generate HRDWRE

SAGEWARE

Final Report Document

Primary Contact

Sage Antonio

Project Team

Nola Hallemeier - Project Lead
Lucas Poulos - ECE Technical Lead
Mihir Narayan - ME Technical Lead
Charlene Lam - Industrial Designer
Chitraksha Kashyap - Firmware Engineer
Wisena Joseph - Hardware Engineer
Ireh Hong - Hardware Engineer
Mia Miller - Hardware Engineer
Jeffrey Burt - Hardware Engineer
Michelle Montenegro - Hardware Engineer
Sahithi Gollakota - Hardware Engineer
Sadeel Alhazim - Hardware Engineer
Michael Marchev - Hardware Engineer

TABLE OF CONTENTS

Executive Summary

Purpose

Millions of tons of fabric waste are created every year by consumers around the globe. Sageware seeks to address this by upcycling fabric scraps into beads that can be used in jewelry designs or sold wholesale. With Generate, a system has been developed that automates this process. Generate's engineers developed a process for hardening the fabric to be cut into rigid beads with high repeatability, utilizing ABS hot glue sheets that are heated, molded, and cut into beads in a fully autonomous process. Manual validation of these processes were conducted throughout the semester, while the electromechanical design to automate this process was developed in parallel. Within the time and budget constraints, individual mechanical subsystems were fully developed, as well as a custom printed circuit board, and a basic framework of firmware was developed. The product was fully assembled and preliminary testing was completed, according to the timeline.

As a student-led endeavor, the main purpose of the project was to facilitate the technical and personal development of the team while operating at a high level of engineering caliber. This goal was achieved in the development of Sageware's systems, with each of the engineers learning important new skills relating to their discipline, as well as demonstrating and utilizing their extensive knowledge in their respective fields. The foundational work conducted throughout the semester provides a strong jumping off point for further development and refinement of Sageware's system, either in another semester in Generate, or an outside firm.

Nola Hallemeier
Project Lead
hallemeier.n@northeastern.edu

Systems Overview

Figure 1: External View of Sageware

Sageware's process consists of four steps: heating, molding, cutting, and dispensing. The fabric is prepped by being with two 12 inch width pieces of any length being layered with a PC-ABS hot glue sheet in the center. This sheet gives the fabric rigidity once heated and cooled. The fabric is fed into the slot in the front of the machine, where it enters the heating chamber. The heating chamber is heated to a temperature of 90 degrees celsius, the melting point of the hot glue sheet. It is then moved by a belt into the molding rollers, which mold the fabric into a bell shape. These small raised bells are then moved into the cutting stamp, where they are cut into a five-pointed flower. The cut beads are dispensing back down to the front of the machine. There is a UI screen that gives the user insight into whether heating is occurring, as well as how many beads are made once a batch is started. There are also error and warning messages that can be displayed in the event of jamming or other issues. There is an emergency stop button that will cut power to the entire system at any time if needed for safety reasons. There are also removable panels on either side of the system that can be taken off for any maintenance.

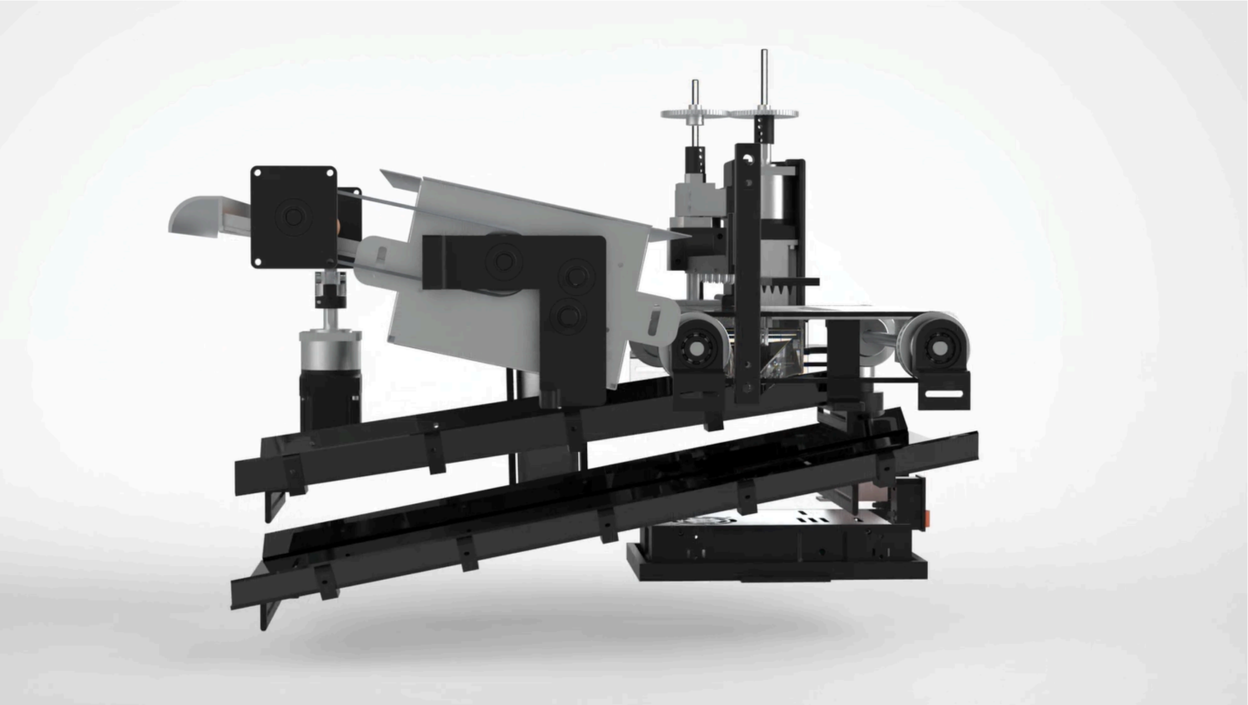


Figure 2: Internal Architecture

The main interface of electromechanical integration is the motors, which control the fabric's movement through the system, and the mechanics of cutting. There is also a sensor that indicates when fabric has entered the cutting stage. There is a heating loop controlled by our PCB, and utilizes AC wall power to heat the heating chamber, but on a separate power source than the rest of the electronics for safety reasons. The PCB has firmware on it that controls each step of the process through the electronic elements including the motors, screen, and heating element.

Mechanical Design

Assembly Overview

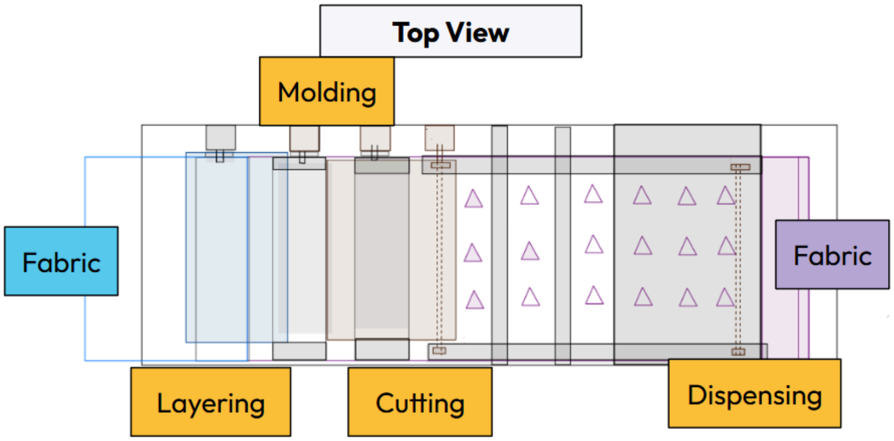
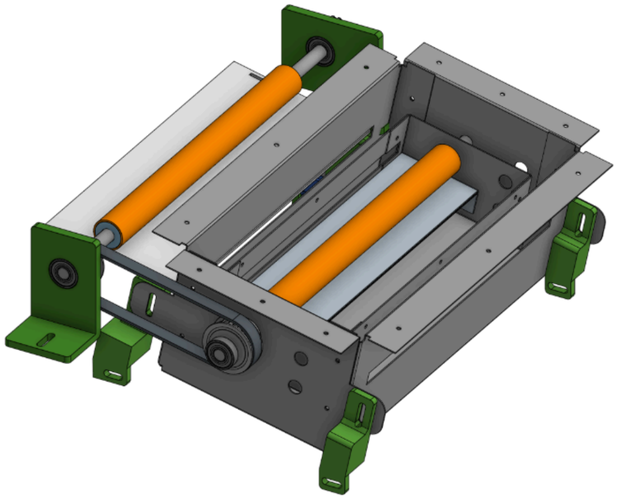


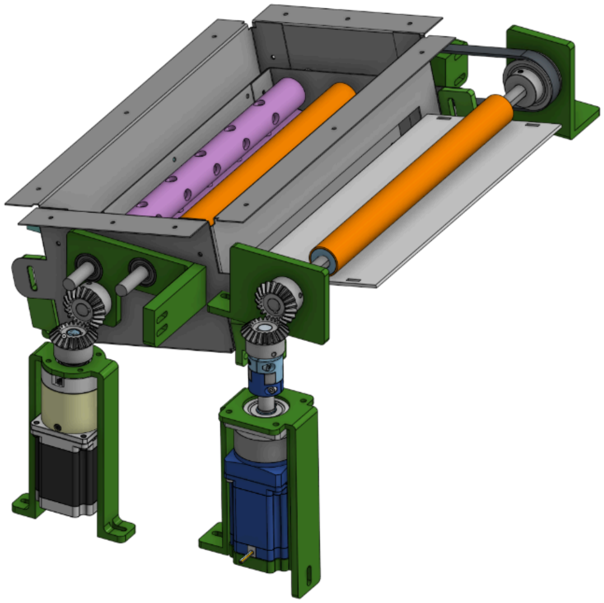
Figure 3: Top View Subsystem Layout

A key focus of Sageware's mechanical design was to prioritize automation and repeatability. The machine was designed with the goal of minimizing user input while also producing multiple beads simultaneously, making the machine more suited for large-scale fabrication rather than single-part processing. Another focus was to maximize the amount of fabric used when creating each batch of beads. Design decisions were also made to manage the state of the glue throughout the process, such as maintaining flexibility during molding and ensuring rigidity during cutting. This was achieved by enclosing the heating and molding stages within an insulated box, enabling a safer and more efficient system.

The primary challenge encountered was subsystem integration, especially figuring out how to align the molding rollers with the cutting mechanism during continuous operation. While each mechanical subsystem functioned as intended in isolation, time constraints limited full testing of the complete system. Heat management was also a significant challenge, as the machine needed to reliably reach approximately 90 degrees Celsius to melt the glue layer between the fabrics while still allowing for relatively quick cooling before cutting.

Insertion and Heating





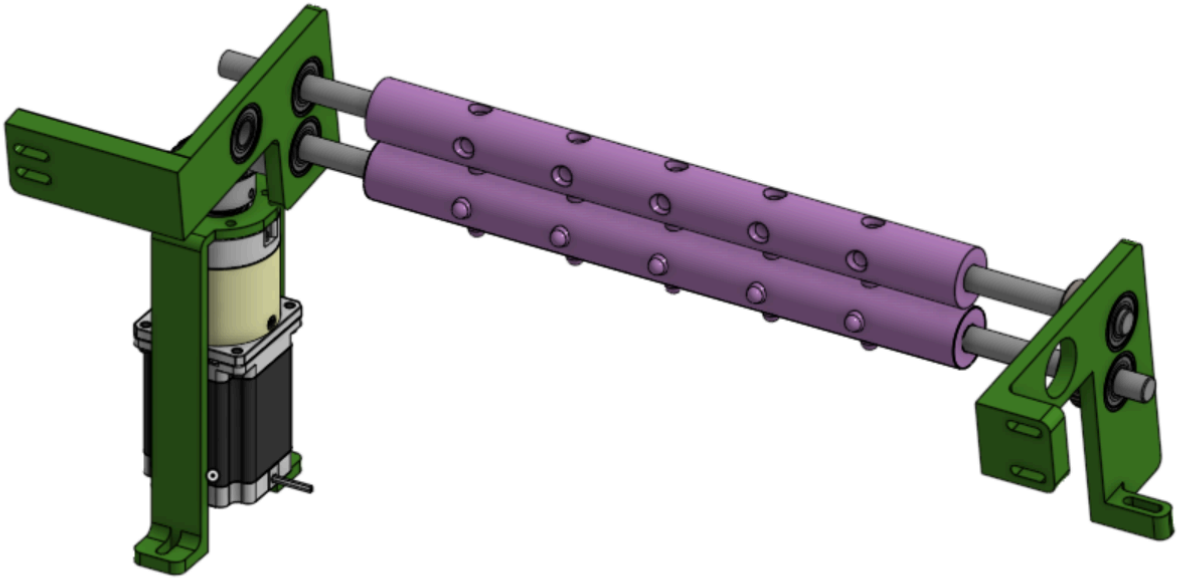
The layering subsystem is the first point of interaction between the user and the Sageware system, serving as the foundation for all subsequent stages of the process. In this step, the user inserts two fabric layers with a PC-ABS hot glue sheet sandwiched between them into the front of the machine. This subsystem aligns, transports, and thermally bonds the composite to ensure consistent bonded material for the molding and cutting stages. It consists of two rollers and is divided into a non-heated entry section followed by an insulated, heated section containing a heated plate maintained at approximately 90°C.

In the non-heated region, the composition is guided along a 12-degree slanted plate, based on a user study. The first roller captures the material and drives it forward, transitioning it from the unheated entry region into the insulated heating zone. This roller is driven by a vertically mounted motor through bevel gears, with motion transferred to the second roller using a belt-pulley system, ensuring both rollers rotate in the same direction. The motor was placed vertically in order to minimize the width of the machine; hence, the integration of the bevel gears. The length of the purchased timing-belt was determined based on the spacing between the rollers while allowing for a tolerance such that the rollers can be pushed further away from each other to ensure sufficient tensioning on the belt.

In the heated section, the composite passes between a fixed aluminum heated plate with an adhesive-backed heating element and a roller mounted directly above it and located in the insulated box along with the molding rollers. The tolerance for the vertical position of this roller is set based on the nominal thickness of the composite layer, allowing for sufficient pressure for bonding while accommodating minor thickness variation.

Heat management and user safety were key drivers in the design of the insulated enclosure. The heated section is enclosed by a 1 mm thick sheet-metal aluminum box filled with a 1 inch thick ceramic fiber blanket, with another inner aluminum box used to reflect radiation. The insulation thickness was determined using the thermal resistance method in heat transfer principles to limit heat loss while keeping the overall machine compact. The enclosure includes a removable lid for maintenance access, cutouts for material entry and exit, and opening for the roller shafts. The rollers were manufactured using high-temperature resin 3D printing with a steel D-profile shaft running through their length to provide structural rigidity and reliable torque transmission. Most standard components in this subsystem can be purchased online on Amazon or McMaster, but the sheet metal box was manufactured through SendCutSend with a cost of around $160 not including the lids. This cost depends on the metal selected, its thickness, number of bends present in the box, and hardware insertion such as PEM nuts, which was minimized in the selection made for this product. The SendCutSend quote for the sheet metal box can be found in the appendix.

Molding



After the layering process is completed in the heated chamber, the fabric glue sandwich sheet is guided into the molding subsystem. This subsystem uses a pair of male and female rollers with five dome-shaped impressions, creating the initial 3D geometry of each bead. The original concept combined both molding and cutting into a single integrated mechanism, with the mold containing a built-in cutting edge. However, this approach introduced complexity in a small space, increasing the risk of jamming, misalignment and overall interference. For that reason, the team separated the process into parts: molding, and then cutting.

The molding stage uses rollers because it simplified the motor control; it would only need to drive rotation in one consistent direction. A flat press-style mold was considered, but would require an ejecting mechanism to remove the molded sheet and move it forward. The rollers remove this issue, naturally feed the sheet through it.

The rollers are made from high temp resin, chosen for its stability inside the heated box and its ability to maintain structural integrity when in contact with the hot sheet. This material also offers good durability with minimal risk of cracking or warping, making it a great alternative to a metal roller.

Tolerances were a critical consideration throughout the design. Since the sheet has a measurable thickness, the rollers could not be designed to be fully tangent. The gap, roller diameter, and profile depth were all set to consider this thickness while achieving the right molding pressure. Spur gears were also selected and sized based on the gap, ensuring smooth rotation motion between the rollers. Bearings were also chosen to support rotation and were intentionally smaller than the roller diameter to simplify housing and mounting.

Most components within this subsystem are manufactured using standard processes. For example, the bearing mounts can be produced via injection molding. The rollers themselves are more geometrically complex, but still feasible to manufacture by fabricating it in two horizontal halves and then bonded together. The other parts of the subsystem can be purchased online as well.

Cutting

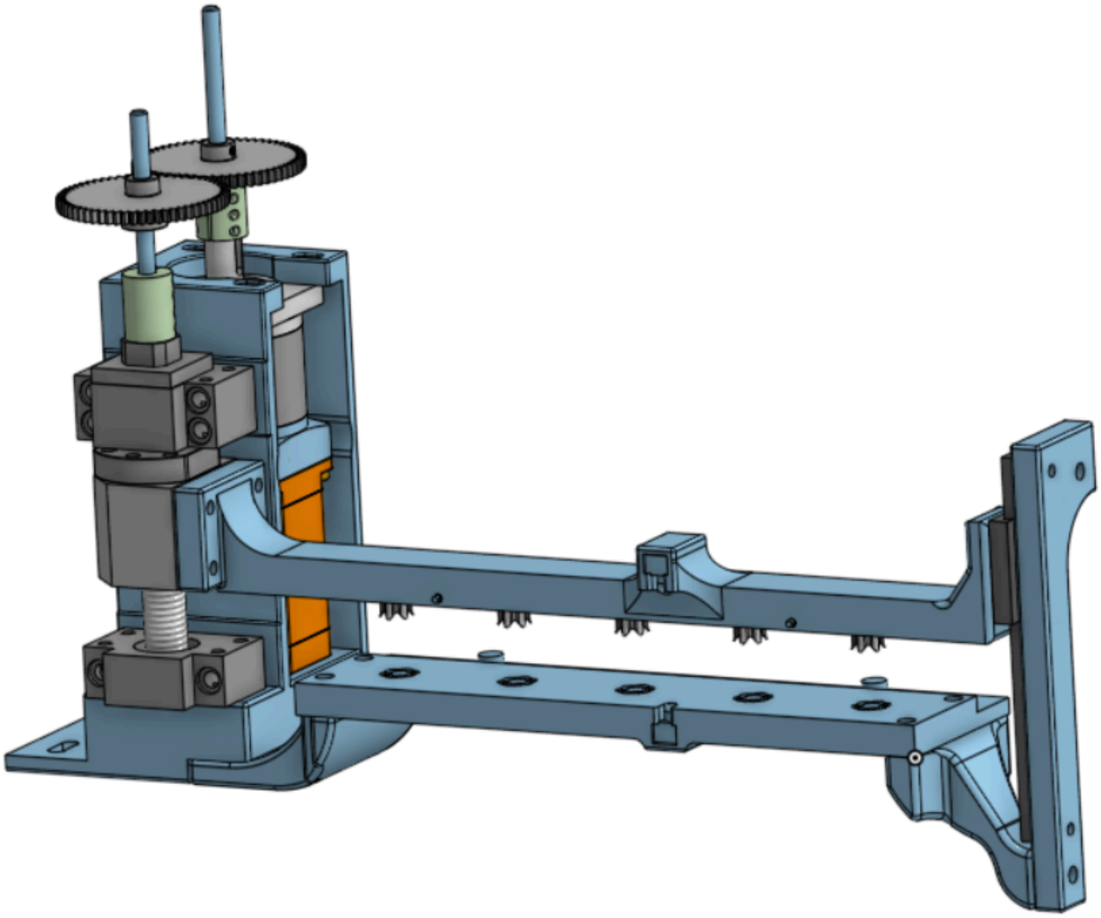


Figure 6: Cutting Subsystem Whole View

Once the fabric has been fused with the glue and molded with the 3D dome shape, it is introduced to the cutting subsystem. The purpose of this subsystem is to stamp out a flower shape on top of/around the domes that were previously molded into the fabric. The client has specifically requested that the beads feature clean and consistent cuts across all edges, so we must prioritize this alongside functionality and repeatability. Though originally planned to be a roller-based mechanism, this was left in favor of a stamping mechanism to introduce less chance of bead misalignment with respect to scrap fabric (important to the next subsystem, dispensing, as the beads must fall through the holes they were stamped out of).

The heart of the cutting subsystem is a custom-machined steel stamp with five flower-shaped blades. For this, hard tool steel was used to ensure retention of a sharp edge with repeated use, requiring minimal service (and keeping cuts cleaner, as the client wanted). This is fastened to an SLA resin jig for interfacing with power transfer components, reducing the total stock used (and therefore machining cost) when compared with machining the jig together with the stamp as one part. Considering this part will eventually have to be remachined due to slow wear on the edge, it is especially prudent to be conscious of the cost (~$370 from Xometry). The jig/insert assembly is actuated vertically by a lead screw at one end, and fastened by a linear rail on the other. While deviation from horizontal level was a concern, it was not within the scope of this project to introduce a lead screw at each end, much less to mechanically bind them together.

The bottom piece against which the fabric is cut was also made of SLA resin. This material was chosen for the “cutting board” and the jig for its high thermal resistance and dimensional accuracy. With many moving parts, tolerance stackup can easily lock up a system like this. The mounts for this bottom plate were FDM 3D-printed straight upwards vertically at 30% infill (gyroid) and 0.2mm layer height, as were the linear rail and motor mounts. These were then impregnated with heat-set inserts to interface with both the 8020 frame and the ball screw end supports–not possible with SLA resin. As such, we had to take the potential hit with dimensional accuracy.

The motor is from StepperOnline, while the shaft collars, lead screw, and linear rail are from Amazon. The remaining parts–shafts and gears–are all from McMaster. As mentioned above, the machined insert is custom-ordered from Xometry.

Dispensing

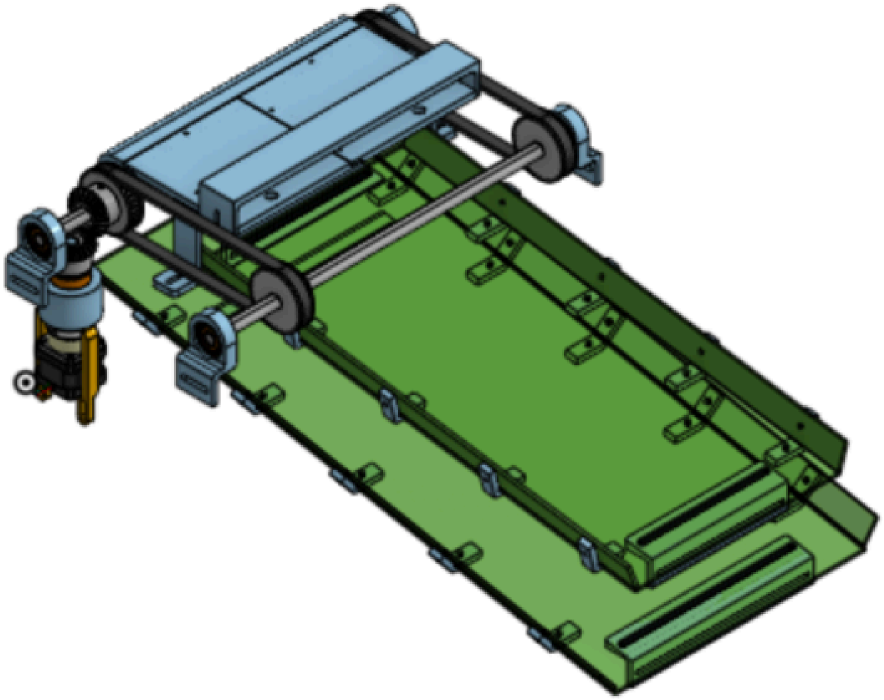


Figure 3: Dispensing Assembly

The dispensing subsystem is designed to separate cut fabric from shaped beads and direct each material to its respective collection area. After the fabric exits the molding process, it is transferred onto a continuous dual-belt conveyor that carries the material through cutting and into the dispensing stage. As the fabric advances, beads fall through a small opening while the remaining fabric continues towards a separate exit. This approach ensures reliable material separation while maintaining consistent flow and minimizing jamming.

The final design consists of two parallel belt-driven shafts mounted within an 8020 frame. Each shaft supports two pulleys and a belt, allowing the entire system to be driven by a single motor. A plate separator is positioned between the belts to allow beads to fall through while supporting the fabric above. An overhang is attached to the plate, which applies slight downward pressure on the fabric to help release beads.

Below the separator, two angled ramps guide the separated materials toward the front of the machine: the first for the beads and the second for the remaining fabric. These ramps are optimized with minimal slope to ensure the beads fall smoothly under gravity. They are assembled by individual brackets: eight for the bead ramp and ten for the fabric ramp.

The system was developed through multiple design iterations by prototyping and experimental testing. Early concepts explored roller-based separations; however, this approach raised concerns regarding roller synchronization and the potential for fabric entanglement. These challenges led to the adoption of a dual-belt system with a plate separator for improved reliability and control. Key parameters such as bead gap spacing, ramp angles, and bearing tolerances were evaluated using 3D printed test components. A gap of 0.7 inches was found to be optimal for consistent bead release, while shallow ramp angles allowed for smooth, gravity motion. All structural and mechanical components were fabricated using FDM 3D printing, while ramps were produced from laser-cut acrylic. Standard off-the-shelf hardware was used for the remaining components. Future improvements include refining the plate geometry for higher output and optimizing ramp surfaces for lower friction.

Industrial Design

Figure 3: Sageware Enclosure

Enclosure

This enclosure balances aesthetic and function through carefully selected features. All panels are constructed from heat-formed acrylic that was finished with spray paint and mounted with button head screws as seen in Figure 3 above.

The enclosure was designed in CAD through OnShape as seen in FIgure 4 below.

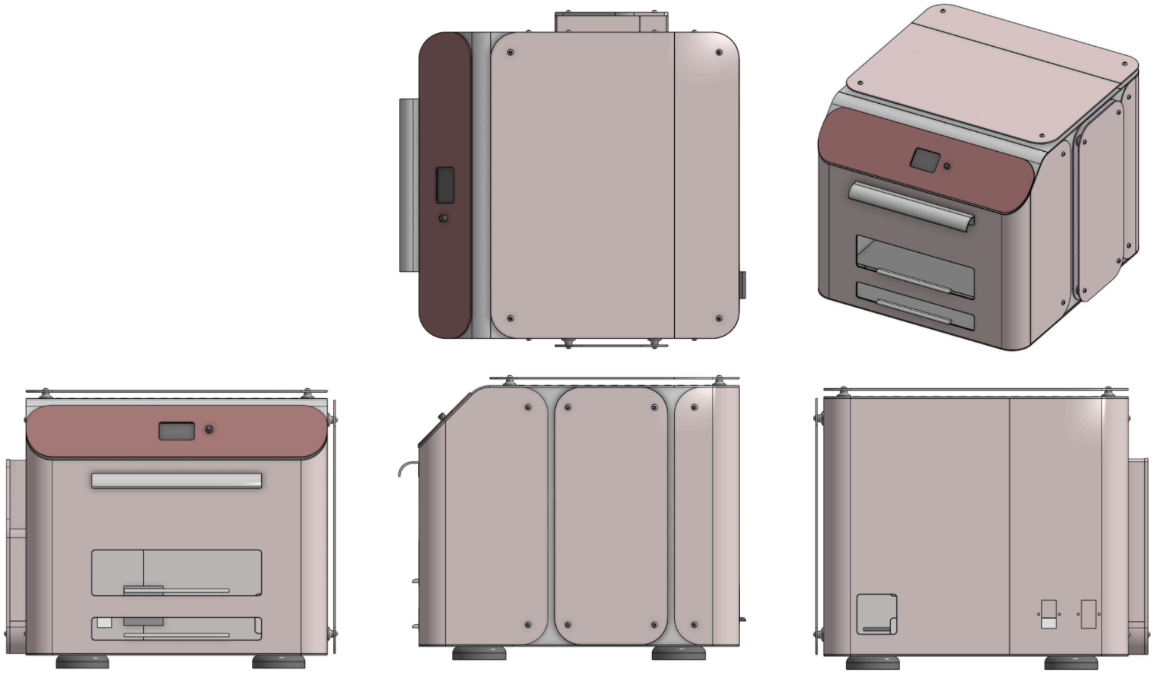


FIgure 4: standard CAD views of Sageware enclosure

Key Features

- **LCD screen** - Allows users to select the desired fabric insertion length
- **Fabric insertion tray** - Enables users to pull out and insert a fabric sandwich consisting of two fabric layers with an adhesive sheet between
- **Removable panels** - Provides easy access to internal components, with hidden vents located beneath the top panel for ventilation
- **Hinged doors** - Features a top flap for collecting beads and a bottom flap for collecting scrap fabric
- **Glue sheet holder** - Provides convenient storage on the left side

These features are labeled on the enclosure in Figure 5 below.

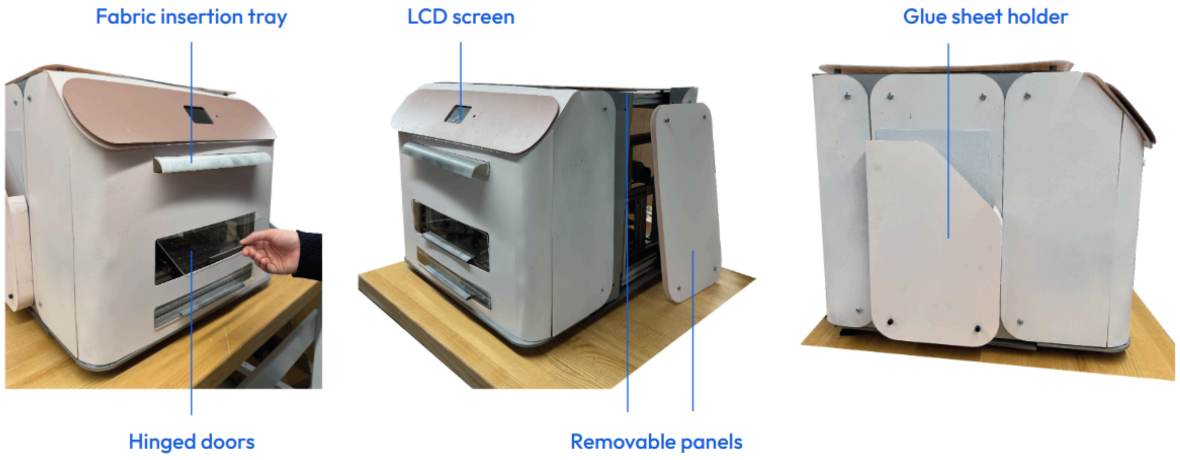


FIgure 5: CAD of Sageware enclosure with features called out

User Studies

Several user studies informed key design decisions throughout the development process. Figure 4 shows viewing angle preference testing, which resulted in a 45-degree tilt for the LCD screen based on user feedback. Figure 5 presents fabric insertion lip usability results, which determined the optimal lip length and guide angle. The final insertion plate measures 5.5 inches which was slightly shorter than optimal due to mechanical design constraints, but still maintaining the optimal guide angle identified in testing.

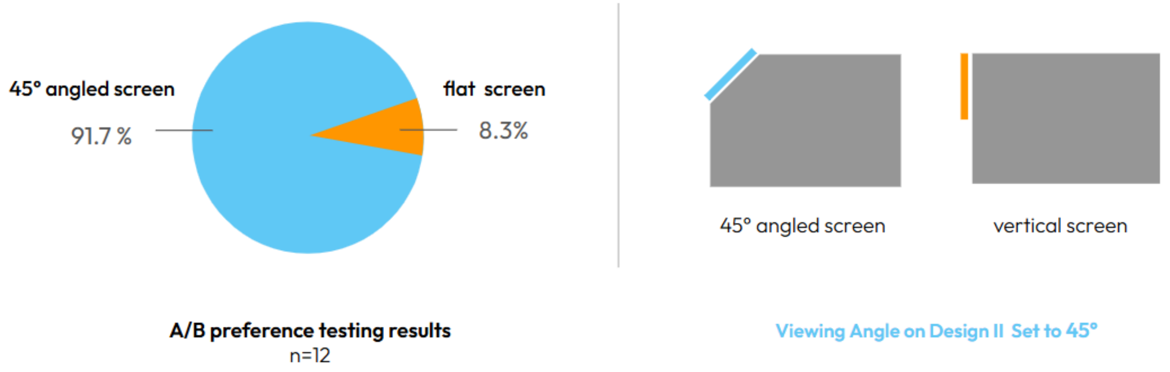
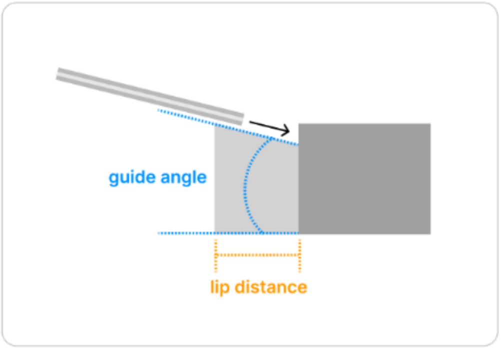


Figure 4: Viewing Angle A/B Study

	6° guide	12° guide	18° guide
3.5” lip	6.00	7.63	7.75
6.5” lip	7.25	8.44	7.19
9.5” lip	4.56	5.56	5.56

average ranking by configuration
1 (worst) - 10 (best) scale ; n=12



Summary of Results

Best Configuration: 6.5” lip distance with 12° guide angle
Worst Configuration: 9.5” lip distance with 6° guide angle

FIgure 5: Fabric Insertion Lip Usability Study

Fabrication

To fabricate the enclosure panels, each part was modeled as a sheet metal component in CAD, and the patterns were laser cut onto acrylic sheets. A custom heat-forming fixture was designed to shape the large exterior curves. This fixture was 3D printed with PPA-CF given its high temperature resistance. Figure 6 shows this heat forming process. Once cooled, the panels retained their desired shape as shown in Figure 7.

Figure 6: Heat forming acrylic with heat gun, custom PPA-CF fixture, clamps, fan, and acrylic

FIgure 7: Heat formed acrylic

After the acrylic was heat formed, they were finished with the following spray paints:

- Rust-Oleum Low Odor Premium Spray Paint in Matte Dusty Rose
- Rust-Oleum Painter's Touch 2X Ultra Cover in Satin Vintage Blush
- Krylon Fusion All-In-One Adhesive Spray Paint in Aluminium

Assembly

Enclosure-enclosure mounts were designed to connect the individual panel pieces together, which were fabricated separately due to laser cutting bed size limitations. Additional enclosure-8020 mounts were created to attach the complete enclosure assembly to the 8020 frame for full system integration. The placements of some of these mounts can be seen in Figure 8 below.

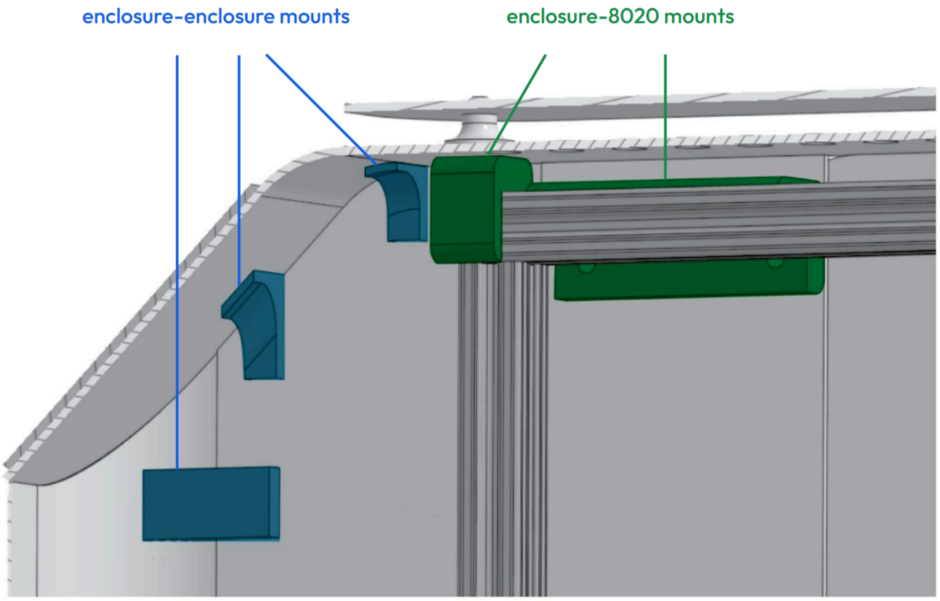


Figure 8: enclosure-enclosure mounts and enclosure 8020 mounts shown on CAD section view

Electrical Design

Design Overview

Motors

The purpose of this subsystem is to operate and control motors for each mechanical subsystem. One motor is responsible for insertion and layering of the fabric. Another motor molds the beads, and then another motor cuts the beads from the fabric. Finally, a dispensing motor outputs the product. In terms of torque, the cutting motor is expected to require the most torque to pierce through the layers of fabric and glue. Molding requires some, but not as much torque, and the insertion and dispensing do not require much torque, outside of what is needed to operate a belt. The team decided to use stepper motors, due to their high precision (even without feedback loop) and high holding torque (applicable to the molding and cutting subsystems). With torque specifications from the ME team, the following motors were selected:

Subsystem	Type of Motor	Gear Ratio	Torque Rating (N*m)
Insertion	Stepper Nema 23	10:1	15
Molding	Stepper Nema 23	15:1	25
Cutting	Stepper Nema 23	20:1	30
Dispensing	Stepper Nema 17	5:1	3

Because the team wanted to ensure these motors were properly able to operate their respective mechanical subsystems, they tended to over-spec torque, which in turn made for larger and heavier motors. In the future, it would have been preferable to assemble mechanical subsystems and then test how much torque is actually needed to run the system. This way, the motors could have been specced to be smaller and lighter. Due to the lack of time in this semester and issues with tariffs, the team was unable to delay the project in this way and needed to order the motors early on in the project.

In terms of controlling the motors, four DM542T digital stepper drivers were used to control each motor. These are simple, plug and play, customizable controllers compatible with the PCB. If the PCB were to be redesigned, a 5V line would be included so that the integration between the motors, drivers, and PCB would be simplest. Because the PCB could not be redesigned during this semester, four level shifters from 3V3 to 5V were implemented. This ensured proper communication between the board and the drivers, and thus, to the motors.

Sensors

We used two sensors to keep the process consistent and timed correctly: a thermistor to monitor the heater temperature during lamination (AC heating pad), and a beam-break sensor to detect when fabric is in position and trigger the cutting step.

Circuit Board

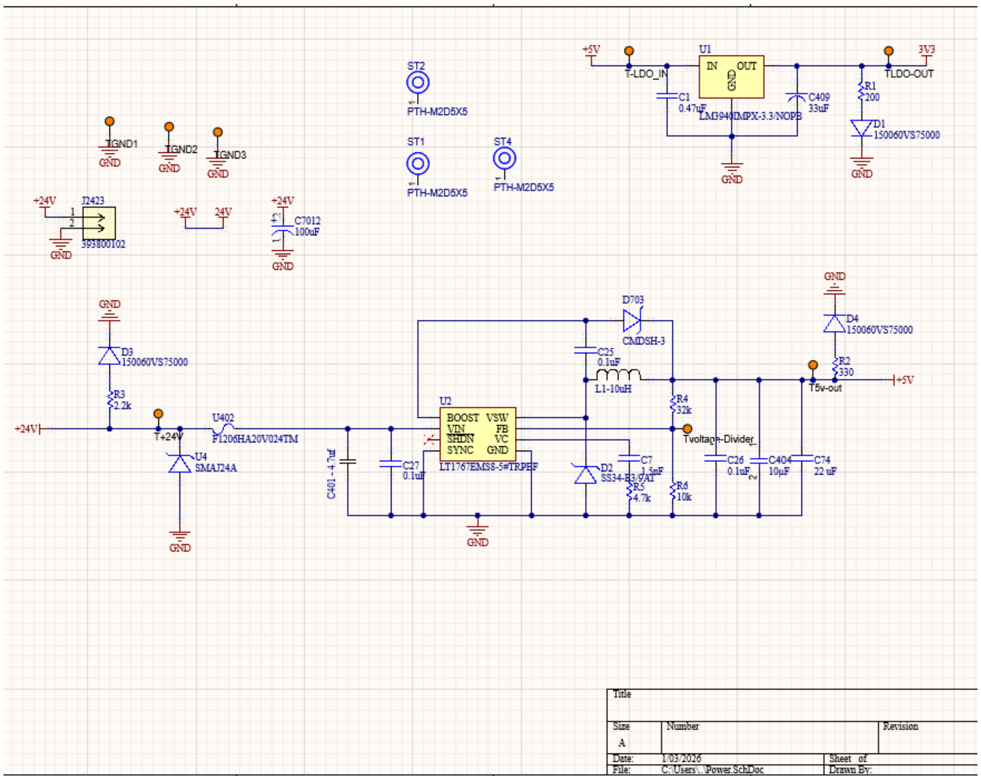


Figure 9: Schematic of power subsystem

The schematic diagram shown in Figure 9 depicts the power subsystem, showing the different voltage rails, including the 5V and 3.3V power rail. The system is first powered by a 24V power supply, which uses the outlet and an AC-DC converter to achieve the 24V. A buck converter is used to step down the 24V to 5V, which feeds into the motors and the heating subsystem. The 5V rail is then converted to 3.3V using a LDO converter. The 3.3V rail is used to power the MCU. The schematic above shows test points in different parts of the circuit, which were used to ensure that the correct voltage was indeed being delivered during PCB bring-up.

Microcontroller

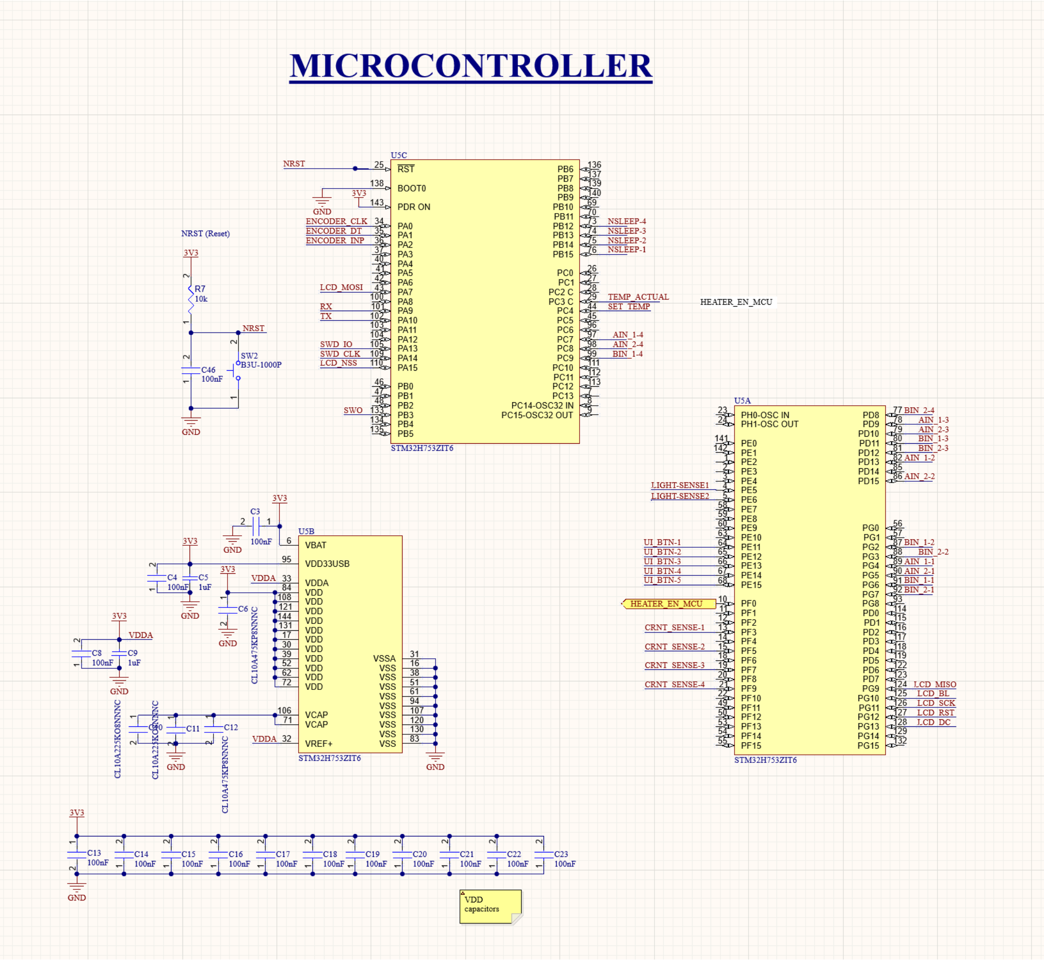


Figure 10. Schematic of microcontroller

]

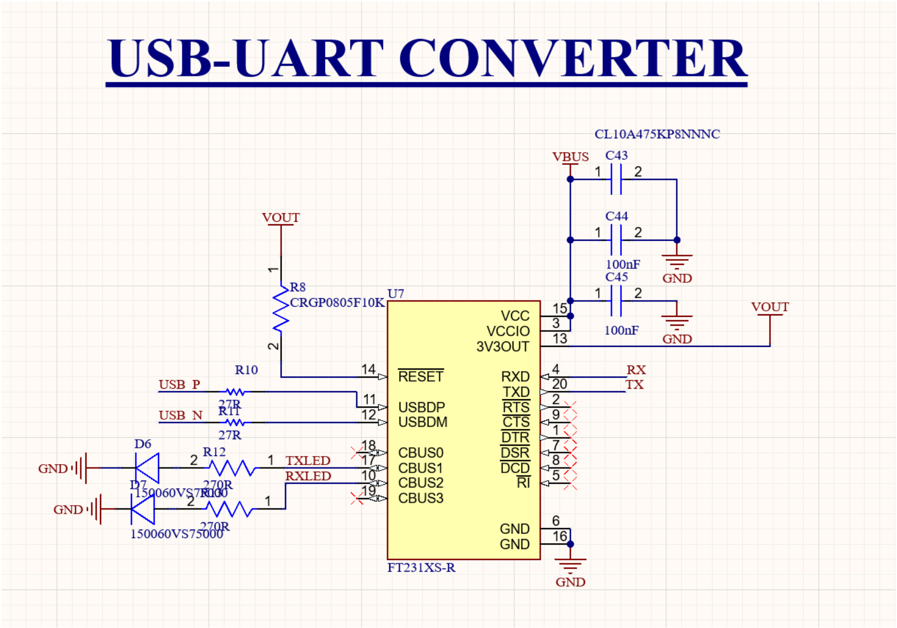


Figure 11. Schematic of USB/UART converter

The schematic diagram in Figure 10 depicts the microcontroller (MCU) and the various components that it connects to. The MCU consists of a reset and a boot button to allow for flashing a program and is powered by the 3V3 rail. It also has output Tx and input Rx for flashing and communicating, which are inputs from the USB/UART converter shown in Figure 11. As a secondary method of flashing, the MCU also supports serial wire debug (SWD) using the SWD pins labeled on the schematic.

The MCU consists of 5 outputs (AIN1, AIN2, BIN1, BIN2, NSLEEP) for each of the four motors, resulting in 20 outputs to control the speed and direction for each motor. It includes 4 current sensing input pins to monitor the current for each motor. In addition, the MCU consists of 7 output pins to the LCD (liquid crystal display), each named with the LCD tag on the schematic, to control the display. It includes 5 input pins for buttons, which the user can use to interact with the LCD. The MCU is also able to measure temperature using an input temperature sensing pin.

Heating System

The heating is responsible for efficiently and safely heating the fabric and thermal adhesive. Given the size of fabric needing heating and the temperatures required, AC mains power is used. Secondly, the heating system is designed to run with as little firmware as possible. Specifically, a discrete temperature controller is used rather than an embedded control algorithm. This embedded controller relies on op-amp and comparators to implement a PI controller to maintain the set temperature.

Temperature feedback is provided by a single thermistor. In order to simplify the control loop, the thermistor is roughly linearized in the region of interest (roughly 65 to 95 degrees C). Additionally, given the physical proximity of the thermistor to AC mains in the heating plate, an isolated amplifier is used to maintain galvanic isolation between the low voltage DC system and AC mains. Overtemperature protection is implemented by a failsafe windowed comparator. This circuit combines 2 open-drain comparators; one which detects an over-temperature scenario (characterized by a low thermistor divider voltage) and a second which detects an overvoltage. The latter of these detects faults in the thermistor circuit. Any disconnect of the thermistor will cause the divider voltage to swing high and engage the safety shutoff.

The heater itself is toggled by a fused solid-state relay. This relay also features zero voltage switching, which only allows the relay to be toggled on a zero crossing of the AC mains voltage, this helps reduce EMI and improves relay longevity. While the heater system itself is fused and included in the hard-wired emergency stop system, it is somewhat vulnerable to a relay failure. There likely exists a failure mode in which the relay fails short but current through the heater is not sufficient to trip the fuse, leading to a thermal runaway. While the system is sufficiently safe for prototype usage, future implementations should include either a thermal switch or thermal fuse to protect against this failure mode.

Finally, while a discrete control system is interesting as a learning opportunity, it is not a practical control scheme for this class of product. Products targeting simplicity and workability should instead implement an embedded control control algorithm using a microcontroller ADC to directly read temperature data and a GPIO to toggle the control relay. While not trivial to implement, this system should still be much simpler to implement, faster to iterate and tune, and cheaper than a discrete system. That said, over temperature events should still have an independent failure detection and prevention system. This can either be a discrete system such as a windowed comparator or a mechanical system such as a thermal switch.

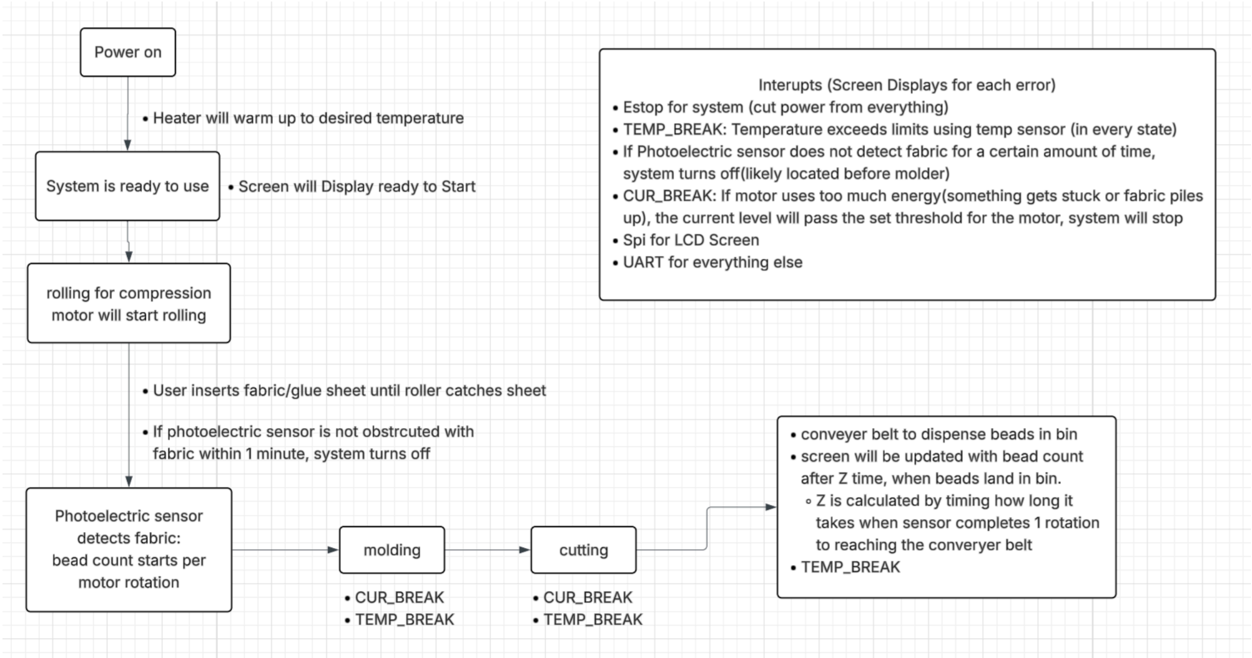
Software Design

General Software Design

The firmware is developed using Zephyr RTOS with the West command-line tool for build management. Zephyr was chosen for its industry-standard status and robust support for real-time embedded systems, making it well-suited for the precise timing and multi-threaded control required in this manufacturing application.

The project uses Zephyr's native APIs rather than external libraries. Key components include the GPIO driver for motor and sensor control, ADC driver for current sensing and temperature monitoring, and SPI driver for the ILI9341 LCD display. Device tree overlays configure the hardware interfaces for the STM32 microcontroller. Stepper motor control is implemented through custom state machines using Zephyr's threading and timing functions.

The software uses a state-machine architecture across multiple threads. A background thread continuously monitors heater temperatures and sets status flags when ready. The main thread handles the production sequence: initialization and warm-up, user input for bead count selection, waiting for the start button, then cycling through laminating/heating, molding, and cutting until the target count is reached. Photoelectric sensors and limit switches trigger state transitions, while ADC current sensing on the cutting motor detects when cutting is complete based on the 2.4A torque threshold.



- Heater will warm up to desired temperature
- Screen will Display ready to Start
- User inserts fabric/glue sheet until roller catches sheet
- If photoelectric sensor is not obstrcuted with fabric within 1 minute, system turns off

Interupts (Screen Displays for each error)
- Estop for system (cut power from everything)
- TEMP_BREAK: Temperature exceeds limits using temp sensor (in every state)
- If Photoelectric sensor does not detect fabric for a certain amount of time, system turns off(likely located before molder)
- CUR_BREAK: If motor uses too much energy(something gets stuck or fabric piles up), the current level will pass the set threshold for the motor, system will stop
- Spi for LCD Screen
- UART for everything else

molding:
- CUR_BREAK
- TEMP_BREAK

cutting:
- CUR_BREAK
- TEMP_BREAK

- conveyer belt to dispense beads in bin
- screen will be updated with bead count after Z time, when beads land in bin.
  - Z is calculated by timing how long it takes when sensor completes 1 rotation to reaching the converyer belt
- TEMP_BREAK

Explanation of Overall Software Decisions

The first step was figuring out the hardware stack. I wanted to develop on Zephyr RTOS because of its tooling and modularity, so I selected an STM32 MCU and then worked with the team to choose motors, sensors, buttons, and an LCD that would all integrate cleanly with Zephyr. Once the hardware was set, I created a high-level state machine for how the entire system should behave. From there, I built each subsystem: motor control, Sensor control, Button Control, ADC, and the LCD interface, in separate modules with their own headers and C files, testing everything on a dev board before connecting the custom PCB.

After supporting the electrical engineers through PCB bring-up, flashing and validation were straightforward since we used the same MCU as the dev board. With oscilloscopes and multimeters, I verified signals, fixed peripheral issues, and made sure each subsystem behaved exactly as expected. When trying to integrate everything into the main state machine, it didn't come together immediately. A lot of unexpected timing issues and edge cases showed up once all the hardware was running at the same time. With time and dedication we were able to get to a working prototype.

Next Steps

As of December 2025, Sageware's system is fully assembled mechanically, and there is a tested printed circuit board that can be integrated with electronic elements. There has been manual testing of the molding and cutting systems, and they work, however, they have not been implemented in the automatic process. The electromechanical integration of the heating system has not been tested, however, it is fully assembled and can be tested once another printed circuit board is fully assembled. There is a large amount of calibration that will need to be completed to confirm the automation of the process, in order to correctly synchronize especially the molding and cutting subsystems. The project is also very bulky, mostly due to the size of the motors and power supply needed to generate the force to support our current process, as well as the size of our heating chamber, which does not fit within the product requirements.

To verify the minimum viable solution (MVS), more work must be done on Sageware. The fundamental pieces are all there, but they have not been tested and calibrated. For next steps , the following is recommended from a product development standpoint with a group such as Generate, or in a more formal capacity:

1. Further development on firmware and implementation with PCB
2. Further optimization work on weight and form factor
3. Verification of electromechanical integration of each individual subsystem
4. Restructuring of power system to integrated heating and the rest of the electronics onto one power source
5. Thermal analysis of the heating system to verify safety and feasibility

Generate's tight timeline of three months from ideation to assembly allows for fast-paced creative thinking, however, there are limitations, as with any engineering project, on timeline, and this semester, Sageware's engineers were not able to fully deliver a fully verified MVS. However, the work done this semester provides an extremely solid foundation for a fully automated solution that requires finishing touches on development.

Appendix

- SendCutSend Quote “Insulation” - Insertion and Heating:
    - https://app.sendcutsend.com/customer#/cart?accept=aWQ9MjAyMTczJnRva2VuPTgxNDA3MzQ3LTJkZGYtNDBjMC05NmYwLTg0YWE5%0AYTkyYTkxNg%3D%3D%0A