MEMS 411 Group L (Fall 2019) - Speedy Seeder Final Report

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Speedy Seeder

The Speedy Seeder or "SS" is a device designed to decrease the time it takes to fill one seed plot by hand to roughly sixteen percent of the time. The customer of the SS is EarthDance Organic Farms School. EarthDance fills a large number of plots each year by placing a seed in every single compartment which come in three sizes: 32, 72, and 128 compartments per plot. Filling a single plot by hand can take roughly 8 minutes. The SS makes filling a plot much easier and faster, allowing a single plot to be filled in under 75 seconds. The SS also allows for plots to be filled with varying seeds sizes.

The SS uses two sheets of clear cast acrylic and is made with an aluminum frame. It is easy to use, requiring only the ability to lift and rotate the SS, and slide one of the Acrylic sheets. The SS has dimensions of 13.5” x 21” and is easily assembled. The manufacturing cost of the SS is roughly $120, which is approximately $330 less than the nearest competition. The SS was made primarily with a laser cutter to cut the cast acrylic quickly and accurately, and a band saw to cut the aluminum frame.

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1 Introduction

The customer for the “Speedy Seeder” is the EarthDance Organic Farms School. EarthDance is looking for a product that they can use to efficiently plant hundreds of seeds with each year.

Speaking with customer our primary objective is to speed up the process of filling seed plot with seeds. The current method of seeding is done by hand and is estimated to take about 8 minutes per plot. A seed plot can hold up to 128 seeds. Secondary objectives consist of the product being durable, and easy to use preferably by one person.

2 Problem Understanding

2.1 Existing Devices

These three designs we believe fit the description of our product idea. They all are meant to do the same thing, and that is to fill different size plots with seeds quickly.

2.1.1 Existing Device #1: Vacuum Seeder Design

Figure 1: Vacuum seeder

Description: This product is vacuum operated with a plastic box framing and a dimpled aluminum panel where the dimples in the panel are used to collect each seed in the various dimples through the use of the vacuum while it is in suction mode. The seeds are first placed on the panel where it is then picked up and maneuvered from side to side while the vacuum is on and in suction mode in order to help the seeds reach each dimple. Once the seeds have filled out each dimple with the vacuum still in its suction mode the box is then turned over covering the seed plot and the vacuum is then turned into its blowing mode which delivers each seed to its corresponding compartment. In our group’s opinion this design seems to be one of the major competitors to our project due to the simplistic design and accuracy of seed delivery that could potentially serve as a huge benchmark for our final design.

2.1.2 Existing Device #2: Drop Seeder

![Drop Seeder Image](https://www.bootstrapfarmer.com/products/drop-seeder?variant=13671655997530&sfdr_ptcid=6730_4_374526999&sfdr_hash=fa78582d75990e3a8e5c7ddd7c24890c&gclid=EAIaIQobChMIjuWb5tq_5AIVMf7jBx01Lw8sEAQYASABEgJDG_D_BwE)

Description: This product design consists of a rectangular aluminum frame that holds together two dimpled panels with the bottom panel being stationary while the top panel is controlled by a handle that moves it from left to right manually. The two panels are staggered so that once a seed fills a dimple in the top panel it doesn’t fall straight through into the seed plot. Once each dimple
is filled the user simply slides the panel to the right which then aligns the dimples of of the two panels allowing the seed to fall straight down into its specific planting compartment. Just like the vacuum seeder this design is one that could be a concerning competitor for our design because of its ease of use for its customers and cuts down the seeding process greatly, making this design another potential benchmark for our design.

2.1.3 Existing Device #3: Vacuum Wand Seeder

Figure 3: Vacuum Wand Seeder

Link: https://www.greenhousemegastore.com/tm-1-vacuum-wand-seeder

Description: The Vacuum Wand Seeder consists of a small vacuum, vacuum hose, a seed holding tray, and the vacuum lines that protrude from the wand that deliver the seeds. This design works by compiling seeds into the white seed tray and maneuvering the wand to hover just over the seed plot and covering the top suction hole of the wand allowing for the wand to create enough suction to pick up and carry one individual seed for each of the vacuum line wires that protrude from the wand. Then simply moving the want over the seed tray with the vacuum lines lined up with the planter holes the user removes his/her thumb from the top of the wand suction hole to break the suction thus opening the system and dropping the seeds into their appropriate compartments. Just like the other two designs this design is another one of our major competitors, and thus can serve as a potential benchmark for our design.
2.2 Patents

2.2.1 Method of producing a multi-plant product  
(EP2690944B1)

This patent is a very basic form of sowing equipment. The patent is a form with evenly spaced holes in it that allow for placing a single seed at a desired distance from other seeds. There are no moving parts on the design and it appears to be used as a template in other sowing equipment.

![Figure 4: Multi-Plant Product](image)

**FIG. 1**

Figure 4: Multi-Plant Product

2.2.2 Seed Planter  
(US3986638A)

This patent uses a vacuum to pick up seeds from one location and then release them into a plot for sowing. The apparatus has a set number of individual apertures which is where the vacuum pulls the seeds to. The apparatus requires an operator to move the vacuum device from the first location to where the seeds will be dispersed as well as up and down when hovering over each location. The operator must also turn the vacuum on and off.
Figure 5: Seed Planter
2.3 Codes & Standards

2.3.1 Standard Test Method for Measuring Air Performance Characteristics of Vacuum Cleaners
(ASTM F558-18)

This ASTM Standard tests different types of vacuums for their air performance. The air performance specs that are tested are suction airflow, air power, and input power. The tests run might be helpful in designing the “Speedy Seeder” if the design decided upon requires suction. The “Speedy Seeder” has a maximum suction number so that the seed is not damaged and a minimum suction so the seed is held in place.

2.3.2 Standard Test Method for Determining A-Weighted Sound Power Level of Central Vacuum Power Units
(ASTM F2544 - 11)

This standard details the commonly practiced method of determining the sound power level of a central vacuum system, consisting of the suction source and dirt repository. Were our design for the "Speedy Seeder" to include a vacuum source, the sound power level of said source may need to be limited to prevent hearing loss of the machine operator and noise disturbance in other areas of the establishment.

2.4 User Needs

2.4.1 Customer Interview

Interviewee: Rae of EarthDance Farms
Location: EarthDance Organic Farms
Date: September 6th, 2019
Setting: The Interview was conducted outside where the seeds are planted and the process was demonstrated to us. The whole interview took ~20 min.

Interview Notes:

- Will the seeding be on the scale of a tray or larger (i.e. a row of crops)?
  - The seeding will be in trays of 3 different sizes. These trays themselves are of the same size, however, the number of cells differ, meaning the template would have to differ. The 3 separate cell numbers are 32, 72, and 128.

- Essentially, what’s needed is something to put one seed in each cell?
  - Pretty much. The most “extravagant” piece would be the varying templates to accommodate the different numbers of cells. The only other feature would be to add divots to the templates, then plant the seeds.

- How far do the seeds get planted in each cell?
  - It varies by the size of the seed. The way we estimate it to keep it easy for everyone is “to the back of your fingernail”.
What does the process of seeding consist of and what kind of area does the seeding take place?

- We have a seeding table (a simple table top). The seeding process begins with filling each cell with soil, then individually dropping a seed in each cell. The cells are then covered up with more soil. It takes anywhere from 4 to 8 minutes to do a flat.

Are there any additives (i.e. nitrogen) added to the soil?

- The soil mix is nutrient-rich enough to start and maintain crop nutrition for roughly 6 weeks, and rarely does anything live in the cells for longer than that.

2.4.2 Interpreted User Needs

The needs listed in this table were drawn from the customer interview and then were rated on a scale of 1 to 5 on importance. Five being the most important.

<table>
<thead>
<tr>
<th>Need Number</th>
<th>Need</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The SS must plant seeds in varying cell sizes</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>The SS must complete seeding quickly</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>The SS must be durable</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>The SS needs to be lightweight</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>The SS should be easy to use</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>The SS cannot exceed 5A of power</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>The SS cannot damage the seed</td>
<td>4</td>
</tr>
</tbody>
</table>

2.5 Design Metrics

The design metrics are based off of the Interpreted Customer Needs and the Codes and Standards. They are rough goals to hit for the completed product.

<table>
<thead>
<tr>
<th>Metric Number</th>
<th>Associated Needs</th>
<th>Metric</th>
<th>Units</th>
<th>Acceptable</th>
<th>Ideal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>Total weight</td>
<td>lb</td>
<td>&lt; 5</td>
<td>&lt; 2</td>
</tr>
<tr>
<td>2</td>
<td>2, 5</td>
<td>Seeding Time</td>
<td>min</td>
<td>&lt; 2</td>
<td>&lt; 3/4(45sec)</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>Electric Current Used</td>
<td>A</td>
<td>&lt; 5</td>
<td>&lt; 3</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>Installation Time</td>
<td>min</td>
<td>3</td>
<td>&lt; 2</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>Vacuum Suction Pressure</td>
<td>kPa</td>
<td>&lt; 30</td>
<td>&lt; 20</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>Sound level</td>
<td>dB</td>
<td>&lt; 85</td>
<td>&lt; 75</td>
</tr>
</tbody>
</table>

2.6 Project Management

The Gantt chart in Figure 6 gives an overview of the project schedule.
Figure 6: Gantt chart for design project
3 Concept Generation

3.1 Mockup Prototype

This mockup shows a mounting option for the “Speedy Seeder.” The mounting plate, mounts, hinges, and arms are designed to make using the seeder easier by allowing the operator to quickly maneuver the SS over the primed plots and align the SS smoothly. This takes the weight of the SS out of the equation. Conflicts from this mockup are if the SS needs support on the backside of the rotation so it does not rest on the ground and is more convenient to refill. Also, the SS needs a device to stop it so it does not over rotate and throw seeds out.

Figure 7: Mockup for Speedy Seeder Mount
3.2 Functional Decomposition

Figure 8: Function tree for Speedy Seeder, hand-drawn and scanned
3.3 Morphological Chart

Figure 9: Morphological Chart for Speeder Seeder Part 1
Figure 10: Morphological Chart for Speeder Seeder: Part 2
3.4 Alternative Design Concepts

3.4.1 Mounted Vacuum Seeder

Figure 11: Preliminary sketches of Mounted Vacuum Seeder concept
Figure 12: Final sketches of Mounted Vacuum Seeder concept
Solutions from morph chart:

1. Handles mounted on sides
2. Holes to hold seeds
3. Mount SS/Move using arms and hinges
4. Use vacuum and cut power to drop seeds
5. Squeeze template and latch
6. Excess tray for seeds to rest in when hinged over
7. Have small vacuum mounted directly on SS

Description: The Mounted Vacuum seeder is designed to allow the operator to use the "Speedy Seeder" without having to worry about the weight of the SS and aligning the SS with the plots. The side mounted handles allow for the SS to be flipped easily and pressed down securely. Also, the vacuum is directly on the SS so that it is compact, easy to maneuver, and easily switched on and off. This design functions by turning the vacuum on so that the seeds are sucked to the template with holes, then the SS is rotated over the plot and the vacuum is cut so that the seeds drop. The excess seeds are caught in an excess seed bay on the hinging side of the SS so that they do not go everywhere.
3.4.2 Vacuum Seeder

Figure 13: Initial sketches of Vacuum Seeder concept
Figure 14: Final sketch of Vacuum Seeder concept
Solutions from morph chart:

1. Handles mounted on side

2. Interchangeable templates with holes to hold seeds

3. Speedy seeder is manually moved over soil cells

4. Vacuum to hold seeds, drop when switched off

5. Bolt secures template onto seeder base

6. Excess seeds not an issue

7. Vacuum switch on vacuum base

Description: The Vacuum Seeder operates as follows: The hose of an vacuum is attached to the side of the seeder base and switched on, sucking seeds into small holes on a thin template. The template is attached to the rest of the apparatus via bolts on each corner. Depending on the desired number of seeds to plant (which is 32, 72, or 128), the template can be interchanged with another that has the necessary number of holes. To prevent the seeds from being sucked into the vacuum, a thin layer of cloth is put above the template (opposite side of the seeds) to catch the seeds. While the vacuum is on, the operator uses handles mounted on opposite sides of the seeder base to position the seeds over the seed plot. Once the seeder is in position, the vacuum is switched to OFF, dropping the seeds into the compartments.
3.4.3 Drop Seeder

Figure 15: Initial sketches of Drop Seeder concept
Figure 16: Final sketches of Drop Seeder concept
Solutions from morph chart:

1. Handle mounted to top acrylic plane
2. Interchangeable top template with offset holes to hold seeds
3. Speedy seeder is manually moved over soil cells
4. Stud with wing-nut secures bottom template onto seeder base
5. Excess seeds collect on far-left of acrylic plane (extended surface)

Description: The “Drop Seeder” comes with a wooden lightweight frame that is extremely durable for extended use. It is equipped with two cast acrylic planes that have holes drilled into them and fit into grooves within the sides of the frame that are offset from one another when the planes are in the complete right position. The bottom plane has a constant 128 holes in it and is secured with studs that are tightened down with wing nuts. The top cast acrylic plane serves as a template and comes with three different hole specifications to match the amount of plots within the planting tray which are 128, 72, and 32. The top template has a handle so that the user can slide the plane right to left. The apparatus works by having both the planes in the far left position and pouring the seeds onto the top plane. The design is then picked up and moved from side to side to where one seed drops into each hole of the top plane. The excess seeds can be brushed to the left side of the apparatus to the extended part of the plane. Then the apparatus is placed over the seed plot and the user slides the top plane to the right. This aligns the top and bottom holes to allow the seeds to drop directly down into the prepared soil directly in the middle of the plot. The excess seeds will then be on the top of the bottom plane and should be dropped into a bucket or tray to be used again. Just repeat the process again for all the templates based on the size of the seed plot being used.

4 Concept Selection

4.1 Selection Criteria

![Analytic Hierarchy Process (AHP) to determine scoring matrix weights.](image)

Figure 17: Analytic Hierarchy Process (AHP) to determine scoring matrix weights.
4.2 Concept Evaluation

Figure 18: Weighted Scoring Matrix (WSM) for choosing between alternative concepts. Design Concepts (left to right): Drop Seeder, Vacuum Seeder, Mounted Vacuum Seeder

4.3 Evaluation Results

The final concept that was selected is the Drop Seeder style Speedy Seeder. This concept we found to excel in the "Durability" metric due to there only being one moving part (the top template). This design also requires no power supply, giving it a good score in that metric. The Drop Seeder scored lower in the "Ease of Use/Speed" metric than both the vacuum style seeders because the vacuum used in the other two designs will allow them to sow a plot quicker. The mounting plate in the third design may eventually be incorporated into this design because it will increase speed in the aligning of the seeder. For the "Multifaceted" metric, the seeder must be able to change templates and do it easily. To change templates for this design one template is slid out and the next template slid in. All the seeders are roughly the same size and the weight of the Drop Seeder could be improved by the mounting plate which will be considered when making the prototype.
4.4 Engineering Models/Relationships

Figure 19: Model deriving the required force to slide the top layer of the drop seeder

Understanding the force needed to slide the top layer of clear plastic is crucial in our consideration of the materials used for the structure of the box and the sliding planes. This is due to the importance of ”ease of use” of our product; if the force needed to slide the top layer, which leads to the seeds being dropped into their individual cells, is too large, it effectively makes our design difficult to use, as the operator would need to be able to apply a large load to work the product.
Thus, we need to minimize this required force. To do so, materials for the sliding planes and the sides of the box must be selected based on the resulting coefficient of friction each makes with the top layer as it’s sliding. Our group must come to a decision on what materials will have small frictional coefficients with the top plane to minimize the sliding force.

![Figure 20: Plexiglass Diameter Size Diagram](image)

This diagram of the Speedy Seeder shows the template of the top plane of the project design where the diameter cut into the cast acrylic is essential to the proper functionality of the apparatus. The diameter cut size is important because our design calls for only one seed to be dropped into the plot at a given time. If the hole size is too large there is a potential of multiple seeds finding their way into the diagram which in turn falters the initial designs constraints. For example, say there is a seed with a diameter of \( \frac{1}{4} \) in. we want our hole to be just big enough the hold and transfer the seed successfully to the bottom cast acrylic template so we wouldn’t cut the hole to a \( \frac{1}{2} \) in. We would want to cut it to a 9/32 in. which is just slightly bigger than the seed’s diameter, but not so much so that the hole can occupy two seeds at once.
This chart shows a list of potential materials that could be used in the design of the Speedy Seeder. This is important for our decision-making process because of a few variables. Our goal is to make the apparatus as lightweight and as durable as possible. As well as consider the possible friction coefficients that apply to the design between the materials. As they could all be possible options for each part of the design.

<table>
<thead>
<tr>
<th>Types of Material</th>
<th>Friction with Other Materials</th>
<th>Weight of Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plexiglass</td>
<td>Plexiglass- Static: 0.8 Sliding: N/A Wood- Static: N/A Sliding: N/A Steel- Static: 0.4-0.5 Sliding: N/A Aluminum- Static: N/A Sliding: N/A</td>
<td>0.042-0.043 lb/in³</td>
</tr>
<tr>
<td>Wood</td>
<td>Wood- Static: 0.25-0.5 Sliding: N/A Steel- Static: 0.2-0.6 Sliding: N/A Aluminum-0.2-0.6 Sliding: N/A</td>
<td>Balsa: 0.004 lb/in³ Maple: 0.023-0.027 lb/in³ Red Oak: 0.026 lb/in³</td>
</tr>
<tr>
<td>Steel</td>
<td>Steel- Static: 0.78 Sliding: 0.42 Aluminum- Static: 0.45 Sliding: N/A</td>
<td>0.291 lb/in³</td>
</tr>
<tr>
<td>Aluminum</td>
<td>Aluminum-Static: 1.05-1.35 Sliding: 1.4</td>
<td>0.98 lb/in³</td>
</tr>
</tbody>
</table>
5 Concept Embodiment

5.1 Initial Embodiment

Figure 22: Assembled projected views with overall dimensions
Figure 23: Assembled isometric view with bill of materials (BOM)
Table 3: Parts List

<table>
<thead>
<tr>
<th>Component</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/8” Cast Acrylic Template</td>
<td>12” x 24” x 0.125”</td>
</tr>
<tr>
<td>3/40” Cast Acrylic Template</td>
<td>12” x 24” x 0.075”</td>
</tr>
<tr>
<td>2 Wooden Side Frames with Runners</td>
<td>1.25” x 21” x 2”</td>
</tr>
<tr>
<td>PVC End-Rails</td>
<td>13.5” x 0.835” 0.835”</td>
</tr>
<tr>
<td>Phillips Flat Head Wood Screws</td>
<td>Zinc-Plated Steel, Number 5 Size, 1 − 1/4” Long</td>
</tr>
</tbody>
</table>

When determining the material that would be used for the sides of the drop seeder, we had to choose one that would minimize the friction between the sliding cast acrylic sheet and the two sides. Thus, we needed to find a material that had a relatively low static coefficient of friction with acrylic, as the required force to slide the cast acrylic sheet is proportional to this coefficient, seen in the Eq. 1 below:

\[
F_{\text{required}} = \mu_{\text{sheet}}mg + 2\mu_{\text{side}}N_{\text{side}}
\]  

where \(\mu_{\text{sheet}}\) is the static coefficient between the two cast acrylic sheets, \(\mu_{\text{side}}\) is the static coefficient between the sliding sheet and side of the seeder, and \(N_{\text{side}}\) is the normal force acting on the sliding sheet due to the seeder’s sides. Given this design consideration, we decided to use pine wood as the side material. This type of wood dry wood has a relatively low static coefficient of 0.4 with hard plastics like the sliding acrylic sheet [1]. Assuming a low normal force between the sliding sheet and the wood sides, this static coefficient of 0.4 is beneficial to a low required force to slide the acrylic.

Similar to how we chose the side material for the drop seeder, determining the mass of the unmoving cast acrylic sheet, \(m\), was done to also minimize the required force to move the sliding sheet. Relating back to Eq. 1, the required force is proportional to the mass of the stagnant sheet. Therefore, it was clear that we should keep the mass of the unmoving sheet to a minimum. While the density of acrylic is constant, equal to 1.18 g/cm3, the volume of the sheet was an independent variable we had to determine. That being said, we chose to keep the area of the sheet equal to that of the sliding acrylic sheet to keep consistency between the two. Thus, the only true variable we decided upon was the thickness of this top sheet, \(t\). Given that the area of the sheet was 288 in.2 (12 in. x 24 in.), we chose the thickness to equal 0.075 in. The mass of the unmoving sheet is derived using the density \(\rho\) and volume \(V\) of the sheet, as shown below:

\[
m = \rho \ast V = (1.18 \frac{g}{cm^3})(12\text{in.})(24\text{in.})(0.075\text{in.}) \ast \left(\frac{2.54 cm}{1\text{in.}}\right)^3
\]

\[
m = 417.67g = 0.418kg
\]  

The derivation of the force to move the cast acrylic sheet based on the mass of the unmoving sheet is seen below:

\[
F_{\text{required, sheet}} = \mu_{\text{sheet}}mg = (0.2)(0.418kg)(9.81\frac{m}{s^2})
\]

where the static coefficient of friction between the casty acrylic sheets, \(\mu_{\text{sheet}}\), equals 0.2.

The material for the end sides of the seeder (perpendicular to the wood sides) were determined based on minimizing the overall weight of the prototype. This design parameter was considered to increase the ease of use of the seeder; if the seeder is too heavy, it becomes significantly more difficult to use for longer periods of time due to muscle fatigue. Also, these parts must be small
enough to allow the sliding acrylic sheet to move in between them. In addition, the end pieces
needed to be durable to keep the base of the seeder together through extended use. In the end, we
chose to PVC pipes with a outer diameter of 0.835 in. (inner diameter of 0.685 in.) and length of
13.5 in, with two pipes attached to each end of the seeder (4 in total). The small outer diameter
allows the sliding sheet access to move in between the PVC parts, and the total mass added to the
seeder from the pipes, derived below, is very small:

\[
m_{PVC, total} = 4 \rho_{PVC} \cdot V = 4(1.45 \frac{g}{cm^3}) \cdot \frac{\pi}{4}[(0.835 in.)^2 - (0.685 in.)^2](13.5 in.) \cdot \left(\frac{2.54 cm}{1 in.}\right)^3
\]

\[
m_{PVC, total} = 229 g = 0.229 kg
\]

The idea behind the side runners is that the acrylic is not stiff enough to stay level in the middle
and will flex without support. The reason acrylic was chosen is because the holes need to been seen
when they are offset in order to work, the acrylic could be cut with the laser cutter, and the acrylic
has a low coefficient of friction. The end rails were made in order to allow one of the templates to
move through while the other was held at that end. This helps in that a bracket is not needed as
much in order to hold the stationary template in place.

The prototype performance goals are as listed: must complete 4 plots in under 5 minutes, must
complete largest seed at a 90 percent success rate, and must complete smallest seed at a 90 percent
success rate. (success = one seed per hole)

5.2 Proofs-of-Concept

The proof-of-concept showed that having two acrylic templates offset, then having one template
fixed, and sliding the other so that the holes aligned, and the seed dropped would work. Also, it
was determined from the proof-of-concept that the interchangeable template for the different seeds
sizes should be fixed and the bottom template that has the largest hole diameter moves, so that
the seeds never have to move laterally.
One difference between the selected concept design and the initial prototype is that the initial prototype does not have studs sticking out of the frame to secure the bottom template. It was determined that this was not useful; if the bottom template was secured in the base with runners and stoppers at the ends, then there is a constant force applied to the plexiglass sheets to keep them from moving in unwanted directions. The thickness of the acrylic sheets were much smaller than the concept design because of limited resources in the MakerSpace. However, this slightly lowered the weight of the sheets making them easier to move in the initial prototype.
6 Working Prototypes

6.1 Overview

Both the initial and final prototypes work by placing around 100 seeds onto the top acrylic sheet while the two acrylic sheets are offset. The seeds then fill the holes on the top acrylic sheet which has holes cut to specific seeds sizes. The holes are filled by lifting the SS and tilting it back and forth until a single seed falls into every hole. After each hole is filled, the SS is placed on the seed plot and the bottom acrylic sheet is slid to align the holes, allowing the seeds to fall into the seed compartments. The prototype performance goals are as listed: (1) Complete 4 plots in under 5 minutes; (2) Complete a plot of the largest seed size with a 90% success rate; (3) Complete a plot of the smallest seed size at a 90% success rate. Note that the term "success" for each compartment equates to having one and only one seed per hole.

6.2 Initial Prototype

![Initial Prototype Isometric View](image)

Figure 28: Initial Prototype Isometric View
The initial prototype completed one of the three performance goals; the prototype was able to complete four plots in under five minutes. However, the other two performance goals were not achieved due to the holes not being of the appropriate size for the different seeds. The largest seed, which was the beet seed, varied greatly in diameter. This presented the challenge of finding the optimal size that could handle the worst case scenario of two of beet seeds that are relatively small fitting into one hole. The smallest seed, a kale seed, had a small diameter variance, but the initial prototype did not have the correct hole dimensions to adequately fit one kale seed. This is due to trying to account for any small seed size variance as well as the thickness of the cast acrylic sheet.
6.3 Final Prototype

Figure 31: Final Prototype Isometric View

Figure 32: Final Prototype Side View
The final prototype was able meet all three performance goals. Improving upon the initial prototype, the holes were cut smaller and then gradually increased in size until optimal diameter was achieved for both the largest and smallest sets of seeds. The final prototype was also made with aluminum rather than wood and plastic, thus increasing its protection to wear over time and damage due to impacts such as being dropped. Also, the acrylic sheets were cut again in order to improve the hole alignment when the seeds were to be dropped into the plot, and decrease the unwanted lateral movement of the sheets. Another design change was that the number of holes from the initial prototype was cut in half (from 72 to 36) to separate the excess seeds from the ones ready to be put into the plot. This lessens the possibility of any unwanted seeds from accidentally falling into a compartment that already contains a seed, resulting in complications with the seed germination process. In addition, due to the number of holes in the acrylic sheets being halved, to fill an entire plot, the user must simply refill the holes in the top acrylic sheet with seeds, rotate the SS 180°, and drop the seeds into the unfilled compartments by aligning the holes in both acrylic sheets.
7 Design Refinement

7.1 FEM Stress/Deflection Analysis

To determine if a part can properly undergo the amount of stress given material properties and as close to real life constraints a FEM stress and deflection analysis are ran on the different components of the design. When running these types of analyses, the component mush then be meshed to be either coarser or more fine. The finer the mesh the more accurate the results from the test ran. Then real life constraints are applied to part such as loads and supports. The force/forces should be as realistic as possible. For the Speedy Seeder the component that is likely to undergo the most amount of stress and deflection is the 6061 aluminum T-slotted frame. As can be seen in Fig. 34 the mesh was set to more fine, but not fully fine in SolidWorks to ensure for more accurate results. Then supports were added to each end to simulate where the T-slotted frame is bolted to the rest of the design. Lastly, a force of 1 \textit{lbf} was applied evenly along the length of the beam to signify the weight of the two acrylic sheets. With the bar being supported on both ends the mass of the acrylic sheets is its greatest in the center of the beam. These various boundary conditions (supports) and the applied load best mimic the real life application of the stresses the T-slotted frame undergoes in the actual Speedy Seeder assembly.

![Figure 34: Assembled projected views with overall dimensions](image)

When a component of a design is created and the stress and deflection analyses are run on that given part a factor of safety is then calculated. This is to determine whether it is truly safe to use the component depending on whether the material can safely withhold the stress/stresses being applied to it. For the T-slotted frame the factor of safety is 5,730.05 using maximum shear stress theory. The reason for the factor of safety being so high is because with only 1 \textit{lbf} being applied to the component the max stress the component undergoes is 47,120 \textit{Pa} while the tensile yield strength of 6061 aluminum is 270 MPa \cite{2}. The reason for using the maximum shear stress theory is because with the beam being fixed at both ends and the force being applied along the beam there will be shear stresses and both end of the component. The Von Mises stress plot and the Deflection analysis can be seen in Fig. 35 and Fig. 36.
In order for the component to cause a significant problem within the system the beam would have to deflect roughly about 2 - 3 mm in order for undesired contact and compression with the acrylic sheets. With the deflection calculated from the analysis that was run on the design the predicted deflection is nowhere close to 1 mm so therefore this component of the design more than adequately supports the system with lots of wiggle room. Just in case that any more components needed to be added that would increase the amount of force applied to the T-slotted frame, the 6061 aluminum material would with no problems be able to adequately support this new added mass.

7.2 Design for Safety

7.2.1 Risk #1: Sharp Acrylic Corners

Description: The corners of the acrylic are rather sharp, so it is possible a person operating of the drop seeder could harm themselves if they happen to grab or scrape these corners with bare flesh. This would most likely occur when the operator grabs hold of the bottom acrylic to drop the seeds into the plot, as this period is when the acrylic must be held in order to be moved.

Severity: The level of severity due to this risk, when using the drop seeder appropriately, is marginal at worst, as it may only cause a minor scrape or cut, and not anything more critical.

Probability: The chance of this risk is likely, due to the fact that there is a possibility of being scratched by the acrylic corners every time a person operates the seeder since they have to grab the bottom sheet.
Mitigating Steps: Both the severity and probability of this risk could be reduced by grabbing the acrylic edge slightly towards the center of its width when operating the seeder. This prevents the corner from injuring the operator, since their hand is away from the danger area, and the chance of the corner hitting their forearm is minimal. Another way to reduce severity and probability is to wear long-sleeved clothing when using the device; this allows for the corner to only scratch the clothing, and not the operator.

7.2.2 Risk #2: Being Hit by Seeder Housing (Sides)

Description: As the housing of the drop seeder consists totally of metal, receiving a significant impact from this device in critical areas of the body specifically the head, can be very dangerous. This risk would most likely occur if the seeder is incorrectly stored, especially on an elevated surface.

Severity: The level of severity of this risk is critical, though it depends on the type of impact and body part hit by the metal. For example, an impact on the head can be extremely dangerous.

Probability: The likelihood of this risk is occasional, as it can occur if the device is not stored properly, or if the user accidentally hits the device.

Mitigating Steps: The probability of this risk can be reduced by ensuring that the device is securely stored when not in use. When in use, allow for ample room to move the seeder. To reduce the severity of this risk, do not store the seeder in elevated locations.

7.2.3 Risk #3: Screw and Washer Choking Hazard

Description: If by chance the seeder were to break or be dismantled, the screws and washers used for the housing become potential choking hazards if inserted into one’s mouth.

Severity: The level of severity of this risk is catastrophic, as choking on one of these pieces can lead to potential death.

Probability: As this risk only occurs if the screw and washers are separated from the rest of the device, the likelihood of realizing this risk is unlikely.

Mitigating Steps: The probability of this risk can be reduced by properly storing the device so it may not fall and break apart. To reduce this risk’s severity, keep the device out of the reach of children and others who have no knowledge of how to operate the device.

7.2.4 Risk #4: Finger Pinching

Description: There are many locations on the device, whether idle or in use, that can pinch one’s fingers. Examples include the grooves on the sides of the housing and the space between the acrylic and housing. This risk will occur if one chooses to insert their extremities, specifically fingers, into these areas.

Severity: The severity of this risk is negligible, as though a person can pinch themselves, it won’t lead to any terribly damaging results.

Probability: The likelihood of this risk is likely, as one may choose to put their fingers in these places when cleaning or holding the device, or to get seeds that may slip into these areas.

Mitigating Steps: The probability of this risk can be reduced by holding the seeder about the outside of the housing. In addition, for cleaning the device, use a brush or blower instead of your hands.
7.2.5 Risk #5: Cumulative Stress Disorder

**Description:** As the seeder requires cyclical wrist and forearm motion for proper use, stress within these areas will arise with use of the device after extended periods of time. This can result in arthritis, carpal tunnel, and general wrist and forearm injury over time.

**Severity:** The level of severity due to this risk is marginal, as the risk only affects the extremities of the operator, and not in a significantly life-altering fashion.

**Probability:** The chance of this risk is seldom, since significant ailments will not occur until years of using the device. However, preexisting conditions of the operator can change the speed at which these issues arise.

**Mitigating Steps:** The probability of this risk can be reduced by limiting the operating time in a given session. Risk severity could be reduced by using other parts of the body to move the device besides the wrist and forearm, such as the shoulders.

7.2.6 Risk Heat Map

<table>
<thead>
<tr>
<th>Category</th>
<th>Frequent</th>
<th>Likely</th>
<th>Occasional</th>
<th>Seldom</th>
<th>Unlikely</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Likely to occur immediately or in a short period of time; expected to occur frequently</td>
<td>Likely to occur in time</td>
<td>Occasional to occur in time</td>
<td>Seldom</td>
<td>Unlikely</td>
</tr>
<tr>
<td>Catastrophic</td>
<td>Screw and Washer Choking Hazard</td>
<td>Being Hit by Seeder Housing</td>
<td>Sharp/Flexglass Corners</td>
<td>Cumulative Stress Disorder</td>
<td>Finger Pinching</td>
</tr>
<tr>
<td>Critical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marginal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negligible</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The heat map seen above, based on the risks prevalent when using the Speedy Seeder, recommends that a person being hit by the seeder’s housing to be the top priority. The next priority to account for is injury due to the sharp acrylic corners. This is followed by the choking hazard caused by the screw and washer pieces of the seeder. The final two risks, cumulative stress disorder caused by extended use of the seeder and pinching one’s finger when operating the device, are both on the lowest priority level. Thus, it would be best to first focus on preventing a hit by the Speedy...
seeder, avoiding the acrylic corners second, keeping the screws and washer from becoming potential choking hazards next, and lastly using the seeder in a way to avoid the pinching of fingers and cumulative stress occurring from years of use. The heat map, based on the risks prevalent when using the Speedy Seeder, recommends that a person being hit by the seeder’s housing to be the top priority. The next priority to account for is injury due to the sharp acrylic corners. This is followed by the choking hazard caused by the screw and washer pieces of the seeder. The final two risks, cumulative stress disorder caused by extended use of the seeder and pinching one’s finger when operating the device, are both on the lowest priority level. Thus, it would be best to first focus on preventing a hit by the Speedy seeder, avoiding the acrylic corners second, keeping the screws and washer from becoming potential choking hazards next, and lastly using the seeder in a way to avoid the pinching of fingers and cumulative stress occurring from years of use.

7.3 Design for Manufacturing

![Figure 38: Pre-Draft Analysis (Front View)](image)

![Figure 39: Pre-Draft Analysis (Side View)](image)
Figure 40: Pre-Draft Analysis Hole Cutouts

Figure 41: Post-Draft Analysis (Front View)

Figure 42: Post-Draft Analysis (Side View)
For the Draft Analysis the simple part chosen from the Speedy Seeder was the \( \frac{1}{8} \) in thick acrylic sheet. Fig. 38, Fig. 39, and 40 all show the original draft analysis before any changes were made. While Fig. 41, 42, and 43 show the part once the revisions to the draft analysis were made. To make these adjustments to the part the original draft parameters had to be set such as the top piece of the sheet was chosen as shown above and the draft angle was set to 2 degrees. From this the selected face of the acrylic sheet was a positive draft while the holes and side of the sheet required drafting and the back side was negative draft. To reduce the required draft portions the extrusion of the part was edited to include draft and was set to 3 degrees, and the same steps for the face of the sheet was applied to the cut extrusion for the holes. With these draft changes all of the yellow portions were eliminated leaving only the green and red as seen in the figures above.

Using the DFM analysis the chosen manufacturing process chosen for Fig. 44 was injection molding where rule 1/2 failed. The reason for this failure is that when creating the part is done by injection molding then there would be parts within the design that will begin to warp or create sink marks because there is enough time for the part to cool and solidify while the heated metal is still being applied. The main reason for this error is the design is too complex and too thick for the software to be able to properly run the injection molding.
Figure 45: DFM - Mill/Drill Error 1

Figure 46: DFM - Mill/Drill Error 2
Using the DFM analysis the chosen manufacturing process chosen for Fig. 45, Fig. 46, Fig. 47, and Fig. 48 was drilling/milling only where rules 4/10 failed. The reason for these errors was due to the complex design of the system mainly due to the cuts that have already been made to the part such as the rails in the part that would make it difficult to apply any type of drilling or milling. As well as the curved surfaces when drilling/milling especially is done by hand and not a machine can cause the drill help to slip off the surface, or not allow the person drilling to make a precise cut that can result in the shear and breaking of the T-slotted frame. Lastly, the unusual drills that it would take in order to perform such cuts would cause the manufacturing and inventory costs to be too large to seem reasonable or feasible.
7.4 Design for Usability

7.4.1 Vision

The problem with vision impairment for the final prototype of the SS comes from the acrylic being clear. When dealing with very small seeds it becomes difficult to determine if the seed is filling the hole it is suppose to be placed in. A possible solution, which was done in the initial prototype was make one of the acrylic sheets a different color so the seeds could more easily be distinguished when they are in place.

7.4.2 Hearing

The SS makes no noise when being operated, since there is only one moving part and no motor or powered device needed to operate the SS. Also, the SS does not require good hearing in order to operate properly since it does not use power and is operated by sight and touch.

7.4.3 Physical

There are a couple of problems with physical impairments with the SS. The first is that the device needs to be lifted and suspended in order to operate. The SS is not particularly heavy, but someone suffering from muscle weakness could find it difficult. The second physical impairment comes from the SS requiring the operator to slide one acrylic sheet back and forth. This is not very difficult, but the acrylic is thin and could be difficult to squeeze in some cases.

7.4.4 Control

The SS may cause excessive fatigue when controlling it. As stated previously, the SS final prototype would be difficult to lift for someone with muscle weakens, but the SS also needs to be suspended for a period of time in order to operate. that is when the 6360 Aluminium T-Slotted frame can become difficult to handle.

8 Discussion

8.1 Project Development and Evolution

Does the final project result align with its initial project description?

- Yes, the final project result aligns with the initial project description. The final project result completes all predetermined prototype performance goals set out by the customer and our team.

Was the project more or less difficult than expected?

- The project was more difficult than anticipated due to the large spectrum of seed size variance for each individual seed type.

On which part(s) of the design process should your group have spent more time? Which parts required less time?
More time should have been spent on increasing the usability of the SS, making it easier to use without much practice. The decision of converting the SS frame from wood and PVC plastic to aluminum required less time.

Was there a component of the prototype that was significantly easier or harder to make/assemble than expected?
- Finding the right hole size for the seeds was significantly harder than expected, as stated before the large variance in a single seed size made the project much more difficult.

In hindsight, was there another design concept that might have been more successful than the chosen concept?
- Going with a vacuum seeder could have been a better design choice due to it not requiring as dependence on finding an optimal hole size for each seed type.

### 8.2 Design Resources

How did your group decide which codes and standards were most relevant? Did they influence your design concepts?
- Our codes and standards were based off of what we thought would be our final design which was the vacuum seeder. Obviously, we did not go with the vacuum seeder so they did not influence our design.

Was your group missing any critical information when it generated and evaluated concepts?
- No critical information was missing, our project description was pretty simple.

Were there additional engineering analyses that could have helped guide your design?
- If we could have analyzed a more optimal shape for our holes, that could have possibly helped our design. However, due to time constraints and a lack of industry information regarding a drop seeder optimal hole design, we were unable to make this a reality.

If you were able to redo the course, what would you have done differently the second time around?
- Try and have the final prototype done during initial prototype phase so that some of the finer details that add up could have been corrected.

Given more time and money, what upgrades could be made to the working prototype?
- Mounting vibrating motors on our design in order to move the seeds around without shaking the whole frame would be a substantial upgrade. Also, some sort of brush to move the seeds around could be an option.

### 8.3 Team Organization

Were team members’ skills complementary? Are there additional skills that would have benefited this project?
- Team members skills were complimentary in that we were able to cover most areas that we needed to complete the project. We could have benefited from someone who has a better knowledge of machining. This would have allowed us to better our final design.

Does this design experience inspire your group to attempt other design projects? If so, what type of projects?
- Yes, another project our group would be interested in attempting would maybe be more in the areas of robotics and automotive design.
Bibliography


# A Parts List

Initial Prototype

<table>
<thead>
<tr>
<th>Component</th>
<th>Dimensions</th>
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</thead>
<tbody>
<tr>
<td>1/8&quot; Cast Acrylic Template</td>
<td>12&quot; x 24&quot; x 0.125&quot;</td>
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<tr>
<td>3/40&quot; Cast Acrylic Template</td>
<td>12&quot; x 24&quot; x 0.075&quot;</td>
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<tr>
<td>2 Wooden Side Frames with Runners</td>
<td>1.25&quot; x 21&quot; x 2&quot;</td>
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<tr>
<td>PVC End-Rails</td>
<td>13.5&quot; x 0.835&quot; x 0.835&quot;</td>
</tr>
<tr>
<td>Phillips Flat Head Wood Screws</td>
<td>Zinc-Plated Steel, Number 5 Size, 1 – 1/4” Long</td>
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</tbody>
</table>

Final Prototype

<table>
<thead>
<tr>
<th>Component</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
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<td>11.81” x 21.44” x .125”</td>
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<tr>
<td>3/32&quot; Cast Acrylic Template</td>
<td>11.81” x 21.44” x 0.09375”</td>
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<td>T-Slotted Frame</td>
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<td>90° Blockers</td>
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<td>1/4 – 20” Bolt</td>
<td>Zinc-Plated Steel, 1” Long</td>
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<tr>
<td>1/4” Flat Washer</td>
<td>Zinc-Plated Steel</td>
</tr>
<tr>
<td>1/4 – 20” Wing Nut</td>
<td>Zinc-Plated Steel</td>
</tr>
<tr>
<td>Nylon Strip Brush</td>
<td>Galvanized Steel, 11.81” x 1” x 0.125</td>
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