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Grater-Inator

Automated Cheese Grater

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ABSTRACT

Turning a hand tool into a power tool is the quintessential efficiency upgrade. Grating cheese manually is time consuming and physically demanding, especially in a restaurant setting like Olive Garden. This report details the design and creation of a proof-of-concept for a fully automatic cheese grater. This was done by investigating similar products and alternatives to chosen design criteria. Input from current Olive Garden employees was gathered to direct the team in its investigation of critical design elements. The central design mates the currently-in-use manual cheese grater to an accompanying 3D printed chassis to create a power-assist system that handles the rotation of the drum and the pressure necessary to compress the cheese. The proposed design meets defined criteria and increases convenience for users. Moreover, ergonomic considerations such as ambidextrous grip design and intuitive controls promote user comfort and ease of use. The resulting power tool makes the job of grating cheese more efficient, ergonomic, and fun for the end user.

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1 INTRODUCTION

Olive Garden Italian Restaurant is a subsidiary of Darden Restaurants, Inc. Darden is comprised of multiple subsidiary companies that amount to over 1,900 restaurants. Of these 1,900 restaurants, there are over 900 owned and operated Olive Garden restaurants in North America [1]. Patrons stepping foot into an Olive Garden for the first time immediately sense three core inspirations: Italy, family, and value. Along with inspiration comes a purpose: "To delight everyone we serve with our spirit of Italian generosity." The execution of this purpose routinely falls on the servers who so graciously wait on patrons' wants and needs. One of these wants and needs is cheese! "Would you like cheese on that?" is a phrase uttered hundreds of times a day throughout the hallowed Olive Garden dining rooms of the world. The machine responsible for delivering the cheese we all desire is the standard Olive Garden cheese grater. This manually operated grater has been a primary tool used by servers for years. Here lies the need for improvement. Convenience and efficiency headline the effort to provide a better option for Olive Garden servers who prioritize speed and accuracy. This report will detail the elaborate design considerations for an electric cheese grater, engineering principles explored, ergonomic factors, and user suggested criteria. Various aspects of cheese grater design will be examined including safety features and ease of maintenance. In addition, opportunities for innovation and improvement will be investigated to provide future iterations of the project with a path forward.

1.1 RELEVANT BACKGROUND

Cheese is a dairy byproduct that is created through various methods to achieve hundreds of types of often shelf stable food product that is consumed all over the world. It is one of the oldest foods that arose from the time when ancient humans started to keep livestock animals and figured out how to make the milk harvested from mammals keep for longer periods of time [2]. Cured cheese can be very tough and hard when ready to consume. This characteristic necessitated the invention of tools, cheese tools. Romano cheese is a hard cheese variety that can be made from cow's, goat's, or sheep's milk [3]. Each variety has a name, and the type used at Olive Garden is a blend of sheep's and cow's milk-derived Romano. While the blend of cheese is not technically considered Pecorino Romano Figure 1, this variety was considered for all cheese related data acquired for this project because it is the closest variety that there is data available on and one of the most common hard cheese varieties consumed [2].

Figure 1: Pecorino Romano Cheese

Various tools have been invented through the millennia that are used to break down large portions of cured cheese into smaller, more manageable portions for cooking or otherwise consuming. Getting cheese into small shavings was in antiquity a way to conserve resources and a mechanism for dispersing the cheese into whatever they were cooking at the time. Graters have been a staple in kitchens for over 1000 years and are used to break all manner of foods down into long shreds or thin slices. The holes in the metal surface dictate the shape of the product and have sharpened edges so that they efficiently cut through food matter with no more than hand pressure Figure 4 [4]. Until the 20th century, there were no mechanical means to grate food [5]. Once electric powered kitchen tools became available, electric graters of all types, shapes, and capabilities made grating cheese and other foods effortless. Food processors Figure 2, stand mixers, and even stand-alone hand cranked graters all work by virtually the same method: a rotating metallic drum with holes punched or cut in it is driven and food is forced against it cutting the food into small shreds or ribbons.

Figure 2: Zyliss Cheese Grater

Figure 3: Robot Coupe Food Processor: A Restaurant Industry Staple

Figure 4: Antique Cheese Graters

Olive Garden Italian Restaurant Figure 5 is a corporately owned restaurant chain owned by Darden Restaurants Inc. It is one of the most popular and most successful casual dining concepts of the last 30 years [6]. A big draw, representing a generous portion of items ordered at the restaurant is the All You Can Eat: Soup, Salad, and Breadsticks. To this day it is one of the most cost-effective items available at Olive Garden (currently $9.49 from open till 4:00 p.m., locally). Part of the experience while dining at any Olive Garden is that the server will offer you fresh grated cheese on your food. The kind of cheese used at Olive Garden to grate tableside is the Romano variety [1].

Figure 5: An Olive Garden Restaurant

1.2 STATEMENT OF PROBLEM

Servers have a difficult job that is physically and mentally demanding. Servers work at the behest of their tables and the people sitting at them. Speed and accuracy are two of the most important qualities of the work a server does [1]. At Olive Garden, servers grate cheese by hand, and it can get difficult and tiring for the hands when a guest requests a lot. Employee retention at any restaurant is a major problem due to the nature of the work, the variability in pay, and the availability of capable people who can physically perform the work activities [7]. Retaining more employees or opening new employee possibilities by making aspects of the job easier for less dexterous people would be beneficial to the company overall (Appendix F).

Furthermore, easy of attachment and detachment of the manual grater from the designed device is paramount so that the cheese grater can be placed in an industrial dishwasher and cleaned/sanitized according to Indiana Health Code and ISO food safety standards [8].

1.3 DELIVERABLES

The deliverables for this project are the following:

- Functional automated cheese grater
- Ambidextrously used
- Single-handed use
- Battery powered

This project will be fully functional upon completion and be tested in Olive Garden shown in Figure 6.

Figure 6: Full Assembly

2 EXISTING SOLUTIONS

There are several existing solutions to the problem of making cheese grating easier and more efficient for servers at Olive Garden. Those include the currently in use manual Zyliss brand cheese graters shown in Figure 7. There are automatic cheese graters available from retailers such as Amazon, Temu, and Ali Express. These existing cheese grater options are the closest available options that operationally accomplish the same thing. They, however, do not do so 100% automatically. The various solutions evaluated and compared are detailed below.

Figure 7: Zyliss Manual Cheese Grater

2.1 MANUAL ZYLISS CHEESE GRATER

A rotary cheese grater available from Swiss manufacturer Zyliss is currently in use at Olive Garden. This current cheese grater is a well-liked and established tool that achieves its goal of being efficient, reliable, easy to use, and inexpensive available commercially for about $22.95 [9].

2.2 SEMI-AUTOMATIC CHEESE GRATERS

Several semi-automatic cheese graters are available from online retailers such as Amazon and eBay as shown in Figures 8 & 9. These almost automatic units all follow a similar form of manual cheese graters in that the user must manually compress the cheese against a rolling drum with holes in it. In the case of the automatic version, an electric motor is mounted parallel to the axis of rotation of the grating drum. The motor is connected to the drum via a plastic gearbox system to obtain the necessary speed to turn the drum. There is still a common manual component to these designs in that the user still needs to compress the cheese against the moving wheel by hand. The two evaluated in this report were the Cushore cheese grater priced at $39.99 and another simply labeled Electric Cheese Grater priced at $34.99 [9]. They both shared the same design form and even shared the exact same type of battery and charger.

Figure 8: Semi-Automatic Cheese Grater

Figure 9: Semi-Automatic Cheese Grater

2.3 BUDGET

The initial budget we composed in the spring semester can be seen in Table 1. The initial budget for the Grater-Inator project totals $179.84 and covers all essential components and materials needed for its design and construction. Efforts were made to balance affordability with quality by sourcing materials from both online platforms and local secondhand markets. The 3D printing filament, including PLA, PETG, and TPU, was acquired from Amazon to meet the structural and functional requirements of the design. Heat set inserts and hardware were also purchased from Amazon to ensure durable threaded connections for assembling the 3D-printed components. A secondhand cordless brushless electric drill, purchased from a pawn shop, served as a cost-effective solution for powering the device.

Additional critical components included replacement angle grinder gears, sourced from Amazon, which were utilized for reliable mechanical transmission, and a Zyliss cheese grater repurposed from Olive Garden to provide the primary grating functionality. The precision and reliability of the linear motion system were ensured by a T5 trapezoidal leadscrew and brass nut and two linear rails, both sourced from Amazon. Each item in the budget was selected for its specific role in achieving the project's functionality and performance goals while adhering to cost constraints. This budget demonstrates a thoughtful approach to material selection, combining affordability with practicality to meet the objectives of the Grater-Inator project.

Table 1: Initial Budget

	Item	**Cost**
1	3D Printing Filament (PLA, PETG, TPU, etc)(Amazon)	$20.00
2	Heatset inserts/hardware (Amazon)	$45.00
3	Cordless Brushless Electric Drill (Used/Pawn Shop)	$36.00
4	Replacement Angle Grinder Gears (Amazon)	$10.00
5	Zyliss Cheese Grater (Olive Garden)	$14.99
6	T5 trapezoidal leadscrew and brass nut - 100mm length (Amazon)	$32.55
7	9mm width x 100 mm length Linear rail (x2) (Amazon)	$10.65
Total		$179.84

The final budget for the Grater-Inator project which can be seen in Table 2 amounts to $260, reflecting the expanded scope and refinement of the design. Each item was carefully selected to enhance the performance, durability, and functionality of the device while maintaining cost-effectiveness. Three kilograms of 3D printing filament were acquired, providing sufficient material to fabricate the intricate components required for the project. Heat set inserts and hardware, ensured secure and reliable assembly of the 3D-printed parts. A cordless brushless electric drill served as a cost-efficient and robust power source for the system.

Key mechanical components included a pair of bevel gears for efficient torque transmission and a Zyliss cheese grater, which was repurposed to fulfill the primary grating function. To support smooth and precise linear motion, two linear rails with carriers were obtained, while a leadscrew and two leadscrew nuts, purchased for each, provided stability and accuracy in the system's movement. Additional functional enhancements were achieved with a hex shaft and a thrust bearing, both integral to the machine's operation.

This comprehensive budget highlights the thoughtful integration of essential components to meet the Grater-Inator's design and operational requirements. The allocation of resources demonstrates a commitment to optimizing performance while adhering to financial constraints, ensuring the project's successful completion.

Table 2: Final Budget

	Item	**Cost**
1	3D Printing Filament (1kg) (x3)	$40.00
2	Heat set inserts/hardware	$45.00
3	Cordless Brushless Electric Drill	$36.00
4	Bevel Gear (x2)	$20.00
5	Zyliss Cheese Grater	$21.00
6	Linear Rail and Carrier (x2)	$20.00
7	Leadscrew	$28.00
8	Leadscrew Nut (x2)	$28.00
9	Hex Shaft	$20.00
10	Thrust Bearing	$2.00
Total		$260.00

2.4 SCHEDULING

The proposed schedule for designing and completing this project is outlined in Table 3. This schedule was largely adhered to. The design presentation review took place on Thursday, November 2nd. Construction began over the summer after the ordered components were delivered. The first major milestone was completing the 3D-printed body, which required the most time. Once the body was nearly finished, component integration commenced. Afterward, the required parts were machined, and the electrical system was rearranged shortly thereafter. The schedule in Table 3 played a crucial role in keeping the team focused and organized throughout the project.

Table 3: Project Schedule

Date	**Task**
First Semester, 2024	
Monday, January 8th	First Day of Class
Wednesday, February 14th	First Conceptual Senior Design Report
Wednesday, March 13th	First Senior Design Report Draft
Wednesday, April 3rd	Second Senior Design Report Draft
Wednesday, May 1st	Oral Presentation of Projects
Wednesday, May 1st	Final Senior Design Report
End of Semester	Order Parts need for Prototype
Over the Summer	Start Constructing the Prototype
Second Semester, 2024	
Wednesday August 21st	First Day of Class
Monday, August 26th	Adjust 3D Printed Parts
Tuesday, September 10th	Machine Parts

Thursday, September 26th	Extend Drill Wiring
Wednesday, October 16th	First Test Run
Friday, November 1st	Fix Failures in the Prototype
Friday, November 8th	Design Presentation Review
Friday, November 15th	Draft Report to Advisor
Friday, November 15th	Project Poster
Monday, November 18th	Run a Speed Test
Monday, November 25th	Collect Data
Thursday, December 5th	Final Presentation
Thursday, December 5th	Final Report to Advisors
Thursday, December 5th	Final Report Submitted to SOAR

3 DESIGN

The Grater-Inator is similar in form factor to a cordless power drill. It employs a 3D-printed plastic body that the Zyliss manual cheese grater mates to via the internal threads of the grating drum. The body holds a brushless DC motor repurposed from a used Dewalt DCD777 drill driver, and it's integrated double reduction planetary gearbox. This motor is powered by the lithium-ion battery pack that came with the drill. The motor functions are controlled by the integrated trigger mechanism that includes all relevant electronics to control the motor and get it to interface with the battery. The system hierarchy is shown in Figure 10 below.

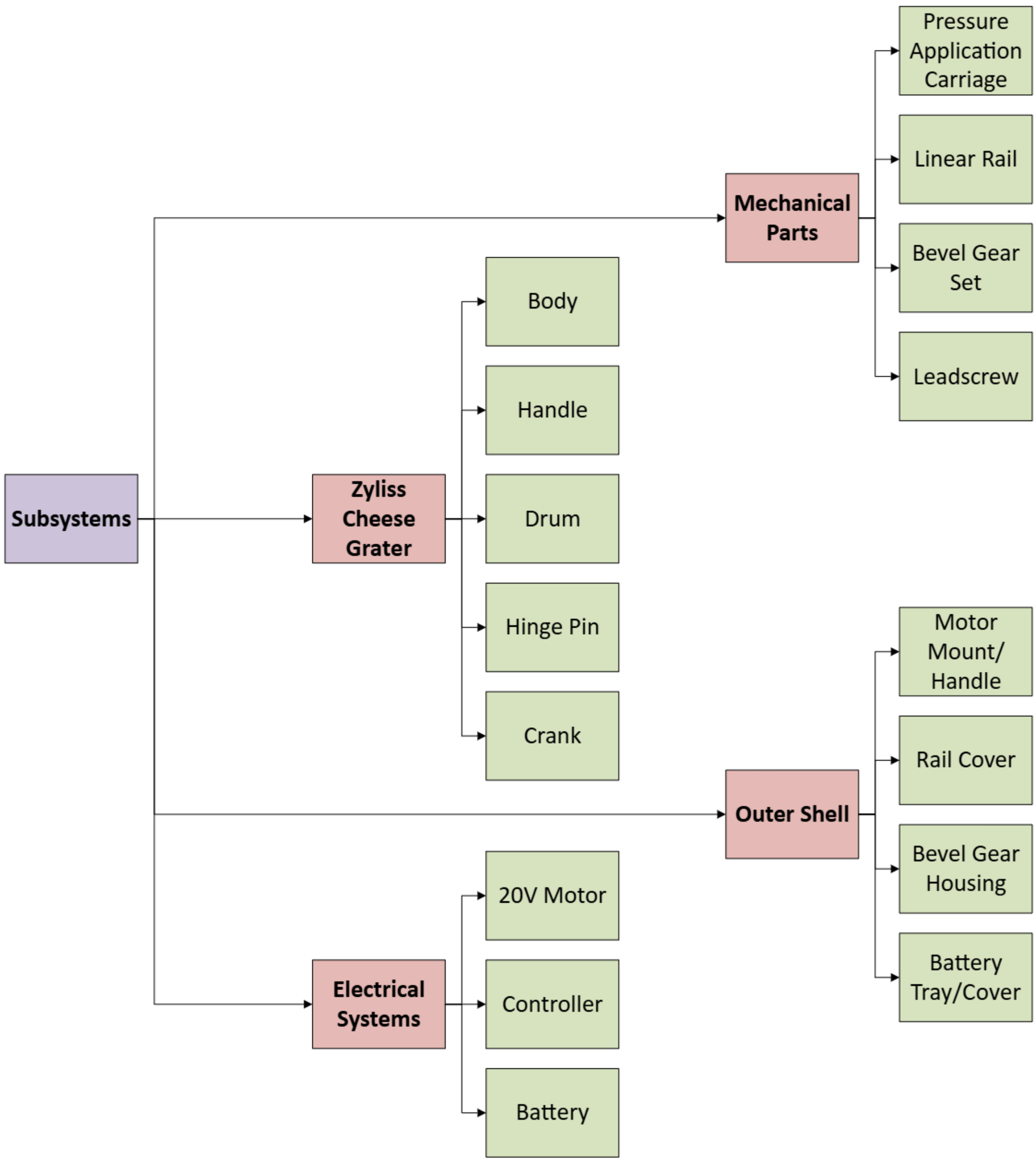

Figure 10: Subsystem Hierarchy

The design was optimized to continually utilize the end-goal of ergonomics and ease of use. Special consideration was given to current Olive Garden service standards that require servers to lean out over a guest's table to grate cheese in front of them. This leaning action can lead to maneuvers that while not outside the recommended reach standards established by the

NIOSH lift equation can contribute to unnecessary strain [10]. Therefore, extending the reach of the device beyond that of the current solution would lessen the potential strain associated with leaning and grating cheese manually.

4 OUTER SHELL DEFINITION

The outer shell component of this project refers to the 3D printed body of the cheese grater shown in Figure 11. The outer shell is responsible for housing the pressure application carriage, leadscrew, linear rails, bevel gear hub, brushless drill motor, controller, switch, and trigger. This outer shell allows for the grater's driving components to be housed separately from the grating mechanism that encounters the cheese.

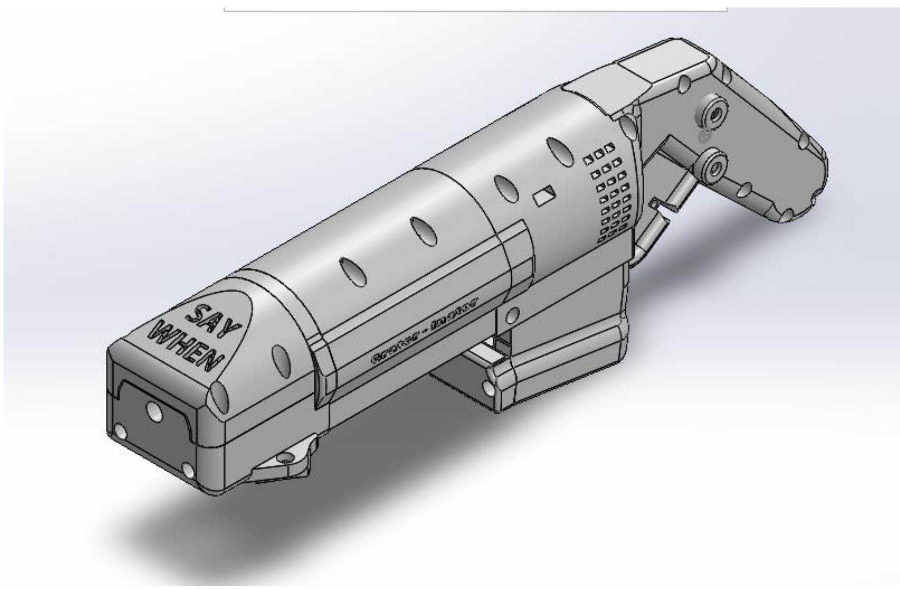

Figure 11: Outer Shell (Body)

4.1 3D PRINTING BACKGROUND

3D printing is a method of manufacturing where a part is created via addition of material rather than traditional subtractive manufacturing where a part is created by removing the material that is not needed until the part has the desired geometry. There are many different types of 3D printing such as FDM (Fused Deposition Modeling), SLS (Selective Laser Sintering), SLA (Stereolithography), to name a few [11]. The materials used in each type of printing vary but are usually polymers that are either made into liquid and then cured in the desired shape or are formed permanently into their desired shape via some sort of additional heat treatment process.

FDM printing is the most commercially available and affordable option for creating prototypes and will be used extensively for this project shown in Figure 12.

Figure 12: 3D Printing Plastic Filament

The static structures of the Grater-Inator will be constructed through FDM 3D printing from the machine shown in Figure 13. The main material for this will be polylactic acid (PLA) plastic in Figure 11, which is inexpensive ($15-25 per kg). PLA was chosen because of the cost but also because it has good stiffness and is easy to print with few complications.

Figure 13: FDM 3D Printer

4.2 MOTOR MOUNT AND HANDLE

The heart of the system is where the sourced components that drive everything else will reside. The motor mount and handle house the electric motor, the control components associated with that motor and serve as the main mount point for the battery mount shown in Figure 14.

Figure 14: Handle & Motor Mount

4.3 BATTERY MOUNT

The mount for the battery was reverse engineered from the drill shell to interface with all the standard size Dewalt 20V batteries. The mount has provisions so the battery leads that came from the drill could be repositioned and mesh nicely with the battery. This is shown in Figures 15 & 16.

Figure 15: Battery Mount and Battery

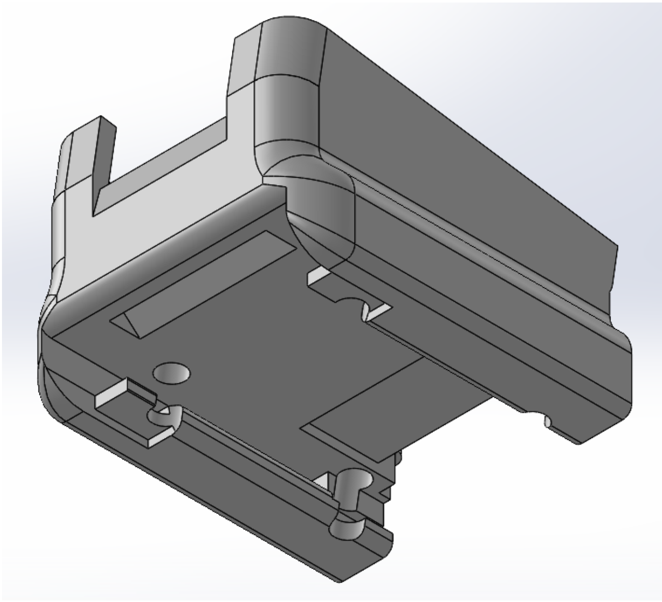

Figure 16: Battery Mount

4.4 RAIL COVER

The mid-section of the Grater-Inator serves as both a way to safely house the pressure application carriage and leadscrew and serve as a mount point for the linear guide rails that keep the pressure application carriage in line and reliably moving through its range of motion. The rails present a pinch point which would be potentially hazardous to the operator. Both are shown in Figures 17 & 18.

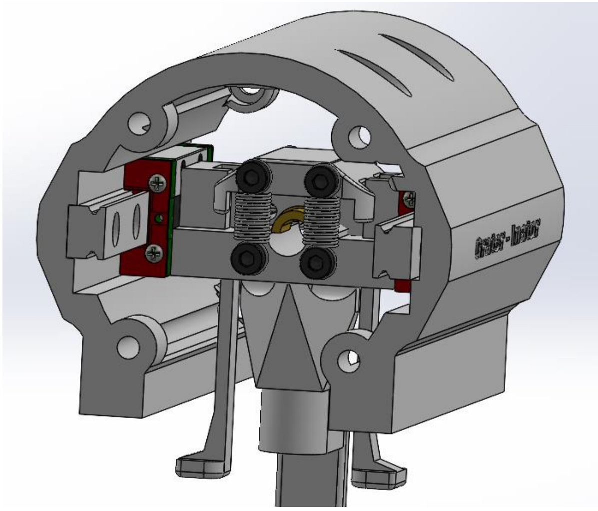

Figure 17: Rail Cover Front View

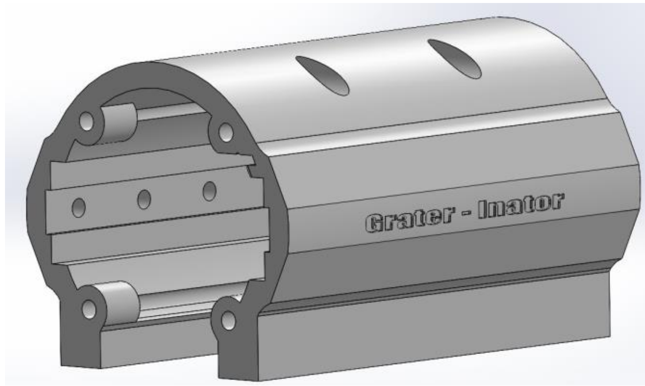

Figure 18: Rail Cover

4.5 GRATER MOUNT/BEVEL GEAR HOUSING

The section of the Grater-Inator that was developed first in the design process was the piece that was to mate to the existing Zyliss cheese grater and act as both a mount point and a power transmission point, shown in Figure 19. This piece went through the most iterations as the design was modified and updated.

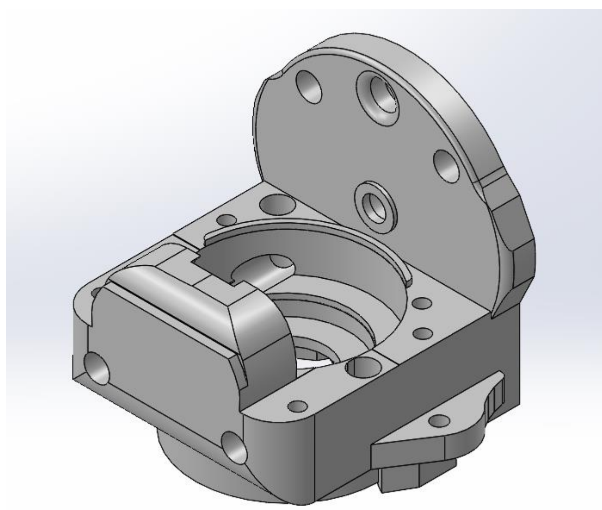

Figure 19: Grater Mount V6.5

Many iterations were designed and printed as the design evolved. As each design was tried, new deficiencies were discovered, redesigns occurred, and subsequently printed and tried. The process was repeated many times for each 3D printed component until that component served its purpose and functioned as intended. Figure 20 shows the many parts printed to achieve the current model.

Figure 20: Final Grater-Inator Design surrounded by all its previously iterated parts

5 ELECTRICAL SYSTEMS

The electrical systems component of this project is what drives and controls the speed at which cheese is grated. The systems include the brushless drill motor, controller, switch, battery pack, and LED light. All electrical components are repurposed and customized from existing electronics sourced from a Dewalt DCD777 drill driver.

5.1 DRILL MOTOR

The motor is a brushless 3-phase induction type motor that runs on 18 volts, shown in Figure 21, produces 340 watts of output power, and can generate a max torque of 65 NM. The motor runs at speeds dictated by the attached reduction planetary gearbox and has two selectable gear ranges. The gear ranges are 1st gear and 2nd gear and the speeds that they operate at are 0-500 RPM and 0 1750 RPM, respectively.

Figure 21: Drill Motor

5.1.1 COMPONENT SELECTION

The recycled drill brushless motor and control with battery stands out as the best option for motor and control systems, boasting the highest total score of 27. Its power score of 8 indicates strong performance and efficiency, which is essential for demanding applications. Coupled with a cost score of 9, it offers excellent value, and its perfect availability score of 10 ensures it can be readily sourced without delays. This combination of power, affordability, and availability makes it the most well-rounded and reliable option among the three.

In comparison, the recycled brushed drill motor and control with battery, while achieving a high total score of 25, falls short in power with a score of 5, making it less suitable for high-performance needs. However, it matches the brushless motor in cost and availability, highlighting its strong points as an economical and accessible option for less demanding applications. The component drill motor and control, despite its high-power score of 9, has the lowest total score of 20 due to its significantly higher cost (score of 3) and reduced availability (score of 8). Ultimately, the brushless motor delivers the best combination of performance, cost-effectiveness, and reliability, making it the superior choice. Table 4 below shows the comparisons.

Table 4: Motor and Control Component Selection

Motor and Control				
Options	**Power**	**Cost**	**Availability**	***Total**
Recycled Drill Brushless Motor and Control and Battery	8	9	10	27
Recycled Brushed Drill Motor and Control and Battery	5	10	10	25
Component Drill Motor and Control	9	3	8	20

5.2 TRIGGER ASSEMBLY

The trigger assembly houses the electrical system which controls the speed of the grater, including the PCB board which is epoxied in place and is considered non-serviceable. Shown in Figure 22.

Figure 22: Trigger & Control PCB

5.3 CHARGING SYSTEM

The batteries that can be used to power the Grater-Inator are the same batteries available to power the Dewalt 20V cordless tool system, shown in Figure 23 & 24. There are various size batteries available, but the ones used for development and testing will be the Dewalt 20V Max 1.3Ah, and 5Ah batteries. The battery connection terminals will be rearranged for optimal placement of the battery pack to aid in maintaining a good balance while in use.

Figure 23: Dewalt 1.3 Ah Battery

Figure 24: Dewalt 5 Ah Battery

The charger that is used will be the Dewalt DCB 107 charger, specifically designed to charge the above utilized battery packs. This charger could be substituted by any available Dewalt 20V battery pack chargers shown in Figure 25.

Figure 25: Dewalt DCB 107 Battery Pack Charger

6 MECHANICAL PARTS

6.1 LINEAR RAILS

The moveable carriage that applies pressure to the top of the cheese grater handle is guided by two 9mm linear rails that are 150mm in length shown in Figure 26. They attach to the carriage via metric socket head bolts and brass heat set threaded inserts.

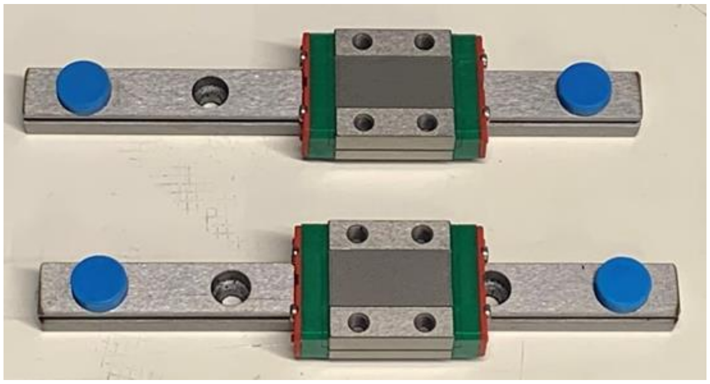

Figure 26: 9mm Linear Rail

6.2 LEADSCREW

The carriage has linear force applied on it to move forward in the grating cheese phase of operation using a trapezoidal thread leadscrew that is 6mm in diameter and has a 1mm thread pitch and a 1 mm lead pitch shown in Figure 27. This leadscrew allows the carriage to move slowly and apply an even and consistent pressure to the top of the cheese grater handle.

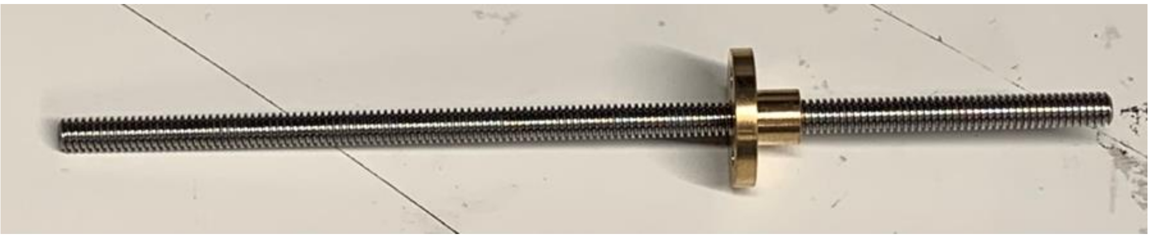

Figure 27: T5 Leadscrew

The leadscrew attaches to the carriage via its paired brass leadscrew nut that has been cut in half longitudinally. The half nut is affixed to a upper portion that will allow the half nut to move into mesh with the leadscrew while in the grating phase of operation and can be disengaged to manually move the carriage back to the start position during the reload portion of the process.

6.2.1 COMPONENT SELECTION

A selection matrix was completed to choose between the best qualities in linear motion actuators. Three options were considered: the leadscrew, the acme threaded rod, and a conventional threaded rod.

The leadscrew is clearly the best option for linear motion actuators, as demonstrated by its highest total score of 24. With a low lead pitch score of 10, it provides superior precision and smooth motion, making it ideal for applications requiring accurate positioning. Its cost score of 6 strikes a favorable balance between affordability and performance, while its availability score of 8 ensures it can be sourced relatively easily, reducing potential delays in project timelines. This combination of precision, cost-effectiveness, and accessibility places the leadscrew ahead of the other options.

In comparison, the acme threaded rod, while offering good durability and a slightly higher cost score of 8, falls behind with a total score of 21 due to its lower lead pitch score of 6, indicating reduced precision. The standard threaded rod fares even worse, with the lowest total score of 16. Its low lead pitch score of 4 sacrifices precision, and while its availability is high at 10, its cost score of 2 makes it the least economical choice. Overall, the leadscrew's superior precision and well-rounded performance make it the most reliable and practical solution among the three options. The comparison is shown in Table 5.

Table 5: Linear Motion Actuator Component Selection

Linear Motion Actuator				
Options	**Low Lead Pitch**	**Cost**	**Availability**	***Total**
Leadscrew	10	6	8	24
Acme Threaded Rod	6	8	7	21
Conventional Threaded Rod	4	2	10	16

6.3 PRESSURE APPLICATION CARRIAGE (3D PRINTED PART)

The assembly, shown in Figure 28, that applies pressure to the handle of the cheese grater forcing the cheese into the spinning wheel is called the pressure application carriage. It centers around a modified brass leadscrew nut that has the same thread pattern as the leadscrew. The leadscrew nut has been milled along the axis of the leadscrew so that it may function like a half nut on a lathe or a machine vise as shown in Figure 29.

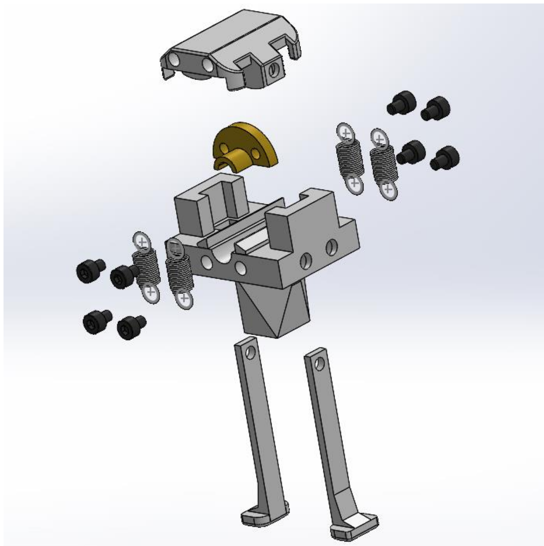

Figure 28: Pressure Application Carriage

Figure 29: Leadscrew Half Nut

The half nut is mounted within the upper portion of the pressure application carriage. It also rides on top of the motor driven leadscrew which moves the carriage forward. The half nut is kept in contact with the leadscrew via tension springs on each corner of the carriage pulling the upper portion of the carriage toward the lower portion as shown in Figure 30.

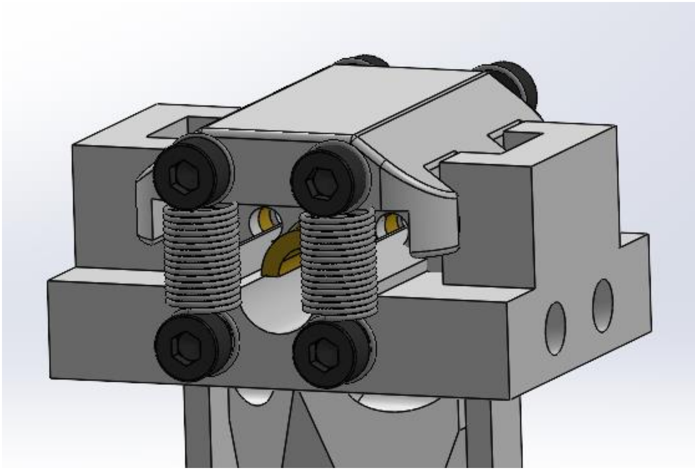

Figure 30: Tension Springs on Carriage

The carriage is guided by two identical linear rails and guides that are mounted on either side of the rail cover. The rails, in Figure 31, keep the carriage aligned so that it cannot twist or become misaligned during operation.

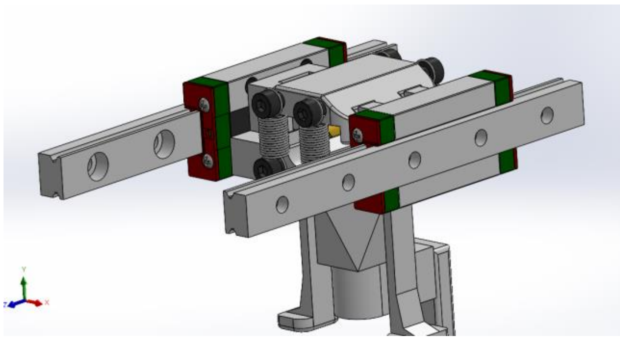

Figure 31: Sliding Assembly

Once the carriage has reached the end of its range of travel it can be decoupled from the leadscrew by applying pressure to either of the pegs alongside of the bottom of the carriage. These pegs interface with the top portion of the carriage and force against the spring pressure holding the half nut against the leadscrew which forces the carriage to be free moving on its linear rails and can be reset to the start position. Once in the start position the pegs can be released and the half nut will again be forced via spring pressure against the leadscrew.

6.4 BEVEL GEARS

Torque from the motor is transmitted down the leadscrew to the end where it meets with a 90-degree bevel gearbox. The gearbox was designed and 3D printed in PLA. This portion of the design was changed several times as testing was accomplished and deficiencies in performance were observed. The flexibility of 3D printing as a rapid prototyping made it possible to evolve the design as was necessary. An example of this is in an early design the input gear was mounted behind the output gear which proved to be a faulty design and was updated to mount the input gear ahead of the output gear and run the motor in reverse as shown in Figures 32-35.

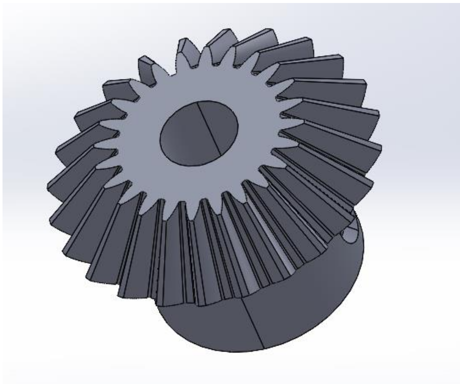

Figure 32: Bevel Miter Gear

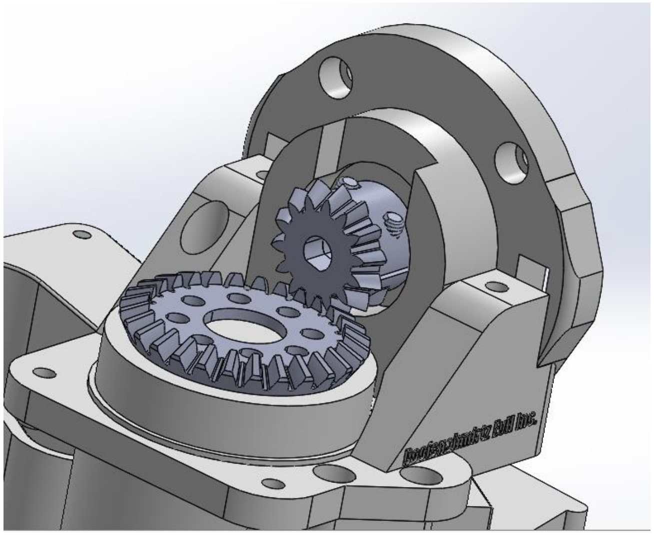

Figure 33: Early Design: Grater Mount V3

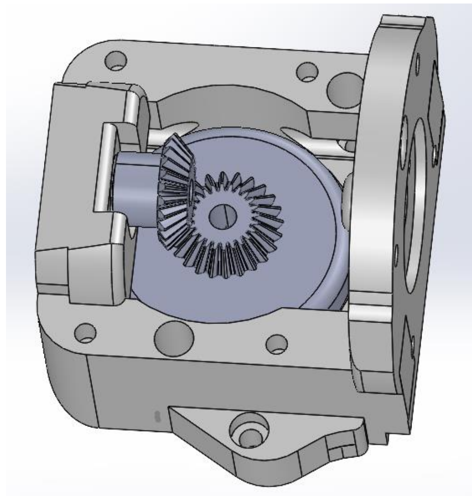

Figure 34: Early Design, Grater Mount 4.5

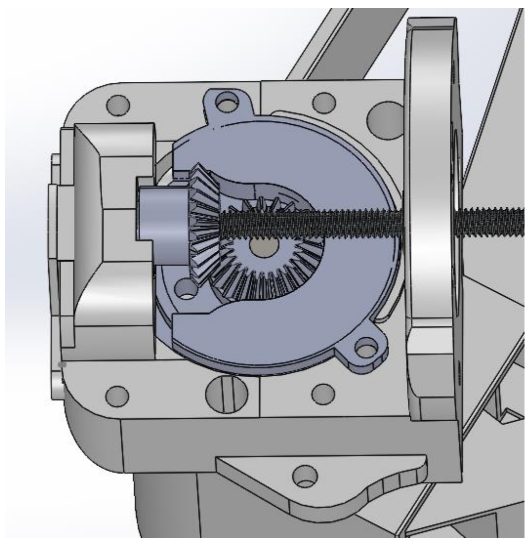

Figure 35: Current Bevel Gear Hub Design

The final design of the gearbox is a 1:1 mitered transmission of power into the drum of the grater. It utilizes two needle roller bearings sandwiched around the output gear hub. The input gear riding on the end of the leadscrew is supported by a thrust-style ball bearing ensuring that the input gear could not come out of mesh in that direction. The output gear itself is attached via a set screw, shown in Figure 36, to a ¼" stainless steel hex shaft that was turned on a lathe to the ID of the gear.

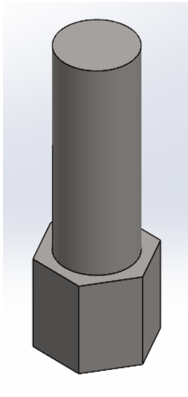

Figure 36: Bevel Gear Output Shaft

The shaft is set into a hub that is 3D printed from PLA plastic. This hub has a splined square shaft on the bottom of it that interfaces with the lower portion of the hub that attaches to the grater itself via the internal threads of the drum. The whole hub is sandwiched against the bottom of the grater mount via preload supplied by a cap on top of the upper hub. Preload pressure can be adjusted by adjusting the screws that affix the cap in place. Shown in Figures 37-43.

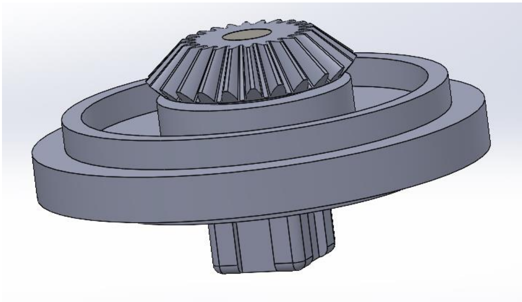

Figure 37: Bevel Gear Output Hub

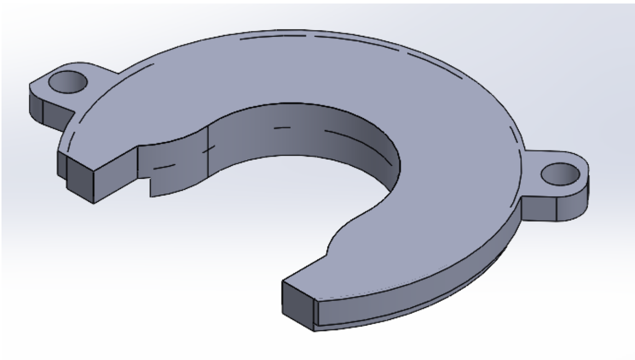

Figure 38: Bevel Gear Hub Hold Down

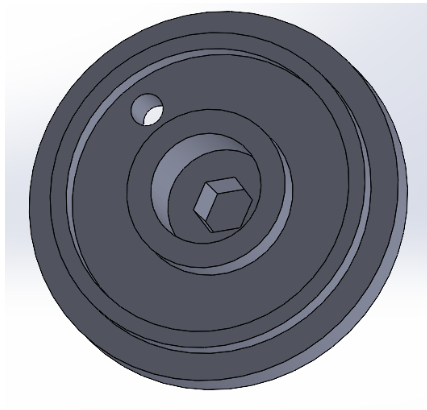

Figure 39: Bevel Gear Hub Upper

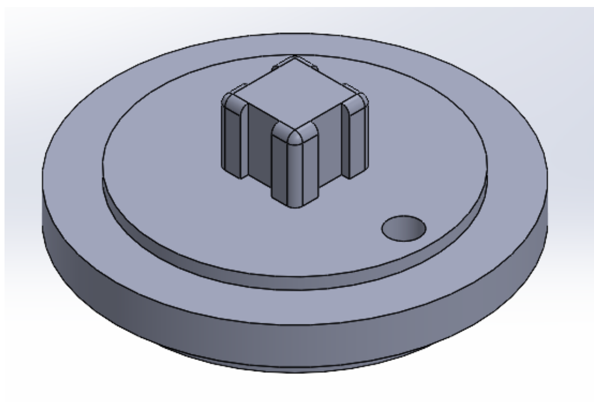

Figure 40: Bevel Gear Hub Upper

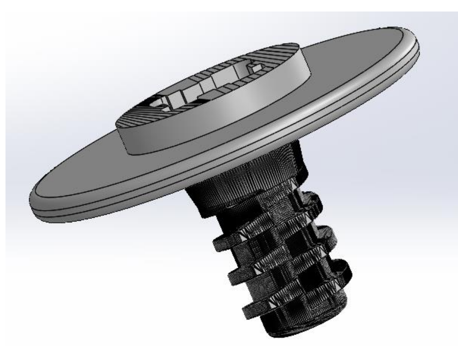

Figure 41: Bevel Gear Hub Lower

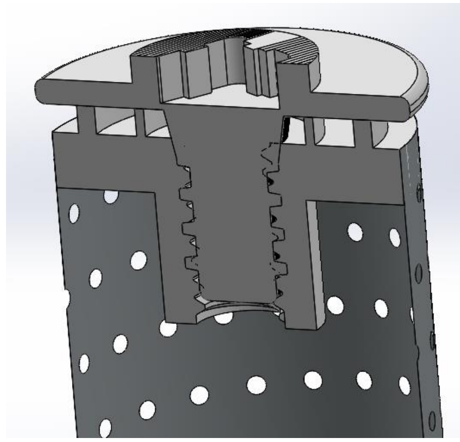

Figure 42: Lower Gear Hub attached to grater drum

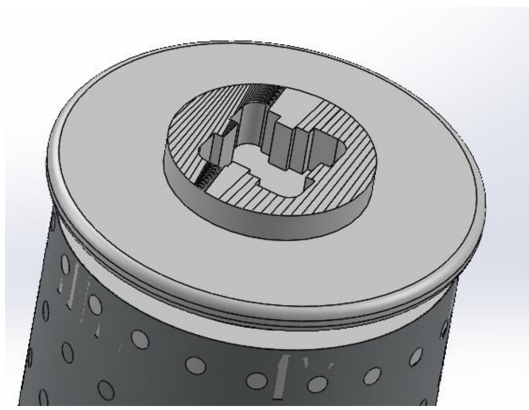

Figure 43: Lower grater hub attached to grater drum

Considerations were made as to the forces that this hub would be subjected to. FDM prints are weakest at the layer lines, so when printed it is important to orient a part that will face torsional forces such that it will be 45 degrees offset from the build plane. This way the torsional forces will not be paralell with the width of the threads and therefore be much less prone to breakage as shown in Figures 44-46.

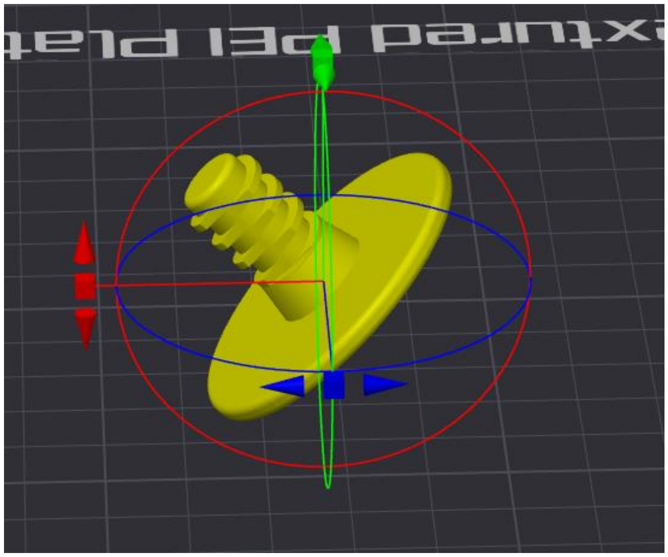

Figure 44: Ideal print orientation in slicer program

Figure 45: Thrust style ball bearing

Figure 46: Needle Roller Bearing

6.4.1 COMPONENT SELECTION

Consideration was given during the design process as to the speed of the output gear relative to the rate at which the pressure advancement carriage was traveling. Initially it was hypothesized that advancement of the pressure on cheese that couldn't be grated didn't make any sense, so it was decided to reduce the output ratio at a rate of 2:1.

When compared to the other two options—the 2:1 Reduction Bevel Gear and the 3:1 Reduction Gears—the 1:1 Direct Drive Bevel Gear clearly stands out as the best choice. Its spindle speed of 10 surpasses the speeds of both the 2:1 and 3:1 option, which are 8 and 4, respectively. This makes the 1:1 gear the optimal choice for applications requiring fast operation without sacrificing efficiency. While the cost score is consistent across all options at 5, the 1:1 gear's higher availability score of 9 ensures it can be procured with minimal delay, a factor that is critical in time-sensitive environments.

In contrast, the 2:1 and 3:1 reduction gear sets prioritize torque at the expense of speed, making them better suited for specialized tasks where power amplification is needed over quick rotational motion. However, their lower total scores of 22 and 19 reflect a trade-off in overall utility. The 1:1 gear not only provides the best balance of speed and reliability but also eliminates the mechanical complexity associated with reduction systems, which can lead to higher maintenance needs over time. This combination of high speed, availability, and simplicity makes the 1:1 Direct Drive Bevel Gear the superior choice for most applications. Gear options shown in Table 6.

Table 6: Gear Component Selection

Gears				
Options	**Spindle Speed**	**Cost**	**Availability**	***Total**
1:1 Direct Drive Bevel Gear	10	5	9	24
2:1 Reduction Bevel Gear	8	5	9	22
3:1 Reduction Gears	4	5	10	19

7 ZYLISS CHEESE GRATER

The Swiss-made Zyliss Hand Crank Cheese grater is the heart that is necessary for all the other parts of this project to exist. Without this piece of hardware, we have created something that spins and moves and nothing more. It has three major parts and 2 major subassemblies. The parts are the main body, the grater drum, and the crank handle. The main body is a subassembly comprised of the pressure application handle, the body, and a stainless-steel hinge pin for the two to connect. The drum is also a subassembly comprised of the stainless-steel tubular cutting element, and two molded POM end caps; one for the outlet side where the grated cheese exits and the other with molded female threads to interface with the male threads on the crank handle. The crank handle has the male threads opposite the crank element to simultaneously hold the crank handle tight to the grating drum but also act as a tension agent to hold the drum and crank against its designated socket in the main body of the cheese grater. Shown in Figure 47 & 48.

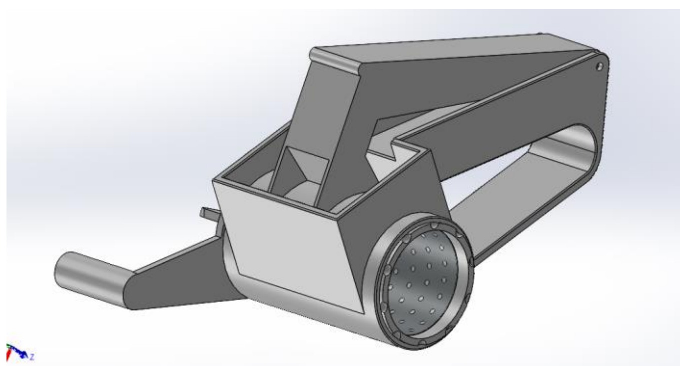

Figure 47: Zyliss Cheese Grater

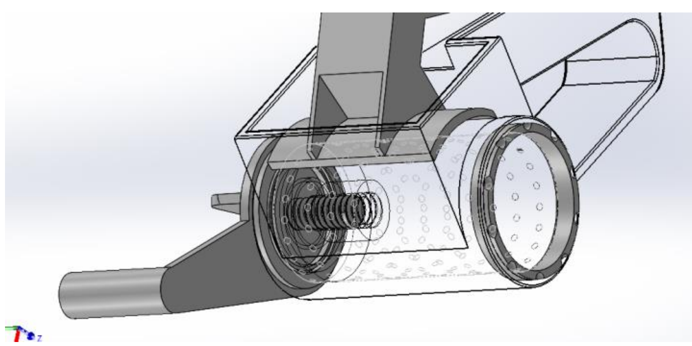

Figure 48: Zyliss Cheese Grater Internal Structure

This kitchen gadget, when attached to the end of our device becomes significantly more capable than it once was.

7.1 Grater Mount

The cheese grater assembly is attached to the end of the Grater-Inator via a 3D printed strap and mount legs as shown in Figures 49 and 50.

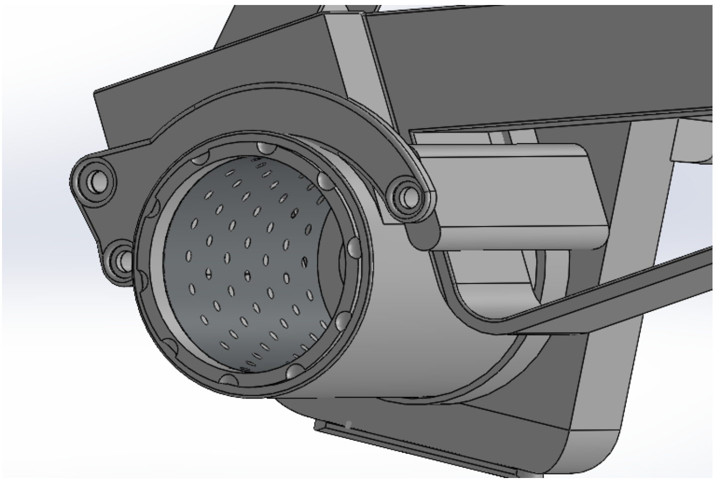

Figure 49: Grater Mount Straps

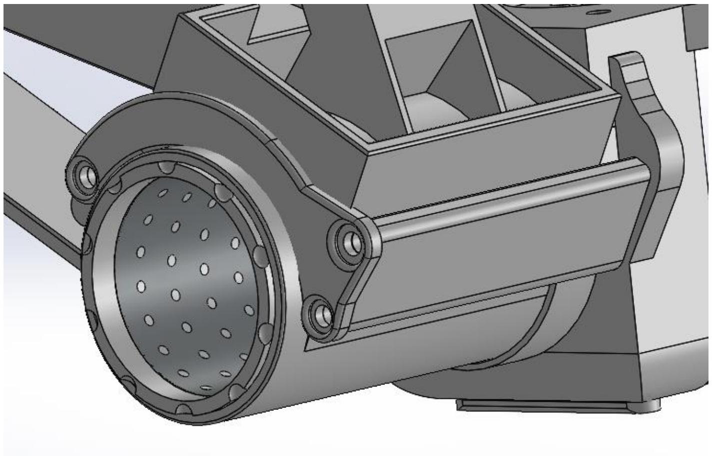

Figure 50: Grater Mounted on Grater-Intator

8 Testing

Testing was completed utilizing low speeds only. Speed tests were conducted, and times were tabulated. The Grater-Inator ended up not being faster than manually grated cheese. The reasons for this were functional in nature. Testing revealed further deficiencies in the design that could not be addressed within the time limit allotted to complete the project and present the results. The pressure advance against the cheese, when under load, caused the threads of the half nut to come out of mesh with the leadscrew causing the upper carriage portion to “hop” leading to a loss of pressure against the cheese. This symptom, combined with a lack of range of motion of the pusher arm made the protype incapable of grating an entire block of cheese.

9 RESULTS

We were successful in solving the original problem set out before us at the beginning of this project. We created a functioning one-handed, ambidextrous, battery powered cheese grater. After getting the initial prototype working, it was noted by the team that the bevel gearset was not performing reliably. It would lose alignment causing the gears to lose mesh therefore causing loss of function and damage to the gearset. The gearbox and grater mount section were redesigned to be more rigid and aligned in all axes. After the redesign and remaking of new parts, the grater spins flawlessly. Once under load of grating actual cheese the pressure applied by the carriage was less effective than we had thought. The spring pressure was not enough to overcome the torque created by our electric motor and the motor was able to push the upper carriage portion up away from the leadscrew therefore losing power transmission. This happens more frequently at higher speeds and to keep the grater running consistently a slow and steady speed was needed. This also kept the speed that it would operate at lower than was originally hoped for.

10 SUGGESTIONS FOR FUTURE WORK

With the results being mostly successful, future work would revolve around getting the current version to apply pressure more evenly. This could be made possible by removing the leadscrew and pressure application carriage completely or redesigning it altogether to account for less slippage in the pressure application carriage. The pressure aspect of the concept could be achieved by springs that would apply constant and consistent pressure to the block of cheese therefore negating the need for any kind of timing of pressure advance with rotation of the drum.

11 TEAMWORK EXPERIENCE

During our project, teamwork was structured to maximize collaboration and efficiency. The team was organized with a clear hierarchy: a project leader coordinated activities, while individual team members specialized in areas aligned with their strengths. Communication was primarily conducted through weekly meetings, complemented by daily updates via a group chat platform to address real-time issues. Tasks were assigned based on expertise, with flexibility to redistribute workload as needed. For instance, when we encountered a technical issue with the bevel gear hub, the team brainstormed during a meeting, and one member volunteered to research a solution while another 3D printed potential fixes. Disagreements, such as differing opinions on material choice, were resolved through open discussions where all perspectives were heard, followed by a consensus-driven decision-making process. This approach ensured all team members felt valued and contributed to the project's success.

12 REFERENCES

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APPENDICES

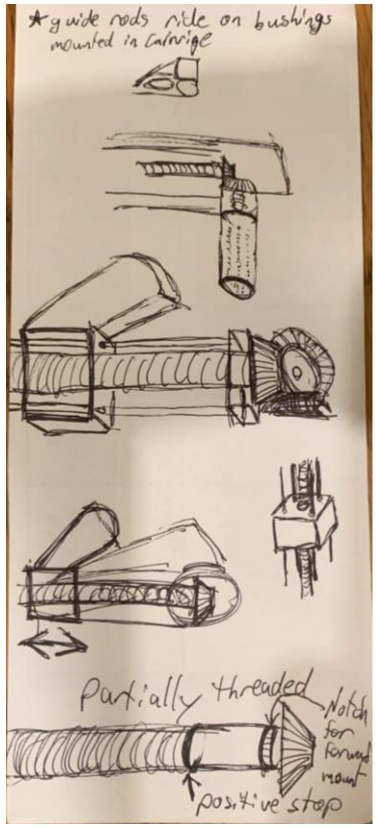
APPENDIX A: BILL OF MATERIALS

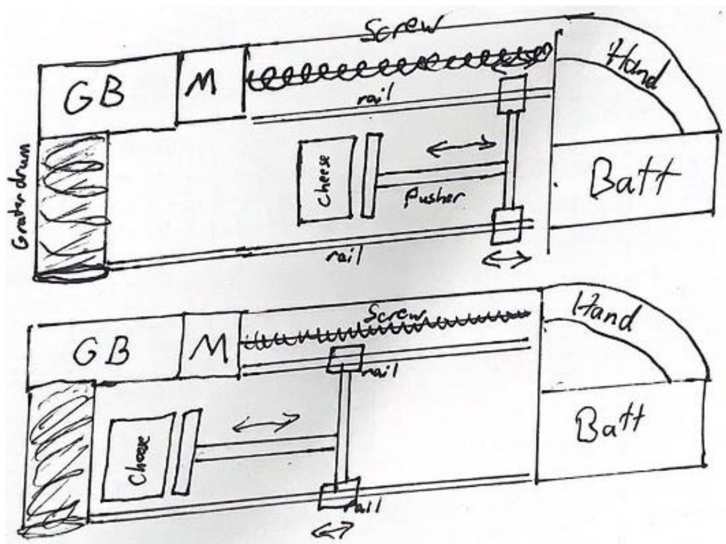
	Item	Cost
1	3D Printing Filament (1kg) (x3)	$40.00
2	Heatset inserts/hardware	$45.00
3	Cordless Brushless Electric Drill	$36.00
4	Bevel Gear (x2)	$20.00
5	Zyliss Cheese Grater	$21.00
6	Linear Rail and Carrier (x2)	$20.00
7	Leadscrew	$28.00
8	Leadscrew Nut (x2)	$28.00
9	Hex Shaft	$20.00
10	Thrust Bearing	$2.00
Total		$260.00

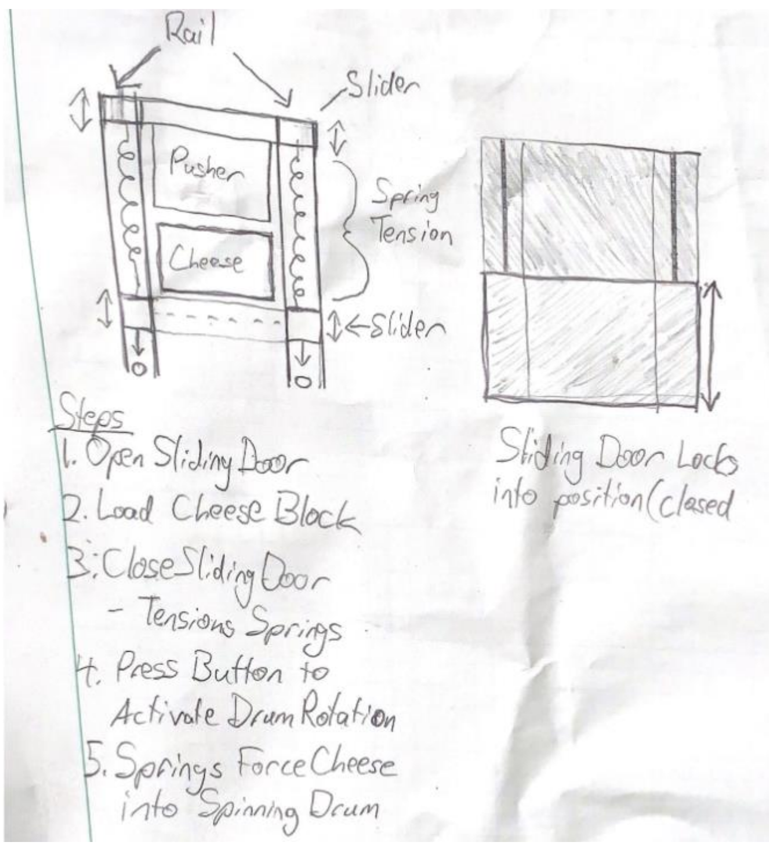
APPENDIX B: PRELIMINARY PROJECT SCHEDULE

Date	Task
First Semester, 2024	
Monday, January 8th	First Day of Class
Wednesday, February 14th	First Conceptual Senior Design Report
Wednesday, March 13th	First Senior Design Report Draft
Wednesday, April 3rd	Second Senior Design Report Draft
Wednesday, May 1st	Oral Presentation of Projects
Wednesday, May 1st	Final Senior Design Report
End of Semester	Order Parts need for Prototype
Over the Summer	Start Constructing the Prototype
Second Semester, 2024	
Wednesday August 21st	First Day of Class
Monday, August 26th	Adjust 3D Printed Parts
Tuesday, September 10th	Machine Parts
Thursday, September 26th	Extend Drill Wiring
Wednesday, October 16th	First Test Run
Friday, November 1st	Fix Tweaks in the Prototype
Friday, November 8th	Design Presentation Review
Friday, November 15th	Draft Report to Advisor
Friday, November 15th	Project Poster
Monday, November 18th	Run a Speed Test
Thursday, December 5th	Final Presentation
Thursday, December 5th	Final Report to Advisors
Thursday, December 5th	Final Report Submitted to SOAR

APPENDIX C: DRAWINGS FOR CUSTOM DESIGNS




Screw
GB
M
rail
Hand
Cheese
Pusher
Batt
Grater drum
rail
Screw
Hand
GB
M
rail
Batt
Cheese
rail


Rail
Slider
Pusher
Spring Tension
Cheese
Slider
Steps
1. Open Sliding Door
2. Load Cheese Block
3. Close Sliding Door
- Tensions Springs
4. Press Button to Activate Drum Rotation
5. Springs Force Cheese into Spinning Drum
Sliding Door Locks into position(closed

APPENDIX D: FMEA

Process Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Process Controls	Detec	RPN
Grating Cheese	Grater Doesn't Work	Can't grate cheese	3	Dead Battery	8	Get manual grater	10	240
		Can't grate cheese	3	Mechanical Failure	4	Maintenance	10	120
	Grater breaks causing parts to fly into food	Food contamination	7	Mechanical Failure	4	Getting new food	4	112
	Grater Catches on Fire	Fire, burns, destruction of property	9	Battery failure	2	Electronic controls on battery pack and drill controls	10	180

Recommended Action(s)	Responsibility and Target Completion Date
Training	Management
Maintenance	Maintenance
Comps	Management
Replace batteries at regular intervals	Maintenance

APPENDIX E: DESIGN CONSIDERATIONS AND STANDARDS

Table N.1, Design Factors Considered

Design Factor	Page number, or reason not applicable
Public health safety, and welfare	21,25
Global	No global implications of a cheese grater
Cultural	11
Social	11
Environmental	No environmental implications
Economic	Improved efficiency and reduced operator strain will improve overall company profitability.
Ethical & Professional	No ethical implications
Reference for Standards	11