Introduction to Engineering Design with Professional Development 1

Final Report for *Fil-A-Bot*

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Executive Summary

Plastic waste poses a significant environmental challenge globally. The Fil-A-Bot is a unique and eco-beneficial device that promotes recycling by transforming plastic water bottles into recycled 3D filament, promoting sustainability and providing an affordable source of 3D printing material. The user-friendly system focuses on efficiency and safety, incorporating six main subsystems: Automatic Bottle Heater, Bottle Cutter, Filament Forming/Cooling, Filament Spooler, Filament Measurer, and Completion Alarm System. Each of these subsystems has been individually tested and proven effective, with further testing required for the complete product. The Fil-a-Bot reflects an innovative recycling method and improves from other models in areas such as heating and overall safety. Despite the small and budget-friendly design, this prototype represents a promising step towards a more sustainable and eco-friendly future.

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Revision History

Table 1 - Revisions

Version	Date	Name	Reason for Changes
0.0	3/17/2023	Entire Group	Initial document
1.0	3/17/2023	Entire Group	Introduction, Benchmarking Diagram, Customer Requirements, Professional and Societal Considerations, Subsystem Analysis and Design
1.1	4/21/2023	Entire Group	Subsystem Analysis & Design, User Manual, Results and Discussion
1.2	4/25	Entire Group	Completed Document
2.0	4/26	Entire Group	Final Edits

1 Introduction

Just one year ago, the UN Environment Assembly published its findings that only 9% of plastic waste was ultimately recycled in 2022 [1]. 19% of plastic waste was incinerated, 22% was sent to unregulated dumpsites, and 50% sit in landfills awaiting their decomposition in nearly half a millennia [1]. This staggering figure contributed to the team's mission to reduce plastic waste across the world. With many ways to accomplish this goal, the team needed a unique solution that not only reduces plastic waste but encourages people from all walks of life to think about what that piece of plastic lying on the side of the street could become. From this problem grew the solution to cut plastic waste by 36%, the number of plastic bottles that make up plastic waste globally [2]. This ambitious goal is equivalent to removing 136,800,000 Tons of global plastic waste yearly. The only commercial product capable of accomplishing this is the Fil-A-Bot.

The Fil-A-Bot is capable of taking used PET plastic bottles and turning it into reusable 3D-Printer Filament. PETs are the material that makes up plastic 2 Liter soda bottles for reference. The Fil-A-Bot essentially repurposes this before-doomed plastic into something that inspires creativity and brings to fruition a sustainable future. In creating a product that recycles plastic bottles into a useful material for 3D printing, the team also promotes sustainability and reduces the need for new plastic production. This helps to conserve resources, reduce greenhouse gas emissions, and mitigate the impact of plastic waste on the environment. The product also allows individuals and small businesses to create 3D-printed objects using recycled materials, promoting a circular economy and reducing dependence on single-use plastics.

Before embarking on the project, it was important to consider factors such as the cost and feasibility of producing the machine at scale, the market demand for a product like this, and potential competition from other companies in the industry. The team also examined partnerships and organizations that have experience in plastic recycling or 3D printing that may be willing to help optimize the product and market it effectively. Overall, with careful planning and execution, the team has decided the Fil-A-Bot has the potential to make a positive impact on the environment and the STEM industry, making it worth pursuing.

2 Project Objectives & Scope

2.1 Mission Statement

The team designed the Fil-A-Bot to reduce waste by using a common recyclable material to produce more affordable 3D printer filament.

2.2 Customer Requirements

Prior to starting the actual build or researching already existing products, the team interviewed 3D printing hobbyists and a filament-producing company. These customers were interviewed to determine what features the product would need and what would be the team's focus during the design process. The customer requirements were then tabulated and displayed below. The customer statements were also ranked from 1-3 so that the team could identify which statements were the most important for the projects. The most important needs found in no particular order were: Low power consumption, efficiency, quickness, cost-effectiveness, durability, and safety.

Customer: Sustainable 3D Printing Company		
Customer Statement	**Interpreted Need**	**Importance**
"It must not be expensive to run"	Low power consumption	1
"It must collect and store all the plastic it reduces in some efficient way"	Output must be spooled or compacted	2
"It has to be able to reduce many bottles into filament quickly"	Efficient and quick	1
"Can accept many different types of bottles"	Adjustable bottle input/holder	3
"Shows how much plastic or how many bottles have been reduced"	Connected network of sensors and display devices that measure bottles reduced and plastic filament made	2
"It must be worth the price"	Cost effective and durable	1
"Must be safe to use"	Safe	1

Figure 2.1 - A table showcasing the ranked customer statements and interpreted needs with ranked importance from 1 being the most important and 3 being the least important.

2.3 Technical Specifications

After tabulating and ranking the customer needs, the team then assigned a metric to each need. This was done so that during the design of the product, the team had a way to quantitatively measure the current success of each part of the product. The target of fewer than 24 volts of power corresponds to a low power draw requirement from the customer. The fewer than 150 degrees Celsius and less than 4 moving parts specification help keep the user safe during the device's use. The weight requirement of between 2 and 15 pounds and the volume requirement of less than 12 cubic feet ensure that the customer can easily move and store the device without issue. The less than 200 dollar cost is aimed to make the product affordable for a wider range of customers and allows the customer to get their money's worth from the filament they produce as fast as possible. The resource efficiency and time before failure correspond to the customers' request for an efficient and consistent filament-producing machine. The table of technical specifications is found below (Figure 2.2).

Customer Requirements	Technical Specifications		
	Metric	Target Value	Ranking
Uses as much of the bottle as possible	Resource Efficiency	40%	1
Low power consumption	Power Consumed	≤24 V	3
Doesn't burn users	Safety	≤150 C	1
Convenient/Simple	Number of moving parts.	<4	4
Portable	Weight	2-15 lbs	2
Not too large for a single person to carry	Volume	<2ftx2ftx3ft	2
Get the cost of the machine back from producing filament	Cost of Product	<200$	5
Consistent	Time before failure arrives	5 years	5

Figure 2.2 - A table showcasing the ranked technical specifications and the corresponding customer requirements. The table also includes the target value for each technical specification along with a ranking with 1 as the most important and 5 as the least important.

3 Assessment of Relevant Existing Technologies

In today's market, there are some existing technologies that are able to accomplish similar goals to Fil-A-Bot. In this section, some similar technologies will be discussed and will be compared to the technical specifications created for Fil-A-Bot.

Competitive Product	Title / Description	Relation to this project
Polyformer [6]	Polyformer is a machine that recycles plastic bottles into 3D printer filament. The device reduces plastic consumption, while also producing 3D printer filament at low costs. The open-source machine has already been built in several countries worldwide.	An open-source product that accomplishes the same goal.
PET-Machine [7]	The design turns plastic bottles into 3D filaments. However, the user has to heat and cut the bottle into strips manually.	A design that shares the same goal and some similar processes.
Filabot	The design turns anything that is plastic into 3D printer filament. This product is used for industrial production of 3D printer filament.	One of the accomplishments of the product is the same goal as Fil-A-Bot. Also, Fil-A-Bot shares a similar name with it.
3devo	The design turns anything that is plastic into 3D printer filament. This product is used for industrial production of 3D printer filament.	One of the accomplishments of the product is the same goal as Fil-A-Bot.

Table 3.1: Competitive Benchmarking

Below is a table that compares *Polyformer* to Fil-A-Bot customer requirements and technical specifications

CUSTOMER REQUIREMENTS		TECHNICAL SPECIFICATIONS		
Customer Requirement	Analysis	Technical Specification	Value	Analysis
Low Power Consumption	A low power consumption is met	Power Consumed	<24V	The polyformer does use less than 24V of power
Portable	The polyformer is very portable	Weight of the product	2-15 lbs	While the weight of the polyformer is unknown, it is definitely in the range of 2-15 lbs
Not too large for a single person to carry	The polyformer can be carried by a single person	Volume of the product	<2ft x 2ft x 3ft	The polyformer has a total volume less than 2ft x 2ft x 3ft
Get the cost of the machine back from producing filament	The polyformer does contain 3D printed parts, so the cost is partially refunded as the machine is used	Price of the product	<$200	The polyformer costs around $150, so it fits the technical specification

Below is a table that compares *PET-Machine* to Fil-A-Bot customer requirements and technical specifications

CUSTOMER REQUIREMENTS		TECHNICAL SPECIFICATIONS		
Customer Requirement	Analysis	Technical Specification	Value	Analysis
Low Power Consumption	A low power consumption is met	Power Consumed	<24V	The PET-Machine does use less than 24V of power
Portable	The PET-Machine is very portable	Weight of the product	2-15 lbs	While the weight of the PET-Machine is unknown, it is definitely in the range of 2-15 lbs
Not too large for a single person to carry	The PET-Machine can be carried by a single person	Volume of the product	<2ft x 2ft x 3ft	The PET-Machine is much more compact than Fil-A-Bot. However, it also does not contain a bottle heater. In PET-Machine the user must heat the bottle manually.
Get the cost of the machine back from producing filament	The PET-Machine does contain 3D printed parts, so the cost is partially refunded as the machine is used	Price of the product	<$200	The PET-Machine costs around 70-110$, so it fits the technical specification

Below is a table that compares *Filabot* to Fil-A-Bot customer requirements and technical specifications

CUSTOMER REQUIREMENTS		TECHNICAL SPECIFICATIONS		
Customer Requirement	Analysis	Technical Specification	Value	Analysis
Low Power Consumption	A low power consumption is met	Power Consumed	<24V	The Filabot EX6 does not use less than 24V of power
Portable	The Filabot EX 6 is very portable	Weight of the product	2-15 lbs	While the weight of the Filabot EX6 is unknown, it definitely weighs more than Fil-A-Bot's technical specification
Not too large for a single person to carry	The Filabot EX 6 can be carried by a single person	Volume of the product	<2ft x 2ft x 3ft	The Filabot EX 6 is much more compact than Fil-A-Bot. However, it also does not contain a bottle heater. In Filabot EX 6 the user must heat the bottle manually.
Get the cost of the machine back from producing filament	The Filabot EX 6 does contain 3D printed parts, so the cost is partially refunded as the machine is used	Price of the product	<$200	The Filabot EX 6 costs around 15,000-20,000, so it is way higher than the technical specifications for Fil-A-Bot

Below is a table that compares *3devo* to Fil-A-Bot customer requirements and technical specifications

CUSTOMER REQUIREMENTS		TECHNICAL SPECIFICATIONS		
Customer Requirement	Analysis	Technical Specification	Value	Analysis
Low Power Consumption	A low power consumption is met	Power Consumed	<24V	The NEXT 1.0 Filament Maker does not use less than 24V of power
Portable	The NEXT 1.0 Filament Maker is very portable	Weight of the product	2-15 lbs	While the weight of the NEXT 1.0 Filament Maker is unknown, it is definitely significantly higher than Fil-A-Bot
Not too large for a single person to carry	The NEXT 1.0 Filament Maker can be carried by a single person	Volume of the product	<2ft x 2ft x 3ft	The NEXT 1.0 Filament Maker is much more compact than Fil-A-Bot. However, it also does not contain a bottle heater. In NEXT 1.0 Filament Maker the user must heat the bottle manually.
Get the cost of the machine back from producing filament	The NEXT 1.0 Filament Maker does contain 3D printed parts, so the cost is partially refunded as the machine is used	Price of the product	<$200	The NEXT 1.0 Filament Maker costs around 1,500-2000$, so it does not fit the technical specification

Below is a table of some existing patents that are able to perform similar tasks to Fil-A-Bot.

Patent Number	Title / Description	Relation to this project
EP3012078A1 [8]	Method for producing a supply obtained from the recycling of plastic material of industrial and post-consumer residues, to be used by 3d printers	This patent goes over a process for turning general plastic scrap into 3D printer filament. The scope of this patent is much larger than the scope of Fil-A-Bot, with Fil-A-Bot only recycling plastic bottles.
US7462649B2 [9]	Method to dispose of water bottle that is made by PET so that it can be used for production of new bottles	This patent disposes of water bottles. The input is the same as that of Fil-A-Bot.

Table 3.4 - Patent Research for Related Technologies

4 Professional and Societal Considerations

The team applied the engineering design process to produce solutions that meet the specified needs with consideration for the topics found in Table 4.1 - Engineering Solutions Impact.

Table 4.1 - Engineering Solutions Impact

Area of Impact	Impact	Description of Impact
Public Health and Safety	N	No harmful materials produced during the project processing: The product turns PET (Polyethylene Terephthalate) into 3D printer filaments. During the process, microplastic is likely created due to thermal degradation. Ingestion of microplastic in large amounts is reported to cause fatal internal injuries. However, the production of microplastic is insignificant when the PET is heated at 200 degrees Celsius, which is the highest temperature that the product would achieve. Thus, the product would cause almost no effects related to human health. [5]
Global	Y	Reducing the amount of plastic waste generated globally: The product can convert plastic bottles into reusable 3D printing materials, thus reducing the amount of plastic waste generated worldwide. This helps to reduce the environmental impact of plastic waste and promote a cleaner planet.

Area of Impact	Impact	Description of Impact
		Encouraging sustainable production and consumption: The product promotes sustainable production and consumption patterns by converting waste into useful materials and reducing the need for new plastic production. This supports the goals of the United Nations Sustainable Development Goals (SDGs) and contributes to the overall sustainability of the planet. Promoting environmental awareness and action: The product's use can promote environmental awareness and action globally, helping to improve the environment and reduce waste. This can contribute to global environmental movements and inspire sustainable behavior. Providing economic benefits: The product can help reduce costs for individuals and organizations by providing a low-cost and eco-friendly option for 3D printing materials. This can help people from all walks of life, especially in developing countries, to access technology and improve their quality of life.
Cultural	N	No expected "cultural clashes" between the product and foreign countries: The product does not rely on any specific cultural practices or beliefs, so the group does not anticipate any issues with cultural compatibility in foreign markets. The differences among cultures are getting vague, as interactions among countries are continuously increasing, and different cultures interact with each other more constantly. Therefore, the boundaries among countries are slowly disappearing as more and more cultures merge together.
Societal	Y	Reducing the environmental impact of waste: The product can convert plastic bottles into reusable 3D printing materials, thus reducing the amount of plastic waste. This helps to reduce the environmental impact of waste and promote environmental protection.

Area of Impact	Impact	Description of Impact
		Increasing waste recycling: The product can convert waste into useful materials, increasing waste recycling. This helps to promote sustainable development and environmentally friendly economic models. Promoting environmental awareness: The product can promote environmental awareness and action, helping to improve the environment and reduce waste. This helps to promote global environmental movements and sustainable development. Improving people's quality of life: The product can help people reduce daily expenses and provide them with more options for 3D printing materials. This helps to improve people's quality of life and economic status.
Environmental	Y	Reduction of solid waste: By converting plastic bottles into 3D printing materials, the product can contribute to reducing the amount of solid waste that ends up in landfills or pollutes the environment. Lessen impacts of landfills on surrounding ecosystems: When waste materials are sent to landfills, they can produce harmful gasses and leachate that can contaminate soil and groundwater, negatively impacting surrounding ecosystems. By reducing the amount of waste sent to landfills through the product, the product can help lessen these negative impacts. Fil-A-Bot itself is mostly made of recycled plastic: The product itself is made mostly of recycled plastic, which means it contributes to reducing the need for new plastic production and supports a circular economy by keeping plastic waste in use. This can help reduce the environmental impacts of plastic production and waste.
Economic	Y	Reducing everyday costs for those who have plastic water bottles: By using the product, consumers can convert their plastic water bottles into 3D printing materials, thereby

Area of Impact	Impact	Description of Impact
		reducing their daily expenses. This means that users can better manage their finances and save money for other needs. Reducing waste management costs: Plastic water bottles are a serious environmental issue, and their disposal costs are high. By using the product, people can reduce waste management costs by converting their plastic water bottles into 3D printing materials. This will help reduce the burden of waste management and lower the funds required to handle waste. Reducing profits for companies that sell 3D printing filament: By using the product, people can convert their waste plastic bottles into 3D printing materials without having to buy new filament. This will directly affect the profits of companies that sell 3D printing filament. People can choose to use the product instead of buying new 3D printing materials.

5 System Concept Development and Selection

Reasoning for why the team chose this project area and this exact project can be found in Appendix A. Before the team even began to discuss potential subsystems, they first conducted research on the process that turns a plastic water bottle into a usable 3D printer filament (Figure 5.1). After visualizing the process, the team was able to identify the six most crucial parts of the process, which then became the subsystems of Fil-A-Bot. The six most important parts were: heating the bottle, cutting the bottle, melting the strips, spooling the filament, measuring the amount made, and alerting the user.

To help identify the subsystems in the project, a flow chart of only subsystems was created (Figure 5.2). This figure provides a short description of each subsystem and the respective leader of each subsystem. The subsystems are further detailed in section 6, titled *Subsystem Analysis and Design*.

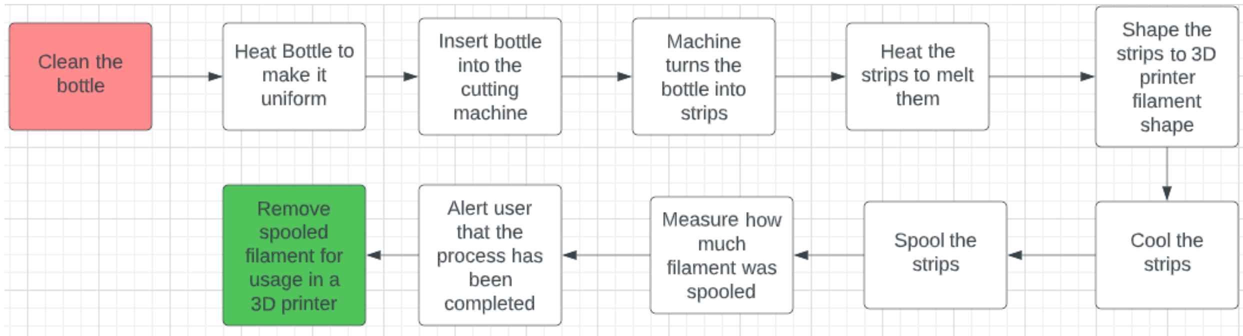

Figure 5.1: A diagram showing the Fil-A-Bot's overall process of turning a plastic bottle into a spool of 3D printer filament.

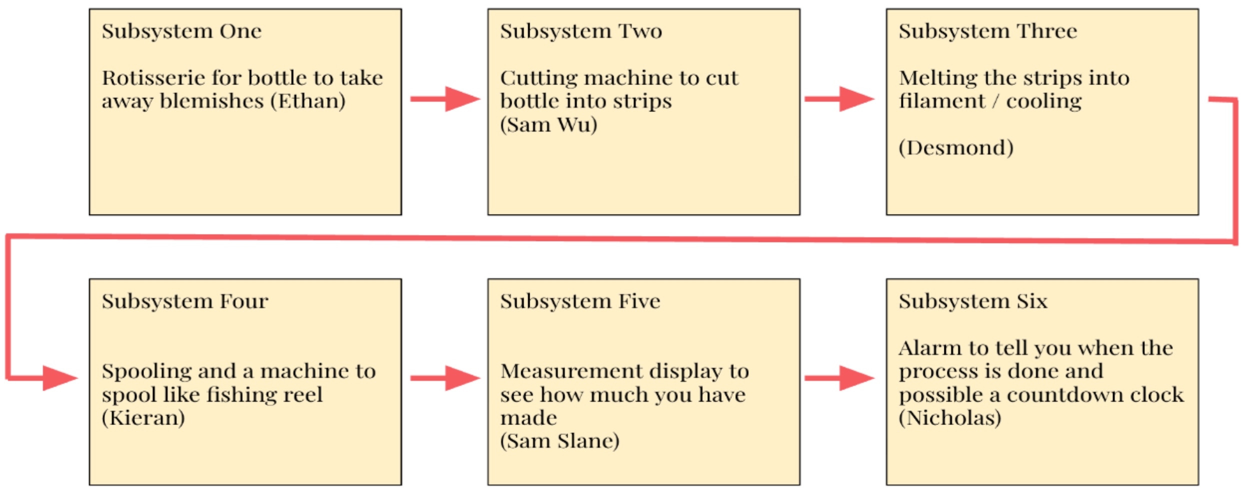

Figure 5.2: A flowchart of the filament-producing process. The flowchart highlights the subsystems and their relation to each other as well as the team member in charge of them.

Due to the process of Fil-A-Bot being similar to a manufacturing line, the orientation and final design of Fil-A-Bot were clear from the beginning. Pictured below are early iterations of Fil-A-Bot's design (Figures 5.3 & 5.4). As seen from these designs, the team had a clear idea of the process of Fil-A-Bot, and all of the subsystems that are included. While the overall process and parts were clear, the exact form of each subsystem was still to be determined. Both sketches had different ideas for the bottle heater, spooler, cutter, and display, showcasing how the team was unsure about the details of the subsystems at the beginning.

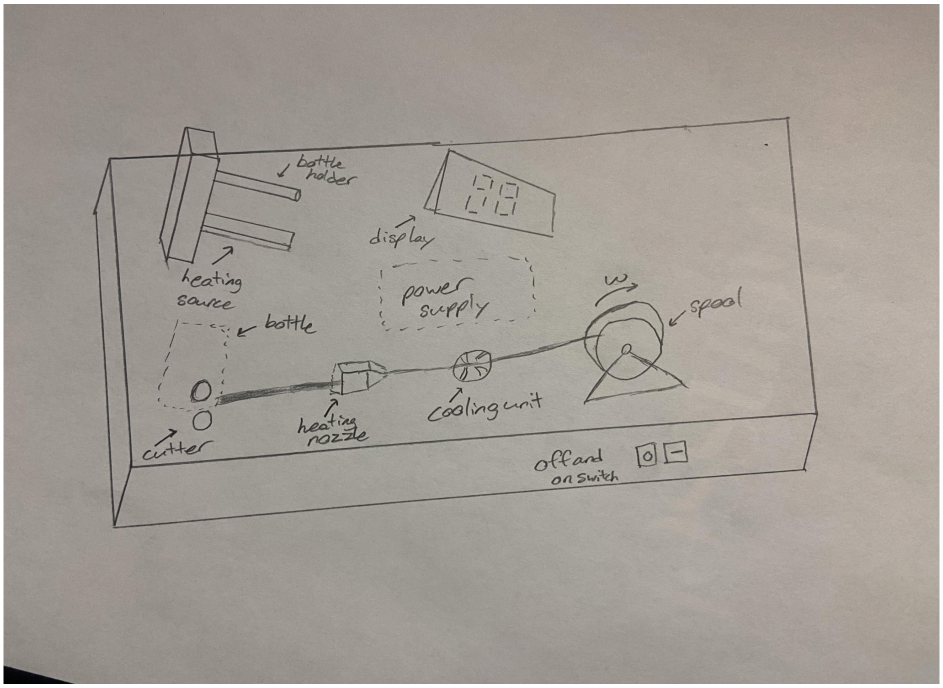

Figure 5.3: An early sketch for Fil-A-Bot. The rough layout of the subsystems as well as how they interact, are pictured. This proposed design excludes a completion alert and uses a horizontal bottle heater.

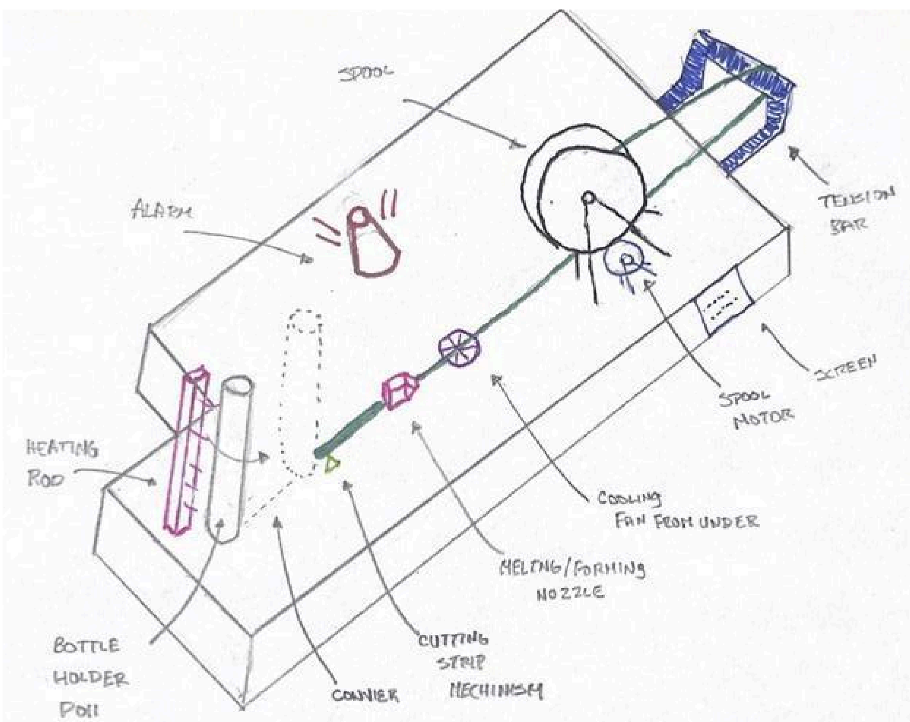

Figure 5.4: A second early design for Fil-A-Bot. This design featured a tension bar for the finished filament and a visual alarm system.

After identifying the overall goal of each subsystem, the team then needed to figure out how to form each subsystem to best achieve those goals. For each subsystem, the team thought of many different ways to implement them. To assist with overall planning and to help organize all of the ideas, a mind map was created (Figure 5.5). The mind map displays the choices that were made and alternative ideas for the subsystems.

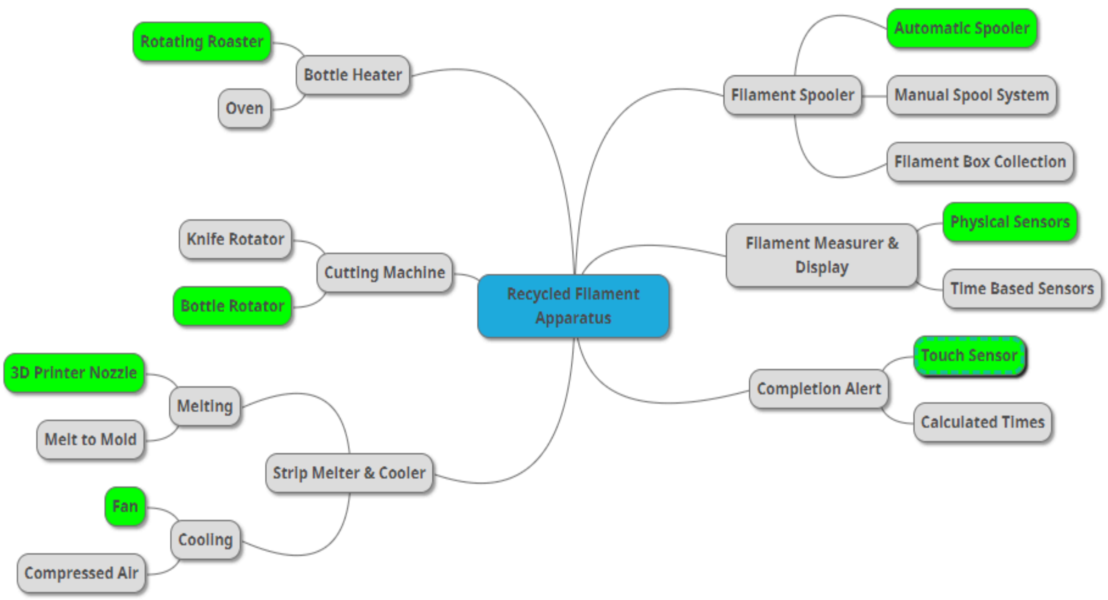

Figure 5.5: A mind map of potential subsystems. The boxes highlighted in green are the methods the team decided to go with. Decision matrices for all of the choices can be found in the Appendix, and a discussion for each specific subsystem is detailed in Section 6, Subsystem Analysis and Design.

A labeled picture of the team's final prototype for Fil-A-Bot is shown below (Figure 5.6). The labeled parts are as follows:

1. Bottle Heater Subsystem
   a. Heating Element
   b. Bottle Holder
2. Bottle Cutter Subsystem
   a. Bottle Rod
   b. Cutting Device
3. Filament Forming/Cooling Subsystem
   a. Temperature Control
   b. Heating Nozzle
4. Filament Spooling Subsystem
   a. Spooler
5. Filament Measurement & Display Subsystem
   a. Filament Measurement
   b. Display
6. Completion Alert Subsystem
   a. Alarm

   b. Alarm Control
7. Power Supply

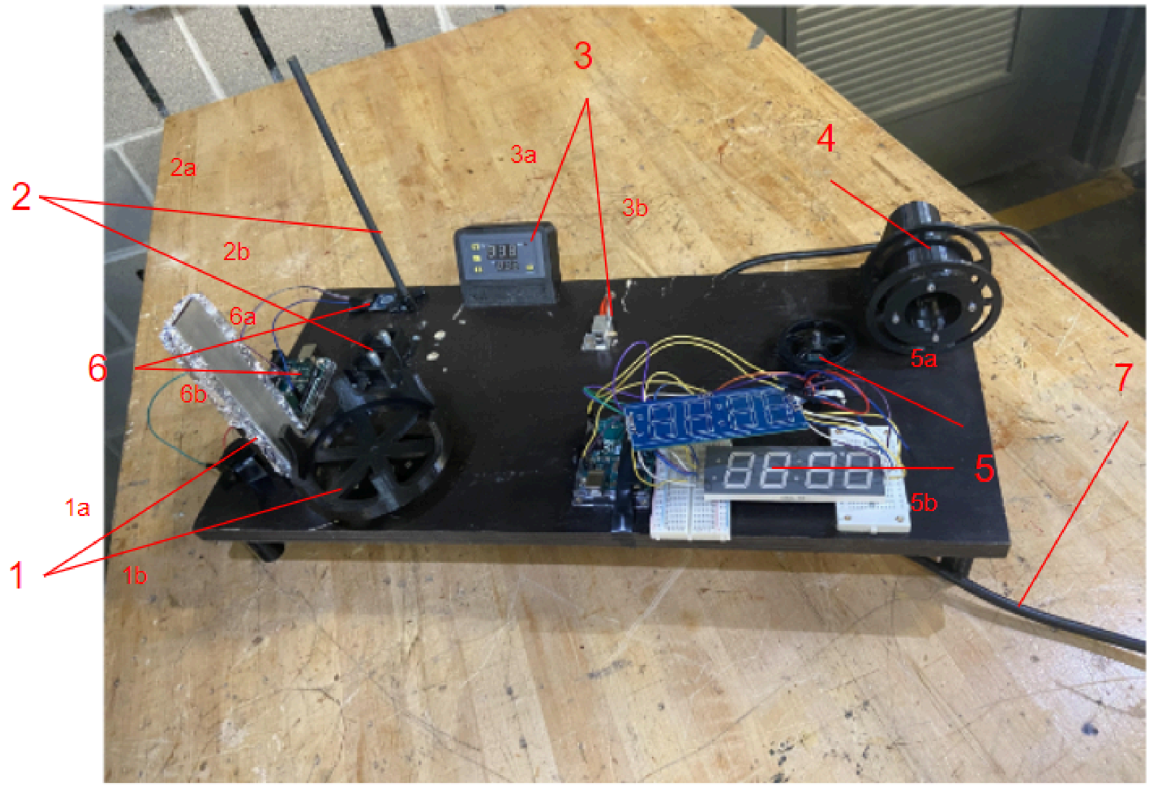

Figure 5.6: A photo of the final prototype for Fil-A-Bot, complete with all of the fully functioning integrated subsystems. The labels on the figure are listed above.

In terms of layout, the final design was most similar to the first early sketch of the Fil-A-Bot (Figure 5.3). The bottle heating system and filament display are off to the side, with the rest of the subsystems aligned linearly. This linear alignment highlights the assembly line inspiration for the Fil-A-Bot. The exact design reasoning for each subsystem will be outlined in the following section of the report. Not seen in this photo are the two 12V power supply units found underneath the black base. These PSUs are found directly under the filament display (5b) and are aligned parallel to the base, taking up the entire right third of the underside. To help prevent the board from laying slanted due to the PSUs and to provide space for wiring, 1.5-inch tall legs were placed on the four corners of the board.

6 Subsystem Analysis and Design

Pictured below is a diagram that outlines the subsystems of Fil-A-Bot (Figure 6.1). These subsystems are the Bottle Heater, Cutting Machine, Strip Melter & Cooler, Filament Spooler, Filament Measurer & Display, and Completion Alert.

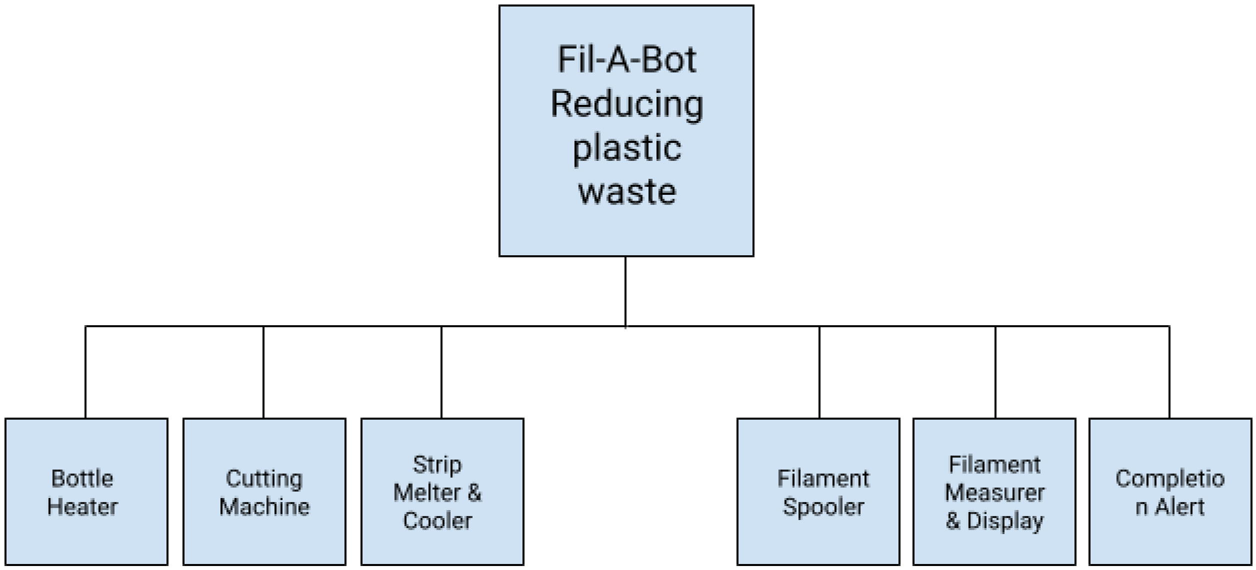

Figure 6.1: A Fil-A-Bot Subsystem Diagram showcasing how all of the subsystems come together to create Fil-A-Bot.

6.1 Automatic Bottle Heater

The main purpose of the bottle heater was to autonomously heat the bottle to remove blemishes and to allow for easier cutting on the cutting machine. To do this, a heating element would have to heat the bottle such that it reaches 100 - 120℃. At the beginning of the design process, the team identified two main ways that the bottle heater could be visualized. The rotating roaster would have the bottle rotate around two heating elements, while in the oven design, the bottle would be placed into a box where heat radiated from all sides. To fully choose which one would be continued, a decision matrix was created (Figure 6.2).

	Choices	
Evaluation Criteria	Rotating Roaster	Oven
Low Power Consumption	1	0
Compact	1	0
Efficient	1	1
Safety	1	1
Accessible/Easy to Use	1	1
Cost Effective	1	-1
Durable	-1	1
SUM	5	3
CONTINUE?	YES	NO

Figure 6.2 - A decision matrix outlining the evaluation criteria for the automatic bottle heater's form: Rotating roaster and Oven.

Some of the benefits of the oven design were that the time taken to heat would be extremely fast, and it would be much more durable than the rotating roaster design as the constant rotation might wear down the parts faster. However, while the oven design had some benefits, it had more negatives than positives. Some of the major negatives that the oven design had were that it was not cost-effective and it would also consume large volumes of power. These two factors went directly against the customers' needs and requirements, which prevented it from being selected. This made it so that the rotating roaster design was selected as it fulfilled more customer requirements than the oven, with the only negative being that it was not as durable. Even without the oven's failure to meet some of the customer requirements, the rotating roaster design was far superior, being the more cost-effective option but also matching the oven in other aspects such as safety, efficiency, and ease of use.

After the team determined to move forward with the rotating roaster, it was then time to acquire the necessary components needed to assemble a prototype. An aluminum PTC heating element sold by Keenso was chosen as the ideal heating element. This was due to the fact that it was the correct size, with the length of the element being almost identical to the length of the body of the bottle. Relative to other heating elements, this heating element was the most power-effective, providing 150℃ at 12 volts. Not only did these two values meet the technical specifications of the product, but keeping the voltage of the heating element low was important due to it being one of the most, if not the most, power-consuming electrical components on Fil-A-Bot. Keeping the overall power requirement for Fil-A-Bot was important based on customer requirement 11.1 A 15 rpm motor sold by Greartisan was then chosen to rotate the bottle holder due to it being the ideal speed that would allow for uniform heating on the bottle.

To ensure that each part was working as intended, all parts were tested prior to moving forward with the design process. The heating element was connected to the power source, and its temperature was measured via an external device. The temperature output was then recorded every 30 seconds. It was then found that the heating element took no more than 2 minutes to reach the desired temperature of 150℃. For the motor, testing was done to ensure that it would be able to rotate even while supporting a small load of 2 lbs.

Frames to hold the heating element and the bottle-holding apparatus were then created. The frames on the heating element were designed to fit tightly so heat generated on the sides other than the front would be absorbed by the frame. To help dissipate the excess heat generation, thin sheets of aluminum were also inserted between the frame and the heating element. On the bottle-holding apparatus, uniform holes were created on the bottom to allow for the legs of the bottle to slot into them, helping the bottle stay on the apparatus. Parts of the perimeter of the apparatus were raised to help support bottles as they rotated on the machine.

For the prototype, the frame and bottle-holding apparatus were made with 3D printer filament due to ease of use, acquisition, and assembly. This caused the frame and holding apparatus to be damaged by the intense heat generated by the heating element. For the final product, these parts would be made out of metal to allow for repeated use. The final product would also have a box put around the subsystem to prevent users from burning themselves on the heating element, which would further support customer requirements 11.4.

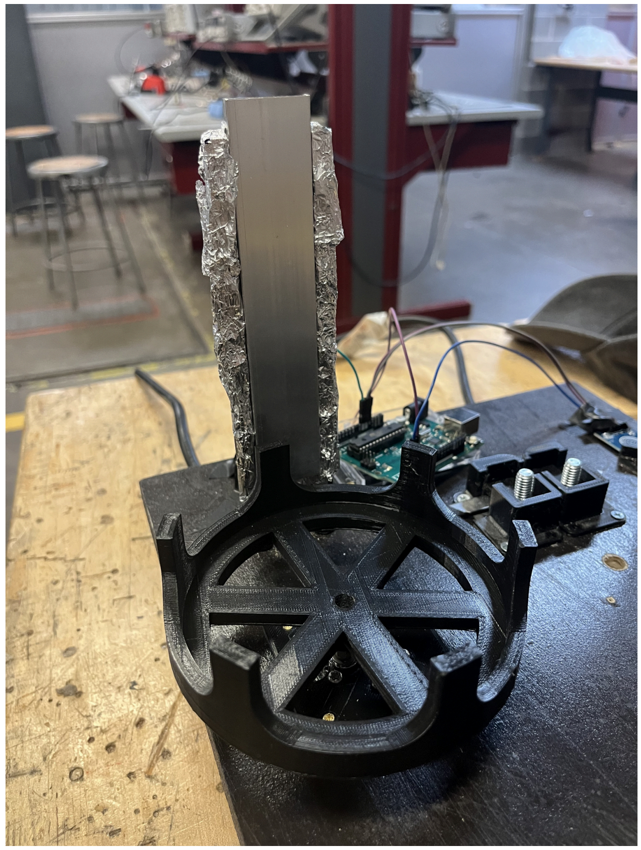

Figure 6.3 - A photo of the bottle heating subsystem. The aluminum heating element with tin foil is pictured alongside the bottle-holding apparatus.

6.2 Bottle Cutter

The bottle cutter turns the plastic bottle into a continuous strip with a uniform and suitable width for later processes. In the beginning, the team found that the operation of cutting bottles is similar to that of cutting apples. Therefore, the designs of apple peelers were taken into the benchmarking for this subsystem. The mechanism of the apple peeler is that the blade can reach any part of the apple by rotating the apple or by rotating the blade. Therefore, inspired by the apple peeler, the team came up with two types of bottle cutters.

In the first design, the bottle is cut by a movable blade that rotates around the bottle and slowly moves toward the bottle's neck. The bottle, on the other hand, is fixed by a support. In the second design, the blade is fixed, and it would touch the edge of the strip that is cut in the preparation procedures. By exerting force on the bottle towards the blade, the blade would be able to cut the bottle into uniform strips. Since the bottle is held vertically, the height of the bottle would gradually decrease as its body is turned into strips and taken into the heating nozzle. Therefore, the blade would be able to touch the edge of the cut strips consistently. As force is applied, the blade should be able to cut the bottle into strips continuously until the neck of the bottle is reached. A decision matrix was created to help the team decide on the design choice (Figure 6.4).

Cutting Machine	Choice	
Selection Criteria	Rotating the Knife	Rotating the Bottle
Low Power Consumption	0	0
Compact	1	1
Efficient	1	1
Safety	-1	1
Accessible/Easy to use	0	0
Cost Effective	1	1
Durable	0	0
Total Score	2	4
Continue?	No	Yes

Figure 6.4 - A decision matrix outlining the criteria for the bottle cutter, comparing the two choices for the bottle cutter: rotating the knife and rotating the bottle.

Since safety is an essential part of the project, the group eventually gave up on the first design in which the blade rotates around the bottle. The chance for the users operating the design with a rotating blade to get hurt is much greater than that for the users operating the design with a fixed blade.

After selecting the design, materials were determined. A sharp blade is needed, and the team selected a blade with a width of 9 mm. A rod is also necessary to vertically support the bottle, and the team eventually selected a threaded rod. Also, the team wanted to add some functions to the bottle cutter, such as adjusting the height of the blade so that the bottle cutter can yield strips with variable widths. In order to achieve this, the team decided to use a motor, screws, nuts, and gears. A 300 RPM motor was selected. For gears, the team decided to acquire them by 3D printing for the flexibility of self-constructed models and cheap cost. Moreover, 3D-printed materials were also chosen for the fixation of the subsystem.

As the team discussed further in the meetings, the team decided the range of widths of the cut strips should be between 4 and 6 mm. The minimum of 4 mm ensures that the strips would not be too thin to be broken for later processes. The maximum of 6 mm was 0.5 mm less than the diameter of the heating nozzle. The team wanted to make sure that the strips can enter the heating nozzle without being too large or too small. Realizing that the width of the strip varies in a very short range, the team eventually decided to remove the function that adjusts the blade height. As a result, the motor and 3D-printed gears were no longer needed after further testing. Thus, the bottle cutter includes an M8 threaded rod to hold the bottle from tilting, a 9 mm wide blade to cut the bottle, 3D-printed parts to support the blade, 2 M8 half-threaded screws, and 5/16 inch nuts to help adjust the blade height if needed.

The main structure of the bottle cutter involved firmly holding the blade in position so the bottle could rotate and be cut. To build the structure, the team started by drilling two holes in the wood plank so that the two M8 half-threaded screws would be able to penetrate the plank. At the bottom of the wood plank, the team used wood screws and 3D-printed supporting models to support the screws from falling. Then the two M8 half-threaded screws were fixed to the wood plank, and the team used 3D-printed parts to hold the blade. The blade holders were two bilateral symmetrical parts that were responsible for each side of the structure. Each part was a cuboid with a hole for the 5/16 inch nut and a gap for the 9 mm wide blade. The nuts entered the part from its front side, and they would not go further into the parts as they reached the position of the hole. The hole was large enough for the M8 screws to pass through. As the nuts were fixed on the screws, the 3D-printed parts to hold the blade were also elevated by the screws. Later, the team could turn the nuts by turning the 3D-printed parts to adjust the blade height if needed. Finally, the team put two frames that prevent the blade holders from spinning around the screws, which could cause the blade to tilt or fall (Figure 6.5).

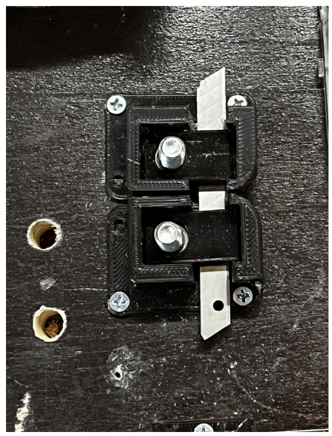

Figure 6.5 - The bottle cutter machine structure as fixed on the platform. The screws, nuts, and bolts hold the structure and the blade in position.

Another important part of the bottle cutter is the M8 threaded rod that holds the bottle vertically. The rod was fixed on the wood plank with the help of the 3D-printed parts. The part is composed of a hole in the middle to hold the rod and 4 small holes at its corners for the wood screws. In later testing, the team found that the position of the threaded rod affects the efficiency of the bottle cutting. The efficiency of cutting the bottle is at maximum if the blade touches the bottle slit perpendicularly. The team concluded that the sine of the angle between the cut strip and the blade should be as close to 1 as possible. As a result, the team set the threaded rod perfectly aligned with the blade in the final prototype so that the blade can touch the slit perpendicularly.

6.3 Filament Forming / Cooling

The main purpose of the Filament Former was to accept a thin strip of PET that was cut from a bottle and passed through a heated nozzle to form the desired filament circular diameter. To do this, the PET strip would have to be heated anywhere from 120º C to 160º C and passed through an orifice of diameter 1.75mm [3]. In accordance with the design process, two concepts were generated that would be able to fulfill the purpose of this subsystem. Concept one for the filament molding portion featured a heating block with a nozzle to extrude the plastic, generating its heat from a thermistor. Concept two featured a melt-to-mold system which would melt down the cut strip completely in a heated collection system and then extrude the melted plastic, similar to pushing a liquid out of a syringe. As shown below, a decision matrix was used to identify the best concept to perform the task of this subsystem (Figure 6.6). The compactness, cost-effectiveness, and repeatability ultimately led to the use of the 3D printer nozzle configuration. Following this, two concepts for cooling the filament down after extrusion were created. One where a fan would air cool the filament after extrusion, or another where compressed air would be shot at the filament to ensure cooling after extrusion. The below decision matrix shows the fan was ultimately decided upon because of its low power consumption, safety, and cost-effectiveness in comparison to the compressed air system.

Filament Heating			Filament Cooling		
Selection Criteria	3D Printer Nozzle	Melt to Mold	Selection Criteria	Fan	Compressed Air
Power Consumption	0	0	Power Consumption	1	-1
Compact	1	0	Compact	0	1
Fast Heating	1	1	Fast Cooling	1	1
Safety	1	0	Safety	1	0
Cost Effective	0	-1	Cost Effective	1	-1
Repeatability	1	-1	Repeatability	1	1
Total Score	4	-1	Total Score	5	1
CONTINUE?	YES	NO	CONTINUE?	YES	

Figure 6.6 - A decision matrix outlining the criteria for the filament-forming (3D Printer Nozzle vs Melt to Mold System) and cooling subsystem (Fan vs Compressed Air)

After the team identified what form this subsystem would take, it was then time to acquire the necessary components to assemble a prototype. The customer made it clear they wanted safety and control over the system at all times, so with this in mind, the team selected a thermo-controller that would be able to control the temperature of the heating nozzle simply and effectively at all times. The W3230 DC 12V Digital Temperature Controller Sensor sold by Greenhouse Accessories was acquired. This product boasts the ability to accurately read and control temperatures in the wide range of -60º C to 500ºC with a 1º C error range. This thermo-controller allows the user to easily set temperatures with the use of its preset values or through the use of the up and down arrow toggle buttons. The top red number displays the current temperature the heating nozzle is at, while the bottom blue number displays the desired temperature set by the user. Once the desired temperature is reached, this thermo-controller automatically shuts off power to the heating apparatus and only cuts back on when the temperature dips below the desired temperature. For safety reasons, the device also has a main shut-off switch, giving the user the ability to shut off the heating system whenever desired or deemed necessary.

To heat up the PET strip, an aluminum block was used, which had a slot milled in it to allow for a thermistor. This thermistor is what transfers the electrical energy from the thermo-controller into heat and is sold by RLECS. This ceramic heater draws 12V and is a component that is inserted into the heat block and ensures the heating of the nozzle. It is a cheap and simple component. The aluminum heating block and the brass nozzle were sold by E-outstanding. When choosing the heating block, it was important to understand that the larger the block, the slower it cools with less temperature fluctuations. The nozzle size that came with this product has a diameter of 0.5mm, so with the use of a drill press, the diameter was increased to the desired 1.75mm.

As mentioned before, to cool down the filament after it is extruded by the heated nozzle, a fan was decided upon by the team. The team decided on a PC fan because of its ability to air-cool systems that draw similar amounts of energy for longer periods of time. The team wanted to keep the dimensions small in order to fit the fan seamlessly into the base and wanted to reduce the noise made, and for this reason, decided to go with the Kingwin 80mm Silent Fan. This fan is very thin, boasts a run-time of ~100,000 hours, and is designed with special high-profile fan blades for maximum airflow.

Figure 6.7: Subsystem Components; Thermo-Controller, Thermistor, Heating Block/Nozzle, Fan

To ensure each component worked as intended, the team tested and verified each component of this subsystem prior to final assembly and final testing. Test 1 was set up to confirm that the filament heating mechanism gets up to the desired temperature of 140° C and can maintain that temperature reliably. 5 trials were prescribed where a digital laser temperature reader was used to confirm the temperature the thermo-controller was reading. Setting the temperature on the thermo-controller to 140° every trial, the laser temperature reader was able to confirm the heating nozzle was, in fact, able to reach an average temperature of 142.2° C on 5 different trials starting at room temperature, with a standard deviation of 1.56° C. This test was within the allowable temperature range of 140° C $\pm$ 10°. Test 2 was set up to affirm that the heating nozzle could get to 140° C in under 90 seconds with a leeway of 5 seconds. For the trials completed in Test 1, a timer was also set to record how long the thermo-controller took to heat up the heating nozzle so that data could later be used for Test 2. In those 5 trials, it was found that it took on average 66.4 seconds to reach a temperature of 140° C starting from room temperature with a standard deviation of 4.27 seconds. This was much less than what the team had expected, which was very positive. Lastly, Test 3 was set up to confirm the plastic strips were consistently made into filament with a diameter of 1.75 mm. A digital micrometer was to be used to take measurements in 10 cm length intervals. The team was looking for the filament to meet that 1.75 mm diameter mark with a deviation of .05 mm. Upon the conclusion of 5 separate trials, it was found that the filament-forming subsystem was able to produce filament at an average diameter of 1.478 mm with a deviation of .04 mm. All three of the tests performed for this subsystem proved to the team that the filament-forming subsystem was ready to be integrated with the rest of the Fil-A-Bot.

Test 1 (Holding Temperature)		
	Desired Temperature (C)	*Actual Temperature (C)*
Measurement 1	140	143.7
Measurement 2		141.1
Measurement 3		142.6
Measurement 4		143.5
Measurement 5		140.1
Average		142.2
Standard Dev.		1.56
Using heat sensor, confirm that the filament mechanism and heating mechanism gets up to the desired temperature of 140° C and can maintain that temperature. A digital laser temperature reader will be used to confirm. ***Temp. Range: 140 C ± 10***		

Test 2 (Getting To Temperature of 140 C)		
	Desired Time (Sec.)	*Actual Time (Sec.)*
Measurement 1	90	73
Measurement 2		64
Measurement 3		62
Measurement 4		65
Measurement 5		68
Average		66.4
Standard Dev.		4.27
Will analyze how fast it takes for the heating mechanism to get to the desired temperature of 200° C. The same laser temperature reader will be used as well as a timer. ***Time Range: < 90 sec ± 5 sec***		

Test 3 (Measuring Filament Diam.)		
	Desired Filament Diam. (mm)	*Actual Filament Diam. (mm)*
Measurement 1	1.75	1.71
Measurement 2		1.7
Measurement 3		1.76
Measurement 4		1.78
Measurement 5		1.79
Average		1.748
Standard Dev.		0.040
Confirm the plastic strips are consistently made to a diameter of 1.75 mm and how much can be made without stretching the material. A digital micrometer will be used to take measurements in 100 mm length intervals. ***Diameter Range: 1.75 mm ± .05mm***		

- ✅ Reaches Temperature of 140º C
- ✅ Within ± 10º C
- ✅ < 90 Sec. to reach 140º C
- ✅ Within ± 5 Sec.
- ✅ Diameter of 1.75mm achieved
- ✅ Consistent diameter ± .05 mm

Figure 6.8: Testing of Nozzle Heating, Time to Temperature, and Filament Diameter

Finally, preliminary calculations were made to find the amount of filament created by the Fil-A-Bot. The team found that this ultimately depends upon the amount of material that can be harvested from the recycled bottle and the size of the filament to be created. The typical 3D printer requires a filament diameter of ~1.75 mm [4]. Bottle cutting is initiated on the part of the bottle where the radius will remain constant for the majority of the cut. Your typical 2L soda bottle is ~300 mm tall, and the amount of that bottle that is suitable for cutting is ~ 250 mm once the skinner top and uneven bottom are removed. With a radius of ~60 mm, a surface area calculation allows an estimation of the length of the PET strip to be created.

$$Volume\ of\ 1\ mm\ Section\ of\ Filament\ =\ \pi hr^2 = \pi(1mm)(0.875mm)^2 = 2.405mm^3$$

$$Volume\ of\ PET\ Strip\ Needed\ to\ create\ 1mm\ Section\ of\ Filament\ =\ lwh\ = 2.5mm^3 \Rightarrow (1)(.5)(5) = 2.5mm^3$$

$$PET\ Strips\ =\ (2\pi rh_{bottle})/(2\pi rh_{strip})\ =\ \frac{[2\pi(60mm)(250mm)]}{[2\pi(60mm)(10mm)]}\ =\ 25\ Strips$$

$$Total\ Filament\ Length\ =\ (Strips)\ *\ (2\pi r)\ =\ (25)\ *\ [2\pi(60mm)]\ =\ 9.4\ m$$

This length of filament allows the user's most creative design to come to life in the 3D world. Typical commercial filament comes in spools of 300 m at a price upwards of $50.00. With just 30 bottles, this length of filament can be achieved, turning a worthless piece of plastic into $1.67 per bottle.

6.4 Filament Spooler

The main purpose of the filament spooler is to pull extruded filament from the outlet of the nozzle and effectively and efficiently store the filament around a compatible 3D printer spooler. From the customer needs and requirements, the team compiled a table to assess the different options for the Fil-A-Bot filament spooler. The team determined the filament spooler must have a constant spooling rate to ensure the filament is consistent and uniform. The spooler should also be compact and easily removable for the user. From the previously stated criteria, the three viable choices were an automatic spooler, a manual spool system, and a filament collection box (Figure 6.9).

Filament Spooler		**Choices**	
Selection Criteria	**Automatic Spooler**	**Manual Spool System**	**Filament Collection Box**
Low Power Consumption	0	1	0
Compact	1	0	-1
Efficient	1	-1	0
Safety	1	0	0
Accessible/Easy to use	1	0	0
Cost Effective	0	1	1
Durable	1	0	1
SUM	5	1	1
CONTINUE?	YES	NO	NO

Figure 6.9 - A decision matrix outlining the criteria for the filament spooling subsystem. This includes the automatic spooler, manual spool system, and filament collection box options and their respective performance in the selection criteria categories.

The automatic spooler would be connected to a power switch and would turn at a constant rate, continuously spooling the completed filament. The manual spooler system would be similar to the automatic spooler but, instead, would require the user to manually turn the spool using a handle crank. The advantage of the manual spool system is that the force produced would easily pull the filament through the nozzle. However, the customer's desire to have the Fil-A-Bot

be as close to autonomous as possible shifted the team's choice away from a manual spooling system. The manual spooling system also performs poorly in the efficient and accessible criteria categories and would likely make producing consistent filament geometry difficult. The final choice for the filament spooler was a filament collection box. This box would involve a type of pulling mechanism within the box to which the completed filament would either be stored loosely or around some sort of storage tool. The main issue with the filament collection box is that once the filament production process is complete for a bottle, removing the finished filament from the box would be challenging. The box would require an unnecessarily complex mechanism inside to compactly store the filament. The automatic spooler option accomplishes this task with ease due to the compact storage of the finished filament and the simplicity of the spool removal and replacement. The automatic spooler also outperforms the manual spooling system in the efficiency, safety, and accessibility criteria. When analyzing and assessing all of the filament spooler options, the team determined the automatic spooler was the clear favorite.
Once the automatic filament spooler was chosen, the team began to brainstorm ideas for how the automatic spooler would look. Through benchmarking of other similar filament recycling designs, the team determined that the most important philosophy was to avoid overcomplications. Therefore, the team decided it would be best to use one motor to produce the RPM value needed to extrude consistent filament and to 3D print the spool to have the most control of its geometry. The motor that was used for the spooler was rated at 7 RPM and was 12 volts and direct current, which complied with the team's power supplies. The spool was designed in Siemens NX and featured two clearance spots to allow for easy attachment to the motor casing as well as four notches on each side for the filament strand to latch onto for the start of the filament production process (Figure 6.10).

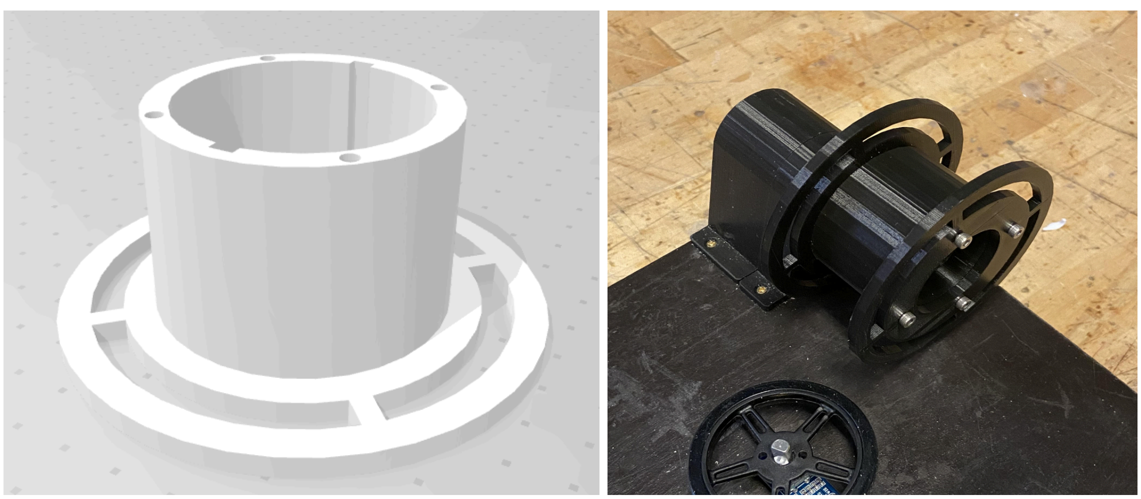

Figure 6.10 - (Left) An STL file of the spool created for the automatic spooling system. The four notches are on the side to attach the produced filament, and the two clearance gaps allow the spool to easily slide onto the motor casing. (Right) An image showing the printed spool attached to the motor casing.

The parts were 3D printed and assembled to ensure that the printed spool and the motor casing were compatible. The motor was then connected to the power supply to make sure the motor operated as intended, which it successfully did. After, the motor was placed into the 3D-printed holder, and the motor casing was attached. The holder was then screwed into the platform on the corner, and the spool was attached to the motor casing, completing the assembly.

6.5 *Filament Measurer*

One of the data points the group wanted to know, and something the customers found important, was the exact length of the filament that had been spooled by the Fil-a-Bot. This is important for 3D printing applications as when giving the printers a design, they will calculate an estimate of filament needed to be used to make the design. Using too little filament will cause the design to become ruined, as joining two separate filament strands together on the same project is inefficient, ineffective, and risky.

The team identified two prospective ways to achieve this. Option one was to record the rotation of the spooling motor, and increment up the length of the filament using that number, along with some supporting math to translate RPM to length of filament. Option two was to have a physical sensor that rotated when the filament moved across it, directly measuring it instead of indirectly calculating the length that had been created. The team decided to go with option two, as measuring the motor speed was indirectly measuring the filament, and if something was to go wrong, like the strand of filament breaking, option two would notice this, while option one would not. Thus, the team decided to pursue more physical sensors, and the clear cut answer was a rotation sensor with some sort of wheel attached.

Since the filament would always occupy roughly the same space, it would just be moving, any sort of velocity sensor would be ineffective, as it would never see an object move into and then out of frame; hence, the rotation sensor was necessary. To control it, an Arduino Uno was the obvious choice, due to its simplicity to operate along with how cost effective it was. And for displaying the final output, a seven-segment display was decided on, once again due to its cost effectiveness and its ease of use.

	Choices	
Evaluation Criteria	Practical Physical Sensors	Time Based Sensors
Low Power Consumption	1	1
Compact	1	1
Efficient	1	-1
Safety	1	1
Accessible/Easy to Use	1	0
Cost Effective	1	1
SUM	6	3
CONTINUE?	YES	NO

Figure 6.11 - The decision matrix used for the sensor for the filament measurer

6.6 Completion Alarm System

The overall function of the completion alarm system is to provide the user with a component that will alert the user when the filament cutting process is completed. This process is an important element to the overall system as it focuses on decreasing the amount of human interaction within the process as a whole while increasing the overall safety of the machine which is reflected below. (Figure 6.12). This user-friendly and seemingly necessary subsystem is one that many comparable competitive models lacked which makes this team's design unique and a touch more refined than others.

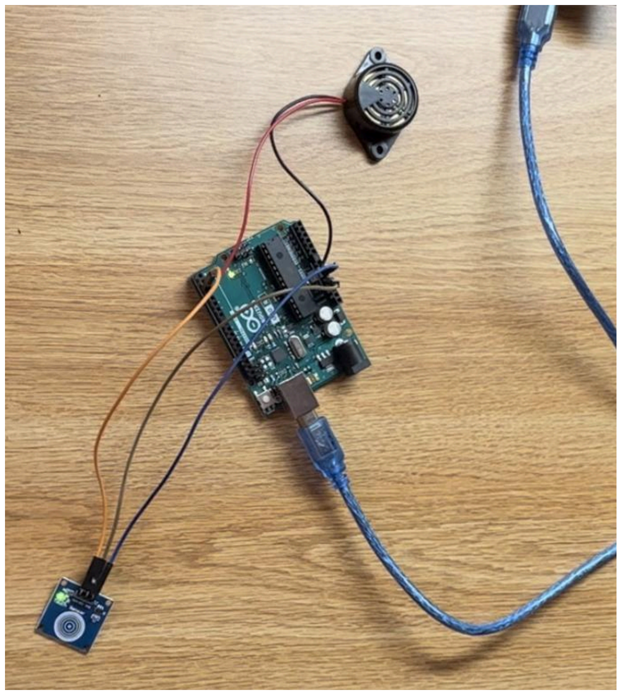

Figure 6.12 - Completed working subsystem. Shown in the picture is the sensor (bottom left), Arduino (middle) and buzzer (top right). The blue wire is connected to the power source

The functioning method is assembled so when the cutting process is nearing completion, and the two liter plastic bottle reaches the bottom of platform, the radius of the bottle will decrease due to the slim neck of the bottle at which stage the plastic will come in contact with the positioned touch sensor which is wired where a piezo buzzer (located in the proximity of the sensor) will sound a ninety decibel alarm to alert the user that the process has been completed and the device should be turned off. The assembly of this process involves three main components: arduino microcontroller, touch sensor, and a piezo buzzer and was constructed around the utilization of both wiring through the arduino and coding through the Arduino IDE software, which is shown below (Figure 6.13).

FULL_COMPLETION.ino

```
#define BUZZER_PIN 3 // Output pin for the piezo buzzer
#define TOUCH_SENSOR_PIN 2 // Input pin for the touch sensor

boolean isTriggered = false; // Flag to indicate if the touch sensor has been triggered
unsigned long startMillis; // Start time in milliseconds

void setup() {
  pinMode(BUZZER_PIN, OUTPUT); // Set the buzzer pin as an output
  pinMode(TOUCH_SENSOR_PIN, INPUT); // Set the touch sensor pin as an input
}

void loop() {
  if(digitalRead(TOUCH_SENSOR_PIN) == HIGH && !isTriggered) { // Check if the touch sensor is triggered
    isTriggered = true; // Set the triggered flag to true
    startMillis = millis(); // Set the start time
  }

  if(isTriggered && millis() - startMillis > 2000) { // Check if 2 seconds have passed
    digitalWrite(BUZZER_PIN, HIGH); // Turn on the buzzer
    delay(500); // Wait for half a second
    digitalWrite(BUZZER_PIN, LOW); // Turn off the buzzer
    isTriggered = false; // Reset the triggered flag
  }

  // Code to turn on the alarm for 1 seconds and then turn it off
  if (isTriggered && millis() - startMillis <= 1000) { // Check if 1 second has passed
    digitalWrite(BUZZER_PIN, HIGH); // Turn on the buzzer
  } else if (isTriggered) {
    digitalWrite(BUZZER_PIN, LOW); // Turn off the buzzer
  }
}
```

Figure 6.13 - A snippet of Arduino software code of buzzer activation

During the early stages of design, the decision between using a touch sensor versus a calculated time to sound the buzzer was heavily considered, however the calculated timer was dismissed due to potential inaccuracies caused by various factors regarding the process of starting the timer. The touch sensor was deemed the better choice, providing a more reliable and accurate method of detection. It was also easier to implement into the system as it required fewer dependencies on other subsystems. This overall decision is reflected below (Figure 6.14).

Selection Criteria	**With touch sensor**	**With calculated times**
Low Power Consumption	0	1
Compact	1	0
Efficient	1	0
Safety	0	1
Accessible/Easy to use	1	-1
Cost Effective	0	1
Durable	1	0
Total Score	4	2
CONTINUE?	YES	NO

Figure 6.14 - The decision matrix used for the sensor for the completion alarm

The way this subsystem's accuracy could be measured was through testing the touch sensor through a designated time interval to ensure that the device would shut off in a timely manner. This element was crucial for the device as without consistent and accurate results, the criteria of keeping this device safe would not be met. The testing of this subsystem involved setting parameters of a time interval of plus or minus three seconds, meaning the alarm would sound within three seconds of the plastic meeting the platform. While this time interval seems large, it's important to keep in mind that this machine as a whole is user operated and so this device does not turn off the machine itself, but rather alerts the user to turn off the device. The testing took three attempts finalizing the completion of the code and each attempt was incrementally more accurate than the rest until it was nearly perfect, meaning there was a time delay too small to calculate without human error affecting the result which is reflected below (Figure 6.15). The reasoning for this increase in accuracy could be influenced in the positioning of the sensor as after each attempt there was a clear area of the touch sensor that was more sensitive than the rest, and so small human interactions could have played a small part in the deviating results for each attempt.

	Delay Error (seconds)
Test 1	0.3
Test 2	0.25
Test 3	0 - No time delay
Overall	0.18 (avg)

Figure 6.15 - Testing data for the completion alarm system. As seen in the table, the average delay was 0.18s which was ideal

7 Results and Discussion

7.1 Results

Although the Fil-a-Bot was made up of six subsystems, all subsystems worked towards achieving one technical accomplishment, which was to produce unbroken flawless plastic filament with a diameter of 1.75 mm. This objective was met almost perfectly, as seen later, the filament ended up having an average diameter of 1.74mm, with a standard deviation within the desired error range.

Many tests were performed on all of the subsystems of the Fil-a-Bot. The first test done was a test on the initial bottle heater, making sure it got the bottle up to 120-130 C^o. It was also important to make sure the bottle rotated consistently and at a constant speed, to ensure that the entire bottle was heated evenly. For this test, the heating element was propped up and the bottle rotator was placed at varying distances away from it. The electronics were then powered, and the time it took for the bottle to reach the desired temperature was measured. From this test, it was found that the ideal distance between the heating element and the bottle should be no farther than 3/16 of an inch. Any farther than this would result in an extremely long time for the bottle to reach the desired temperature, with it taking 15 minutes or longer, which far exceeded the target specifications.

3/16 Inch Away (± 1/16)	
Test Number	**Time Until Deformed**
1	4:23
2	4:19
3	4:08
Average	4:16

Figure 7.1 - Bottle Heating Subsystem test data for a distance of 3/16 of an inch. The average time until deformation was within the target specifications

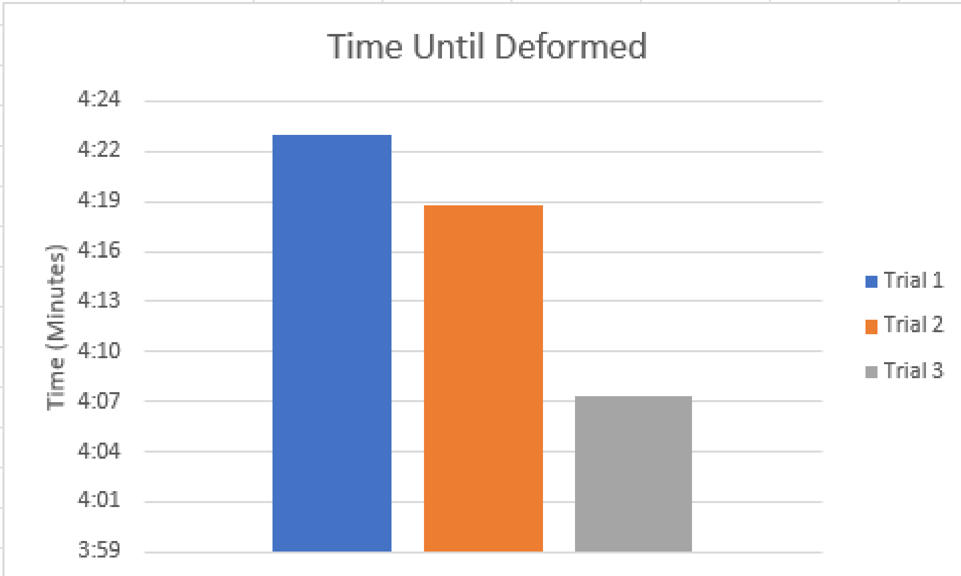

Figure 7.2: A diagram displaying the results of the bottle heating testing at a distance of 3/16 of an inch

The next subsystem tested was the bottle rotator and bottle cutter. The main goal of this subsystem was to ensure that the bottle would not fall over while rotating it and cutting it near the bottle. The desired result of this subsystem was to get a plastic strip that was 4-6 mm thick. As started earlier, it was unable to achieve this specific thickness, due to multiple factors. The blade was not precise or sharp enough, the bottle would end up slightly deformed on the bottom due to the human step of cutting the bottom, and the heat of the plastic would warp the bottle slightly. However, this subsystem did still create a plastic strip that would not break, so it was still successful in performing its designed goal. This device was tested by simply rotating the bottle over the blade and seeing the thickness of the plastic strip produced.

The Width of the Cut Strip	
Trial 1	10mm
Trial 2	7mm
Trial 3	5.5mm
Target: 4-6mm	

Figure 7.3 Bottle Cutter testing data for the width of cut strips

After the bottle cutter came the heating nozzle. The goal of the heating nozzle is to reach a temperature of 140 C° to heat up the plastic strip flowing through it. It does this to mold the plastic into the perfect cylinder shape that filament must be. This subsystem was able to perform its goal near perfectly, and was able to do it in the time designed for it to warm up(Figure 7.4). It was also able to actually experimentally reach and hold this temperature when controlled by its temperature control unit(Figure 7.5). This subsystem was tested by turning it on and reading its temperature with a temperature gun.

Test 1 (Holding Temperature)		
	Desired Temperature (C)	*Actual Temperature (C)*
Measurement 1	140	143.7
Measurement 2		141.1
Measurement 3		142.6
Measurement 4		143.5
Measurement 5		140.1
Average		142.2
Standard Dev.		1.56

Figure 7.4 Heating nozzle testing data for how consistently the nozzle could hold the desired temperature

Test 2 (Getting To Temperature of 140 C)		
	Desired Time (Sec.)	*Actual Time (Sec.)*
Measurement 1	90	73
Measurement 2		64
Measurement 3		62
Measurement 4		65
Measurement 5		68
Average		66.4
Standard Dev.		4.27

Figure 7.5 Heating nozzle testing data for how quickly the nozzle could reach the desired temperature

The third data point that had to be measured with the heating nozzle subsystem was the diameter of the formed plastic filament that is molding by the nozzle. This was measured by measuring the width of the plastic that was outputted by the nozzle, and was desired to be 1.75mm, especially since the width of the nozzle was 1.75mm.

Test 3 (Measuring Filament Diam.)		
	Desired Filament Diam. (mm)	*Actual Filament Diam. (mm)*
Measurement 1	1.75	1.71
Measurement 2		1.7
Measurement 3		1.76
Measurement 4		1.78
Measurement 5		1.79
Average		1.748
Standard Dev.		0.040

Figure 7.6 Heating nozzle testing data for the diameter of the filament the nozzle output

The spooling subsystem was responsible for pulling the plastic filament throughout the entire process. It did this by consistently spinning at a low RPM, which was found to be optimal at 5 RPM. This subsystem had no issues achieving this number or achieving it regularly, and the results of the tests performed on it can be seen below. The first test involved measuring the speed of rotation in RPM multiple times to ensure the motor was able to rotate at the target 5 RPM (Figure 7.7). The second test was measuring the speed of rotation over a prolonged period of time in intervals of 2 minutes to ensure it could achieve the consistency that the customers desired (Figure 7.8).

	Time for One Rotation (sec)	RPM
Trial 1	11.92	5.03
Trial 2	11.98	5.01
Trial 3	12.15	4.94
Trial 4	11.95	5.02
Trial 5	12.04	4.98
Average	12.01	5.00

Figure 7.7 Spooling testing data for the RPM of the spooler. There were five trials and the average RPM is highlighted in green.

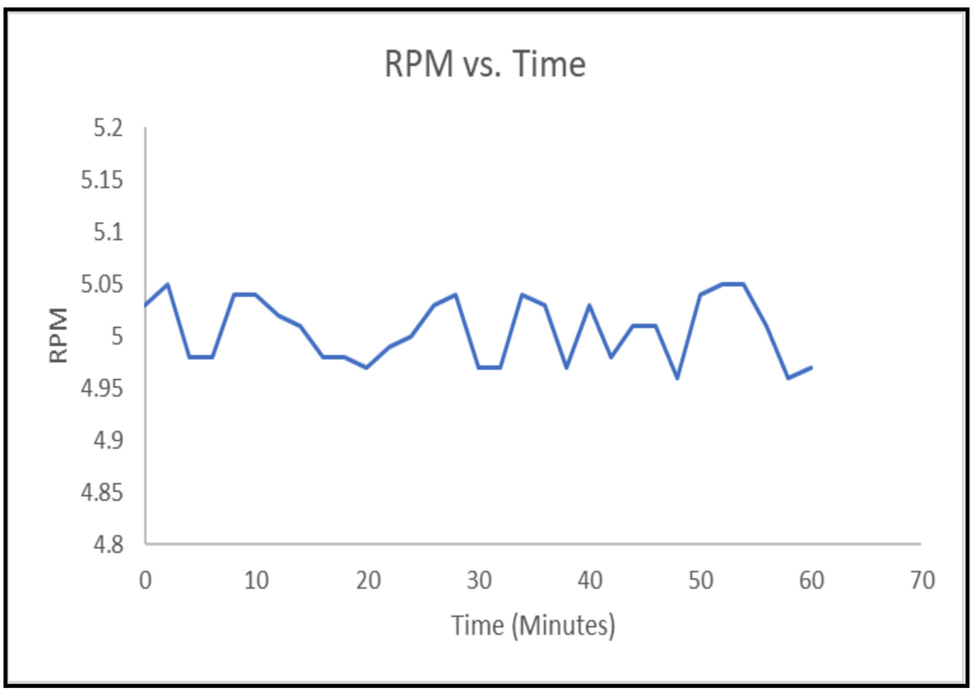

Figure 7.8 Spooling testing data for the second test. The RPM of the motor was measured every two minutes over a 60-minute period. No significant change in RPM was found over the 60-minute period.

Along the way, the plastic filament would roll across a wheel attached to a rotation sensor. This sensor would measure the amount of filament that had passed over it and display it on a separate display piece. The goal was for the sensor to always be within a 5% error of the actual length, which was achieved. This subsystem was tested by getting a strand of plastic with a predetermined and known length, rolling it across the rotation sensor, and calculating the percent error.

	Actual Value (cm)	Measured Value (cm)	Percent Error
Test 1	30.0	32	6.67%
Test 2	30.0	29	3.33%
Test 3	30.0	31	3.33%
Average	30.0	30.67	4.44%

Figure 7.8 Filament measuring testing data for the accuracy of the measurement of the subsystem

The final subsystem was the alarm subsystem. This subsystem would trigger an audio alarm when a bottle was finished being cut for plastic. It would know this because the bottle would slowly be cut down, eventually reaching the narrower neck part of the bottle, which would then touch the touch sensor hooked up to the alarm. This subsystem was tested by touching the touch sensor and ensuring that there was no delay between the touch and alarm.

	Delay Error (seconds)
Test 1	0.3
Test 2	0.25
Test 3	0 - No time delay
Overall	0.18 (avg)

Figure 7.9 Touch alarm testing data for the delay between the bottle finishing and the buzzer alerting

There were no planned tests that were not performed, nor were there any uncertainties. Some results in tests did not meet the exact values the team desired, but there were no failed tests, only tests that did not produce optimal results. Most of these suboptimal results originated from using suboptimal equipment or sensors, which mainly was due to budget constraints and a desire to be cost-effective.

Things that could be changed to enhance the Fil-A-Bot would be:

- Changing the frame and bottle heater on the heating element to metal
- Changing the aluminum on the heating element to thermal management gels

- Preform more robust tests, primarily surrounding the prolonged usage of the entire system

- Combining the bottle heating and bottle cutting subsystem to remove the need for the user to handle an extremely hot bottle

- Having a more precise blade to be able to produce plastic filament at the designed width

- Having more efficient power sources to not run across outage issues, and to only need one plug

- Investing in better sensors for the measurement and touch sensors, as they had to receive a lot of code to get them to work how desired

- Consolidating the alarm and measurement subsystem with one microcontroller

7.2 Significant Technical Accomplishments

During the course of the project, the team encountered several technical challenges that required the team to think creatively and work collaboratively in order to overcome them. One of the most significant challenges faced was the fact that many members had never worked in a machine shop before. This meant that some had to learn how to use tools like the drill press, band saw, and milling machines from scratch. Despite this initial learning curve, the team was able to adapt quickly and work together to create high-quality components for the machine.

Another significant challenge was that a lot of the parts had to be 3D printed, and for many members of the team, this was the first time they had ever worked with a 3D printer. Some members of the team had to learn how to design parts for 3D printing using CAD software, as well as troubleshoot any issues that arose during the printing process. With persistence and collaboration, the team was able to successfully print all the necessary parts for the machine using the Forge at RPI and their assistance.

Not everyone on the team was familiar with CAD software or had experience modeling subsystems and individual parts. This required knowledgeable members of the group to spend time teaching and helping others learn these skills. By working together and sharing knowledge, the team was able to design and model all the necessary components for the machine.

Wiring was a new skill some members of the team had to learn during this project, specifically learning how to deal with power transformers turning AC power into DC. This required research, reading technical manuals, and collaboration to understand how the wiring needed to be done. After many trial and error attempts, the team was able to properly wire the machine and ensure that it functioned safely and effectively.

Coding all of the electrical components was also new for a lot of the team. Arduinos operate using C++, a coding language that a few of the team members knew relatively well. With their assistance and the guidance of online resources and repositories, the team was able to write effective code for all necessary subsystems. This code worked seamlessly per demonstration.

Finally, learning how to safely and effectively heat a metal nozzle up to a potentially dangerous level posed a serious challenge for the team. This required a strong understanding of the properties of the materials worked with and lots of care during the heating process. The team researched the different types of metals that could be used for the nozzle and selected one that was both durable and safe to use at high temperatures. The team also had to learn how to properly install and maintain the heating elements to ensure that they were working correctly and that the nozzle was heating up to the desired temperature. In order to minimize the risk of injury, the team took a number of precautions during the heating process like ensuring adequate ventilation in the room.

In conclusion, Fil-A-Bot presented the team with several challenging technical elements that required adaptability, collaboration, and creativity. Through teamwork, communication, and a willingness to learn, the team was able to overcome these challenges and successfully complete the machine.

8 Conclusions

Overall, Fil-a-Bot was a success in meeting many of the initial customer requirements, and the subsystems were both designed as well as tested to ensure the product was safe, durable, and affordable. Each subsystem was designed and tested to fulfill their intended purposes with safety and simplicity for a wide range of users. The Fil-A-Bot isolated itself from previous other models by adapting to failures of competitive models, such as better temperature control through the use of a thermo-controller to control the temperature of the heating nozzle and an aluminum block to heat the PET strip. Although the team encountered initial difficulties in determining the project direction and deciding on what to create and various setbacks throughout the design process, such as the 3D printed parts being damaged by the intense heat from the bottle heater, the team was able to address these issues and develop a functional prototype. Despite the successful integration of the subsystems, the device's power supply was hindered during the overall testing phase, due to the team's limited budget, however, the prototype was still successful in serving as a base model and a strong starting point for future development. Overall, the Fil-A-Bot prototype has the potential to be a valuable tool in the 3D printing industry, and despite being just a small device, can be used as a base model to benefit the world and encourage earth preservation by offering a cost-effective and environmentally friendly alternative to traditional filament sources. With further testing, improvements, and a larger budget, the Fil-A-Bot could become a widely used product and a unique and beneficial addition to industrial consumer products.

9 References

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10 Appendix A: Selection of Team Project

10.1 *Concepts*

Prior to creating the project, the team first began by selecting the problem area it would work in. After much team discussion, the team was able to identify 3 project areas: Robotic Platform, Biometrics, and Reducing Plastic Waste. To further narrow down the scope of the project, Shown below is the decision matrix the team used to identify a problem area that would be solved with the project(Figure 10.1). While the team was interested in every problem area, Reducing Plastic Waste ended up being selected as it was the least difficult to build, was cost effective, and was identified as the safest project area to work in.

	Choices		
Evaluation Criteria	Robotic Platform	Biometrics	Reducing Plastic Waste
Build Difficulty	1	0	1
Team Interest	1	1	1
Cost	-1	1	1
Safety	0	-1	1
Sum	1	1	4
Continue?	NO	NO	YES

Figure 10.1: Problem Area Selection Matrix. This figure was created prior to the team starting work on Fil-A-Bot

After identifying the problem area the team wanted to work in, the next step was to create a solution to the problem. After doing market research, the team decided that the best way to solve a recycling related problem was from one of three ideas: creating 3D printer filament from plastic bottles, a smart recycling bin, and a trash organizer/sorter. The team then discussed potential pros and cons of each project and eventually each project was evaluated on certain sets of criteria. After evaluating all the ideas, it was decided that the team would continue with the idea of turning plastic bottles into 3D printer filament. The matrix created for this decision is shown below (Figure 10.2).

	Choices		
Evaluation Criteria	Turning Plastic Bottles into 3D Printer Filament	Smart Recycling Bin	Trash Organizer/Sorter
Build Difficulty	1	-1	0
Team Interest	1	0	0
Cost	0	0	-1
Safety	1	0	-1
Enough Subsystems	1	-1	-1
Sum	4	-2	-3
Continue?	YES	NO	NO

Figure 10.2: The concept selection matrix the team used to decide on how to solve a problem of reducing plastic waste

11 Appendix B: Customer Requirements and Technical Specifications

At the very beginning of the design process, after the team decided on the form the project would take, they interviewed customers that could be interested in a product such as Fil-A-Bot. These people included roommates, 3D printer enthusiasts, and a 3D printer filament company. All interviewees were asked what were some typical uses of a machine such as Fil-A-Bot, what they liked or disliked about machines currently available in the market, and if they had any improvements to current designs. The responses were consolidated into the table below (Figure 11.1).

Customer(s): Roommates, 3D Printer Enthusiast, 3D Printer Filament Company		
Question/Prompt	Customer Statement	Interpreted Need
Typical Uses	-Recycle water bottles -Make printer filament	-Able to recycle water bottles -Creates printer filament
Likes	-A fast machine -cheap and durable -Can be used for a long time -Easy to use and safe -If the machine could measure how much filament was made -The machine looks good -Can use different types of bottles	-The machine is efficient and quick -The machine can withstand years of usage, cost effective -Safe -Machine has measurement devices -Visually appealing -Adjustable input
Dislikes	-Manually spooling the filament -Long processes -The machine trips the circuit breaker -Takes up too much space	-Machine has to autonomously spool the filament -Quick/Efficient -Low power consumption -Small
Suggested Improvements		

Figure 11.1: A table displaying the customer's answers to interview questions, organized by question. The team then took the customers statements and turned them into interpreted needs

After conducting the interviews, the team then sorted the priority of each customer's needs into the table below. This would help the team later in the design process when prioritizing specific customer requirements. The table used for this process is listed below (Figure 11.2).

Customer Requirements		
High Priority	Medium Priority	Low Priority
[11.1] Low power consumption [11.2] The machine is able to produce filament efficiently and quickly [11.3] The machine is cost effective and can be used for a long time [11.4] Safe [11.5] The filament after being produced is already spooled [11.6] Adjustable bottle input holder to accept multiple kinds of bottles	[11.7] Connected network of sensors and display devices that measure plastic filament made [11.8] Alerts user when the process is done [11.9] Can reduce multiple bottles at once	[11.10] Able to fit on a shelf [11.11] Sends a text to my phone when the process is done [11.12] Visually appealing

Figure 11.2: A table ranking the importance of the interpreted requirements of the customer. This helped the team prioritize certain requirements over others

To help assign numerical values to customer requirements, the team created this technical specifications table. Each customer requirement from table 11.2 was assigned a metric to help measure and guide team success. The table used for this action is showcased below (Figure 11.3).

Technical Specifications		
High Priority	Medium Priority	Low Priority
[11.1] ≤24 V [11.2] <30 Minutes for completion, 40% of the bottle is used [11.3] <200$ [11.4] ≤150 C, <4 moving parts [11.5] Filament can be spooled 100% of the time [11.6] 100% of bottles fit the machine	[11.7] >2 displays and measurement devices [11.8] >40db noise is made after completion [11.9] >2 bottles can be used at once	[11.10] <1.5ft x 1.5 ft x 1.5 ft [11.11] <1 minute wait time between completion and text [11.12] >65% of people say that it is visually appealing

Figure 11.3: A table ranking the importance of the technical specifications of the interpreted customer needs. This helped the team prioritize certain aspects of Fil-A-Bot over others

12 Appendix C: Gantt Chart

Project Name	Status	Owner	Start	End
Milestone 1	100%	Desmond	2/6/2023	3/1/2023
Team Formation and Introductions	100%	Ethan	2/7/2023	2/10/2023
Problem Area Selection	100%	Kieran	2/10/2023	2/21/2023
Problem Area Solutions	100%	Sam Wu	2/10/2023	2/21/2023
Problem Generation	100%	Kieran	2/10/2023	2/21/2023
Benchmarking	100%	Desmond	2/10/2023	2/22/2023
Prototype Design	100%	Nicholas	2/14/2023	2/22/2023
Customer Solutions	100%	Sam S	2/14/2023	2/22/2023
Customer Needs	100%	Sam Wu	2/14/2023	2/23/2023
Quantified Tech Specs	100%	Sam S	2/14/2023	2/23/2023
Preliminary Sketches	100%	Desmond	2/14/2023	2/23/2023
Subsystem Selection	100%	Desmond	2/10/2023	2/23/2023
Subsystem Selection Matricies	100%	Ethan	2/14/2023	2/23/2023
Budget Breakdown	100%	Sam Wu	2/14/2023	2/23/2023
Information Presentation	100%	Kieran	2/14/2023	2/17/2023
Milestone 1 Presentation	100%	Ethan	2/18/2023	2/24/2023
Gantt Chart	100%	Sam S	2/7/2023	3/1/2023
Milestone 1 Memo	100%	Nicholas	2/10/2023	3/1/2023
	0%			
Milestone 2	100%	Ethan	3/2/2023	4/3/2023
Supply Purchasing	100%	Sam S	3/2/2023	3/13/2023
Subsystem Assembly	100%	Kieran	3/13/2023	3/27/2023
Prototyping	100%	Desmond	3/13/2023	3/20/2023
Testing	100%	Sam Wu	3/20/2023	3/27/2023
Connection Specifications	100%	Sam S	3/13/2023	3/31/2023
Complete Assembly	100%	Sam Wu	3/31/2023	4/3/2023
Testing	100%	Kieran	3/31/2023	4/3/2023
Milestone 2 Demonstration	100%	Nicholas	4/1/2023	4/3/2023
	0%			
Milestone 3	100%	Kieran	4/4/2023	4/25/2023
Peer Evaluations	100%	Kieran	4/19/2023	4/25/2023
Documentation	100%	Sam S	4/4/2023	4/25/2023
General Formation	100%	Nicholas	4/4/2023	4/25/2023
Presentation Construction	100%	Sam Wu	4/4/2023	4/14/2023
Presentation Practice	100%	Ethan	4/14/2023	4/18/2023
Milestone 3 Presentation	100%	Nicholas	4/18/2023	4/18/2023
Presentation to Memo	100%	Ethan	4/18/2023	4/25/2023
Formatting	100%	Sam Wu	4/21/2023	4/25/2023
Proofreading	100%	Sam S	4/21/2023	4/25/2023
Milestone 3 Final Memo	100%	Desmond	4/25/2023	4/25/2023

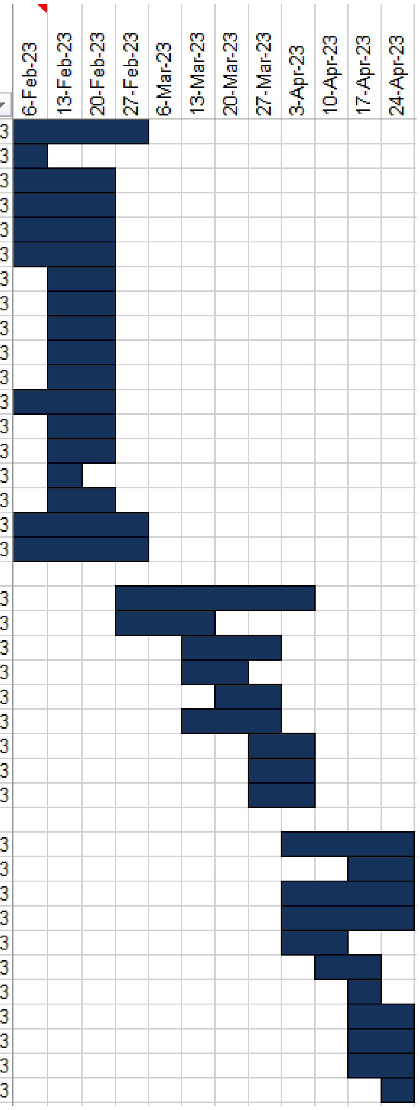

Figure 12.1: Encompassing Gantt Chart for all milestones of the project

The team used the Gantt chart somewhat. The fully completed Gantt, that is with project names, owners, and dates, has existed since before the first milestone 1 memo. The team normally did not follow the owners of the projects, as the owners appeared naturally, but did follow the dates of each project, making sure to get things done on time to allow enough time for the other aspects of the project.

13 Appendix D: Expense Report

The total cost of the project was $231. Many of the parts the team used for this project were the more affordable ones found on amazon, or 3D printed. With extra funding, the team could have purchased higher quality motors, power sources, sensors, or could have metal frames and gears. Truthfully, purchases like this may not affect the outcome of Fil-A-Bot, as filament was made with a low budget. However, the durability of higher quality parts would allow Fil-A-Bot to be used for a longer period of time.

Item	Quantity	Unit Price ($)	Subtotal ($)	Shipping ($)
Heating Element	1	10	10	0
15 RPM Motor	1	15	15	0
Heating Element Frame & Bottle Holder	1	8	8	0
Blade	1	1	1	0
Bottle Cutter Parts	1	7	7	0
Threaded Rod	1	23	23	0
Heating Components	1	6	6	0
Thermocontroller	1	14	14	0
5 RPM Motor	1	12	12	0
Arduino UNO	2	24	48	0
7 Segment Display	1	18	18	0
Rotation Sensor + Wheel	1	3	3	0
Piezo Buzzer	1	4	4	0
Touch Sensor	1	6	6	0
Power Supplies	1	36	36	0
Misc Hardware	1	20	20	0
Total	17		231	

Figure 13.1: A table outlining all project expenses. The grand total to create the Fil-A-Bot prototype was $231 Many parts were purchased via Amazon, or created via 3D printer

14 Appendix E: Team Members and Their Contributions

14.1 Team Member 1: Kieran Schuler

After the project brainstorming phase, I helped benchmark our design by researching similar DIY PET machines online and created the basics for the layout of our device, alongside Desmond. Once the subsystems were divided among the team members, I used available resources to develop an early design of the filament spooler and created many of the STL files for the miscellaneous aspects of the project. Throughout the whole design process, I often dictated team meetings and got all of the team members involved in the main focus of that specific meeting. I worked in the IED shop with all of the team members and often used the drill to tighten screws or drill holes in the platform for various subsystems, including mine. I worked closely with the entire team to ensure the success of each of our subsystems along with the entire device.

14.2 Team Member 2: Ethan Yuan

The subsystem I was in charge of was the Bottle Heating subsystem, and did all of the tasks necessary to make it work. I also helped the team understand the wiring on the filament heater. Alongside Kieran, I also helped attach the bottle holder’s motor to the base, and assisted Sam and Nicholas with attaching various components to Fil-A-Bot as well. For non-technical contributions, I was greatly involved with all forms of documentation, such as memos and presentations. I also presented a fair share of work as well. Lastly, I like to believe that my friendliness and efforts to bring the team together at the beginning of the project helped foster a strong team bond early on.

14.3 Team Member 3: Sam Wu

I was in charge of the bottle-cutting subsystem. I came up with the design of a bottle cutter, and gathered the materials that were used for it. With the help of Desmond, I attached the bottle cutter to the base. I also did my work as a group member in all kinds of group writings and presentations. Also, I assisted Desmond for the testing of the heating nozzle. Lastly, which I have to mention, thanks to all of my teammates who provided me with tremendous help and suggestions on my subsystem.

14.4 Team Member 4: Desmond Von Tobel

I was involved in various tasks such as building and laying out subsystems onto the foundation with Kieran, attaching all components to the base, ordering parts and assembling the filament-forming subsystem, wiring the heating components to the power adapters, and ensuring that the thermo-controller and heating nozzle were working through various tests for the filament-forming subsystem.

Apart from technical contributions, I was also involved in documenting the project, having contributed equally to the writing during all milestones. Furthermore, I was responsible for presenting the filament-forming subsystem as well as the customer requirements and technical specifications, demonstrating that I was involved in both the technical and communicative aspects of the project.

Overall, my contributions to the project were diverse and essential, showcasing my understanding of both the technical and practical aspects of machine design and construction process.

14.5 Team Member 5: Sam Slane

Coming into this class, and into the main project, I was worried about how much I would be able to contribute. I do not know many handsy skills, and really have only tinkered with circuits before. Luckily, our subsystems had a lot of involvement with electronics, and my subsystem was entirely electronics.

I would say my main contribution would be helping the others figure out how to connect their electrical components together. I figured out how to get our power systems working, along with how to correctly connect them to people's motors or heating elements. I was also helpful with providing feedback to the rest of the team, along with procuring the final foundation that every subsystem would drill into, which I found in my house's woodshed.

14.6 Team Member 6: Nicholas Walker

I was involved in the design of the completion alarm system and ensuring that it would work effectively with the rest of the design. My subsystem was specifically dependent on the success of the product as a whole, so I had to work closely with the team, specifically Sam Wu, and figure out how my contributed subsystem.

With a team of nearly all mechanical engineering majors (including myself), and the subsystem that I was in charge of had a central focus on electrical engineering and computer science with its required wiring and coding. Completing this subsystem allowed me to learn and create the code needed for my subsystem as well as integrate my subsystem with the rest of the team's designs.

15 Appendix F: Statement of Work

Statement of Work - Fil A Bot

Team
Nicholas W, Kieran S, Desmond T, Sam S, Sam W, Ethan Y

Semester Objectives
1. Design and build a working device
2. Perform engineering analyses and tests to guide design of a superior design to benchmarked products
3. Design and construct a device that efficiently turns plastic bottles into 3D printer filament
4. Generalize the basic design to work for others who face similar challenges
5. Research and evaluate advanced solutions involving automation and sensor implementation

Approach
Create a prototype of a machine that is able to turn a plastic water bottle into 3D printer filament. Test the project throughout the entire design process and make changes as necessary.

Deliverables and Dates
1. Milestone One: System Concepts (2/23)
    a. Memo & Presentation
2. Milestone Two: Informal Subsystem Demos (3/30)
3. Milestone Three: Final Presentation and Memo (4/20)

16 Appendix G: Professional Development - Lessons Learned

For professional development and teamwork, the team had major takeaways from this project. MBTI and giving/receiving feedback were one of the most important lessons from the project. Understanding and utilizing MBTI were one of the ways team members were able to foster a welcoming and collaborative work environment. Throughout the project, team members also had to effectively give and receive feedback either on work ethic, their subsystems, or on peer-peer relationships. Mastering this skill enabled the team and individuals to work more effectively towards their goals and was one of the reasons Fil-A-Bot was successful. General conflict management skills were also beneficial to the overall team dynamic, as knowing how to handle different types of conflicts allowed the team to maintain a good relationship.

For project planning, one of the most valuable lessons the team learned was staying flexible. Oftentimes, shipments became delayed, or progress was not being made as expected. Staying flexible allowed the team to focus on other tasks when certain goals had to be shifted by a couple of days. The importance of pre-design work was also learned through this experience due to the large scope of the project. Working through the product planning steps, identifying customer needs, and going through multiple design iterations helped the team create a successful prototype. For the subsystems, testing was not as robust as it could have been, and if the team were to do another project, increased testing robustness would be included.

17 Appendix H: Software / Technology Used

17.1 Collaboration Among Team Members

- Webex
- Google Drive
- Phone SMS Group Chat

17.2 Subsystem Design

- Siemens NX
- Desmos Graphing Calculator

17.3 Programming

- Arduino IDE
- PyCharm

17.4 Subsystem Testing/Simulation/Emulation

- Siemens NX
- Arduino IDE
- Diligent Waveforms
- Laser Temperature Reader
- iPhone Camera

18 Appendix I: User Manual

Safety Warning: This machine has multiple elements that could be dangerous without proper knowledge of the operation. Keep this machine away from children aged 0-12, and read all safety warnings and the complete user manual to make sure this machine is operated safely and correctly.

To operate the Fil-a-Bot, two things are needed: an empty, cleaned, 2L bottle and access to two electrical outlets. The outlets must be close to the standard 120 AC volts; any value much higher or lower than that will cause unpredictable behavior with the transformers provided by the machine.

Safety Warning: Many parts on the Fil-a-Bot will exceed 100 C^{o}, be careful touching any of the parts that heat up. This includes the initial bottle heater, which is a large rectangular heater, and the forming nozzle, which is the small triangular prism-shaped former placed in the center of the machine.

Safety Warning: There is a blade on the Fil-a-Bot that has the potential to harm the user if used inappropriately. The blade is encased in plastic, so unless the machine is modified, it should be hard for users to hurt themselves with the blade.

Before plugging the Fil-a-Bot in, place the bottle on the bottle holder and heater. To identify the bottle holder, there is a circle that has multiple holes in the bottle that a normal 2L bottle will fit into, along with a large rectangular heating device. Make sure all paper labels are off of the bottle, along with scrubbing off as much adhesive as possible before using the 2L bottle. Once the bottle is in place, turn the machine on. Once powered, multiple motors will start to spin, along with multiple heating elements heating up. After the bottle has been secured, and the machine has been powered, a wait of ten minutes is necessary to ensure the bottle reaches the correct temperature.

Safety Warning: At this point in time, the bottle will heat up, exceeding 100 C^{o} in temperature, making most parts of it dangerous to touch. Once the machine is turned on, do not touch any part of the bottle other than the top cap area.

After ten minutes of waiting, carefully grab the bottle by its top, preferably by the cap. The bottom foundation part of the bottle must be cut off manually by the user at this point to put the bottle on the next process in the Fil-a-Bot. The machine does not provide any way to do this, but the recommended way to do it is to put the bottle cap up on some sort of temperature-friendly surface. Most 2L bottles come with a small visible line where the bottom of the bottle meets with the rest of the bottle. Cutting there with some sort of sharp knife, like an exact-o knife, is perfect to separate the bottom of the bottle.

Once the bottom has been cut off, unscrew the cap off the bottle, grab it by its highest point, and put it on the next part of the process. It will be clear the bottle is in the right place when the outside border of the bottle fits into the small space in the plastic where the blade is exposed. The bottle will start to rotate, and a small plastic strip will start to get cut from the bottle.

Safety Warning: This next segment includes manipulating potentially hot plastic and pushing it through the heating nozzle. Take caution to not burn your hands on any part of the Fil-a-bot during the process by following the user manual exactly.

The plastic strip should be safe to touch after getting cut and gaining some distance from the bottle due to its small size and large surface area. Grab the plastic strip and slowly pull so as to not break it off from the bottle, and push it into the heating nozzle. Continue to push it in until the correctly formed plastic filament starts to come out on the other side of the nozzle. Once plastic starts coming out the other side, start pulling the correctly formed plastic, instead of pushing in the plastic strip, to ensure that the plastic will not tear or break in any spot. This formed filament will be hot until it cools down, so gently using a pair of pliers or other such heat protection, such as wearing heat-resistant gloves, is recommended. Slowly pull this filament down the length of the Fil-a-bot, across the wheel attached to the sensor, all the way to the spool at the end of the machine. On the side of the spool there is a notch that the filament can be wrapped around. Once this has been done, the user interaction with the Fil-a-bot is finished.

Other features that the Fil-a-Bot offers are the filament measurement display and the alarm system. The display system simply displays the length, in centimeters, of the filament that has been produced. The alarm system sets off a buzzer once the bottle has finished being cut, and a new bottle is ready to be used to restart the entire process. In between bottles, the current spool of filament should be removed, and a new spool should be installed.