The Design and Manufacture of Mass Production Equipment for a Pencil with a Seed

by

Eric A. Del Castillo

Submitted to the
Department of Mechanical Engineering
in Partial Fulfillment of the Requirements for the Degree of

Bachelor of Science in Mechanical Engineering

at the

Massachusetts Institute of Technology

June 2013

Signature of Author: ____________
Department of Mechanical Engineering
May 10, 2013

Certified by: ____________
David R. Wallace
Professor of Mechanical Engineering
Thesis Supervisor

Accepted by: ____________
Anette Hosoi
Professor of Mechanical Engineering
Undergraduate Officer

The Design and Manufacture of Mass Production Equipment for a Pencil with a Seed

by

Eric A. Del Castillo

Submitted to the Department of Mechanical Engineering
on May 10, 2013 in Partial Fulfillment of the
Requirements for the Degree of

Bachelor of Science in Mechanical Engineering

ABSTRACT

Autosprout is the mass manufacturing equipment envisioned to produce Sprout, a pencil with a seed. This pencil concept was developed by MIT students a successful round of funding and first production run through Kickstarter. The goals for Autosprout are to fully automate the manufacturing process, and to reduce the manufacturing costs from eighty cents per pencil to less than thirty, while also producing a completely assembled pencil every five seconds.

The original assembly process was slow and required a lot of manpower. However, it laid a foundation to design the automated process described in this thesis. The new system will feature two carousel systems. The first carousel will load the cedar pencil, cut a shoulder using a specially designed router, and finally add a dab of glue around the shoulder. The second carousel will load a pill capsule body and fill it with soil and two to three seeds. At the end of each carousel process the pill capsule and pencil will come together and the capsule will be placed onto the shoulder and the glue will hold it in place.

Before the capsule is loaded into the carousel, it must be sorted and properly aligned. Models for a vibratory feeder were first designed and tested, but, due to the inconsistent performance of the models, an industrial vibratory feeder was purchased and modified. The modification consists of a chute leading to a vacuum system that removes the capsule from the feeder, rotates, and finally loads the capsule into the carousel by switching a valve making the vacuum into a stream of high air pressure. A similar system will be used for removing seeds from a hopper and placing them in the capsule.

Thesis Supervisor: David R. Wallace
Tile: Professor of Mechanical Engineering

Acknowledgements:

I would like to thank Professor David Wallace for the guidance he has provided in both finding this project and throughout my entire career at MIT. I would also like to thank the entire Sprout team of Ben Peters, Steve Keating, Mario Bollini, and Lauren Hemley, as well as Matthew Hohenberger, another student helping with the design of Autosprout for his thesis. Each one has provided insights that helped me at many different points during this process. Finally, I would like to thank my friends and family for all their support throughout this project, but especially throughout my entire four years at MIT.

Table of Contents:

1. Introduction 6

2. Background 6
   2.1 Sprout: a pencil with a seed 6
   2.2 Original Assembly 8
   2.3 The Autosprout Vision 9

3. Design and Fabrication 10
   3.1 The Context 10
   3.2 An Iterative Process 10
      3.2.1 The Vibratory Feeder 11
      3.2.2 Seed Distribution System 15

4. Conclusions and Future Work 17

References 18

Appendix A: Manual Assembly Process 19

List of Figures:

Figure 2-1: Sprout comes with many different seed types. These are just a sampling.................. 7

Figure 2-3: Wrench crimping device for creating shoulder to insert into capsule. 8

Figure 2-4: Router-Vacuum system for cutting shoulder to insert into capsule............................ 9

Figure 3-1: Styrofoam and clay model used as a proof-of-concept that a vibratory feeder could be used for moving the capsules. 11

Figure 3-2: 3D printed vibratory feeder with attached DC motor with offset counter weight and silicon base layer to control the vibration frequency. In this image is the silicon base (left), the DC motor with counterweight (middle), and the entire system together (right)............. 12

Figure 3-3: Vibratory feeder purchased from eBay. The feeder has multiple locations that can be customized in order to appropriately sort different items. The pill capsule bodies (yellow) will flow clockwise up the ramp as the motor vibrates the system. 12

Figure 3-4: Slotted connection for pneumatic tubing used to sort the capsules. The angle is fully adjustable by tightening the screws at different points along the slots................................ 13

Figure 3-5: Pneumatic system that pulls a vacuum through the blue pneumatic tubing in order to take a capsule from the feeder bowl and then forces the capsule into the capsule's carousel by changing the vacuum to outward air pressure.. 14

Figure 3-6: Three pieces press fit together (left) and the fourth piece (right) that connects the other three pieces to both the pneumatic tubing and the plunger. The capsule is pulled onto the end (left) by the vacuum and runs into the outer sleeve. The vacuum continues to pull until the sleeve presses the black limit switch far enough to tell the swing clamp and piston to activate. 15

Figure 3-7: Three different systems for distributing seeds in gardens. Each was used for testing in order to determine the best system for picking up two or three seed at varying sizes. Eventually the farthest right was chosen as the best design. 16

Figure 3-8: Four different size tips used with the bulb system to distribute seeds. Each tip works for different size seeds. 16

1. Introduction

Development of mass production equipment is essential to the success of most products. The ability to manufacture designs quickly and accurately, not only reduces manufacturing time, but also greatly reduces the costs of manufacturing. With reduced manufacturing costs, products can be sold at lower price points and still be profitable, thus allowing for a successful product.

In the early stages of a products life, from the initial design and through multiple prototyping stages, products are manufactured manually. This means long lead times and, normally, expensive machinery. It also means that to make a profit the product must be sold at high prices and generally manual manufacturing costs do not decrease with increases in production volume. However, if machines can be designed to manufacture the device using automation, all the manufacturing can be done for you.

Developing specialized mass manufacturing equipment presents a new design challenge. There are many constraints that make designing mass production equipment a large challenge. The goal behind designing this equipment is to automate everything, and therefore reducing labor costs, as well as increasing the rate of production for each product. Therefore, the design must try to accomplish these goals.

Sprout (http://www.democratech.us/sprout/), a product idea developed throughout the graduate course 2.744: Product Design (http://web.mit.edu/2.744/www/index.html), is a wooden pencil that, when too short to be used anymore, is planted and "grows into something delicious, beautiful, and fun". This idea has become very popular, but in order to become a successful product the manufacturing time and costs needed to be greatly reduced. This developed into the idea for Autosprout, a system of automated equipment designed to solve these challenges.

2. Background

2.1 Sprout: a pencil with a seed

Sprout is a wooden pencil that replaces the eraser with a pill capsule filled with soil and seeds. The foundation of Sprout is a high quality Ticonderoga cedar pencil body. There is no eraser. This was a design decision based on making a high quality product that will enhance the pencil's usability. It was decided to just replace the eraser with the seeds.

Figure 2-1: Sprout comes with many different seed types. These are just a sampling

Sprout is used just as a regular wooden pencil would be used. The user writes until the tip is dull. Then the user sharpens the pencil and continues to write. However, once the pencil becomes too short to write with, that is when the true design of Sprout shows. The seed capsule on the end is a water-soluble pill capsule filled with dry sphagnum moss and two or three seeds of the same type. Multiple seeds are included to increase the chances of successful germination.

Simply plant the seed capsule end of the pencil into soil. Watering Sprout will dissolve the capsule and then begin the seed's germination. Within the first week of watering Sprout should begin to show signs of becoming a flower, herb, or vegetable (as specified on the packaging). At this point, the pencil shaft can be removed, but can also be left in the soil as a plant marker.

Figure 2-2: When Sprout is too short, just plant in soil and provide enough sunlight and water and Sprout "grows into something delicious, beautiful, and fun."

2.2 Original Assembly

When being designed for 2.744, Sprout was assembled on an individual basis with the only time constraint being the necessity to complete it before the end of the semester. The original assembly process began with cutting the eraser end off of a basic cedar pencil with a bandsaw. To finish preparing the pencil, a crimping tool, seen in Figure 2-3 below, using a wrench with specially cut parts is squeezed tightly to reduce the diameter of the bottom end of the pencil, allowing the pill capsule to fit snugly.

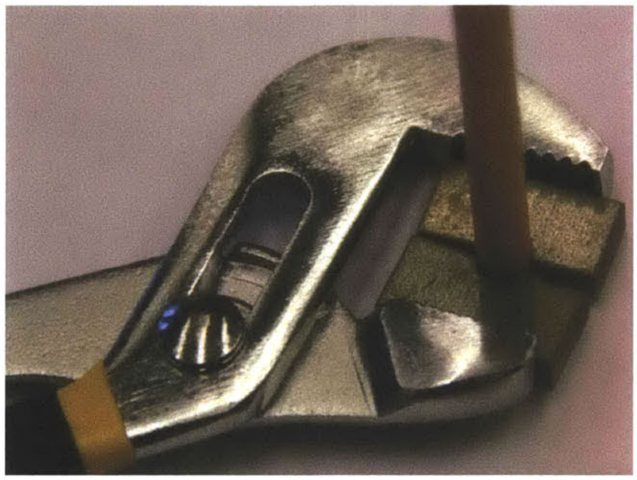


Figure 2-3: Wrench crimping device for creating shoulder to insert into capsule.

The next step was to prepare the pill capsules to be placed on the crimped end of the pencil. The capsules are first placed into a capsule receptacle. Only the long body is used, so the capsule caps are discarded. Then, two or three small seeds of the desired type are placed into each capsule and covered with loose soil. Now the crimped end of the pencil is dipped into a sponge with glue. This places a thin layer of glue over the whole crimped region without creating a surplus. Now, the crimped pencil end is placed into the capsule. When the glue dried, one complete Sprout was finally ready.

This method worked perfectly during the semester. However, shortly after the end of the semester Sprout made its way to Kickstarter (http://www.kickstarter.com/), a site used to help find financial backing for many new start-up companies. When putting itself out there, Sprout began taking orders and many of these orders could not be filled with the original assembly process. The design team began contracting an outside manufacturing company in Minnesota to assemble Sprout and made some quick adjustments to the assembly process.

The most necessary adjustment was the need for a more precise cut instead of crimping. The crimping resulted in errors that should be avoided in a manufacturing process. The most common problem being the capsules could not always slide all the way onto the crimped region for the pencil. This led to the combination of a router, with some slight adjustments, and a vacuum. The router was fitted with a Teflon tube with a backstop. To create the cut shoulder the pencil would be inserted into the tube until reaching the backstop and then rotated at least one full turn. This made a nice even cut at the appropriate diameter for fitting the capsules onto the end. The vacuum attachment to the router is used to prevent the wood chips from building up in the cutting region enclosed by the tubing. The setup can be seen below in Figure 2-4.

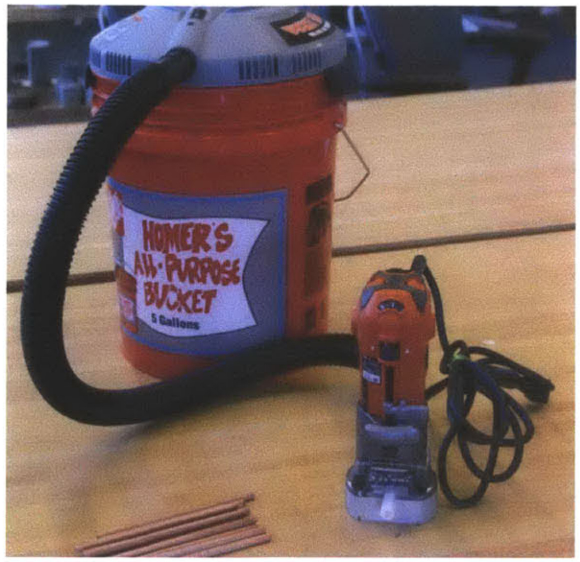


Figure 2-4: Router-Vacuum system for cutting shoulder to insert into capsule.

The rest of the assembly process continued to look the same. Some processes were enhanced to aid in mass production and only varied in the scale of the operation. The entire assembly guide used by the contracted manufacturer can be viewed in Appendix A.

However, this process, while not taking up the time of the design team is still not appropriate for mass production and overall profitability. Paying the manufacturing company costs a lot of money and the company is a long distance away. The process also still takes much longer than the ultimate goal for the assembly process. This sparked the idea for Autosprout, an automated system that, with the push of a button will complete the entire assembly process on its own.

2.3 The Autosprout Vision

When Autosprout is completed it will attempt to accomplish two main goals. The first goal is to successfully complete the manufacture and assembly of a pencil approximately every five seconds. Second, Autosprout should run completely unaided and uninterrupted throughout the entire process. Accomplishing these two goals will help reduce the cost of manufacturing. Currently the cost of manufacturing per pencil is roughly $0.90, but through the successful implementation of Autosprout, the manufacturing costs should drop to approximately $0.30 per pencil. This reduction in cost will allow the pencils to be sold at a much more affordable price for consumers and at a better margin for the company.

The savings in the manufacturing costs are due to no longer requiring a third party to manufacture and assemble Sprout, as well as a great decrease in lead-time for each pencil. The current lead-time for each pencil is roughly thirty seconds and requires at least 3 people working together to achieve this speed. If Autosprout can accomplish the goals set, the assembly process will become at least 80% more efficient. This means now 12 pencils can be assembled every minute. This allows much larger and more profitable orders to be filled, which were previously not possible due to the inability to fill them in a reasonable time frame.

The Autosprout system will work in two separate carousels running in circular patterns that come together in the end to finish the assembly. One pattern will carry the pencil through the stages preparing it to be assembled, while the other pattern will carry the capsule through all of it's stages. At the end of both patterns the capsule will align with the pencil and the two will be assembled together before being removed from the system and sent to be packaged.

3. Design and Fabrication

3.1 The Context

A big challenge in the design of Autosprout is preparing the seed capsules. In order for the process to be completely automated, the capsules must be sorted and aligned through some automated process. For many reasons this is challenging. First, and foremost, the capsules have caps that must be discarded. Removing the caps can be difficult. Ridges on the cap align with a valley on the capsule body that requires a firm force to remove the cap. However, the capsules are also fragile and need to be handled with care or they will crack and be rendered useless. This means finding a process that will both remove the cap and not crack the body.

Another challenge presented by the capsules is their weight, or, more specifically, the capsules' lack of weight. With so little mass, finding ways to move the capsules around in an orderly manner is difficult. Many mechanisms were considered, but, through process of elimination, it was determined that using a vibratory feeder mechanism was the most practical system for dealing with the capsules and their light weight.

The capsules must also be packed with seeds and soil. Using too many seeds is unprofitable, but too few seeds and there's a risk that nothing sprouts. Soil presents a completely different challenge. It must be broken up and packed into the capsule, but the process needs to be as clean as possible to prevent jamming systems and must fill a limited containment region inside the capsule. Meeting these constraints for the seeds and soil are already difficult, but then the ability to automate the system must also be considered constantly throughout the design process.

3.2 An Iterative Process

Trying to solve the issues presented by the capsules proved to be difficult. Many solutions were pondered and many of those solutions proved to be especially difficult to implement with consistent accuracy. Many ideas were modeled and produced before any productive progress was achieved. The process proved to take many iterations, with each progressive iteration providing new useful knowledge on what does and does not work. The first stage required studying and understanding vibratory feeders.

3.2.1 The Vibratory Feeder

Before beginning on the Autosprout project, the design team had already made decisions regarding the sorting of the capsule. The decision was to use a vibratory feeder as the main system for sorting and aligning the pill capsules before placing them into the beginning stage of the circular course it will follow. The initial plan was to design a small 5x5x5 cubic inch feeder powered by a small DC motor. The eventual goal would be to 3D printed, but first multiple models were made using clay and Styrofoam bowls to show a proof-of-concept.

Figure 3-1: Styrofoam and clay model used as a proof-of-concept that a vibratory feeder could be used for moving the capsules.

When testing the models. a small DC motor with an offset counter weight was attached to the base to vibrate the bowl. From this quick model, informative lessons were learned. Most notably, it was observed that being able to control the frequency of vibration would be key to facilitating the movement of the capsules through the feeder. The next step was designing a model to be 3D printed. The model designed made use of a silicon layer around the base that can be tightened down with different forces to the table allowing the vibration frequency to be adjusted. Also designed into the feeder were screw holes and a base used for mounting the counter weighted DC motor. The 3D printed vibratory feeder seen in Figure 3-2 functioned, but not consistently, and consistency was a major factor in the final decision on the vibratory feeder.

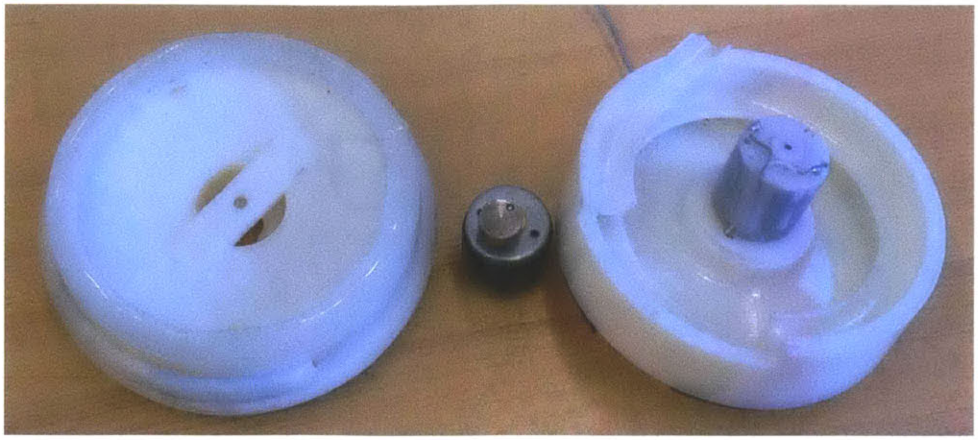


Figure 3-2: 3D printed vibratory feeder with attached DC motor with offset counter weight and silicon base layer to control the vibration frequency. In this image is the silicon base (left), the DC motor with counterweight (middle), and the entire system together (right).

Throughout the design process, outside research was being conducted on the costs of contracting a manufacturer to design a vibratory feeder for Autosprout instead of needing to design and build one. Many quotes were requested. The returned quotes ranged anywhere from $6000 to $15000, all of which were much too expensive to be considered feasible. However, while browsing eBay, a vibratory feeder was stumbled upon for only $100. The feeder was originally used for sorting different styles of screws and bolts, but was easily customizable and, for the price, it was a “can't miss deal”.

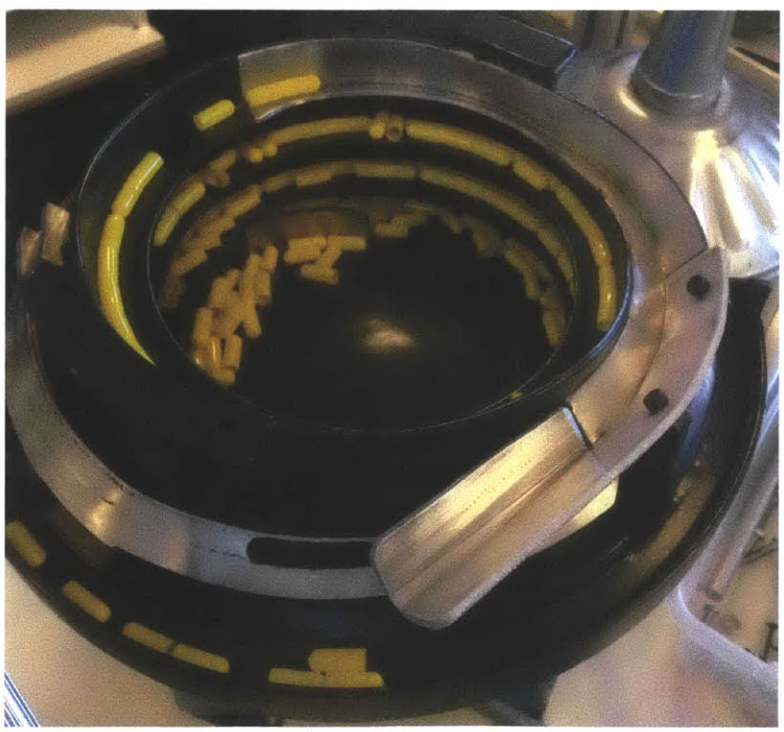


Figure 3-3: Vibratory feeder purchased from eBay. The feeder has multiple locations that can be customized in order to appropriately sort different items. The pill capsule bodies (yellow) will flow clockwise up the ramp as the motor vibrates the system.

Now that a consistently functioning feeder was obtained and the assumption that pill capsules would be purchased without the cap, the next challenge would be making the feeder work for arranging and aligning the capsules appropriately without faults. The process began by using clay to see how different set ups would affect the orientation of the pill capsules. Trying to change the orientation of the capsules proved impossible with the clay. This was mostly due to the fact that clay is tacky, not allowing the pill capsules to continue sliding. However, while using the clay, the vacuum system was being set up and it looked like a promising way of catching the capsules. The capsules have an open end and a closed end. This is perfect for using a stream of air. The air should catch the open end, while flowing over the rounded-off, closed end. Using eighth inch pneumatic tubing, there was a very precise angle and air pressure that would cause the capsules with the open end forward to fly back to the middle of the bowl while allowing the capsules with the closed end forward to continue on through the feeder. However, get the angle or pressure just slightly off and all capsules would go flying everywhere, or even worse, all capsules would just continue on through feeder.

Since using airflow to sort the capsules seemed to be possible, however slight it might have been, a design was pursued. The goal for the design was to attach to the feeder at one of the customizable regions while being fully adjustable so the necessary angle could be achieved and easily adjusted. The simplest design was creating as sheet metal part in SolidWorks and then water jetting the piece from a thin sheet of stainless steel. The piece, seen in Figure 3-4 below, would make two connections along the outside of the bowl and then bend over the top and hang over the edge. The pneumatic tubing would fit between the first and second pieces and then the second piece would connect with two machine screws into the slots. By sliding the screws to different locations in the slots, the angle of the airflow could be adjusted.

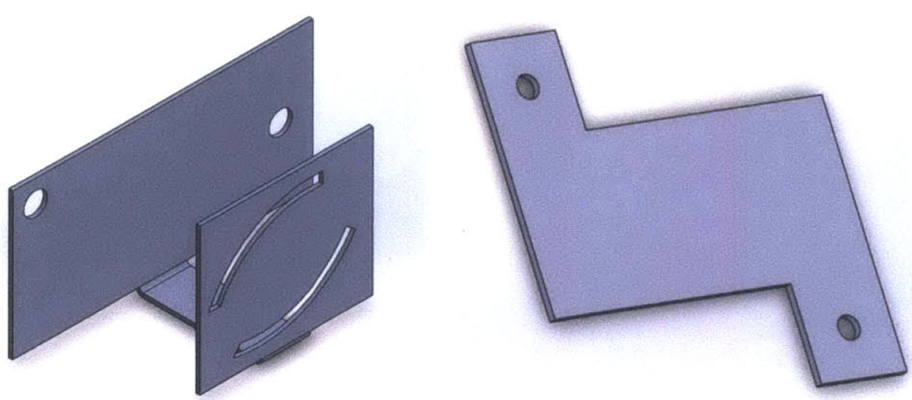


Figure 3-4: Slotted connection for pneumatic tubing used to sort the capsules. The angle is fully adjustable by tightening the screws at different points along the slots.

Once again, this design had inconsistent performance. An angle would be found that successfully blew away the capsules with the open end leading, but eventually the angle would change and the angle would need to be corrected before it would function appropriately again. This was likely due to the vibration of the feeder. With the bowl constantly vibrating, it was impossible to guarantee the angle would remain in place.

From this, it was obvious that the capsules could be easily manipulated using air. However, up to this point, blowing air was not working. The next iteration attempted to use a vacuum. The design made use of the design of the feeder. When capsules reached the end of the feeder, they fell off the highest level and, through the vibration frequency, eventually returned to the middle of the bowl to start the path towards the top all over again. Using a vacuum, the open end of the capsule could be attracted around a rod. Using this feature, two challenges could be solved at once. The first step of drawing a vacuum around the rod would only attract the capsules correctly oriented – thus, correctly aligning the capsules – and the other capsules would reenter the loop. Next, the capsules would need to be placed into the circular pattern. While holding the vacuum, the capsule can be maneuvered and moved wherever desired with the right equipment.

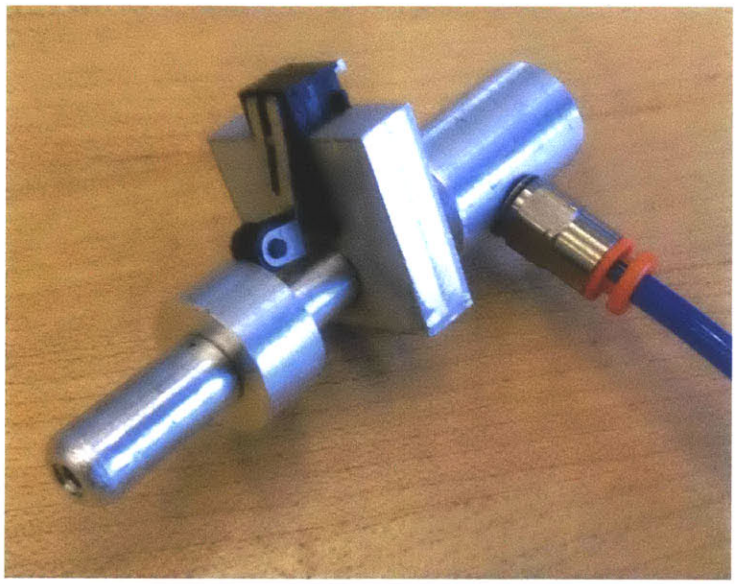


Figure 3-5: Pneumatic system that pulls a vacuum through the blue pneumatic tubing in order to take a capsule from the feeder bowl and then forces the capsule into the capsule's carousel by changing the vacuum to outward air pressure.

A pneumatic swing clamp uses changes in air pressure to rotate from one position to another. The next design, seen above in Figure 3-5, attaches to a pneumatic plunger, which attaches to the pneumatic swing clamp. The device draws a vacuum that pulls a capsule over a rod. As the vacuum pulls the capsule tightly over the rod, the capsule pushes a sleeve until the sleeve pushes a limit switch. The switch tells the pneumatic plunger to bring the capsule away from the feeder while also telling the pneumatic swing clamp to begin rotating. After the swing clamp has rotated ninety degrees, the plunger will extend and place the capsule in its correct position in the carousel. Finally, with the use of a valve the air pressure will change from a vacuum to a steady stream of air that will force the capsule in place and it makes sure the capsule does not back out of the hole with the plunger. Seen below in Figure 3-6 are the four pieces to the system.

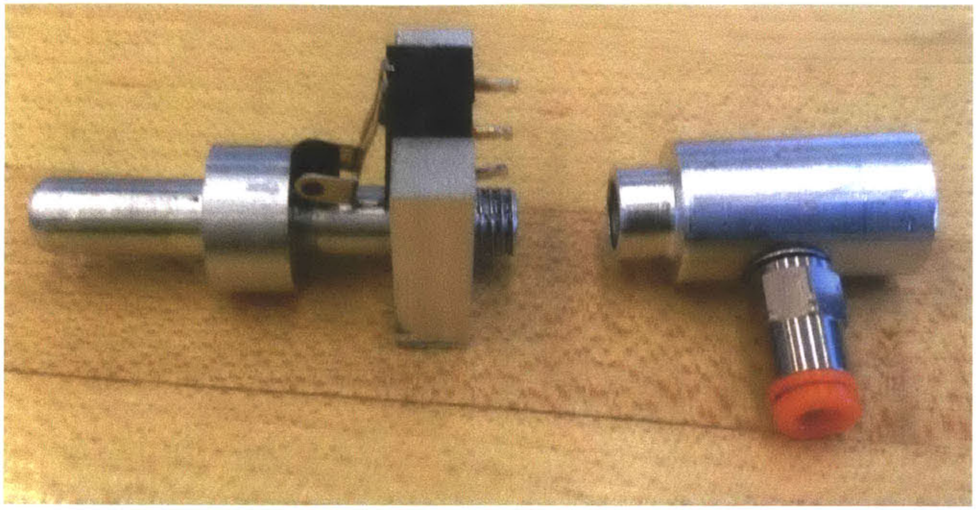


Figure 3-6: Three pieces press fit together (left) and the fourth piece (right) that connects the other three pieces to both the pneumatic tubing and the plunger. The capsule is pulled onto the end (left) by the vacuum and runs into the outer sleeve. The vacuum continues to pull until the sleeve presses the black limit switch far enough to tell the swing clamp and piston to activate.

3.2.2 Seed Distribution System

Determining the most consistent method for placing an appropriate number of seeds is a tricky problem. The seeds used for Sprout currently have a wide range in sizes. The smallest seed, thyme, is approximately 0.65 mm, while the largest seed, cilantro, is roughly 3.3 mm. Since the seed diameters are so varied, finding an easily adjustable method that allows the same number of seeds per capsule – around two or three – to be placed in the capsule, whether Autosprout is producing basil pencils or cilantro pencils, presented the biggest challenge.

Testing out different methods was the first task. Three different styles of seed distribution systems were purchased from Amazon. In Figure 3-7, the three tools can be observed. The first method (left) uses a clear plastic tube as a hopper with a spring-loaded rod running down the middle. At one end of the rod there is a notch that is used to hold a few seeds. When the rod is pressed downward the notch leaves the hopper and releases the seeds. The next seed distributor (middle) has a round, covered base with numbers zero through six on the top. These numbers refer to the approximate number of seeds that will be released through the hole and down the pathway to be planted. However, both of these two methods do not work well for varying seed sizes and are difficult to control the number of seeds distributed to the capsules.

Figure 3-7: Three different systems for distributing seeds in gardens. Each was used for testing in order to determine the best system for picking up two or three seed at varying sizes. Eventually the farthest right was chosen as the best design.

The third system (right) has many benefits. It draws a vacuum when the bulb is first pressed in (if an object, or multiple objects, are clogging the hole) and then releases the objects when pressed in again. This system also came with four different size tips. This allows the tips to be exchanged when a new Sprout product is being manufactured, such as switching from producing basil filled capsules to cilantro filled capsules. These different tips can be seen in Figure 3-8. Each tip is a different size diameter and can either pick up the different amounts of the same seed or allows the same number of different size seeds to be picked up. This device serves as a proof-of-concept for the eventual final design.

Figure 3-8: Four different size tips used with the bulb system to distribute seeds. Each tip works for different size seeds.

The eventual goal for this design is to use another pneumatic swing clamp as the swivel mechanism used to move seeds from one spot to be placed into the capsule. Attached to the swing clamp will be pneumatic tubing that will draw a vacuum, then, after the clamp has rotated a full quarter turn, the vacuum will release, dropping the seeds into the capsule. The pneumatic tubing will be dipped into a hopper designed to function similar to a gravity fed bird feeder. The tips will be easily replaceable, so that when it comes time to begin production with a different seed, both the hopper and vacuum tip will be switched out. Then the process can continue again, uninterrupted until the next seed is required.

4. Conclusions and Future Work

Throughout this thesis many obstacles were encountered when designing the mass production equipment. These challenges were in part due to the goals set forth by the design team to design equipment to manufacture a profitable product. Using the initial assembly guides as a foundation on which to build helped to reduce the challenges faced. However, automating everything was the largest challenge. Creating equipment with easily repeatable and accurate processes was difficult.

In it's current state, Autosprout still has much work remaining. As mentioned previously, there is only a goal in mind for how the final seed distribution system will function. In the near future, this system will be modeled, fabricated, and tested, hopefully becoming a part in the Autosprout system. As for the rest of the capsule carousel, other challenges still remain. The capsule not only must be filled with seeds, but also soil. The biggest challenge, still, will be linking all of these systems together with accuracy and repeatability.

On the pencil body carousel, linking the systems is a challenge as well. However, the biggest obstacle will be overcoming the large amounts of friction in the drive mechanisms. The heavy materials being used and light loading have placed excessive torque requirements on the motors that have been selected. More study is needed on the use of counter weights to help the system and new material choices may be required.

This process has taught many valuable lessons. First and foremost, when designing a product with an eventual goal to be mass produced, always think about designing for the standards demanded by the product. Even a simple product such as Sprout can have many nuances that create trouble in the assembly process. Other lessons learned, include making sure to know the specifications of all parts being used. It's added time and money when equipment must be redesigned or rebuilt due to problems that could have been foreseen before prototyping.

When Autosprout eventually reaches the final form and a pencil with a seed can be produced and sold at reasonable prices for anyone, the entire team will have succeeded beyond expectations. At the beginning of 2.744 the teams may never had anticipated that a product thought up in a class could ever reach a profitable stage. This is particularly true when the team is composed of students still working towards their master's degrees, and even some working towards their bachelor's degrees.

References

"2.744 - Product Design." *MIT - Massachusetts Institute of Technology*. N.p., n.d. Web. 10 May 2013. <http://web.mit.edu/2.744/www/index.html>.

"Kickstarter." *Kickstarter*. N.p., n.d. Web. 1 May 2013. <http://www.kickstarter.com/>.

"Sprout: a pencil with a seed." *democratech*. N.p., n.d. Web. 10 Apr. 2013. <http://www.democratech.us/sprout/>.

Appendix A: Manual Assembly Process

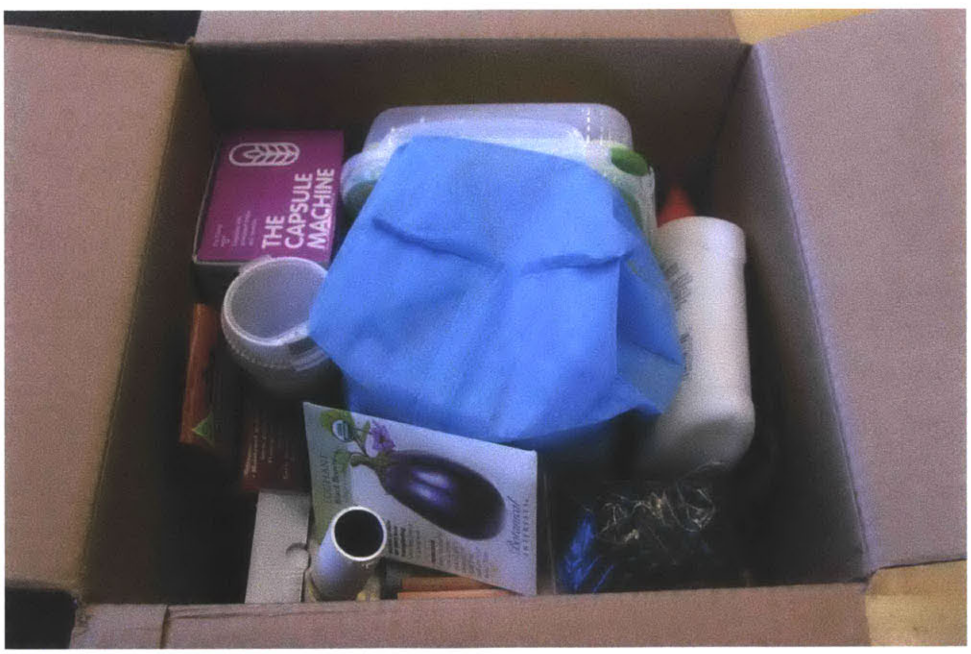
Sprout assembly guide

This step by step guide was prepared to help assemble Sprout: a pencil with a seed inside.
The steps listed below are merely a suggestion, they are what we found works well when assembling the product ourselves. If there is a better or faster way to assemble these pencils, please feel free to deviate from the instructions (as long as the product looks and functions the same!) Laser etching the pencils is not covered, but is still a necessary step to complete sprout (either before or after assembly).

Hopefully you will find these instructions helpful.

Initial assembly package contents (in image below roughly from top left to bottom right):
"The Capsule Machine" pill filler, glue sponge in container, peat disks, peat container, vacuum with hose (5 gallon bucket not supplied), white glue, router/pencil shaper, eggplant seeds, starter pencils and samples, starter capsules.

Not included:
It is recommended to obtain a pair of tweezers for extracting the pills from the pill filler (step 4). A 5 gallon bucket is needed to complete the vacuum chip extractor assembly (step 2).



Contents:
Step 1: Preparing the peat
Step 2: Preparing the pencil blanks
Step 3: Filling the capsules
Step 4: Assembling sprout

<u>Step 1</u>: Preparing the peat
The soil we are using in Sprout is a compressed, dry sphagnum moss that comes in small disks. To prepare for use, the soil needs to be broken up by hand until it is a fine, dry, brown powder.

Figure 1: Standard peat packaging (left); ripping open the pellet (right).

To break up the soil, first pull and rip apart the disks, discarding the dark brown outer casing material. This casing material is too fibrous to use and should be discarded.

Figure 2: Breaking apart small chunks (left); Filling the secondary container (right)

Be sure to break up any clumps or lumps in the powder until the consistency is smooth and the grains are fine. When the powder seems even, it can be stored in the supplied container (or any other) to keep it dry. Feel free to try any tools that might help break up the powder more efficiently.

There is no need to keep preparing small batches of soil if it is easier to break up many or all the pellets in one go. The only concern is keeping the soil **as dry as possible** before it is deposited into the capsules. When wetted, the soil will begin to expand and is unusable until thoroughly dried again.

Step 2: Preparing the pencil blanks

For this project we have prepared a special router jig for shaping one of the ends of each pencil. The router is connected via flexible hosing to a small vacuum to prevent buildup of wood chips in the enclosed cutting area. The router can be adjusted finely (*if need be*; it should be preset to the optimal position, but mishandling during shipping is possible) to the right cut depth into the pencil. Please read the user manual online for this router (Rigid R2401 Trim Router) for more information on operation and proper safety precautions.

Figure 3: Router with attached vacuum

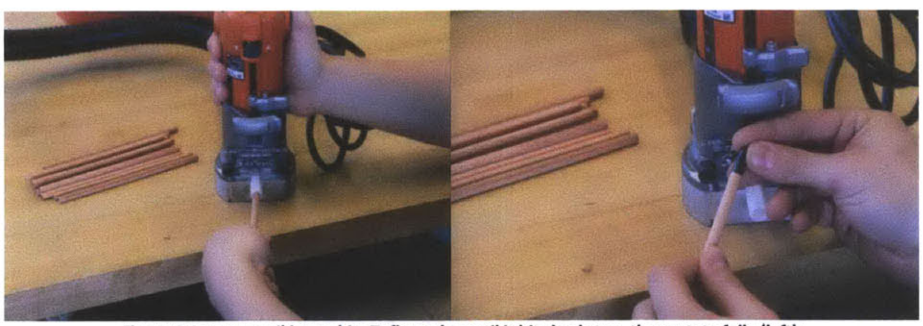


Figure 4: Insert pencil into white Teflon tube until it hits backstop, then rotate fully (left); It is helpful to test the fit of the capsule occasionally while cutting to ensure errors aren't accumulating (right)

To operate, first attach the vacuum to the back of the router, then turn both the vacuum and router on. The router can be turned on by pulling up a grey switch on the top. To shape a pencil, push a pencil blank into the front teflon tube until it hits a solid backstop, then rotate a least one full turn. As the manufacturing tolerance on the diameter of the pencils isn't high, some pencils may go in with more resistence than others (but we weren't able to find one that didn't fit at all, out of the 500 pencils tested)

The router should not require any maintenance during the lifetime of its operation. If problems do arise, please notify the Sprout team representative. Although the cutting bit is completely enclosed, please treat the tool as if it were exposed, observing safety procedures and caution.

Step 3: Filling the capsules

To fill the capsules, we will be employing the help of a traditional "pill filler" tool. This tool will allow the proper filling of 30 capsules at once. It comes in three pieces: pill holder, pill holder support and tamper. Before beginning this step, step 1 should be completed.

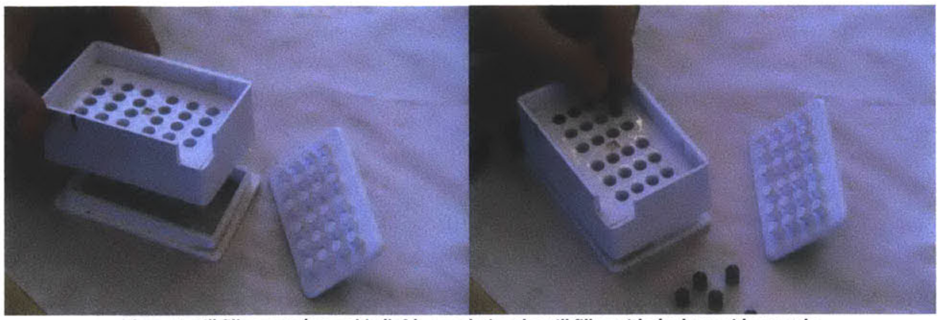


Figure 5: Pill filler parts/assembly (left); populating the pill filler with the large side capsule

Figure 6: Carefully placing 2-3 seeds in each capsule (left); depositing loose soil onto pill filler (right)

To begin, first place the main pill filler unit on top of the holder as illustrated in figure 5. Next fully populate the filler with 30 large side capsule halves. The capsules come in two pieces. The larger side will be used for Sprout and the smaller side will be discarded.

When the pill filler is full of capsules, carefully place 2-3 seeds of the desired type (there are 20 seed types!) into each pill capsule. The redundant seeds make it more likely that Sprout will sprout! Finally, when all the seeds are safe in their capsules, pour a moderate amount of loose peat over the capsules. The proper preparation of the dry peat is covered in step 1.

Turn to the next page to complete the pill filling process.

Figure 7: Filling all the capsules properly with a plastic card (left); unused soil can be scraped off and reused (right)

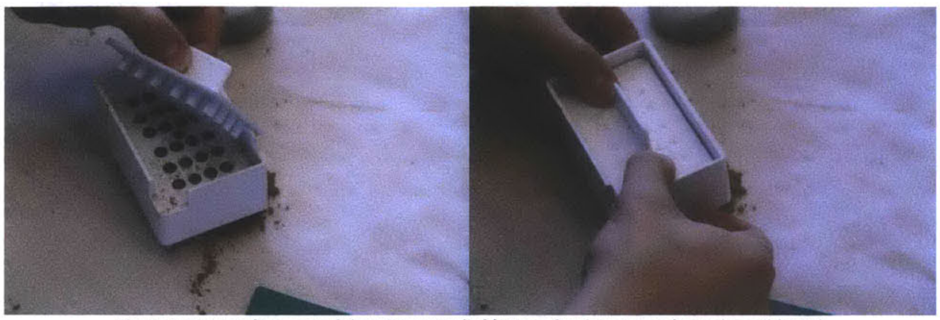


Figure 8: Proper alignment of the pill tamper (left); Press firmly to tamp down the soil (right)

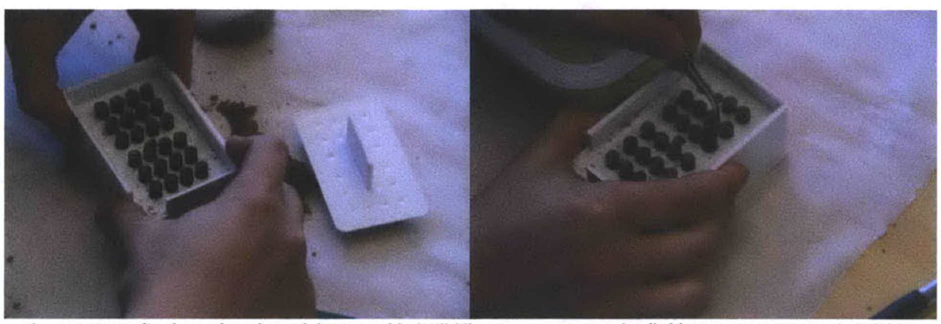


Figure 9: Press firmly on the edges of the assembled pill filler to pop out capsules (left); A tweezers is very helpful for removing capsules from the pill filler (right)

After loose soil is deposited on the pill filler, it can be coaxed into filling all the capsules with the supplied (or any) flexible card. Extra peat can be scraped off and reused (or if particles are too large, broken up again; or if too fibrous, simply discarded). See figure 7.

Next, the tamping tool can be used to compress the soil into the capsules. The soil will "spring back" after a while, but tamping can be helpful to temporarily retain the soil. See figure 8.

Finally, by pressing down on all sides of the pill filler (be sure the filler support is underneath) the pills can be popped up. The pills may fall back down when pressure is released, but this is normal. A set of tweezers can be very helpful and is recommended for easily removing the pills from the pill filler.

<u>Step 4</u>: Assembling Sprout!

When steps 1-3 have been completed, Sprout is ready to assemble.
To assemble Sprout, you will need: shaped pencils (step 2), filled pills (step 3), the glue sponge, a pair of tweezers and some paper toweling.

Figure 10: The glue soaked sponge in container (left); extracting a capsule with a tweezers (right)

Figure 11: Rolling the cut end of the pencil in the glue sponge (left); Pressing on a capsule and wiping off excess glue (right)

To make assembling sprout easy, we have pre-soaked a sponge in white glue to easy application to the ends of pencils. To apply glue to a pencil, roll the shoulder cut end of the pencil on the top of the sponge and gently press down. With pressure, glue will seep out of the saturated sponge and coat the pencil. Only a very light coating of glue is needed to attach the capsule; too much will just make a mess!

When a pencil end is coated in glue, a filled capsule can be pressed onto the glued end. Be sure to press all the way down to the cut shoulder so the capsule is flush with the wooden shaft. Any extra glue that seeps out after the capsule is pressed on should be quickly wiped off with a paper towel. It is best to wipe rotating down toward the shaft of the pencil to prevent any glue getting on the capsule (it can mar the surface of the capsule or, if there is a lot of glue, begin to dissolve it).

After a while, the glue sponge may dry up or run out of glue. More glue can be added to the top of the sponge and squeezed into the pores (be sure to use gloves). The glue sponge should be covered and sealed when not in used. If the sponge is in continuous use, occasionally spraying it with a bit of water will help it from drying out. If the sponge is left out and completely dry, simply replace with any soft kitchen sponge and properly saturate with white glue.