lid Pinch Point
2. Tipping
3. Electricity



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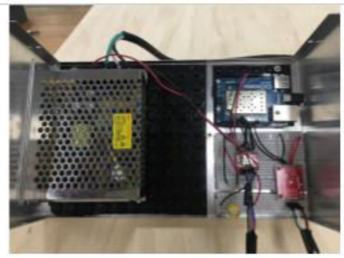
Safety Considerations

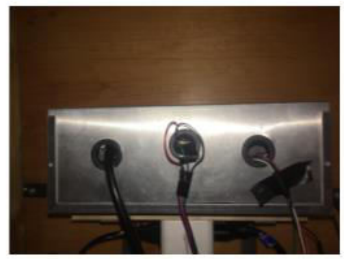
1. Lid Pinch Point
2. Tipping
3. Electricity

50

Safety Considerations

1. Lid Pinch Point
2. Tipping
3. Electricity





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6 Impact

One device... endless potential

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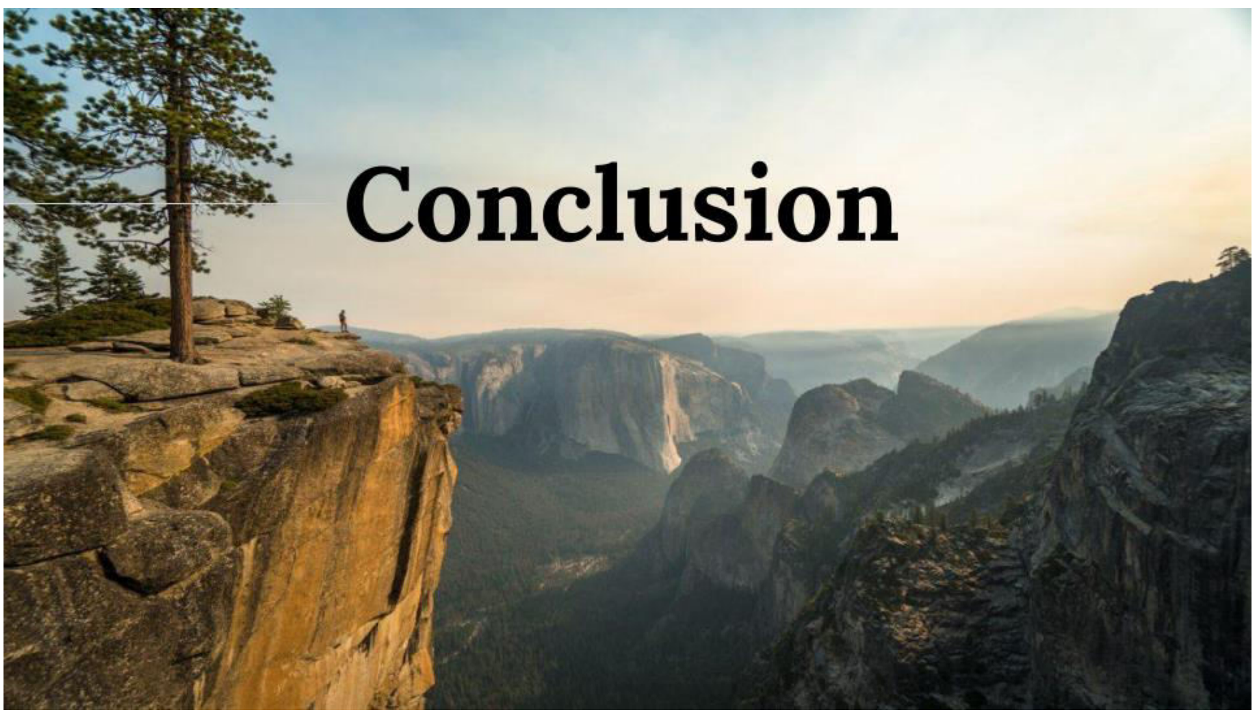
PROJECT IMPACTS
Social, Ethical, Environmental, and Economic

Inform Students

- Education about food waste can reduce food waste by 15%[3]

Provide information to catering services

- Businesses can gather data to optimize...
  - portion sizing
  - meal prep
  - dish size



Acknowledgements

Special Thanks to:

IT & Network Wizards: Rong Wang, Wilfredo Hernández

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Team Advisor in the Mechanical Engineering Dept.: Dr. Timothy Hight

Sustainability Center Liaison and Project Advisor: Lindsey Kalkbrenner

Santa Clara University School of Engineering

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Thanks!

*Any **questions** ?*

56

REFERENCES

[1] Food and Agricultural Organization of the UN (FAO) http://www.fao.org/3/mb060e/mb060e.pdf

[2] Natural Resources Defence Council https://www.nrdc.org/sites/default/files/wasted-food-IP.pdf

[3] Reducing Food Waste: Recommendations to the 2015 Dietary Guidelines Advisory Committee https://health.gov/dietaryguidelines/dga2015/comments/uploads/CID430_Tufts_University-_Reducing_Food_Waste-_DGAC_Comment.pdf

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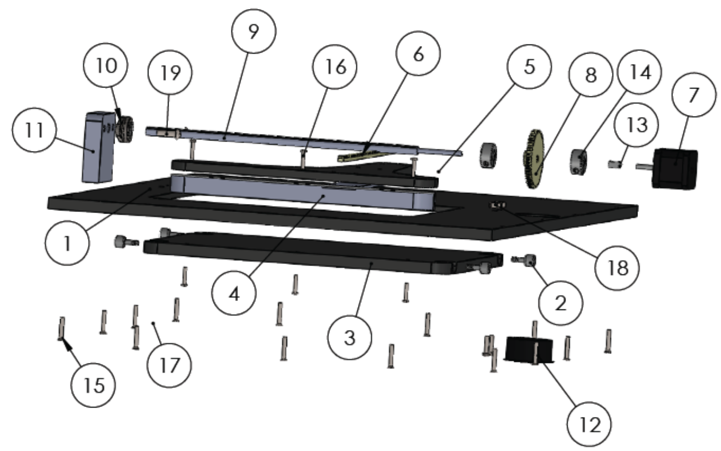
Appendix L: Detailed Drawings

ITEM NO.	Part #	Description	QTY.
1	L001	Top Plate	1
2	L002	Track Roller	4
3	L003	Door	1
4	L004	Tab	1
5	L005	Base	1
6	L006	Rack Gear	1
7	L007	Motor	1
8	L008	Gear	1
9	L009	Shaft	1
10	L010	Shaft Bearing	1
11	L011	Shaft Mount	1
12	L012	Cord Grommet	1
13	L013	Shaft Coupler	1
14	L014	Shaft Collar	2
15	L015	Wood Screws	14
16	L016	Tab Screws	6
17	L017	Base Screws	4
18	L019	Hex Nut	2
19	L020	Bearing Bolts	2



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES

	NAME	DATE
DRAWN	T.Schluep	3/20/19
CHECKED	T.Jaworski	3/20/19
DESIGNED	T.Schluep	3/20/19

INTERPRET GEOMETRIC TOLERANCING PER: GD&T

MATERIAL See BOM

FINISH

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SANTA CLARA UNIVERSITY
SENIOR DESIGN TEAM 15 : WEIGHSTED

TITLE: Lid Assembly BOM

SIZE A | DWG. NO. LA01 | REV 1

SCALE 1:5 | WEIGHT: | SHEET 1 OF 1

Figure L1. Lid Assembly drawing

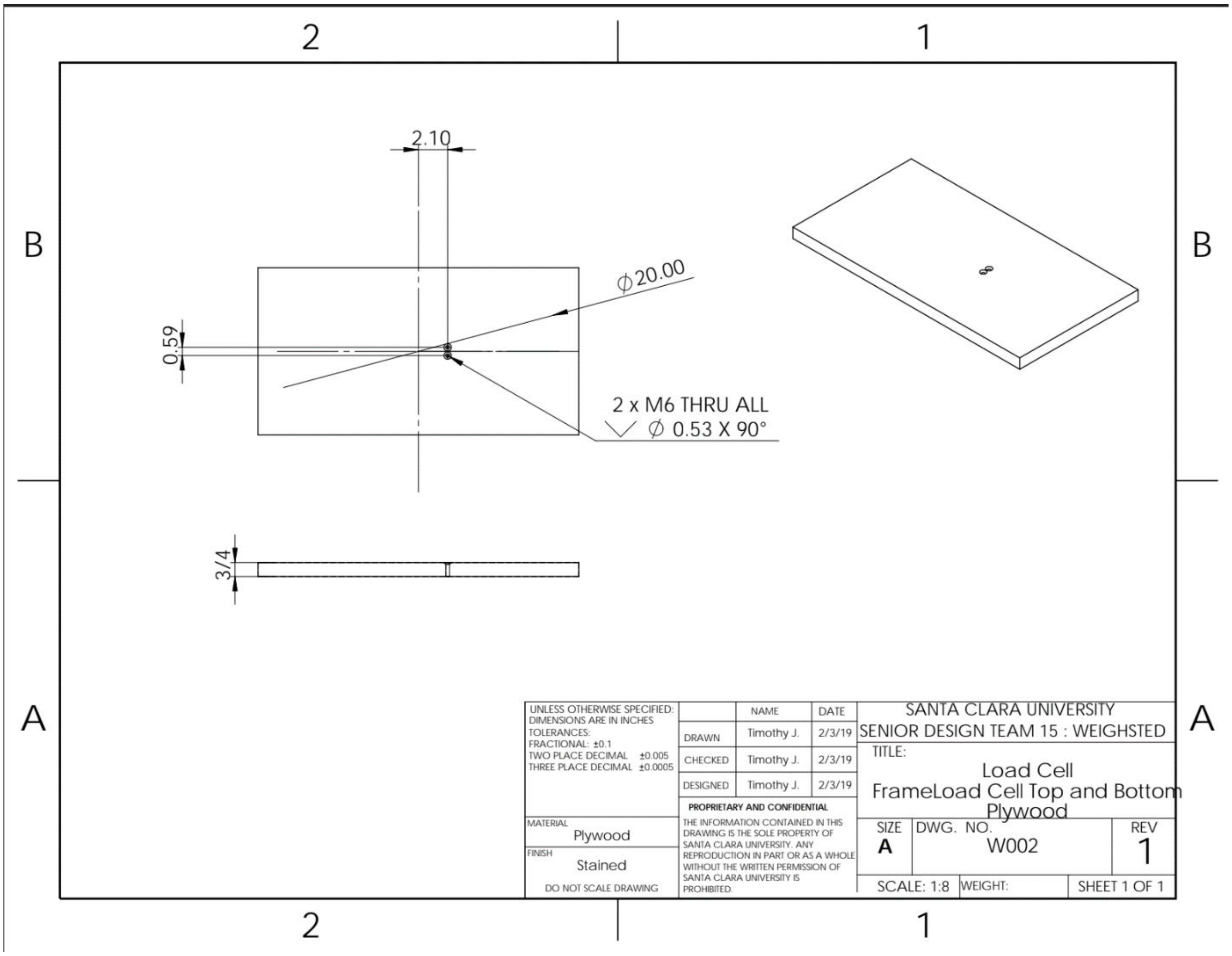


Figure L2. Load Cell frame load cell top and bottom

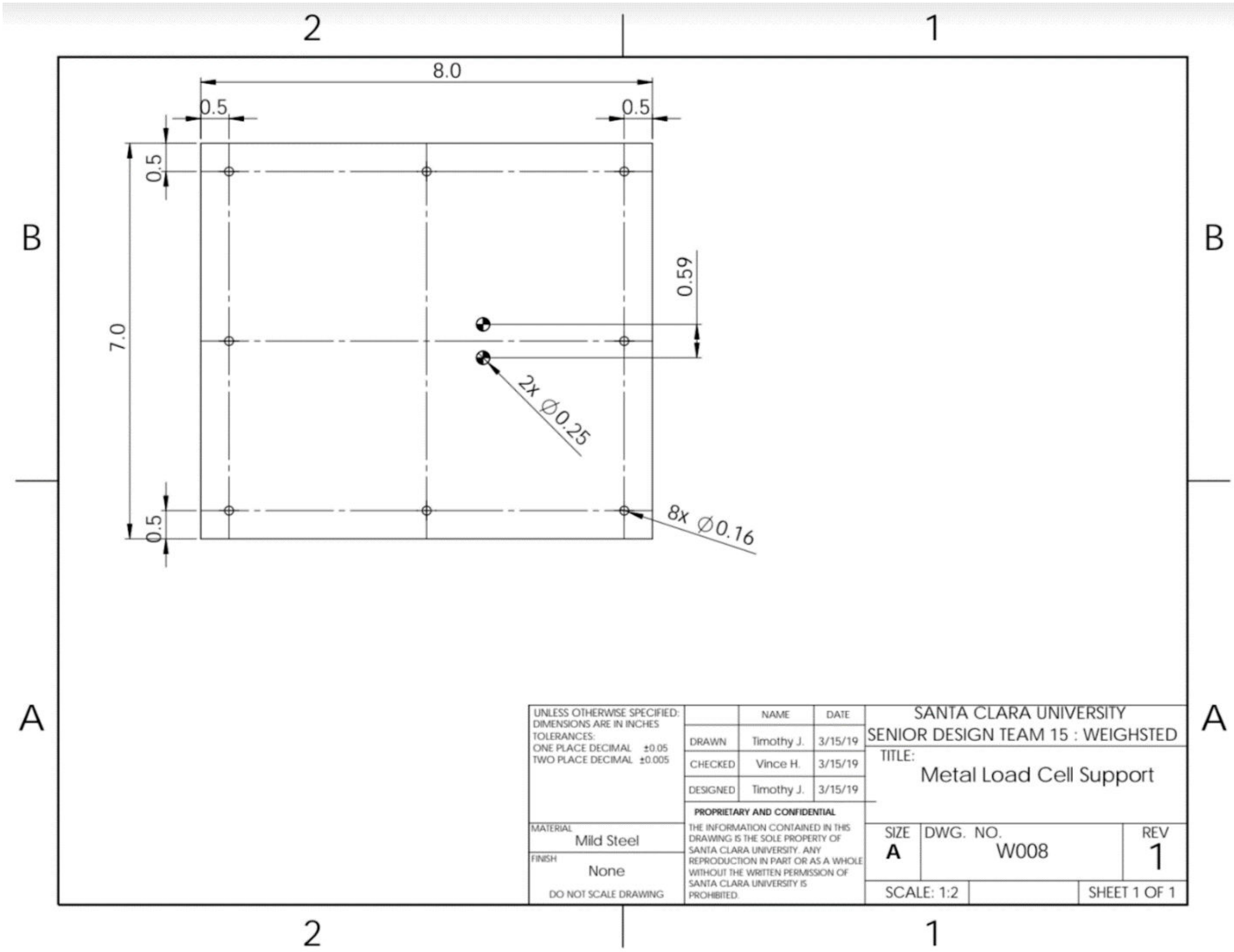


Figure L3. Metal load cell support

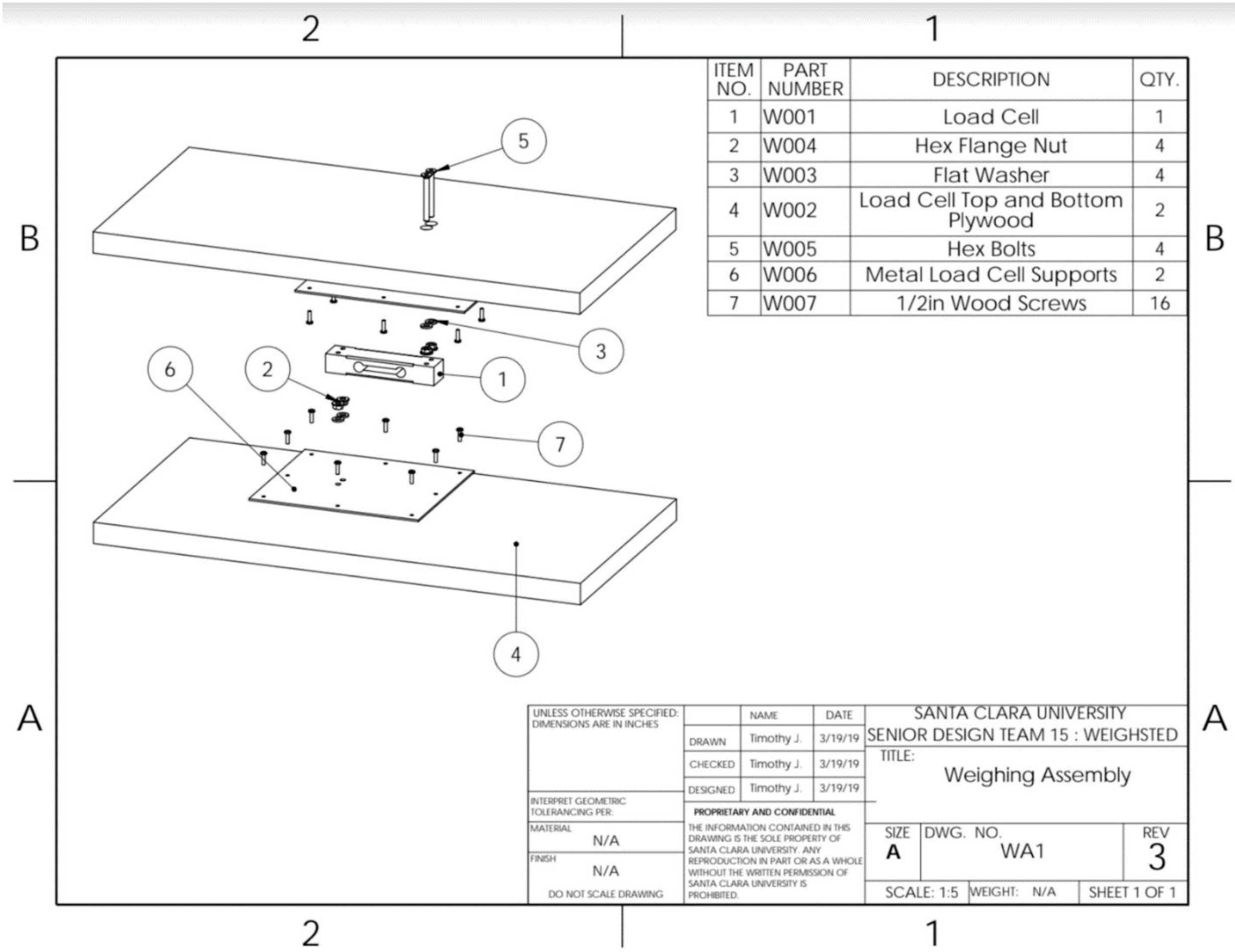


Figure L4. Weighing assembly drawing

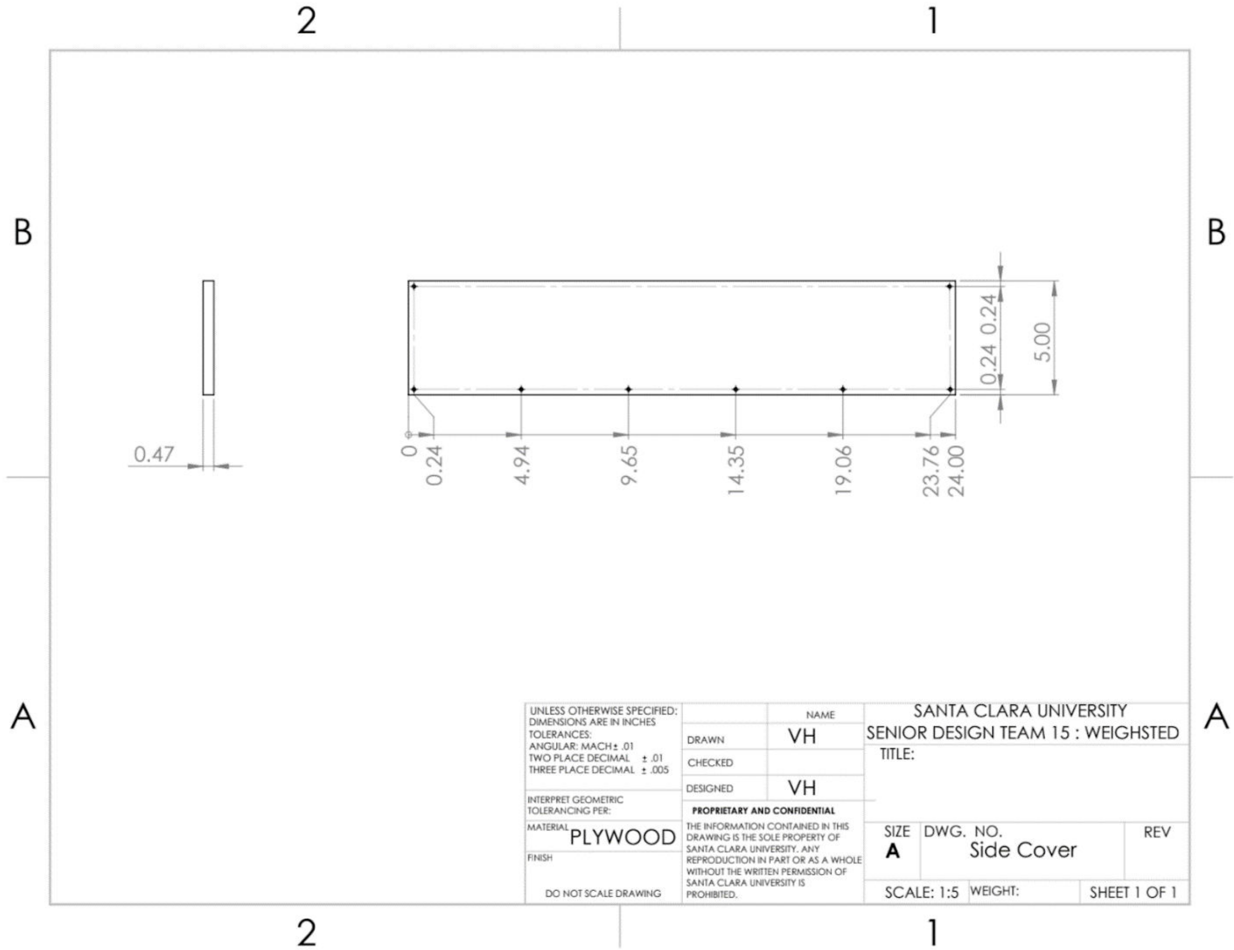


Figure L5. Side Cover

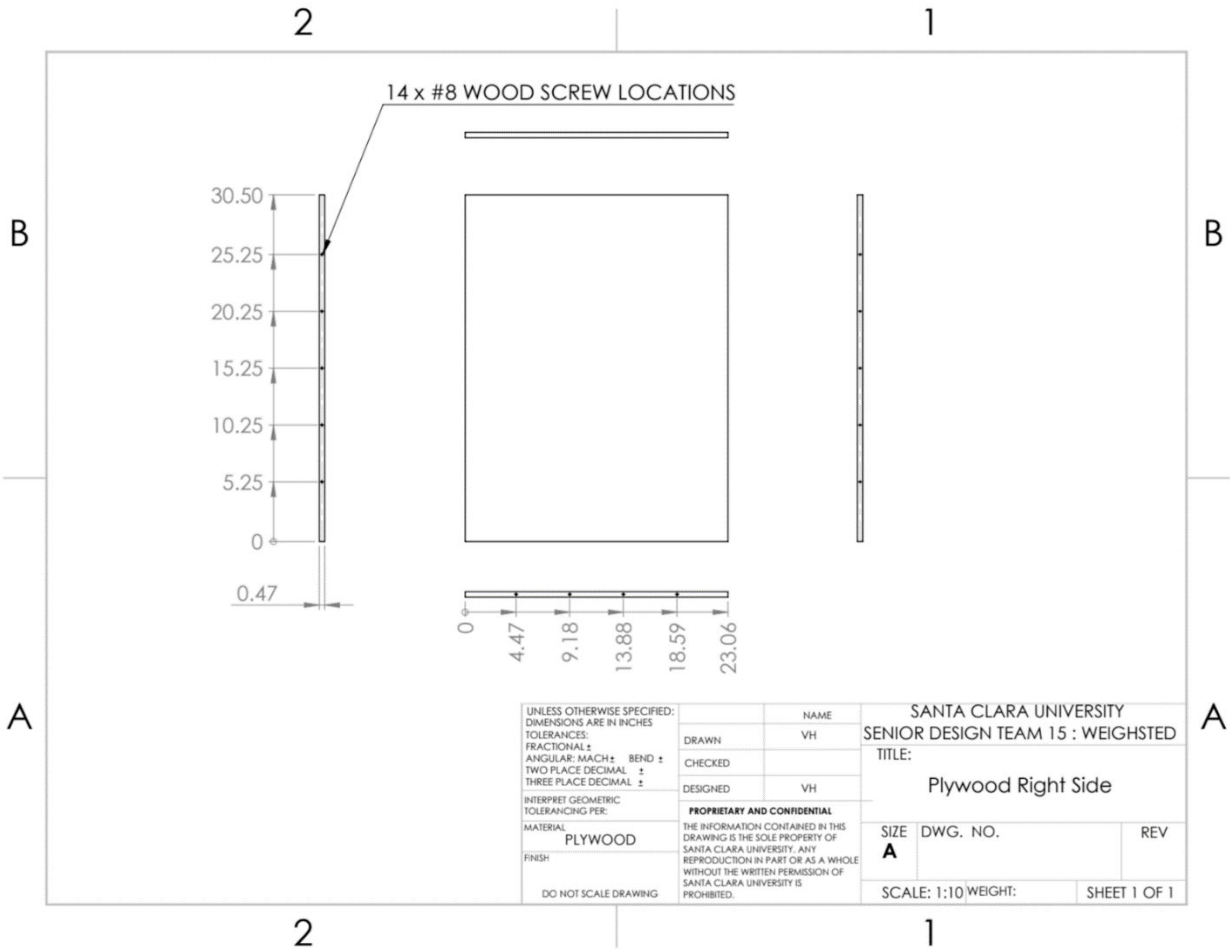


Figure L6. Plywood right side

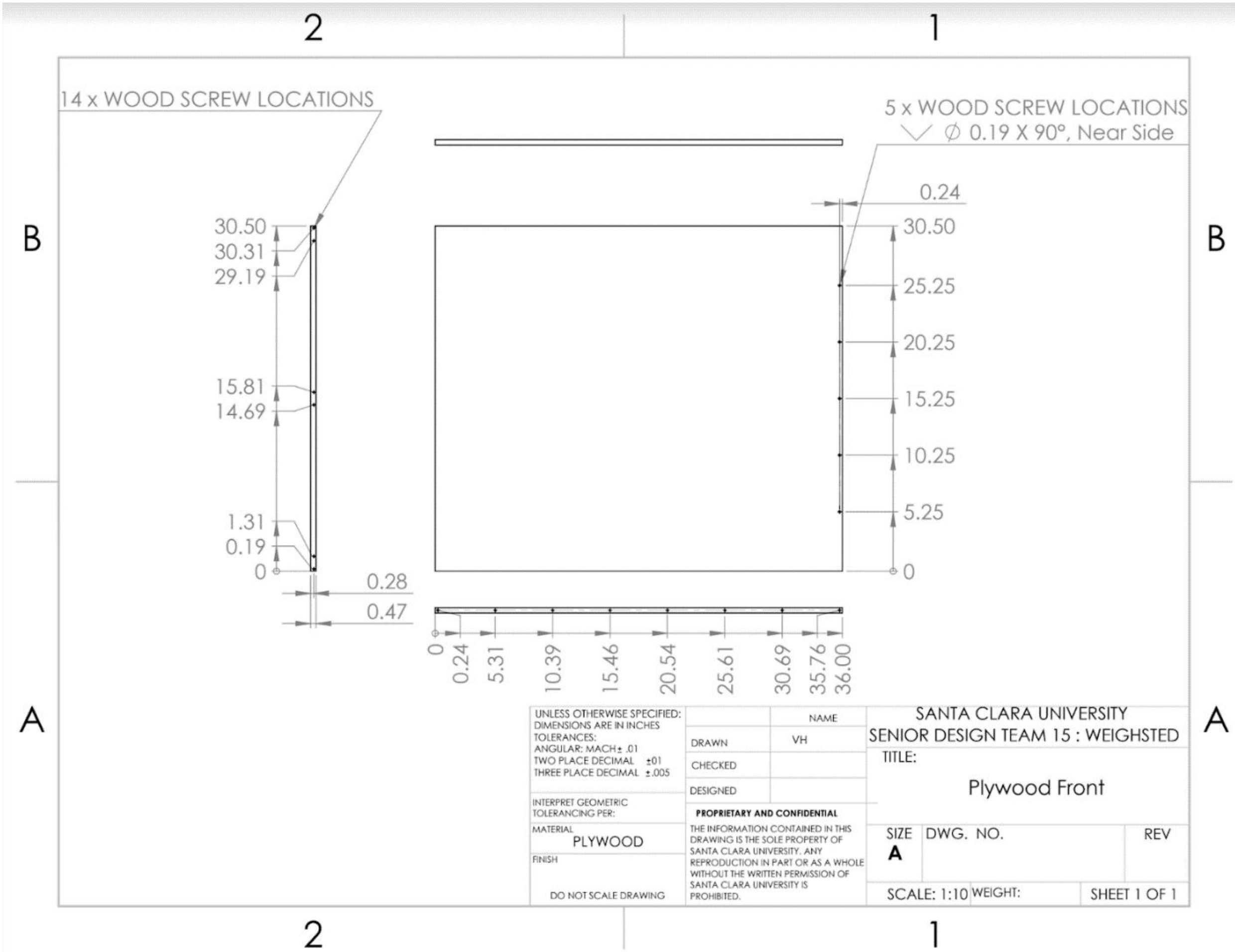


Figure L7. Plywood front

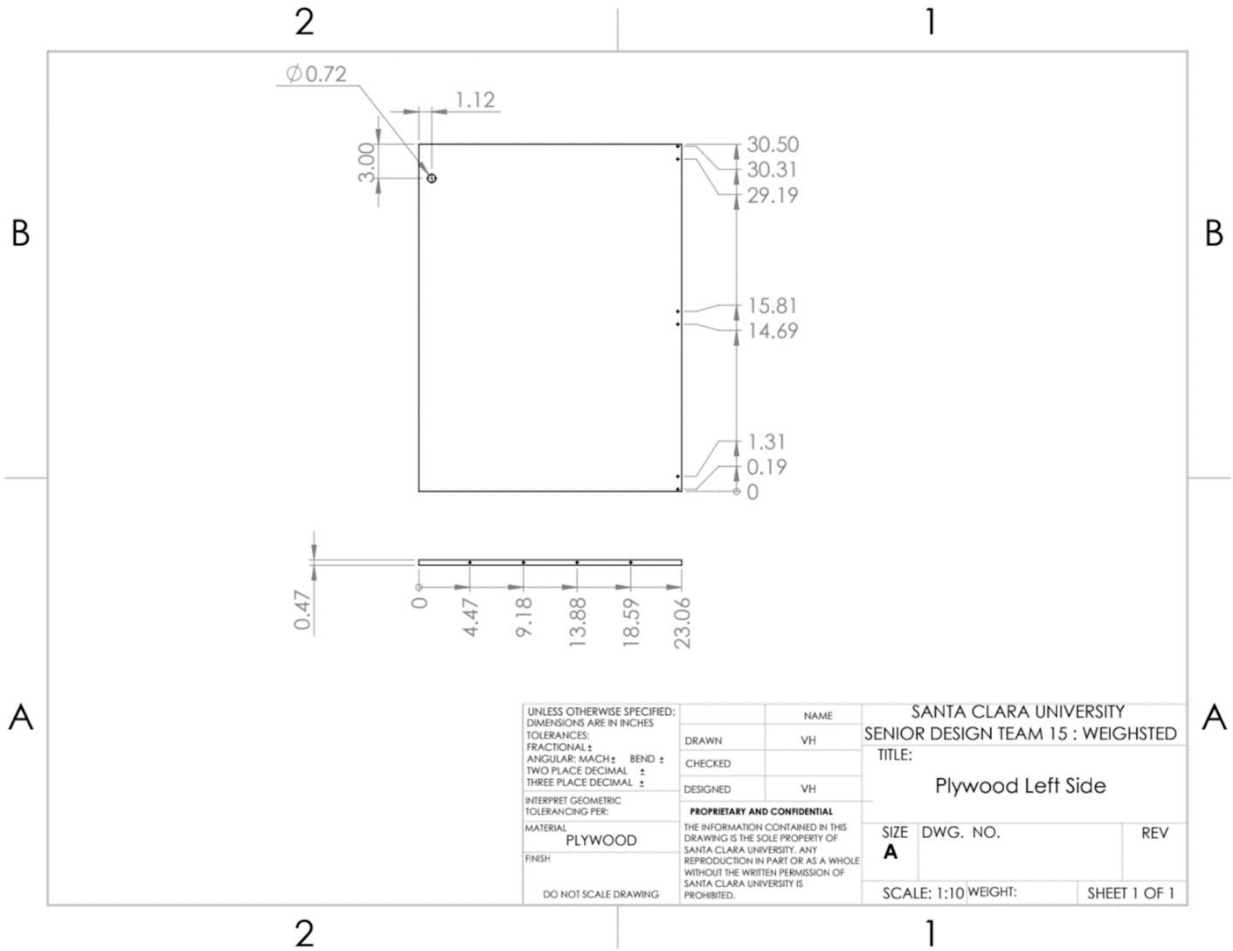


Figure L8. Plywood left side

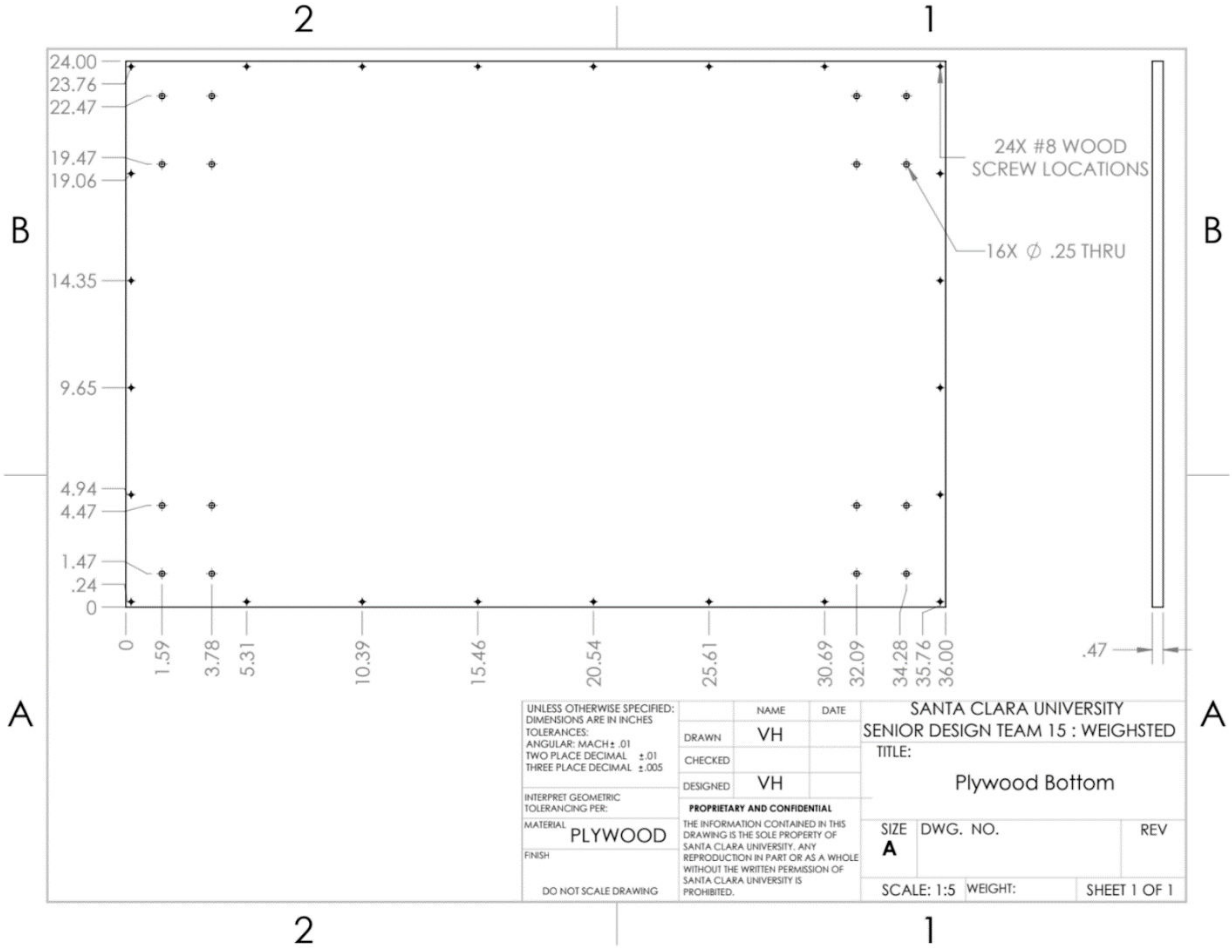


Figure L9. Plywood bottom

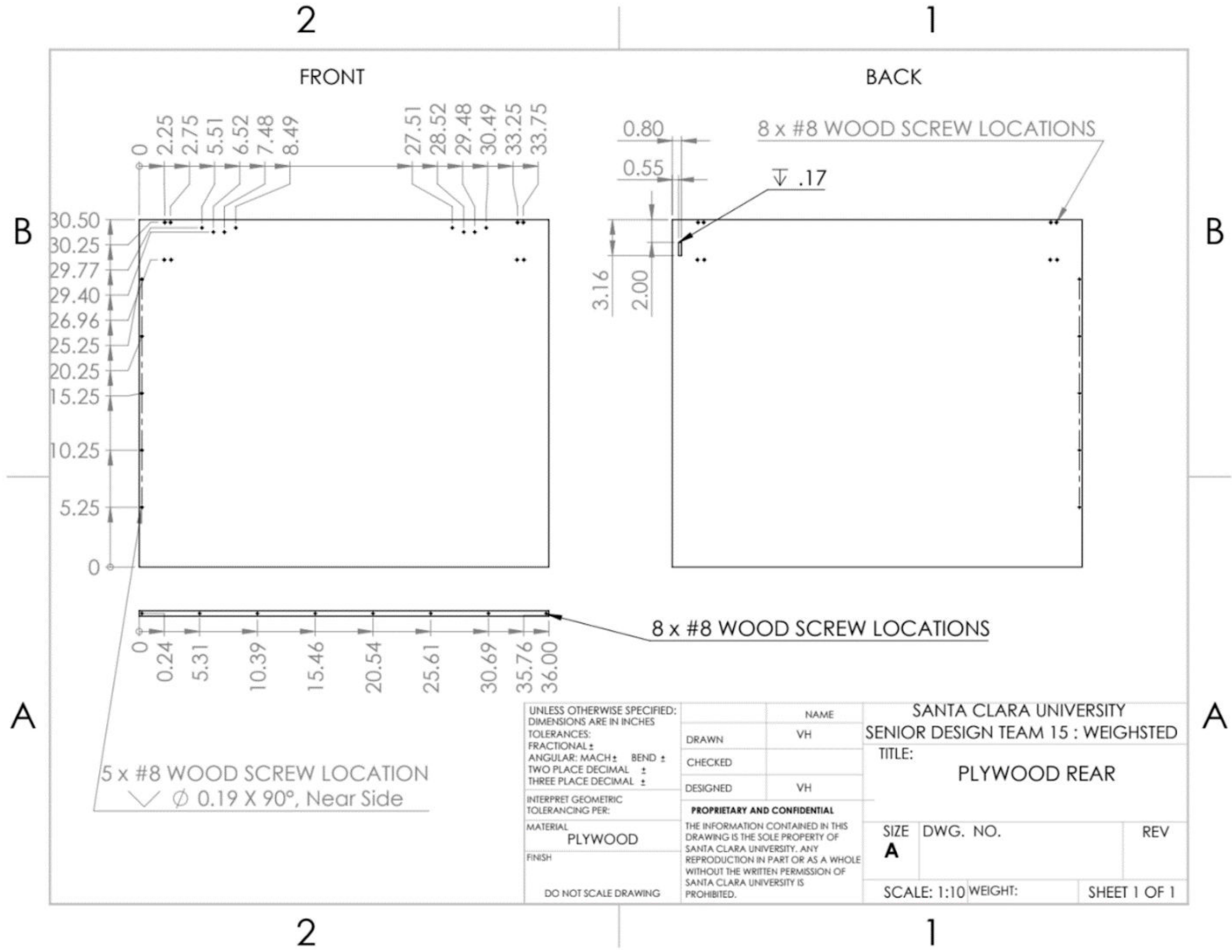


Figure L10. Plywood rear

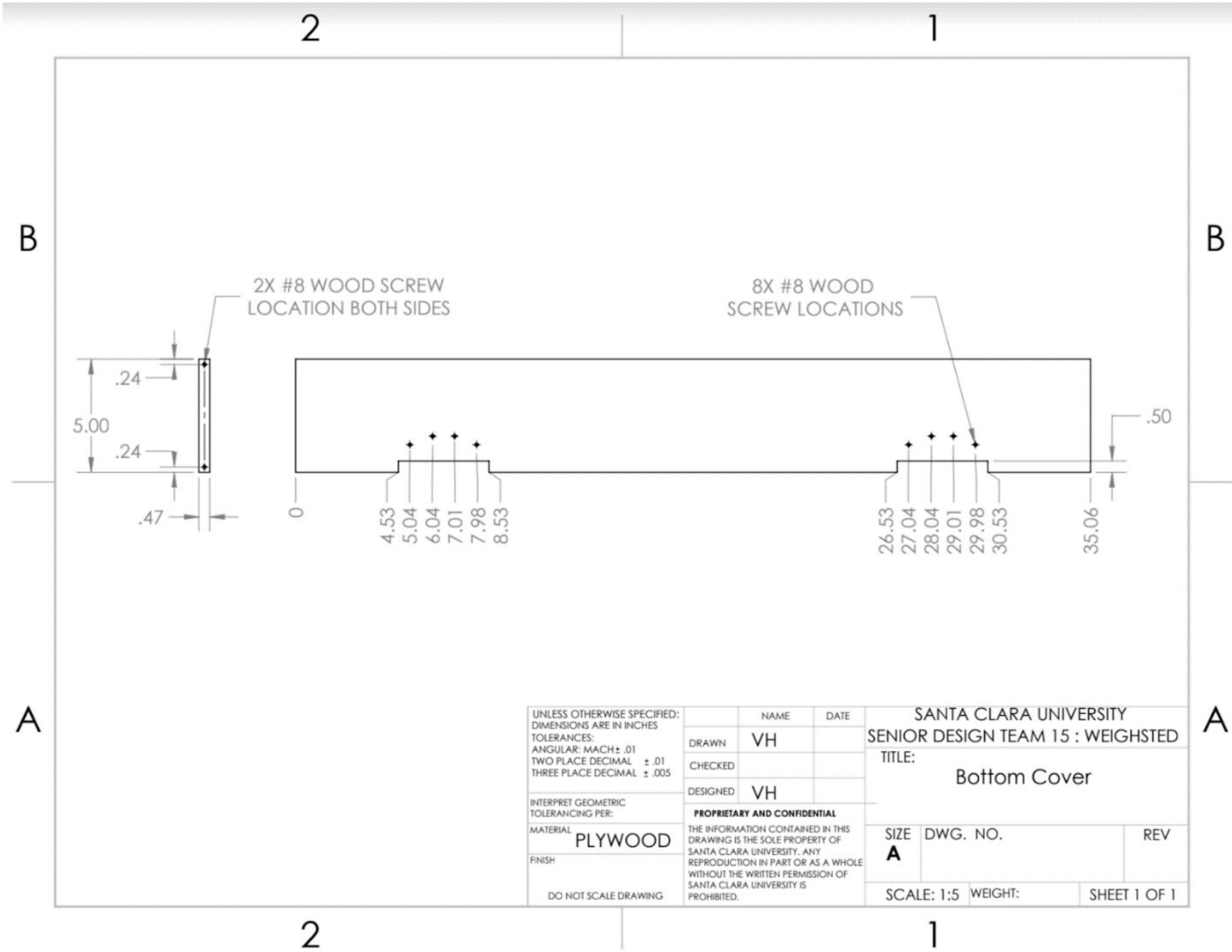


Figure L11. Bottom cover

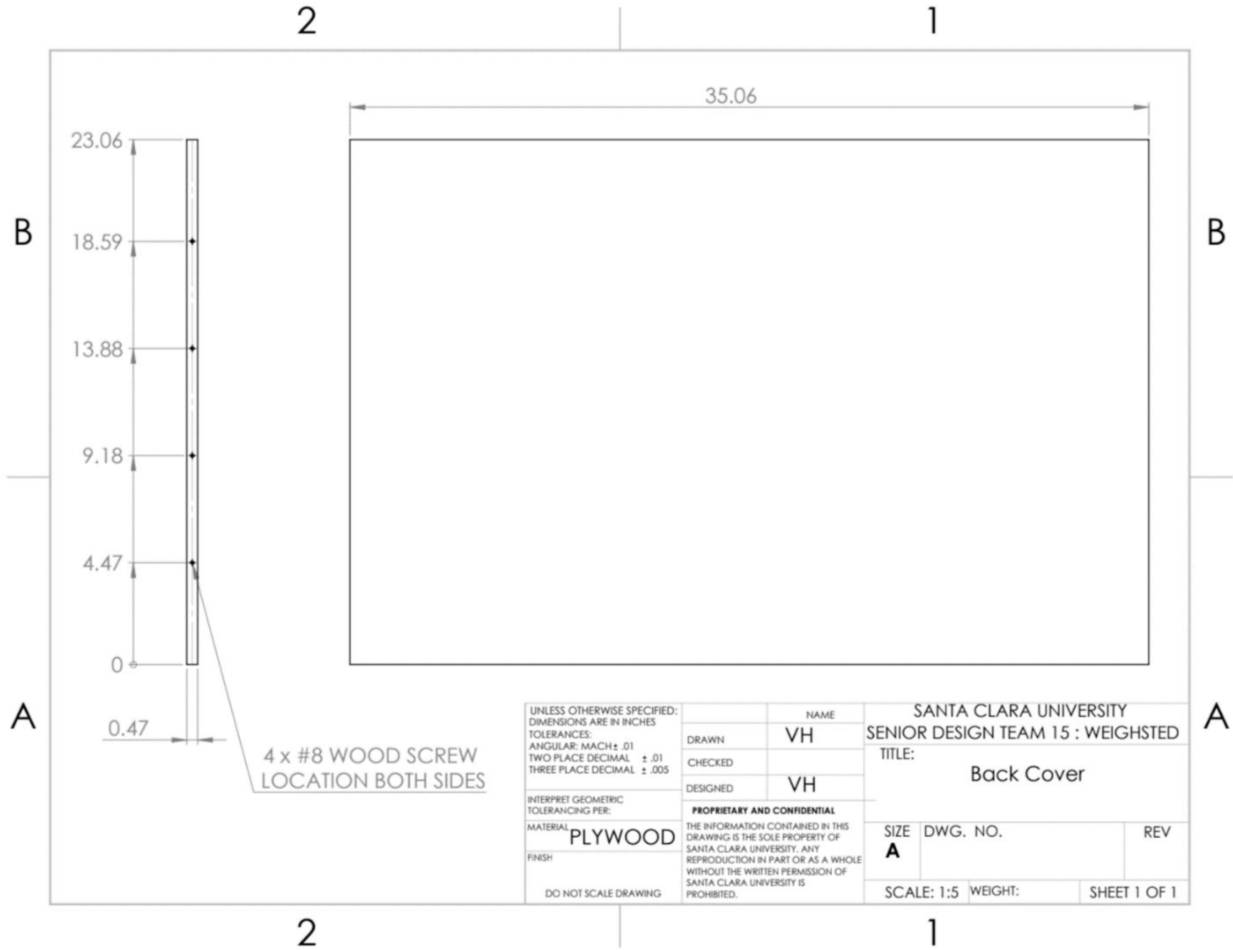
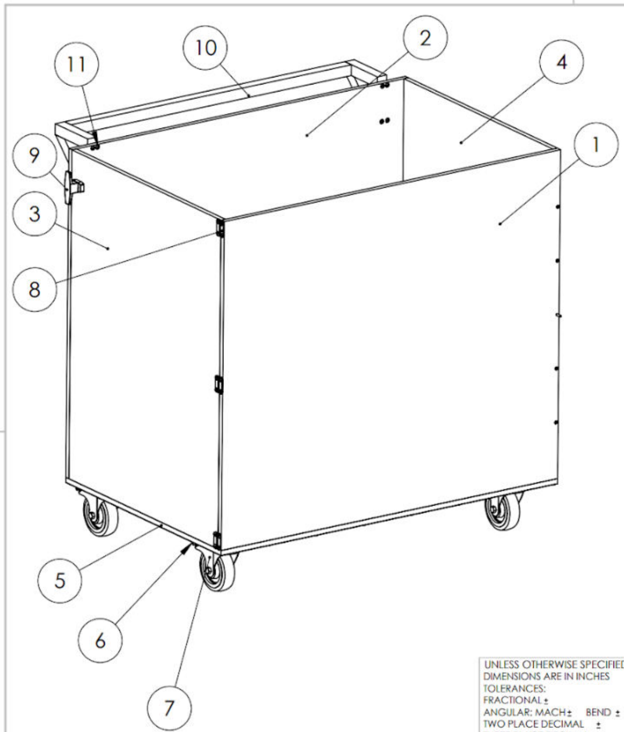


Figure L12. Back cover



ITEM NO.		PART NUMBER	
1	F001	Plywood Front	1
2	F002	Plywood Rear	1
3	F003	Plywood Left Side	1
4	F004	Plywood Right Side	1
5	F005	Plywood Bottom	1
6	F006	Galvanized Steel Base	1
7	F015	Caster	4
8	F016	Plastic Hinge	3
9	F017	Cam Lock	1
10	FB3	Handlebars	1
11		#8 Wood Screws	48
12		HBOLT 0.2500-20x1x0.75-N	16
13		Preferred Narrow FW 0.25	16
14		HNUT 0.2500-20-D-N	16

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME
DRAWN	
CHECKED	
DESIGNED	

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SANTA CLARA UNIVERSITY
SENIOR DESIGN TEAM 15 : WEIGHSTED

TITLE: Base

SIZE A | DWG. NO. FB1 | REV

SCALE: 1:10 | WEIGHT: | SHEET 1 OF 2

Figure L13. Base

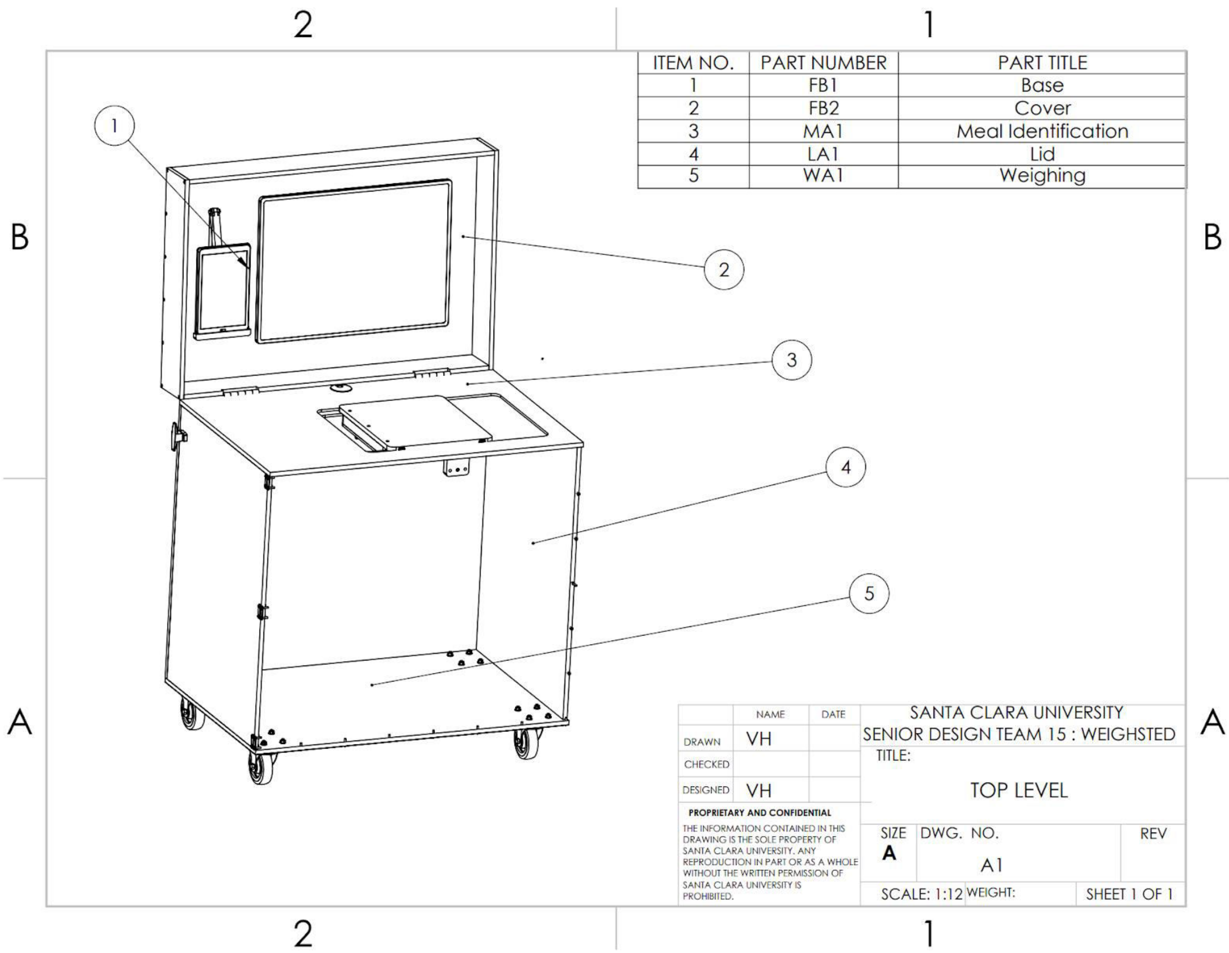


Figure L14. Top level drawing

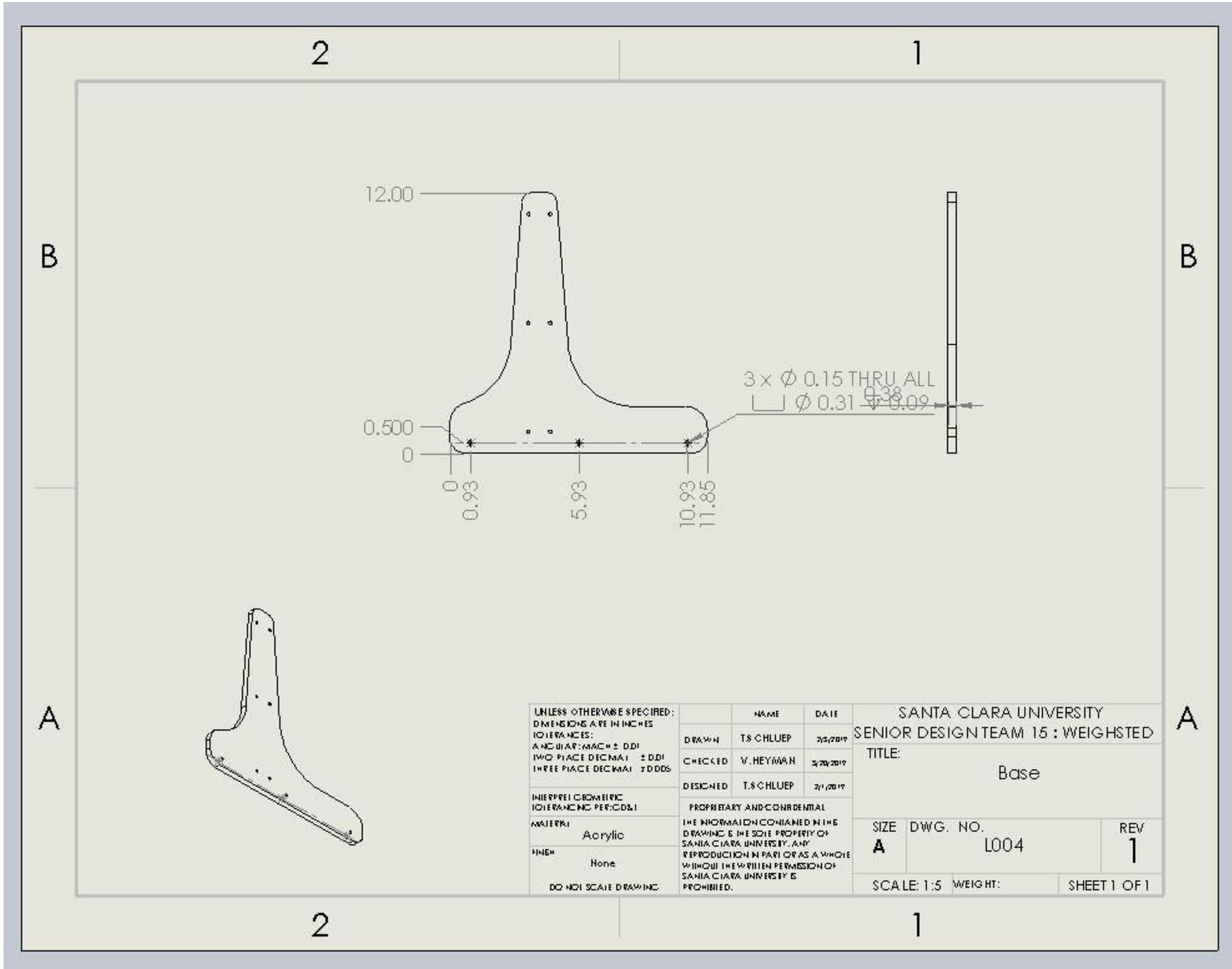


Figure L15. Base drawing

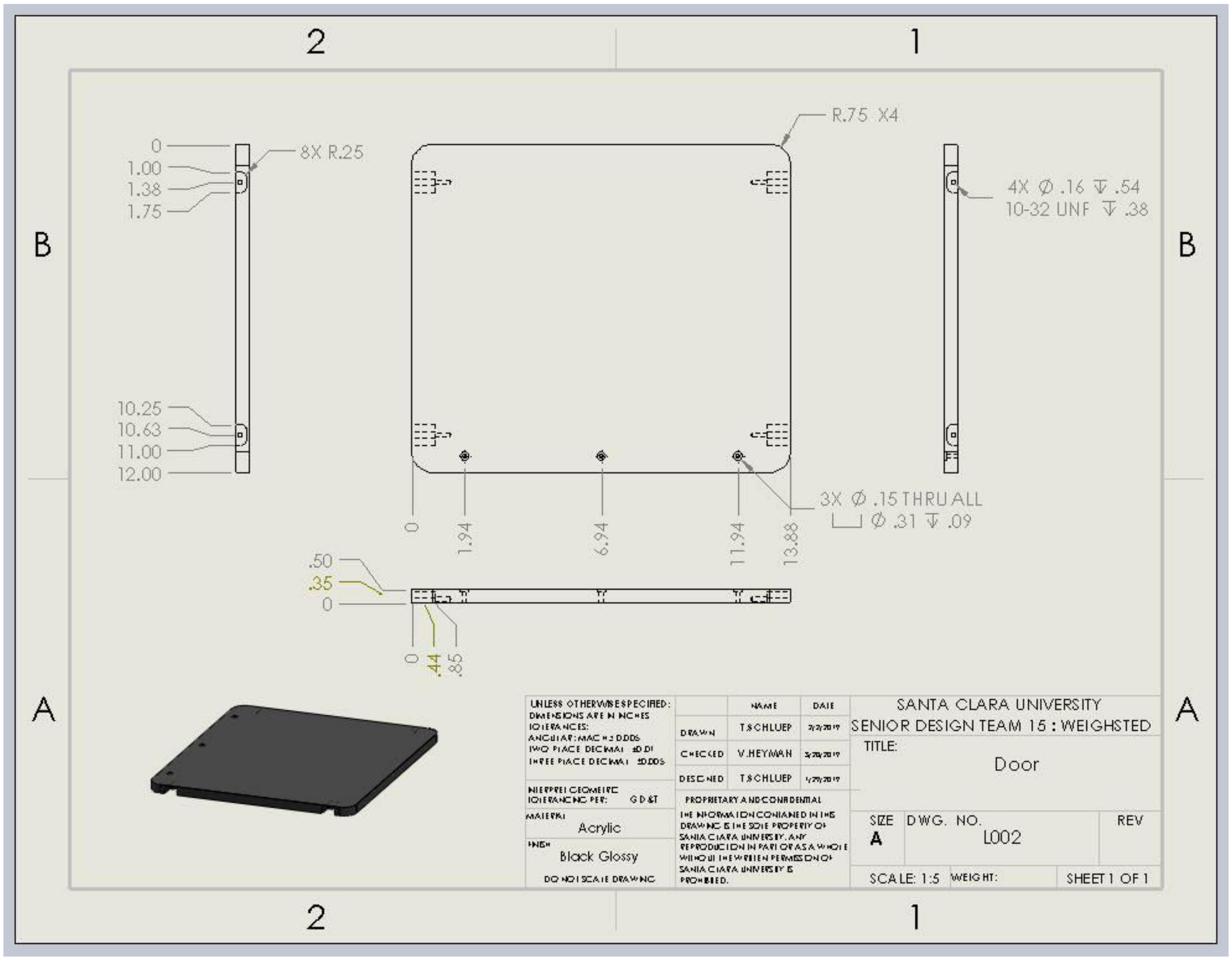


Figure L16. Door drawing

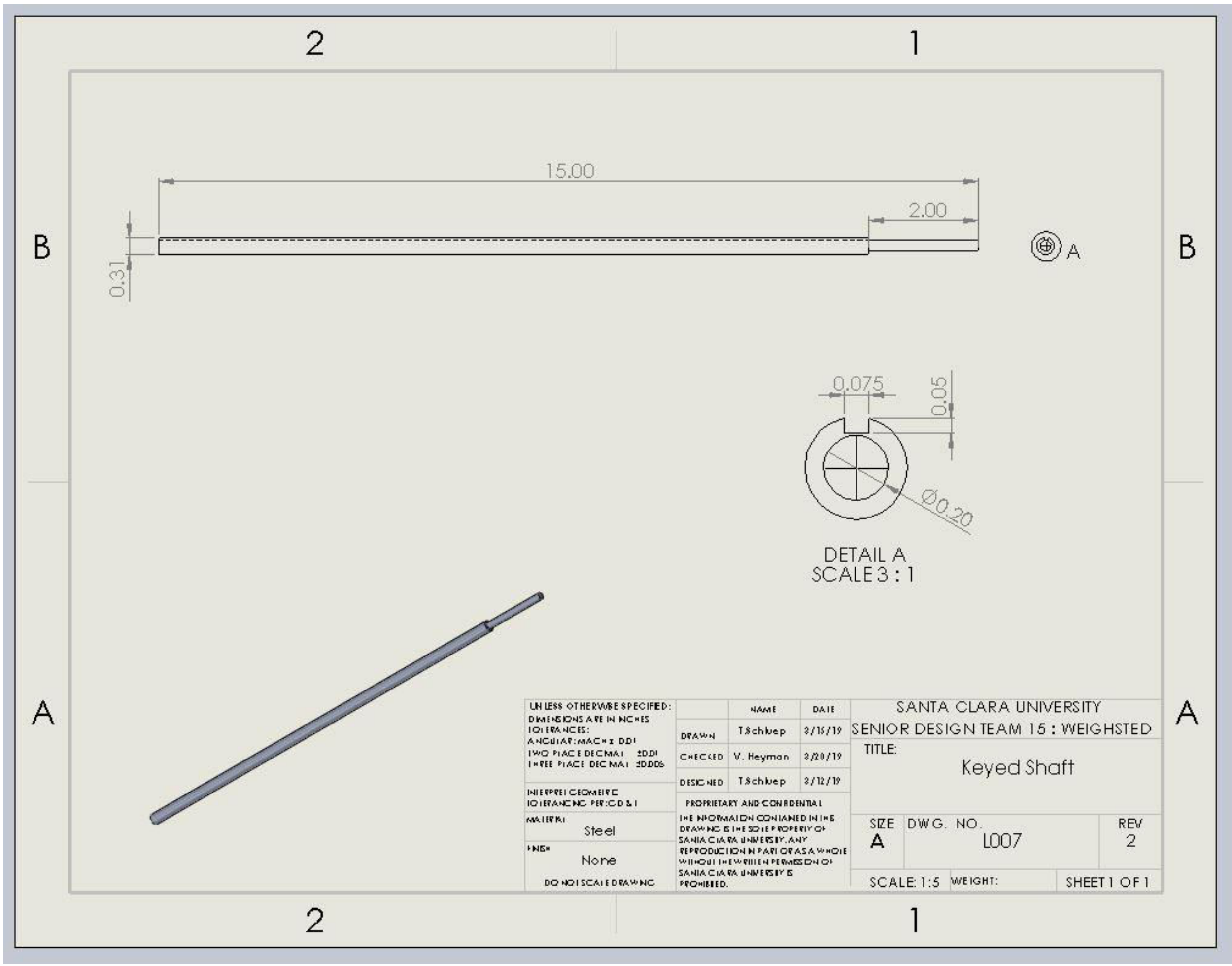


Figure 17. Keyed shaft drawing

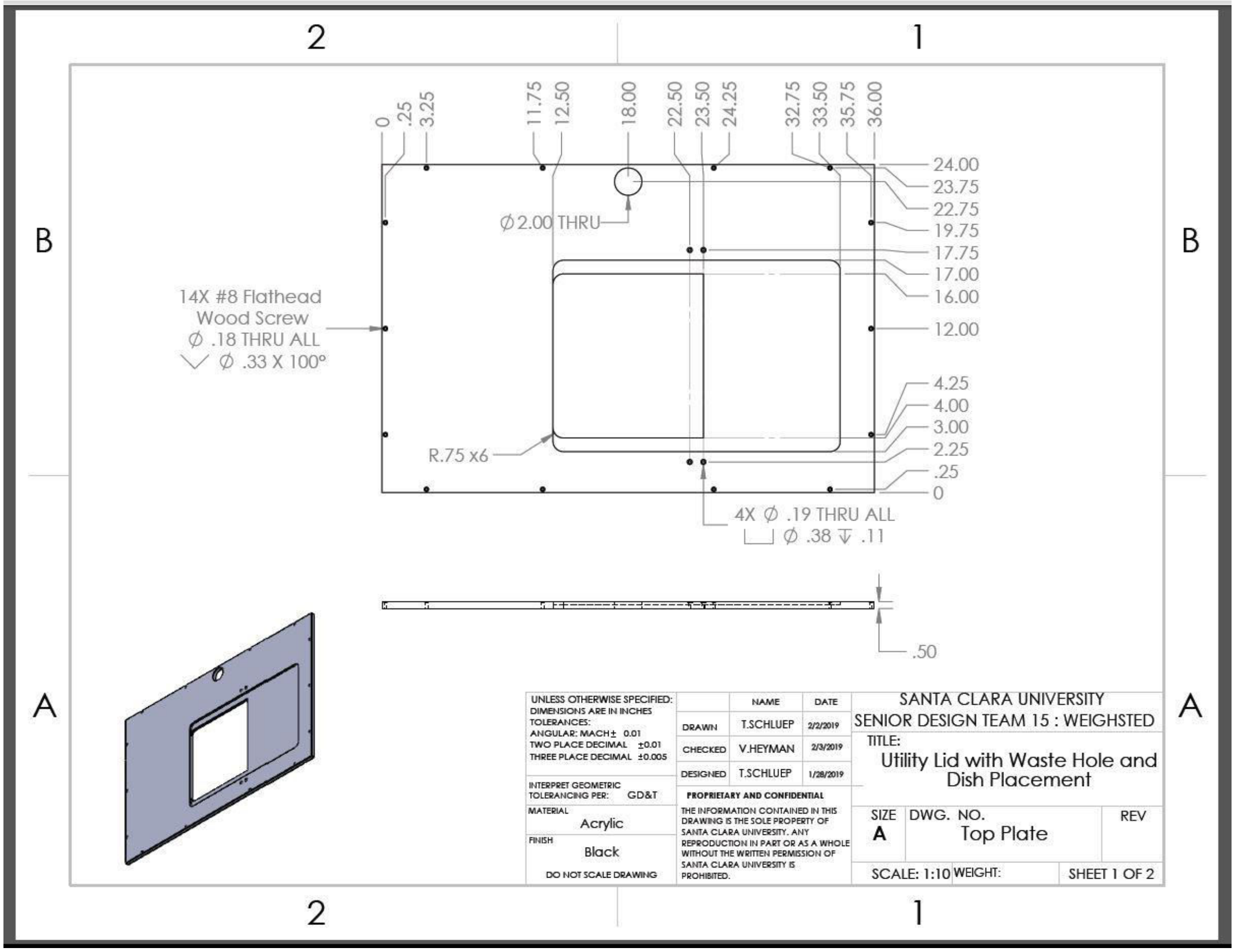


Figure L18. Utility lid drawing

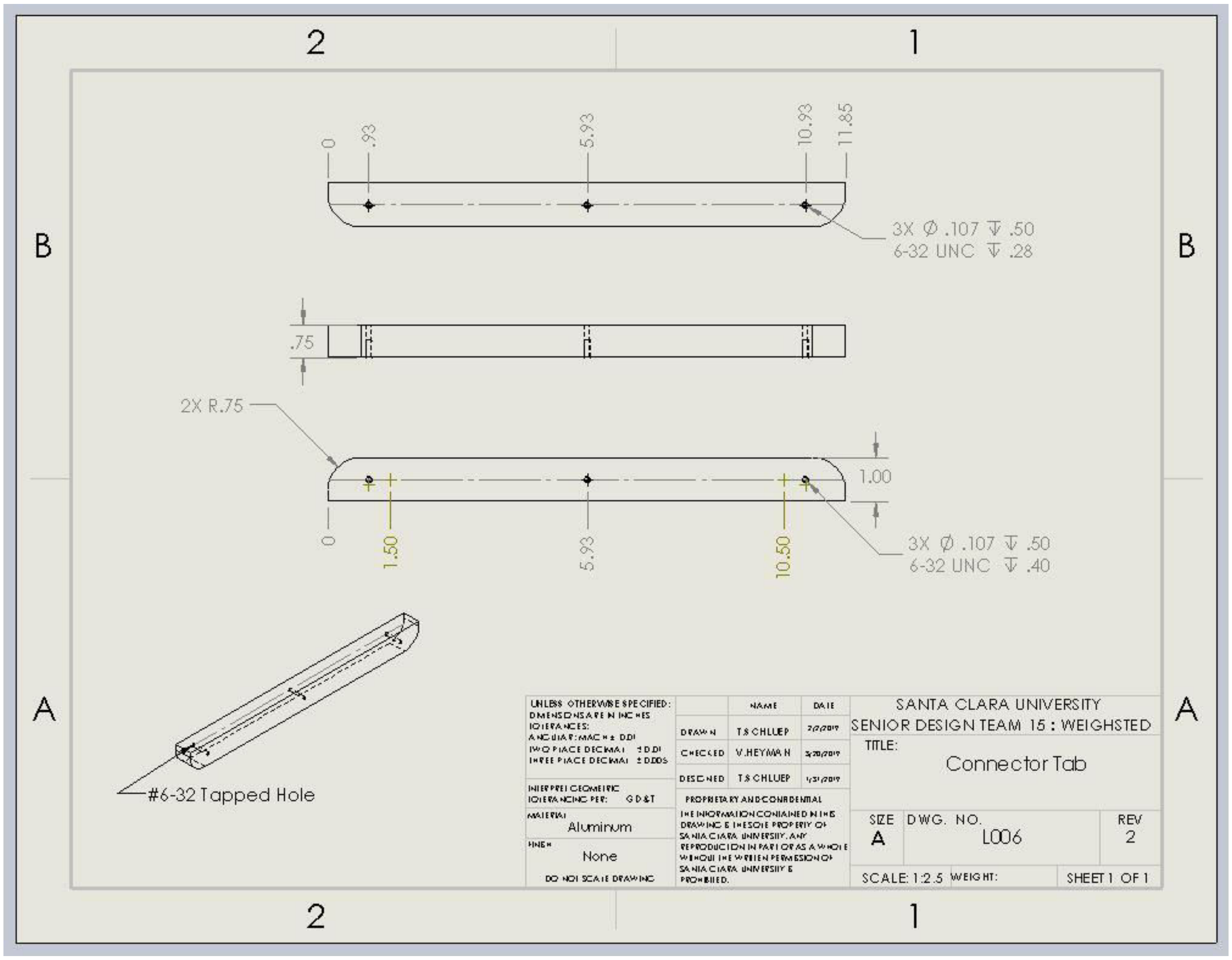
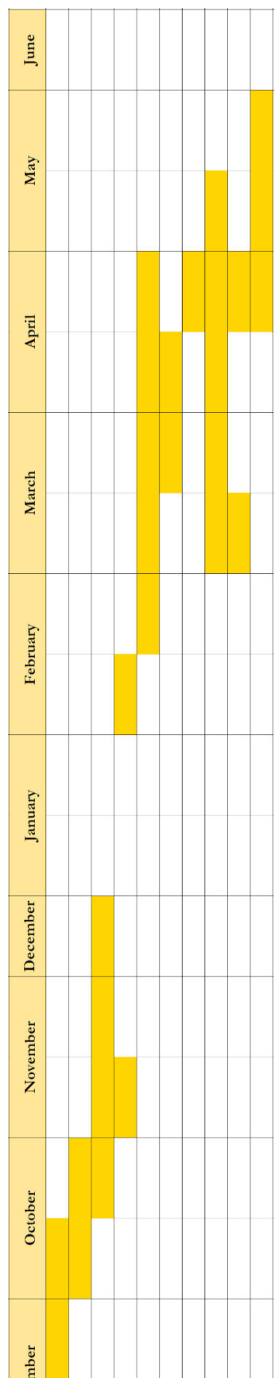
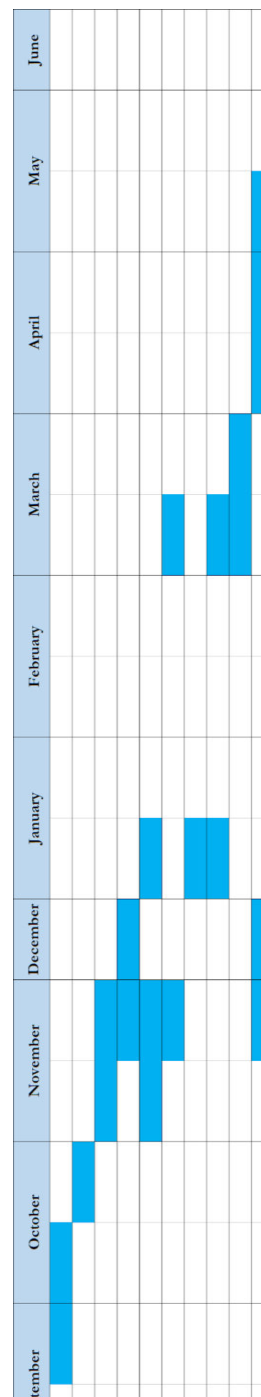


Figure L19. Connector tab drawing


June
May
April
March
February
January
December
November
October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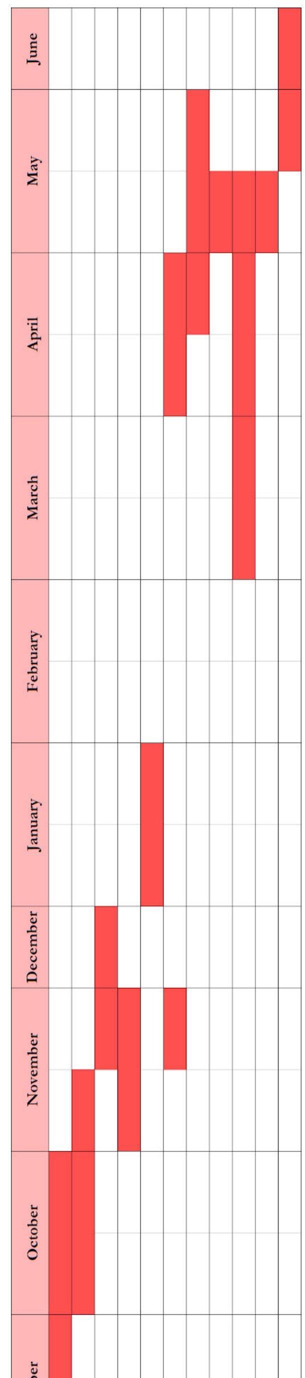
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Appendix C: Scoring Matrices

WEIGHING SUBSYSTEM							
Criteria	**Weight**	**Hanging Scale w/ Loading Cell**	**Weighte d Score**	**Digital Scale Above Bin**	**Weighted Score**	**Digital Scale Below Bin**	**Weighted Score**
Accuracy	0.25	5	1.25	5	1.25	5	1.25
Ease of Use	0.2	3	0.6	4	0.8	5	1
Ease of Manufacture/Assembl y	0.125	2	0.25	4	0.5	5	0.625
Cost	0.15	4	0.6	4	0.6	4	0.6
Durability	0.1	4	0.4	4	0.4	5	0.5
Aesthetics (eye-catching)	0.05	4	0.2	3	0.15	3	0.15
Portability	0.125	1	0.125	3	0.375	5	0.625
Totals	**1**	23	**3.425**	27	**4.075**	32	**4.75**
NOTES	**Ranking (High-Low)**						
Weighted score out of 5	1. Digital Scale Below Bin						
Non-weighted score out of 35	2. Digital Scale Above Bin						
	3. Hanging Scale w/ Loading Cell						

AUTO LID OPENING							
Criteria	**Weight**	**Iris**	**Weighted Score**	**Folding Flaps**	**Weighted Score**	**Sliding Door**	**Weighted Score**
Process Time	0.15	5	0.75	5	0.75	5	0.75
Visual Barrier	0.1	4	0.4	4	0.4	5	0.5
Ease of Manufacture/Assembly	0.15	2	0.3	4	0.6	4	0.6
Cost	0.1	3	0.3	4	0.4	4	0.4
Durability	0.2	3	0.6	4	0.8	5	1
Aesthetics (eye-catching)	0.3	5	1.5	2	0.6	3	0.9
Totals	**1**	22	**3.85**	23	**3.55**	26	**4.15**

NOTES	**Weighted Ranking (High-Low)**						
Weighted score out of 5	1. Sliding Door						
Non-weighted score out of 35	2. Iris						
	3. Folding Flaps						

MEAL IDENTIFICATION							
Criteria	**Weight**	**Tablet**	**Weighted Score**	**Image Recognition**	**Weighted Score**	**Molecular Spectroscopy**	**Weighted Score**
Accuracy/Consistency	0.25	3.5	0.875	4	1	4	1
Time For Identification	0.25	3.5	0.875	5	1.25	5	1.25
Ease of Manufacture/Assembly	0.15	4	0.6	2.5	0.375	4	0.6
Cost	0.075	4	0.3	4	0.3	4	0.3
Durability	0.1	5	0.5	3	0.3	5	0.5
Aesthetics	0.05	4.5	0.225	4.5	0.225	4.5	0.225
Portability	0.125	5	0.625	3	0.375	4	0.5
TOTALS	**1**	**29.5**	**4**	**26**	**3.825**	**30.5**	**4.375**
NOTES	**Weighted Ranking (High-Low)**						
Weighted score out of 5	1. Molecular Spectroscopy						
Non-weighted score out of 35	2. Tablet						
	3. Image Recognition						

CLEANING SUBSYSTEM							
Criteria	**Weight**	**Rolling Wiper Arm**	**Weighted Score**	**Squeegee and Bristles Uni-Directional**	**Weighted Score**	**Mechanical Arm**	**Weighted Score**
Level of Cleanliness	0.2	2.5	0.5	3.5	0.7	2	0.4

Process Time	0.2	5	1	4	0.8	5	1
Ease of Manufacture/Assembly	0.1	5	0.5	4	0.4	5	0.5
Cost	0.1	5	0.5	5	0.5	3.5	0.35
Durability	0.15	4	0.6	3.5	0.525	4	0.6
Aesthetics/Disgustingness	0.15	2	0.3	3.5	0.525	3.5	0.525
Portability	0.1	4	0.4	4	0.4	4.5	0.45
TOTALS	**1**	**27.5**	**3.8**	**27.5**	**3.85**	**27.5**	**3.825**
NOTES	**Weighted Ranking (High-Low)**						
Weighted score out of 5	1. Squeegee and Bristles						
Non-weighted score out of 35	2. Mechanical Arm						
	3. Rolling Wiper						
SECOND ITERATION							
Criteria	**Weight**	**Rolling Wiper Arm + Mechanical Arm**	**Weighted Score**	**Squeegee and Bristles + Mechanical Arm**	**Weighted Score**	**Wiper Arm + Squeegee and Bristles**	**Weighted Score**
Level of Cleanliness	0.2	3.5	0.7	4.5	0.9	4.5	0.9
Process Time	0.2	4	0.8	4	0.8	4	0.8
Ease of Manufacturing	0.1	4.5	0.45	4.5	0.45	4.5	0.45
Cost	0.1	3.5	0.35	3.5	0.35	4.5	0.45
Durability	0.15	4	0.6	3.5	0.525	3.5	0.525
Aesthetics	0.15	3	0.45	3.5	0.525	3	0.45
Portability	0.1	4	0.4	4	0.4	4	0.4
TOTALS	1	26.5	3.75	27.5	3.95	28	3.975
	Weighted Ranking (High-Low)						
	1. Wiper Arm + Squeegee and Bristles						

	2. Squeegee and Bristles + Mech Arm					
	3. Rolling Wiper Arm + Mech Arm					

Appendix D: AGMA Bending of Gears | MatLab Code

```
% AGMA Method for Spur Gears (English Units)

% AGMA bending (english units)
dg = 27; % Gear Pitch Diameter
dp = 9; % Pinion Pitch Diameter

% Ko - Overload Factor
Ko = 1; % No Shock

% Kv - Dynamic Factor
V = 30; %Velocity (ft/min)
Qv = 7; %Quality: (commercial is 3-7) (precision is 8-12)

B = .25*(12 - Qv)^(2/3);
A = 50 + 56*(1 - B);
Kv = (A + sqrt(V)/A)^B;

% Ks (neglect)
Ks = 1;

% Pd - Diametral Pitch
N = 12; % Number of Teeth around gear
Pd = N/dp; %teeth per inch around circumference

% F - Face Width
F = .25;

% Km - Load Distribution Factor
Cmc = 1;

a = F/(10*dp);
if a < .05
        a = .05;
end
Cpf = a - .025;

Cpm = 1;

%Open Gearing
A = .247;
B = .0167;
C = -.765*10^(-4);
Cma = A + B*F + C*F^2;
Ce = 1;

Km = 1 + Cmc*(Cpf*Cpm + Cma*Ce);
```

```
% Kb - Rim Thickness Factor
%tr = % rim thickness
%ht = 2% tooth height
%mb = tr/ht
%Kb = 1.6*log(2.242/mb)
Kb = 1;

% J - Geometry Factor
J = .21; % Use figure 14-6 pg. 745 f(N(desired gear),N(mating gear))

Wt = 2; % Tangential Force
Sy = 6500; % Acrylic Yield Strength

Sb = Wt*Ko*Kv*Ks*(Pd/F)*(Km*Kb/J) % Bending Stress
FS_B = Sy/Sb % Factor of Safety for Bending Stress

%Wtb = Sb/(Ko*Kv*Ks*(Pd/F)*(Km*Kb/J))

%r = dp/2
%w = % angular velocity of gear

%Tb = Wtb*r
%Pb = Tb*w

% AGMA Pitting

Cf = 1;
I = .25*(cos(.349) + sin(.349));
Sp = sqrt(Wt*Ko*Kv*Ks*Km*Cf/(dp*F*I)) % Pitting Stress
FS_P = Sy/Sp % Factor of Safety for Pitting

% Wtp = Sb^2/(Ko*Kv*Ks*Km*Cf/(dp*F*I))
%
% Tp = Wtp*r
% Pb = Tp*w
```

```
Sb =
  1.3731e+03
FS_B =
    4.7340
Sp =
    8.6597
FS_P =
  750.6013
```

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Appendix E: Prototype Lid Finite Element Analysis

Introduction

The subsystem we will analyze is the iris opening mechanism since it will experience the most stress of the entire system due to the most moving parts it contains. First we will examine how one of the five leaves which make up the lid will react to a load applied to the corner of a leaf closest to the center of the opening. This is important to understand what would happen if a small load was applied on the opening which could cause it to fail. And secondly, we will analyze the forces which act on the leading gear of the opening mechanism.

For both analyses the material was modeled as Acrylic (Medium-High impact) from the Solidworks library. Acrylic has a yield strength of 6527 psi, an elastic modulus of 435113 psi, and a Poisson's ratio of 0.35.

Analysis

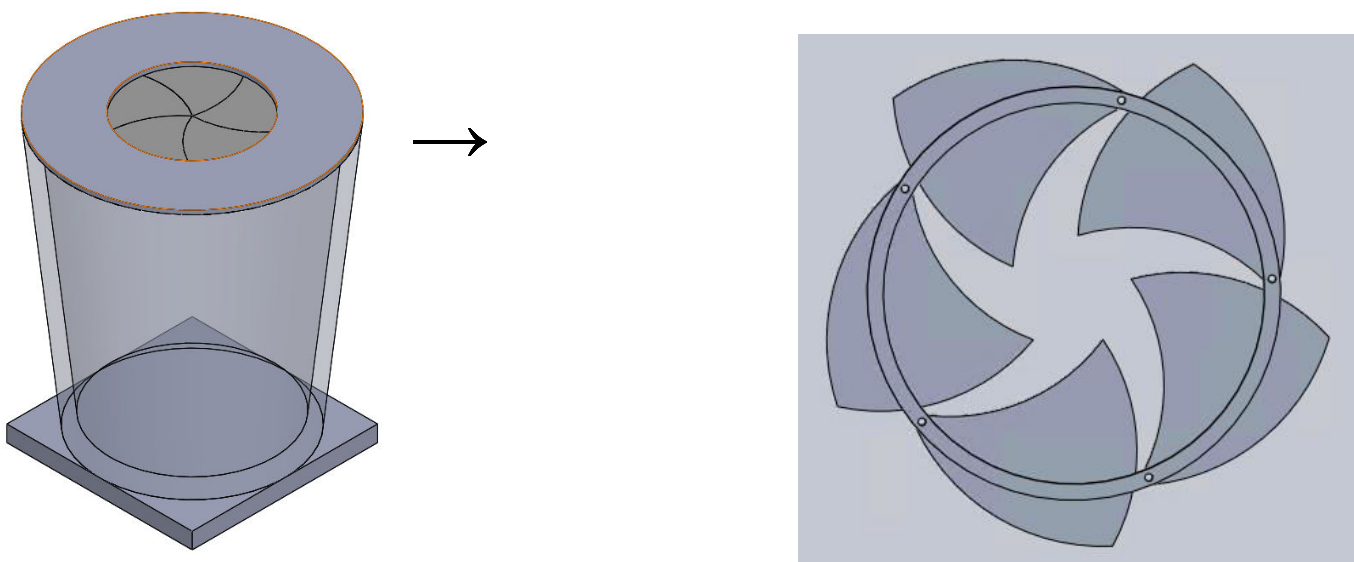


Figure E1: Opening Mechanism subsystem and its location in overall system

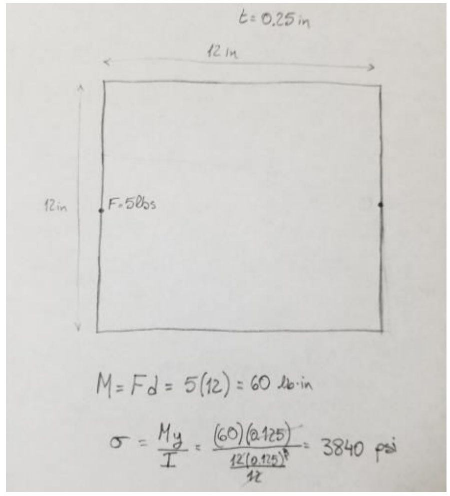


Figure E2: Simplified model and hand calculations for a point force applied to an end of a rectangular flat plate and restrained at the opposite end.

For the preliminary calculations, the plate was simplified as a rectangular thin plate of dimensions 12x12x0.25 inches with a load of 5 lbs applied to one end and restrained at the opposite end as is shown in Figure E2. The stress was calculated using the equations shown in Figure E2 [1] where M is the bending moment, d is the distance between the force and the calculated moment, I is the cross-sectional moment of inertia and y is the midpoint of the thickness of the plate, where the stress is highest.

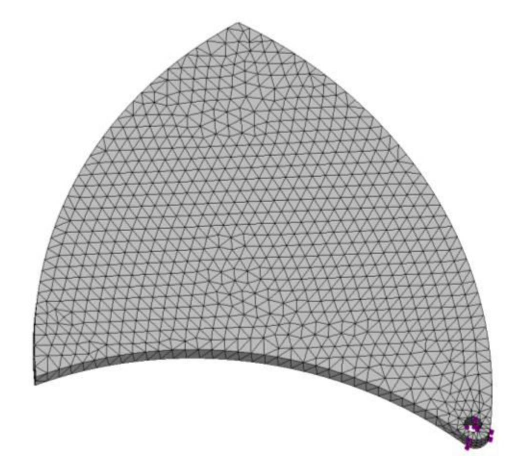


Figure E3: Mesh used for the model of the leaf

For the simulation, a mesh with 9449 elements was used, including a mesh control applied at the hole with the fixed geometry to refine the mesh where the stress concentration was greatest.

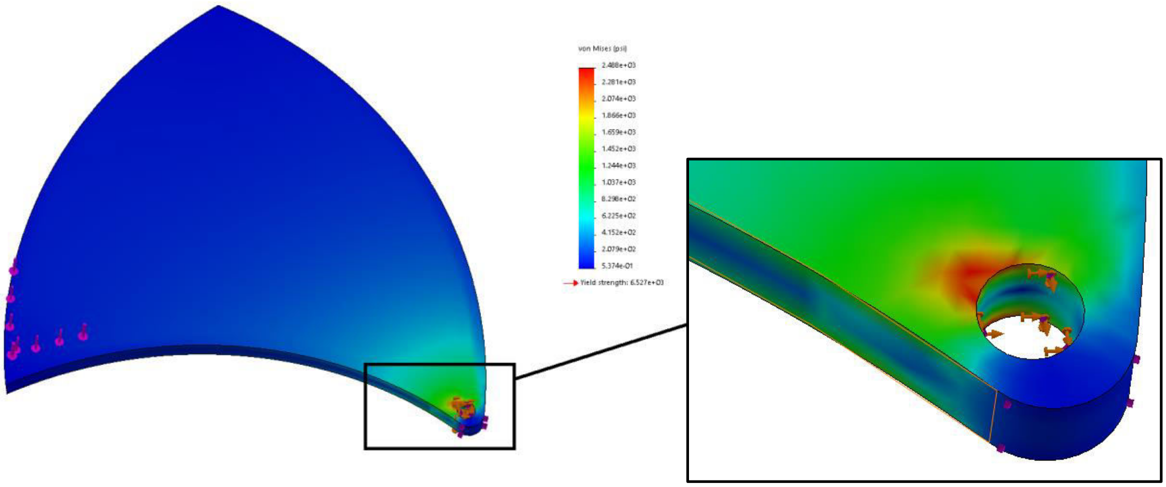


Figure E4: Stress Distribution showing the stress concentration on the acrylic leaf.

A load of 5 lbs was applied to a region on the tip of the leaf. It was expected to deform without reaching critical stress since the yield strength of acrylic used for the model is 6527 psi and the expected stress wasa 3840 psi. After simulating the more complex geometry of the true dimensions and shape of the model in Solidworks the highest stress was found around the hole which will be pinned to restrict movement in the vertical direction when the plate is parallel to the ground. The value of the stress found from the Solidworks simulation was lower than the expected value and had a magnitude of 2488 psi as shown in Figure E4.

The main issues that arose when using the model were establishing the correct restraints and fixed geometry for the simulation to run smoothly. This problem was worked around by assuming that the pinned connection would be treated as a fixed geometry when the load was applied for this simulation. In reality, however, the connection will allow for the leaf to rotate in order to open and close the iris mechanism.

Our second possible mode of failure would occur at the gears. We determined that if the gears could withstand loading while in the locked position they would not fail during normal operation when they are free to rotate. Our gears should be able to withstand this test as a safety and quality precaution. Pinions have higher stress than gears so our analysis has been done on the pinion.

In the Solidworks model the acrylic pinion is fixed around the hinge and a two pound force is applied at one of the teeth. 5896 elements are used and mesh refinement was done at the tooth of interest.

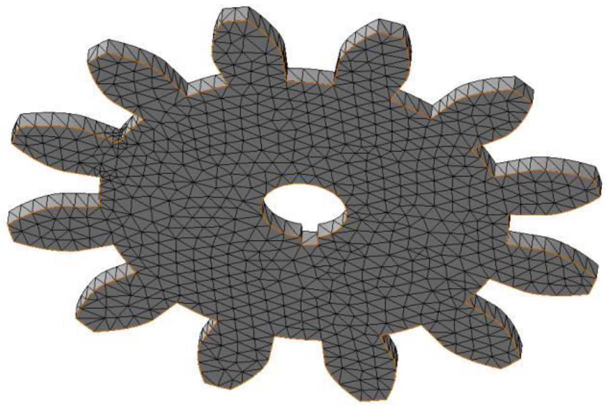


Figure E5: Pinion Mesh

The simulation showed that the maximum Von Mises stress was 29 psi at the tooth transition. In order to check our simulation we made a Matlab code for AGMA method pitting, in which the maximum stress was 10 psi. We believe this discrepancy is because the pinion is moving at 1 ft/s in the code while in our model the pinion is fixed. In both cases the pinion does not fail by a couple of orders of magnitude.

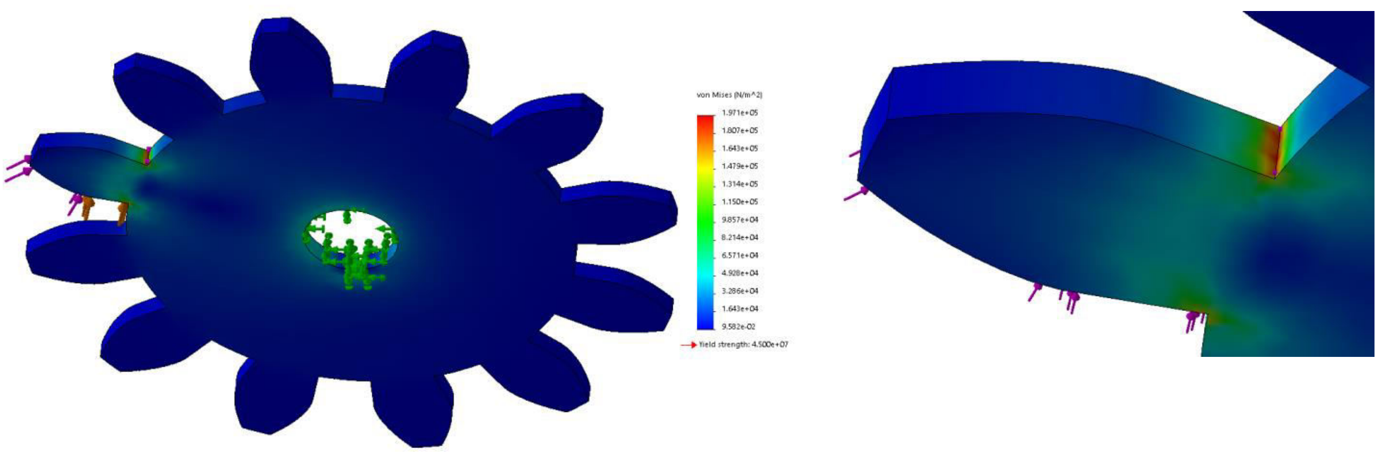


Figure E6: Von Mises Stress Distribution Of Pinion Tooth Under Loading

Conclusion

The analysis undertaken for this report served to analyze whether the geometry of the lid mechanism and material selected for the lid would withstand operational loading with some factor of safety. Due to the relatively low loading experienced by the parts, the Solidworks models passed with enough room for error to give us confidence that our design is feasible and adequate for the loading conditions. Much more in depth modeling must be done on these parts and the system as a whole, along with real world testing to verify the final design.

Appendix F: Door Hub Finite Element Analysis

The track roller locations became a critical feature after failure during manufacture occured. Finite element analysis was completed to determine the ideal location of the track roller hole while prioritizing the thin feature below the threads and maintaining the hub cover to shield the rollers from dust, debris, food, and water. The wheel hub and thin features can be seen below.

Figure F1. Track roller in door showing hub and thin features

To analyze the stresses, FEA was completed on a simplified version of the door and modeled as a distributed load over a surface with the hole held fixed. A load of 10 lbs was tested for different hole locations. The lid assembly and FEA simplification can be seen below.

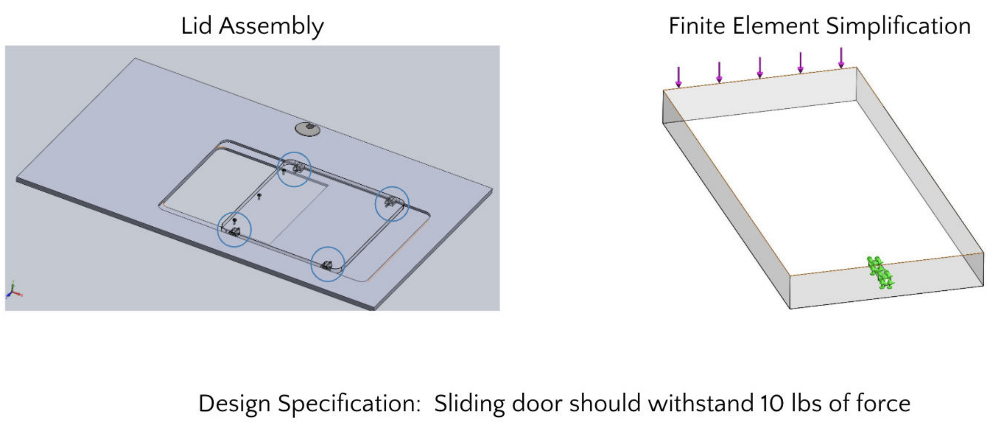


Figure F2. Lid assembly and FEA simplification

From this analysis, shear and normal stresses were created at and along the hole and threads. These two main stresses can be seen in the figures below.

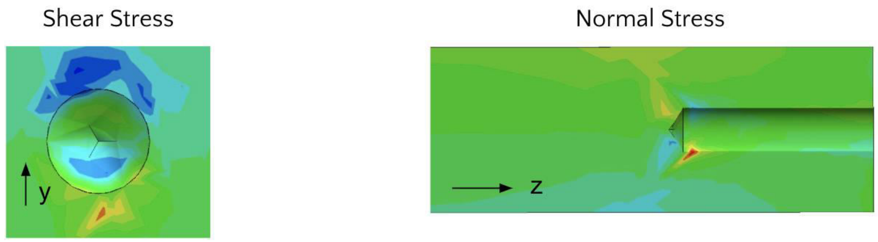


Figure F3. Shear and normal stresses at and along hub hole and threads

To determine whether different whole locations were safe, a failure criterion was necessary. Due to the brittle characteristics of Acrylic and because acrylic is stronger in compression than in tension, Mohr's Failure Criterion was used. To use this failure criterion the shear and normal stresses were used to calculate the principal stresses occurring in each simulation. Theses stresses were then plotted on Mohr's failure criterion graph to determine whether each location would pass and if so with what factor of safety. The following figures show the principal stresses and Mohr Criterion Failure Plot for the accepted hole location.

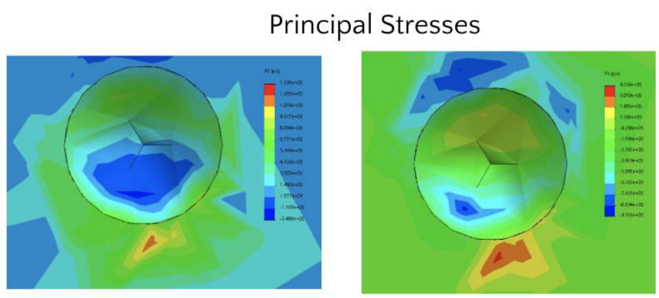


Figure F4. Principal stresses from accepted hub hole location

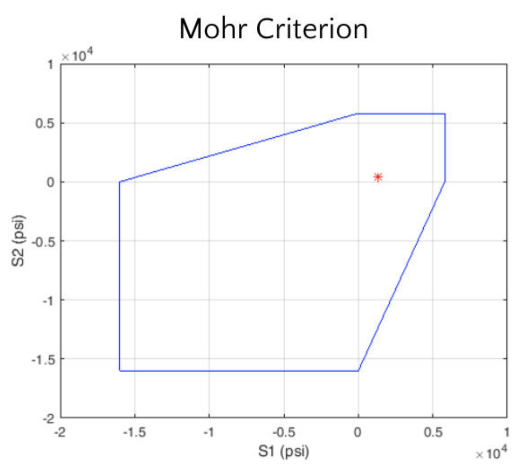


Figure F5. Mohr's Criterion plot showing accepted point

The hole location was accepted with a factor of safety of 4.33.

Appendix G: Food Waste Questionnaire & Raw Data

Food Waste Questionnaire

1. Is food waste an important issue to you?

(Not Important Somewhat Important Important Very Important)

2. How frequently do you eat in Benson?

(Never Rarely Some Meals Most Meals All Meals)

3. What year are you?

(Freshman Sophomore Junior Senior)

4. What gender are you?

(Male Female)

5. How often do you scrape your leftover food into composting?

(Never Rarely Some Meals Most Meals All Meals)

6. How much time would you spend interacting with a food waste collection kiosk after meals in order to help SCU collect information about food waste?

(None 10 seconds 20-30 seconds 30-60 seconds A couple Minutes)

7. Would you need an incentive (ex. reward credits for meal points after certain amount of uses) to interact with a food waste collection kiosk?

(Yes No No Interest in Participation)

Rank the following Incentives (1-4, 1 being most desired):

a. Entries into a raffle _____
b. Reward points that can be redeemed for snacks (cookies, chips, soda, etc.) _____
c. Reward points that can be redeemed for SCU swag (lanyard, sticker, T-shirt) _____

d. Reward points that can be redeemed for discounts at bookstore

______

Raw Tabulated Data

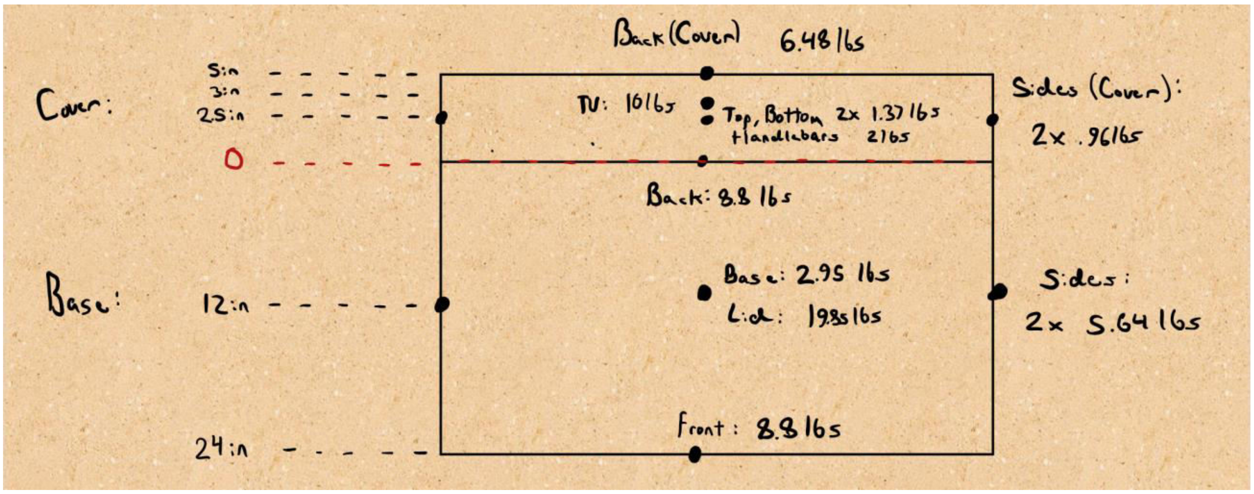
Subject	1	2	4	3	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Question 1	3	3	2	2	2	2	4	2	2	3	4	3	3	4	1	3	2	3	3	2	5	3	2	2	2
Question 2	5	2	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5
Question 3	1	3	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1	1	2	1	1	2	1	1
Question 4	1	2	1	2	2	2	2	1	1	1	2	1	1	2	1	1	1	2	2	2	1	1	1	1	2
Question 5	5	5	5	3	4	5	4	5	2	5	1	2	5	5	5	5	5	5	5	3	2	5	4	5	2
Question 6	1	3	2	2	1	3	3	3	3	4	4	3	3	4	1	4	3	3	3	3	3	4	2	2	2
Question 7	1	2	1	1	2	2	2	2	2	2	2	2	2	1	1	2	1	2	1	1	1	2	2	1	2
a	4	4	4	4	1	4	1	4	4	4	4	4	4	3	2	4	4	4	4	1	2	3	4	4	3
b	1	2	2	1	3	2	4	2	2	1	2	3	3	2	4	3	3	3	1	4	4	2	1	1	4
c	2	1	3	3	2	1	4	3	1	3	1	1	1	4	1	1	1	1	2	3	1	1	2	3	1
d	3	3	1	2	4	3	4	1	3	2	2	2	2	1	3	2	2	2	3	2	3	4	3	2	2

Table XX. Organized data summarizing the results of the SCU student surveys.

<table>
<tr><th>Question</th><th colspan="5"></th></tr>
<tr><td>1</td><td>Not Important</td><td>Somewhat Important</td><td>Important</td><td colspan="2">Very Important</td></tr>
<tr><td></td><td>1</td><td>11</td><td>9</td><td colspan="2">3</td></tr>
<tr><td>2</td><td>Never</td><td>Rarely</td><td>Some Meals</td><td>Most Meals</td><td>All Meals</td></tr>
<tr><td></td><td>0</td><td>1</td><td>4</td><td>18</td><td>2</td></tr>
<tr><td>3</td><td>Freshman</td><td>Sophomore</td><td>Junior</td><td colspan="2">Senior</td></tr>
<tr><td></td><td>20</td><td>4</td><td>1</td><td colspan="2">0</td></tr>
<tr><td>4</td><td>Male</td><td>Female</td><td colspan="3">N/A</td></tr>
<tr><td></td><td>14</td><td>11</td><td colspan="3">N/A</td></tr>
<tr><td>5</td><td>Never</td><td>Rarely</td><td>Some Meals</td><td>Most Meals</td><td>All Meals</td></tr>
<tr><td></td><td>1</td><td>4</td><td>2</td><td>3</td><td>15</td></tr>
<tr><td>6</td><td>None</td><td>10 Seconds</td><td>20-30 Seconds</td><td>30-60 Seconds</td><td>A Couple Minutes</td></tr>
<tr><td></td><td>3</td><td>5</td><td>12</td><td>5</td><td>0</td></tr>
<tr><td>7</td><td>Yes</td><td>No</td><td colspan="3">N/A</td></tr>
</table>

	10	15	N/A

Appendix H: Tipping Calculations



ΣM:

$M_{Cover} = (6.48 \text{ x } 5) + (10 \text{ x } 3) + 2.5 \text{ x } (0.96 \text{ x } 2 + 1.37 \text{ x } 2) = 223.9 \text{ lb x in}$

$M_{Base} = 12 \text{ x } (5.64 \text{ x } 2 + 19.85 + 2.95) + 24 \text{ x } 8.8 = 2780.16 \text{ lb x in}$

$M_{Base} >> M_{Cover}$

We can conclude from this calculation that the assembly will not tip over.

Appendix I: Bill of Materials

Component Description	Part #
Frame Subsystem	
Waste Bin	F001
Plywood Sections	F002
Wheels (lockable)	F005
Steel Hinges For Cover	F006
Hinges For Door	F007
2x4 Support Beams	F008
Fasteners	F009
Angle Brackets	F010
Corner Brackets	F011
Door Handle	F012
Cover Handle	F013
TV Wall Mount	FB04
TV	FB05
Handle Assembly	FA2
Frame Assembly	**FA1**
Weighing Subsystem	
Load Cell (30kg)	W001
Load Cell Amplifier	W008
Plywood - Load Cell Frame	W002
Washers	W003
Nuts	W004
Bolts (M6)	W005
Metal Support	W006
#6 1/2 inch wood screws	W007
Spacers	W008
Scale assembly	**WA1**
Meal ID Subsystem	
LCD Touchscreen	M001
LCD Touchscreen Security Case	M002
Tablet Wall Mount	M003
Meal Identification Assembly	**MA1**

Component Description	Part #
Lid Subsystem	
Top Plate, Door	L001
Stepper Motor Mounting Bracket	L003
Base	L004
Motor	L005
Connector Tab	L006
Keyed Shaft	L007
Motor Mount	L008
Shaft Mount	L009
Shaft Collars	L010
Shaft Collar Key	L011
Shaft Coupler Motor Connector	L012
Track Rollers	L013
Gear	L014
Rack	L015
Acrylic Glue	L016
Stepper Motor Driver Module	L017
Plastic Cord Grommet	L018
Sleeve Bearing	L019
Lid Assembly	**LA1**
Power and Database Subsystem	
Miscellaneous Electronics	E008
Enclosure	E007
Starter Kit (Wires, Resistors, Etc.)	E001

ESP8266	E002
Arduino Yun	E003
HX711 Amplifier	E004
Database	E005

External Power Supply	E006
Power and Database Assembly	**EA1**

Appendix J: Testing Tables

Table J1: Weighing Accuracy Test

	0 lbs before tare		*1 lb Before Tare*		*5 lbs Before Tare*	
	True (lbs)	Measured (lbs)	True (lbs)	Measured (lbs)	True (lbs)	Measured (lbs)
	0.1987	0.198	0.1987	0.198	0.1987	0.199
	0.1987	0.198	0.1987	0.198	0.1987	0.198
	0.1987	0.198	0.1987	0.199	0.1987	0.197
	0.1987	0.198	0.1987	0.198	0.1987	0.198
	0.1987	0.197	0.1987	0.198	0.1987	0.198
Average:		0.1978		0.1982		0.198
Standard Deviation:		4.47E-04		4.47E-04		7.07E-04
Percent Error:		0.45%		0.25%		0.35%

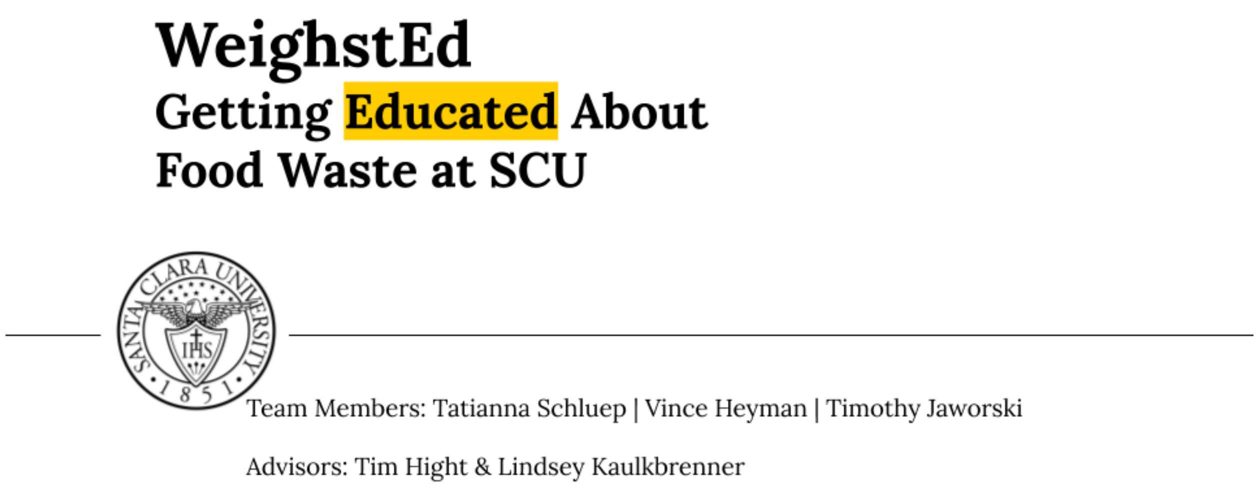
	10 lbs Before Tare		*25 lbs Before Tare*		*50 lbs Before Tare*	
	True (lbs)	Measured (lbs)	True (lbs)	Measured (lbs)	True (lbs)	Measured (lbs)
	0.1987	0.197	0.1987	0.2	0.1987	0.199
	0.1987	0.197	0.1987	0.2	0.1987	0.197
	0.1987	0.197	0.1987	0.2	0.1987	0.198
	0.1987	0.197	0.1987	0.199	0.1987	0.2
	0.1987	0.198	0.1987	0.199	0.1987	0.199
Average:		0.1972		0.1996		0.1986
Standard Deviation:		4.47E-04		5.48E-04		1.14E-03
Percent Error:		0.75%		0.45%		0.05%

Table J2: Process Time Test Data

Trial	*Opening Time*
Trial 1	24.91
Trial 2	23.62
Trial 3	22.56
Trial 4	23.92
Trial 5	26.54
Trial 6	22.93
Trial 7	31.38
Trial 8	28.93
Trial 9	25.47
Trial 10	27.30
Average:	25.76
STD:	2.82
Range:	2.02
N:	10
t9,95	2.262
Target:	30
Percent Difference:	14.15

Appendix K: Senior Design Conference Presentation Slides

This appendix consists of the slides used for the Senior Design Conference Final Presentation of WeighstEd.



1

Problem Identification
Food Waste

A problem in need of more than just a waste bin...

3

Every year in the US . . .

~40%

of all food goes to landfills

70,000,000 tons

of *food wasted*

220,000,000,000$

spent on *food* never eaten

[1]

4

Wasted Resources [2]

Freshwater

21%

Fertilizer

19%

Cropland

18%

Landfill Volume

21%

5

PROBLEM STATEMENT

SCU has made a commitment to reducing its food waste by 10% by 2020.

~ However ~

The school lacks an accurate method for collecting and analyzing food waste data

“

6

2 Project Goals

Driven by Sustainability Center, SCU Student needs and SCU School of Engineering Resources

7

Project Goals

1. Weigh and collect food waste
2. Store and analyze relevant data
3. Educate students about food waste trends

Client Needs

- Collect average food waste
  - Per menu item
  - Tracked quarter to quarter
- No volunteer
- Portable

End User (Student) Needs

- Informative experience
- Fast and Easy

8

3 System Level Run Through

An introduction to WeightstEd

9

System Level Breakdown

- Mobile ✓
- Self Contained ✓
- Educational ✓
- Collects waste data ✓
- Stores waste data ✓
- Analyzes waste data ✓

4 Subsystems

10

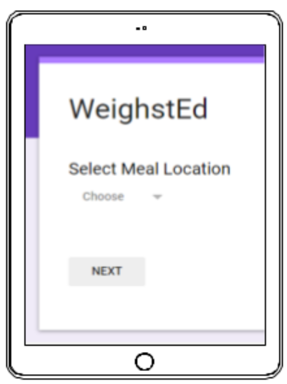
System Level Breakdown

11

Simple 6 Step Process

1

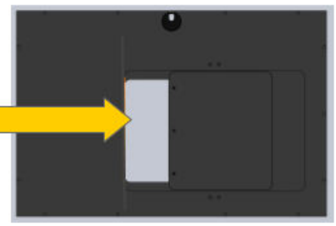
User identifies meal (via tablet)



12

Simple 6 Step Process

1 User identifies meal (via tablet) → 2 Door Opens



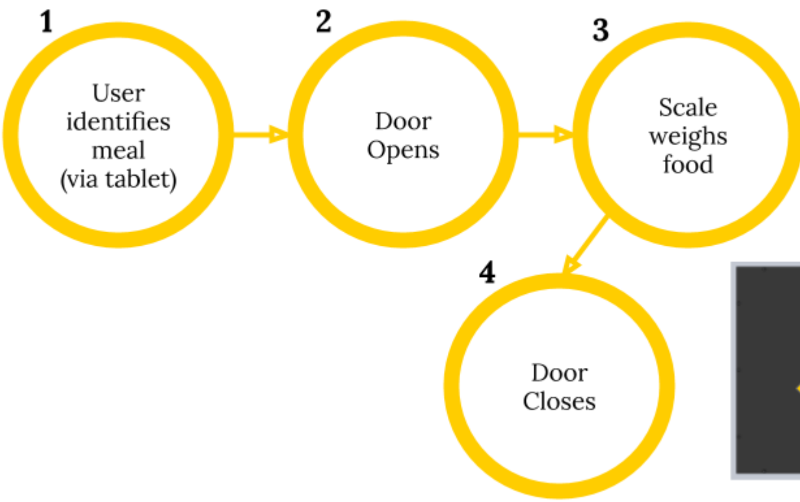
13

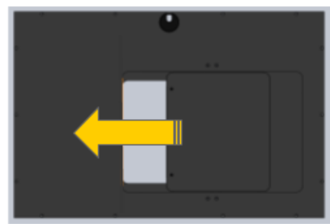
Simple 6 Step Process

1 User identifies meal (via tablet) → 2 Door Opens → 3 Scale weighs food

14

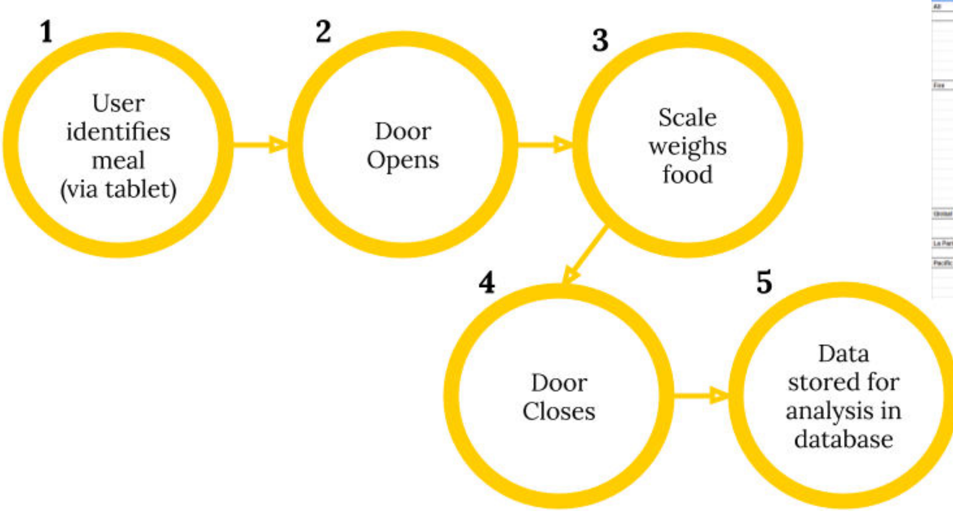
Simple 6 Step Process

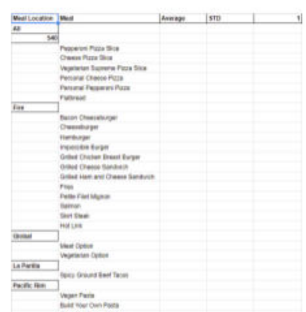




15

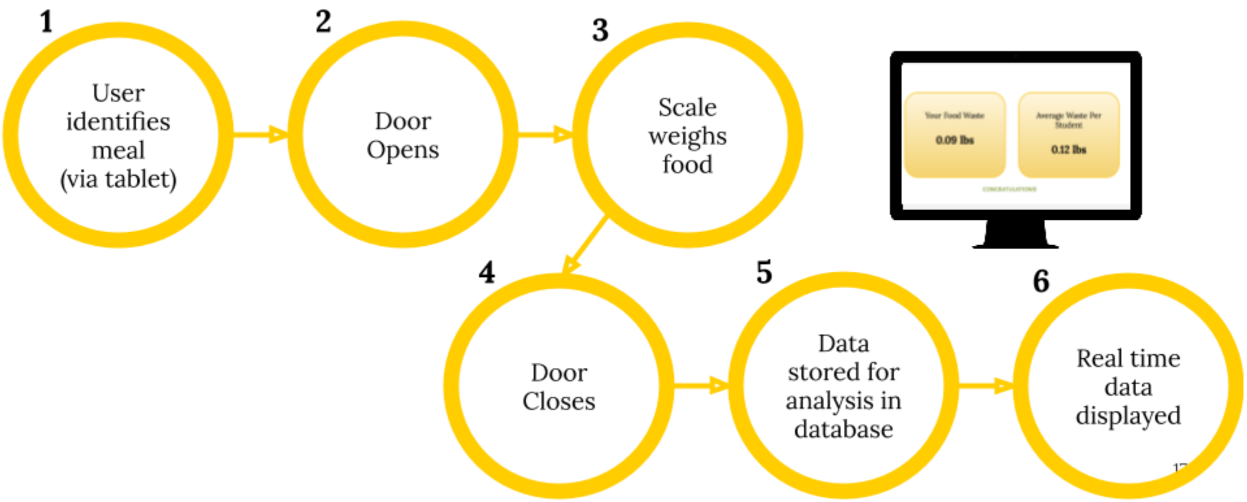
Simple 6 Step Process





16

Simple 6 Step Process



4 Subsystem Breakdown

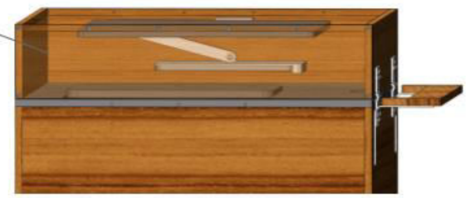
Description, Challenges, Analysis, Improvements

18

Frame & Cover Subsystem

Purpose

1. Provides stability and structural integrity
2. Easy to transport, store, and maintain



19

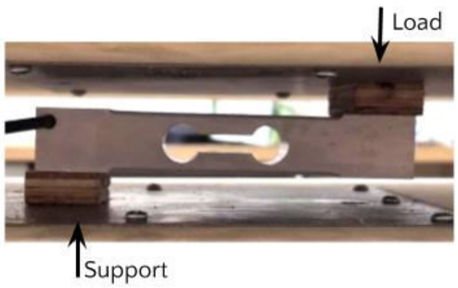
Design Iteration

- Size Reduction

Weighing Subsystem

Final Scale Design

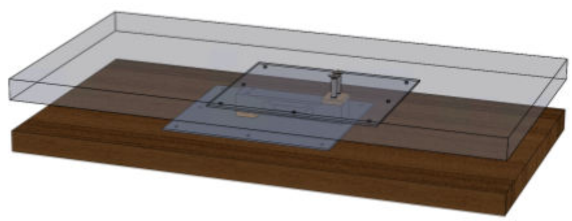
Bending Beam Load Cell



Design Constraints

- Collect accurate weight data of food waste
- Each interaction allows for collection of individual meal information
- Send weight data to microcontroller

Weighing Subsystem



Specifications

Up to 55 lb (25 kg) of food waste

±0.002 lb of accuracy

Ensures accuracy without having to unload the waste often

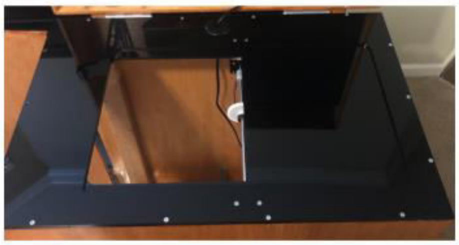
Improvements and Challenges

- Added sheet metal supports and wooden spacers
- Reduce bending and add stability

Lid Subsystem

Description

Automatic open/close acrylic sliding door actuated by a rack gear and pinion transmission assembly.



Purpose

- ensure *methodical* collection of food waste data
- visual/physical barrier to internal components and waste

Specifications

- Door open <1.5 sec
- Improve user composting experience
- Aesthetically pleasing

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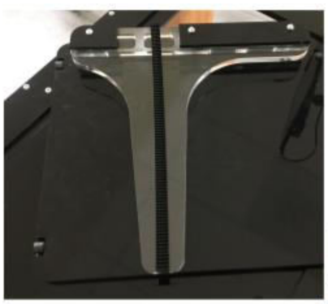
Lid Components

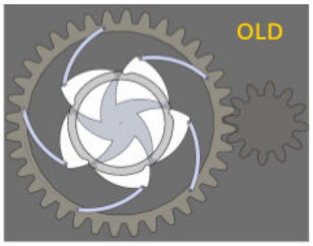


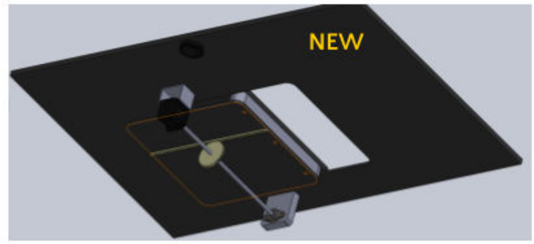
Door Subassembly

Transmission

Lid Base

Challenges & Improvements | Initial Design





- Difficult manufacturability
  - Custom parts
  - Difficult assembly
- Proportion issues
- Complicated geometry
- Poor user interaction

- Simplified layer assembly
  - Single point connection
- Improved proportion
  - 15% hole increase, 78% less space
- Straightforward geometry
- Enhanced user interaction

Challenges & Improvements | Door Manufacture

Challenges

- Door wheel hub broke when manufactured
- Thread location was prioritized over hub thickness

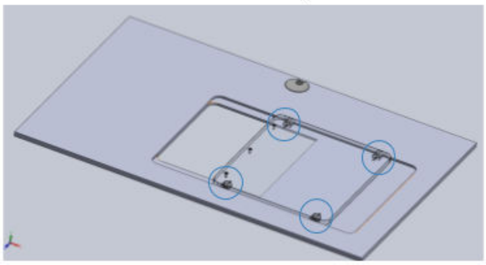
Improvements

- Test and design for thinnest feature with highest factor of safety

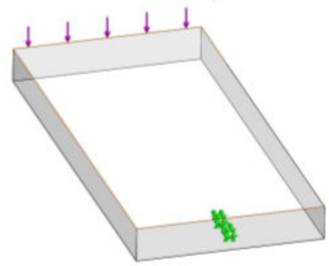
Door Analysis

Finite Element Analysis of Lid at Wheel Threads

Lid Assembly



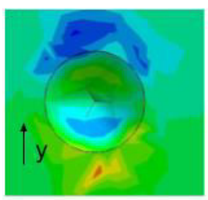
Finite Element Simplification



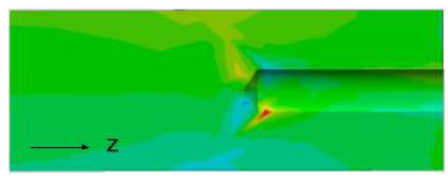
Design Specification: Sliding door should withstand 10 lbs of force

Results

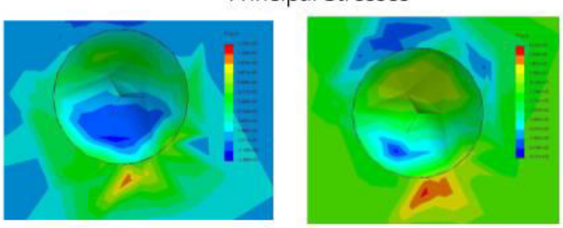
Shear Stress



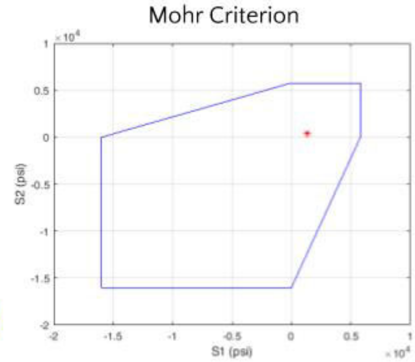
Normal Stress



Principal Stresses

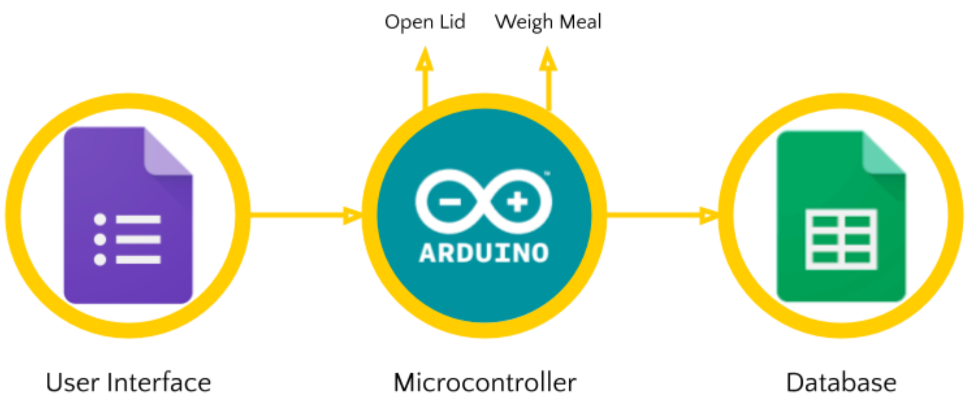


Mohr Criterion

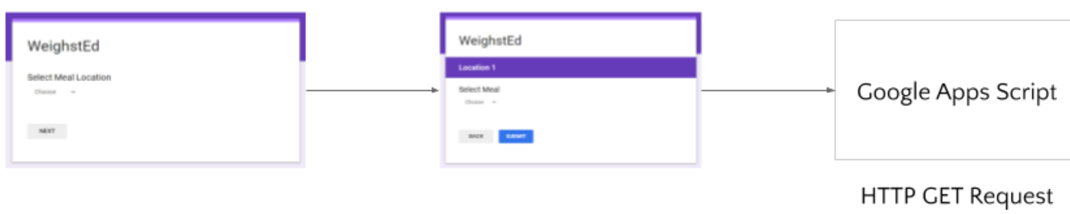


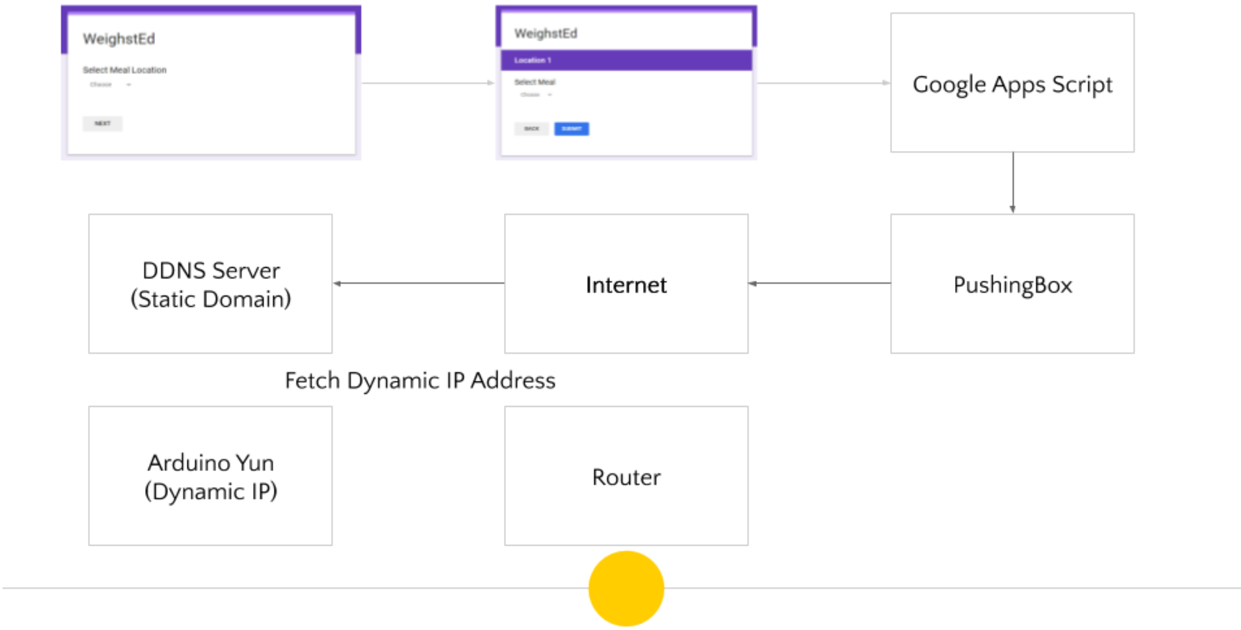
Factor of Safety of 4.33

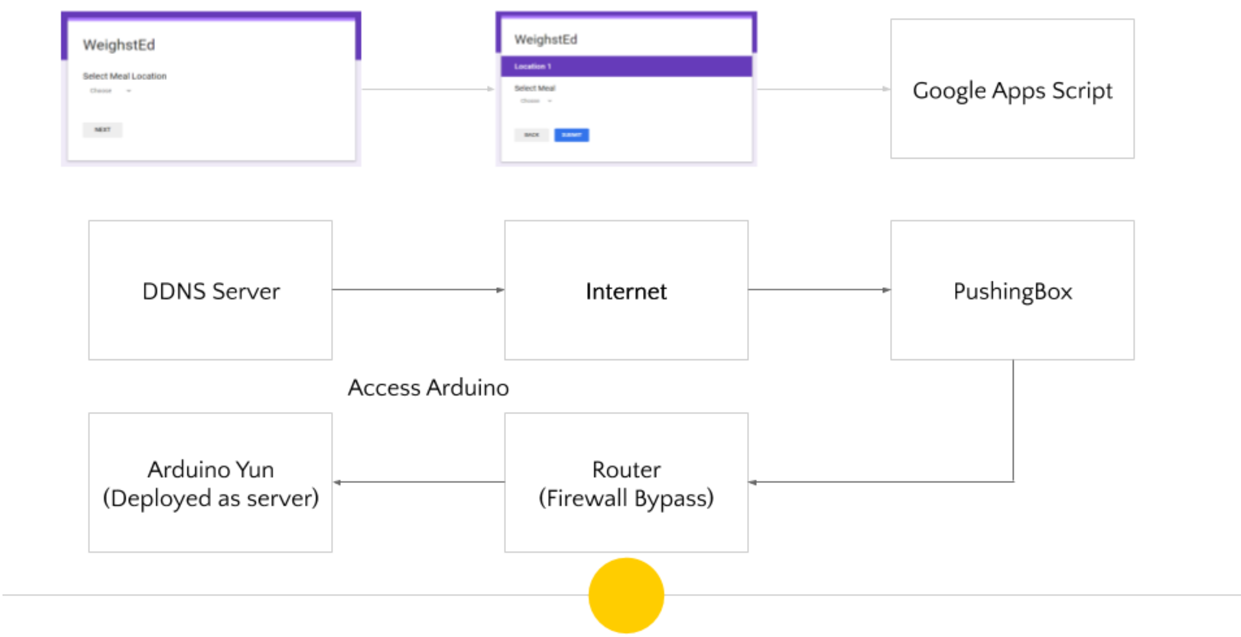
Backend Subsystem
Data Collection & Processing

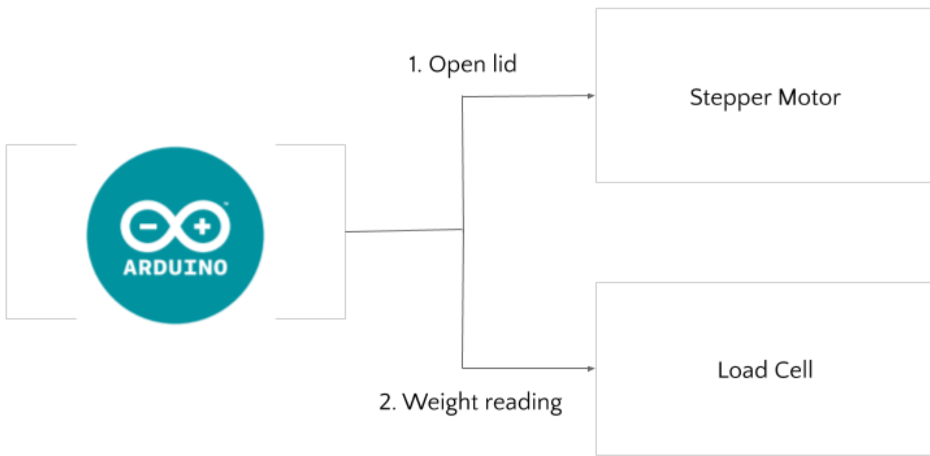


29

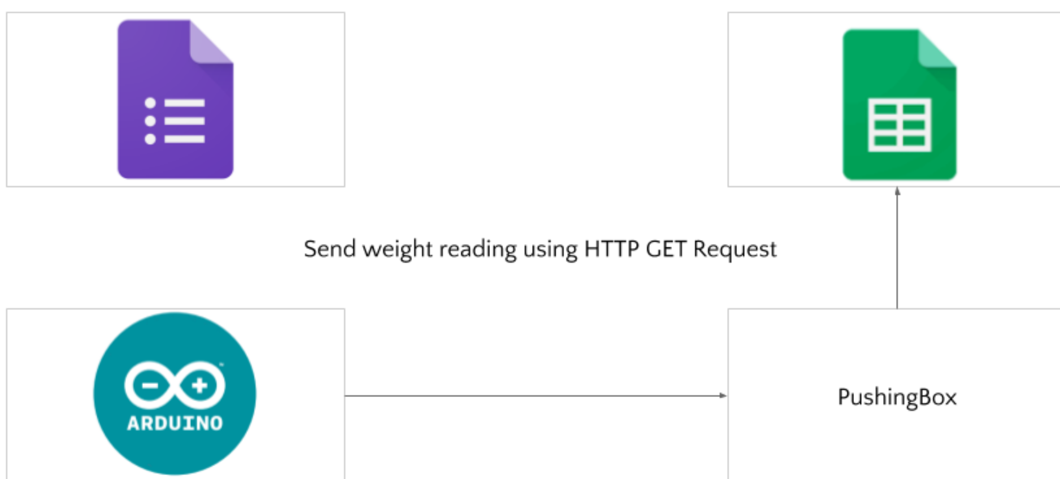



WeighstEd
Select Meal Location
WeighstEd
Location 1
Select Meal
Google Apps Script
DDNS Server
(Static Domain)
Internet
PushingBox
Fetch Dynamic IP Address
Arduino Yun
(Dynamic IP)
Router

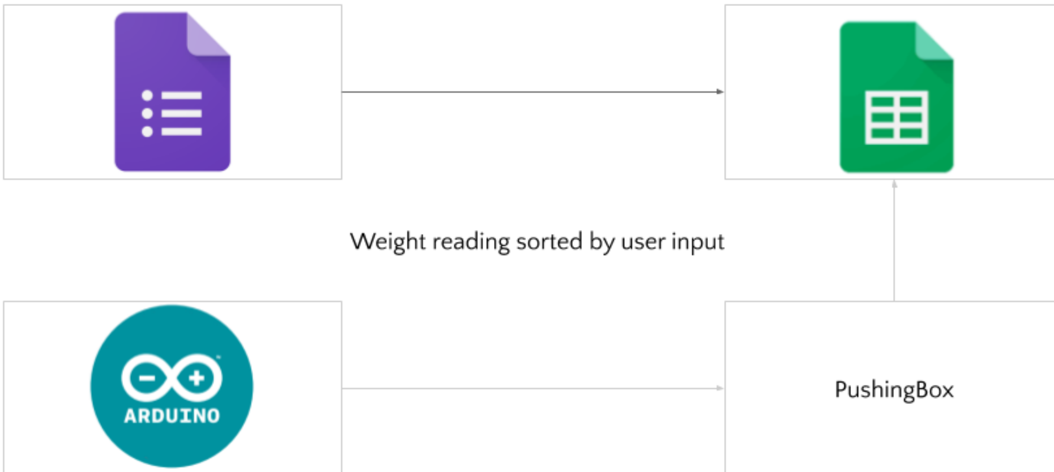

WeighstEd
Select Meal Location
WeighstEd
Location 1
Select Meal
Google Apps Script
DDNS Server
Internet
PushingBox
Access Arduino
Arduino Yun
(Deployed as server)
Router
(Firewall Bypass)



1. Open lid
Stepper Motor
ARDUINO
Load Cell
2. Weight reading



Send weight reading using HTTP GET Request
ARDUINO
PushingBox



Database

Single Quarter

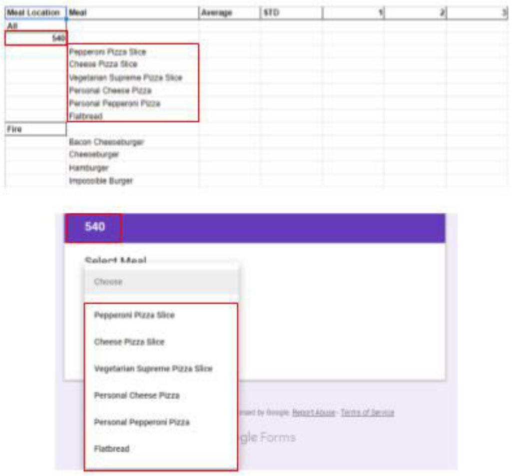
Meal Location	Meal	Average	STD	1	2	3
All						
540						
	Pepperoni Pizza Slice					
	Cheese Pizza Slice					
	Vegetarian Supreme Pizza Slice					
	Personal Cheese Pizza					
	Personal Pepperoni Pizza					
	Flatbread					
Fire						
	Bacon Cheeseburger					
	Cheeseburger					
	Hamburger					
	Impossible Burger					
	Grilled Chicken Breast Burger					
	Grilled Cheese Sandwich					
	Grilled Ham and Cheese Sandwich					
	Fries					
	Petite Filet Mignon					
	Salmon					
	Skirt Steak					
	Hot Link					
Global						
	Meat Option					
	Vegetarian Option					
La Parilla						
	Spicy Ground Beef Tacos					
Pacific Rim						
	Vegan Pasta					
	Build Your Own Pasta					
	Sriracha Honey Chicken					

Quarter-to-Quarter

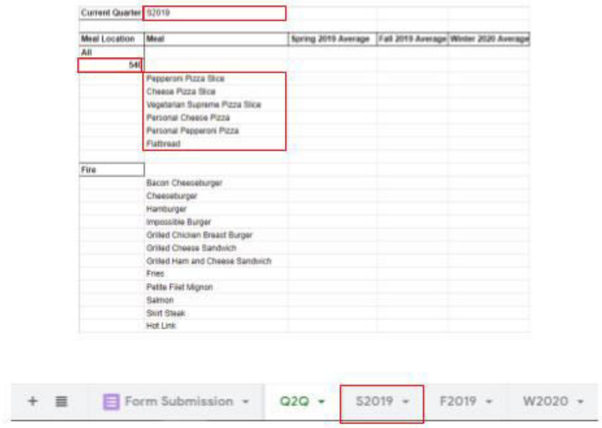
Current Quarter	S2019			
Meal Location	Meal	Spring 2019 Average	Fall 2019 Average	Winter 2020 Average
All				
540				
	Pepperoni Pizza Slice			
	Cheese Pizza Slice			
	Vegetarian Supreme Pizza Slice			
	Personal Cheese Pizza			
	Personal Pepperoni Pizza			
	Flatbread			
Fire				
	Bacon Cheeseburger			
	Cheeseburger			
	Hamburger			
	Impossible Burger			
	Grilled Chicken Breast Burger			
	Grilled Cheese Sandwich			
	Grilled Ham and Cheese Sandwich			
	Fries			
	Petite Filet Mignon			
	Salmon			
	Skirt Steak			
	Hot Link			
Global				
	Meat Option			
	Vegetarian Option			
La Parilla				

Database

Single Quarter



Quarter-to-Quarter



TV Signage

Educate the users about their impact on SCU Sustainability goals...

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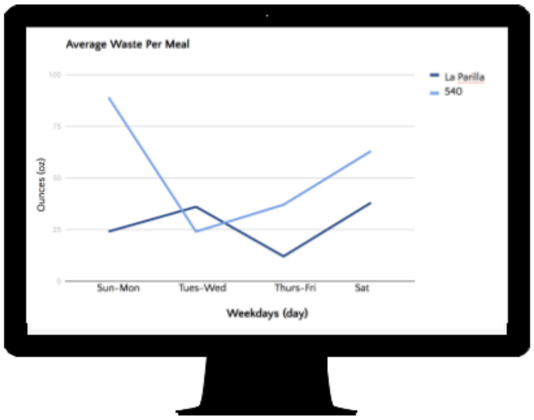
TV Signage

Educate the users about their impact on SCU Sustainability goals…



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Challenges

- Communication between Google Applications and Arduino
- Last minute issues with Pushingbox

40

5 Testing -

Design & Analysis

Testing

Scale

Accuracy of weight measurements.

Want: ±0.002 lb

(1% of avg meal waste from initial data)

Weight added prior to zeroing scale (lbs)	% Error
0	0.45%
1	0.25%
5	0.35%
10	0.75%
25	0.45%
50	0.05%

Adding 0.2 lb weight → always less than 1% error

Compared weights with higher accuracy scales

Testing

Lid open/closing Time

Opening/Closing Time:

Wanted: <1.5 sec

Achieved: ~2.5 sec

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Testing

Future Testing

User Satisfaction Survey

Market Testing

Process time

Goal: <30 seconds

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8 Budget and Costs

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Budget

$1500 granted - $1300.88 used

Final Product	Prototyping	Sunk Costs
~$1100	~$150	~$50
Hardware, Software	Wood, Electronics POC	Handlebars, Fasteners

Frame/Cover	Weighing	Power/Database	Meal ID	Lid
$ 451.98	$ 178.64	$ 217.05	$159.41	$294.16

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6 Safety

Considerations & Implementations

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Safety Considerations

1. Lid Pinch Point
2. Tipping
3. Electricity

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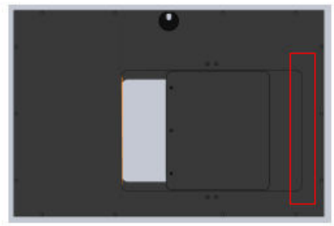
Safety Considerations

1. Lid Pinch Point
2. Tipping
3. Electricity



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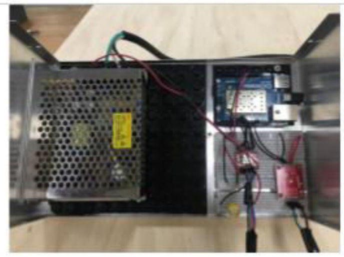
Safety Considerations

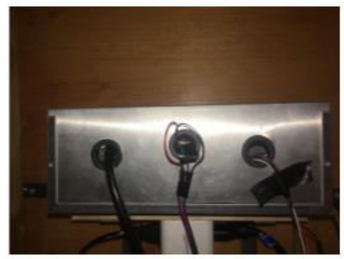
1. Lid Pinch Point
2. Tipping
3. Electricity

50

Safety Considerations

1. Lid Pinch Point
2. Tipping
3. Electricity





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6 Impact

One device... endless potential

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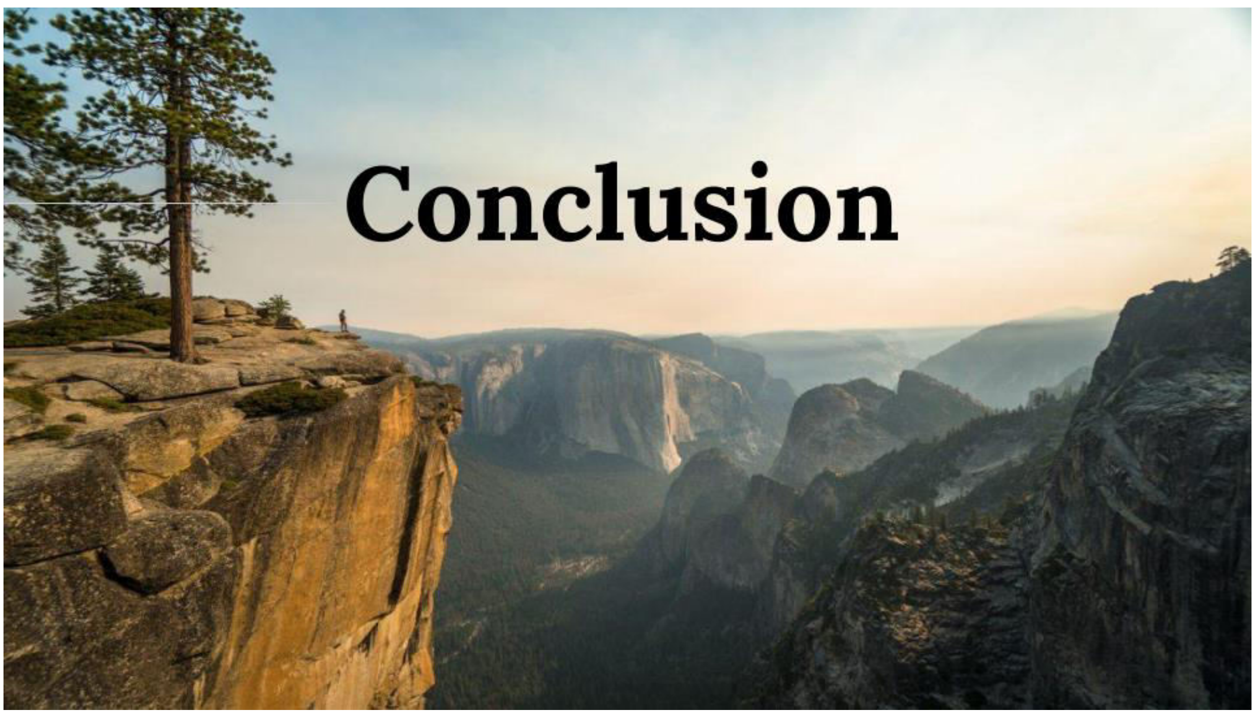
PROJECT IMPACTS
Social, Ethical, Environmental, and Economic

Inform Students

- Education about food waste can reduce food waste by 15%[3]

Provide information to catering services

- Businesses can gather data to optimize...
  - portion sizing
  - meal prep
  - dish size



Acknowledgements

Special Thanks to:

IT & Network Wizards: Rong Wang, Wilfredo Hernández

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Team Advisor in the Mechanical Engineering Dept.: Dr. Timothy Hight

Sustainability Center Liaison and Project Advisor: Lindsey Kalkbrenner

Santa Clara University School of Engineering

55

Thanks!

Any *questions* ?

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REFERENCES

[1] Food and Agricultural Organization of the UN (FAO) http://www.fao.org/3/mb060e/mb060e.pdf

[2] Natural Resources Defence Council https://www.nrdc.org/sites/default/files/wasted-food-IP.pdf

[3] Reducing Food Waste: Recommendations to the 2015 Dietary Guidelines Advisory Committee https://health.gov/dietaryguidelines/dga2015/comments/uploads/CID430_Tufts_University-_Reducing_Food_Waste-_DGAC_Comment.pdf

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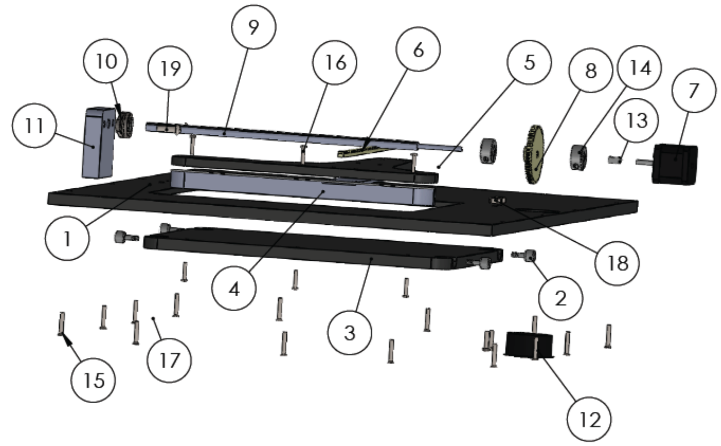
Appendix L: Detailed Drawings

ITEM NO.	Part #	Description	QTY.
1	L001	Top Plate	1
2	L002	Track Roller	4
3	L003	Door	1
4	L004	Tab	1
5	L005	Base	1
6	L006	Rack Gear	1
7	L007	Motor	1
8	L008	Gear	1
9	L009	Shaft	1
10	L010	Shaft Bearing	1
11	L011	Shaft Mount	1
12	L012	Cord Grommet	1
13	L013	Shaft Coupler	1
14	L014	Shaft Collar	2
15	L015	Wood Screws	14
16	L016	Tab Screws	6
17	L017	Base Screws	4
18	L019	Hex Nut	2
19	L020	Bearing Bolts	2



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES

	NAME	DATE
DRAWN	T.Schluep	3/20/19
CHECKED	T.Jaworski	3/20/19
DESIGNED	T.Schluep	3/20/19

INTERPRET GEOMETRIC TOLERANCING PER: GD&T

MATERIAL See BOM

FINISH

DO NOT SCALE DRAWING

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SANTA CLARA UNIVERSITY
SENIOR DESIGN TEAM 15 : WEIGHSTED

TITLE: Lid Assembly BOM

SIZE A | DWG. NO. LA01 | REV 1

SCALE 1:5 | WEIGHT: | SHEET 1 OF 1