F.L.C.S.

Fabric **L**aser **C**utting **S**ystem

Department of Electrical and Computer Engineering
Department of Optics and Photonics

EEL 4914 – Senior Design I
Fall 2025 – Spring 2026

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Chapter 2: Project Description

2.1 Motivation and Background

The idea of F.L.C.S. is a solution solver. The design of this fabric laser cutter will appeal to those who do not have basic computer skills. Instead of needing software and a laptop to upload the desired cut pattern, we can instead use image acquisition and processing to differentiate the desired cut lines from the fabric. It is for those "old-fashioned" hobbyists who might want some technology to assist them in physically cutting, without needing the background knowledge needed for operating software and uploading files.

F.L.C.S can be useful for all types of hobbyists and designers who desire quick cutting of pieces of fabric at the tap of a screen. By drawing using a black marker on light fabric and white on dark fabric, the user can outline the desired shape of their fabric and click a button to cut the desired lines once the fabric is inside the machine. It is small enough to be placed on desks, and quite portable, being less than 2 square feet. If needed, the system can run multiple cuts on the object.

In senior design our objective is to gather and work as a group. With this project multiple subsystems will be utilized, including a laser diode system, mirror guidance system, power systems, and a user-friendly touchscreen. The beam from the laser diode is focused and collimated using the lens system and is directed by the mirror system. The housing includes a user-friendly touchscreen as well as an optical system emergency stop switch. F.L.C.S's design allows for expansion of its' subsystems if needed, to accommodate the students in the group.

2.2 Existing Projects & Prior Related Work

2.2.1 Open Source Buildlog.net 2.x Laser [1]

The Buildlog 2.x laser is a second generation open-source laser cutter that employs a 2-axis rail-based XY gantry system, with an additional manually adjustable vertical axis. Unlike our proposed fabric laser cutter, the Buildlog 2.x does not have a Human-Machine Interface (HMI). Instead, it relies on tethered computer control for job setup and execution. Our design introduces an onboard Raspberry Pi touchscreen HMI to enable stand-alone operation, real-time job management, and user feedback without requiring a connected computer. In addition, while the Buildlog design delivers the laser via a moving gantry, our project employs mirrors that will steer the beam to the appropriate destination. This approach should reduce the mechanical load of moving the entire laser head and potentially enabling faster operation, though it introduces new challenges in precision alignment and control. Despite these differences, the Buildlog 2.x website provides valuable reference material for general mechanical layout, enclosure design, and community-tested best practices that we can include in our own system.

2.2.2 Commercial Epilog Fusion Pro Lasers [2]

The Epilog Fusion Pro is a professional, industry-level laser cutter that integrates a built-in touchscreen HMI, similar to what we intend to implement in our project. Its 7" display allows a user to select between stored jobs, adjust parameters, auto-focus the laser, and rerun previous cuts directly from the machine without requiring a tethered computer**.** In addition, the Fusion Pro incorporates an overhead camera system, which provides a real-time view of the work area. These features align with our project goals for the CLOTH system. By adding an onboard touchscreen interface, our cutter will provide stand-alone job management and ease of use comparable to the Fusion Pro. Although we will not reach the same industrial-grade specifications; we seek to emulate their machine on a smaller and cheaper scale.

2.2.3 DENER FiBER LASER [3]

The DENER FiBER LASER is a high-performance 2D metal sheet cutter designed for industrial applications. It uses an XYZ moving gantry laser system, allowing for precise and efficient cutting across large sheet areas. The machine integrates with custom CAD/CAM software, enabling operators to import digital designs and automatically generate optimized toolpaths, ensuring consistent quality, fast processing, and minimal material waste.

Our project follows a similar principle, but with a different workflow and application. Instead of relying on digital design files and specialized software, the cutting path is physically drawn directly onto the fabric. Our system will interpret these hand-drawn lines and guide the laser accordingly, eliminating the need for intermediate design software. This makes the process more intuitive, accessible, and adaptable.

2.2.4 Wattsan 6090 LT [4]

The Wattsan 6090 LT is a versatile laser engraver and cutter designed for precise work across a medium-format area, using an XYZ gantry system. It relies on digital design files that are transferred by software and processed by its controller. This allows the laser to follow exact paths for cutting a variety of materials.
Like that laser system, our project is based on this same principle, but the design input takes a different form. Instead of software-controlled paths, our system locates hand-drawn markings directly on fabric. This approach combines the precision of gantry-based laser cutting with the creative freedom of drawing patterns physically, rather than needing to generate them digitally.

2.3 Goals

- Laser Diode(LD) System Goals
  - Basic Goals
    - LD driver constantly delivers current to power the LD
    - Beam from the laser diode is delivered to fabric safely
    - Optical power greater than or equal to 3 watts after the focusing lens
    - Collimated beam before contacting mirrors
  - Advanced Goals
    - Beam divergence of less than 15 degrees in both horizontal and vertical directions at point of contact with fabric

        - Focused .1-.15mm diameter spot size using a four-lens system: 3 lenses before the mirrors and one after
    - Stretch Goals
        - Sensor system integration that can identify thickness and corresponding required passes for the fabric
        - Adjust power to account for different types of fabrics
- Mirror Guiding System with Lens
    - Basic Goals
        - Accurately direct beam onto target line
        - Stable and repeatable beam alignment
        - Reflect beam with minimum power loss
        - Direct beam anywhere on the fabric canvas
        - Have secure, adjustable, and rigid mounts
        - Beam directly incident of fabric
        - No stray reflections
    - Advanced Goals
        - Redirect beam at fast pace
        - Mirrors don't heat up over extended periods
        - Precise, small movements/adjustments
    - Stretch Goals
        - Realtime laser power feedback
        - Autofocus for warped/rough fabrics
- Camera Line Tracing System
    - Basic Goals
        - Confidently recognize black or white marker lines
        - Controlled ambient lighting
        - Recognize lines on plain single-color fabric
        - No corrupted images
        - Clear high quality images
    - Advanced
        - Estimate the line center for tight tracking
        - Translate camera pixels into gantry coordinates
    - Stretch
        - Recognize UV-fluorescent marker lines
- Touchscreen goals
    - Basic
        - Mounted Securely
        - Touchscreen boots up with a working UI
        - Options are clear and understandable to the user
        - Provides feedback on errors and job progression
    - Advanced
        - Shows job preview before job execution through the camera system
        - Error messages with accurate description of the problem
        - Buzzer or speaker for audio feedback such as job completion and errors

        - Settings to control the laser such as power and speed
        - Default jobs integrated within the machine. They will be stored within the internal storage of the touchscreen
    - Stretch
        - Supports job file upload via USB flash drive
            - The user will be able to download a file from the internet and upload it to the device
        - Wireless job upload via Bluetooth or Wi-Fi
            - This will work via an app where a user can take the metadata of the job they have done and upload it to the app where another user will be able to upload it on their device
        - Data logging such as previous job information and errors
            - The device will be able to log the information about the job so that a user can upload it on the app or the net
        - Integration with a phone app with functions such as remote monitoring and uploading

2.4 Features and Functionalities

2.4.1 Subsystem Features

- Laser Diode System
    - Laser Diode (LD)
        - Beam from LD is guided by mirror system to burn/cut through textiles
    - Laser Diode Driver
        - Delivers constant current to LD
    - Lens System
        - Aspheric lens collimates beam before entering beam expander
        - Dual lens beam expander system enlarges beam before contacting mirrors with focusing lens
- Beam Guiding System
    - Plane mirrors
        - Mirrors fixed at 45° angle with respect to the beam for redirection in each axis
        - Reflect >99% of the incoming beam
    - Gantry rail/motors
        - Smooth precise movement of mirrors
    - Focus lens
        - Maximizes beam intensity on fabric
        - Adjustable height to compensate for fabric thickness
- Image Acquisition System
    - Camera
        - Capture entire fabric canvas area
        - Minimal/no edge distortion
        - Capture high quality images
    - Image processing

            - Reliably contrast/filter lines from the rest of the fabric, if not then error
            - Convert line pixels into gantry coordinates with <1% error
    - Ambient lighting
        - Steady ambient lighting during image capture
- Touchscreen
    - Interactive User Interface
        - 7” multi-touch capacitive touchscreen with intuitive menu navigation
        - Large buttons/Icons to avoid unintended actions
    - Job Management
        - Upload job files via USB flash drive (stretch)
        - Display job preview before starting
        - Select from default jobs integrated into the machine (advanced)
        - Select from stored jobs previously used that were uploaded into the machine
    - Cutting Controls
        - Start, pause, resume, and stop a job from the screen
        - Adjust laser speed and power
    - Status Feedback
        - Real-time progress display to show percent completed and estimated time remaining
        - Descriptive error messages
        - Indicators of the current state of the machine (running, idle, error)
        - Audio feedback via buzzer or speaker
    - Safety
        - Automatic stop when errors occur
        - Emergency stop button

2.4.2 Optical Systems Diagram

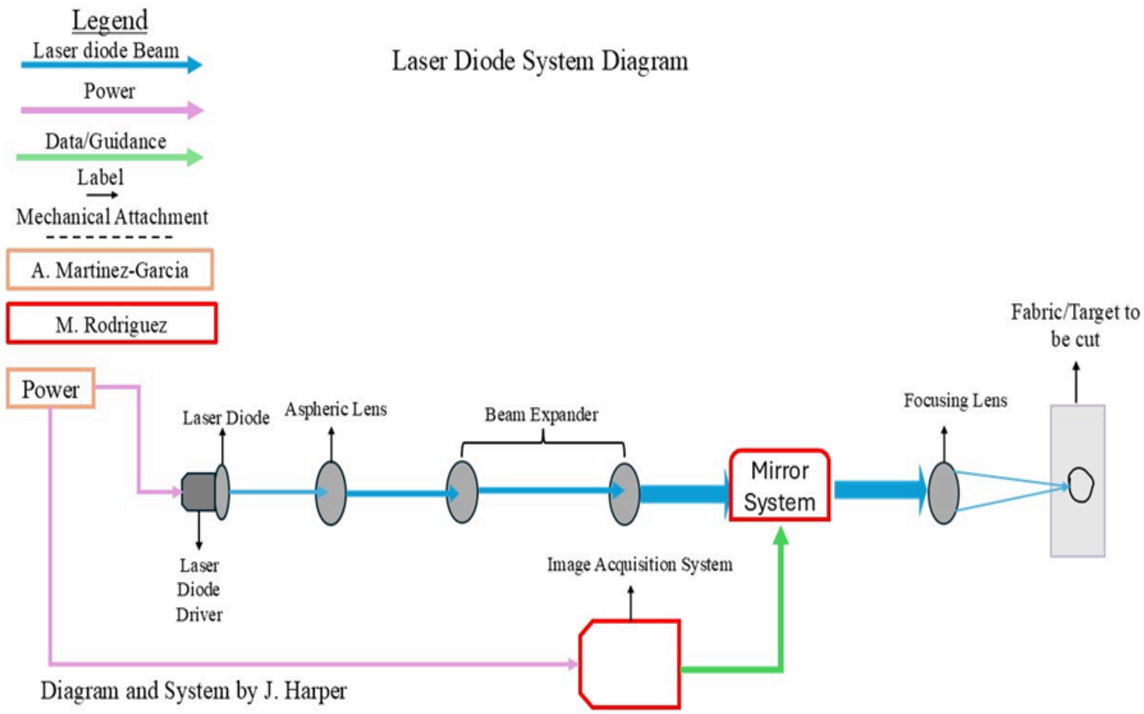

Figure 1: Laser Diode System Diagram

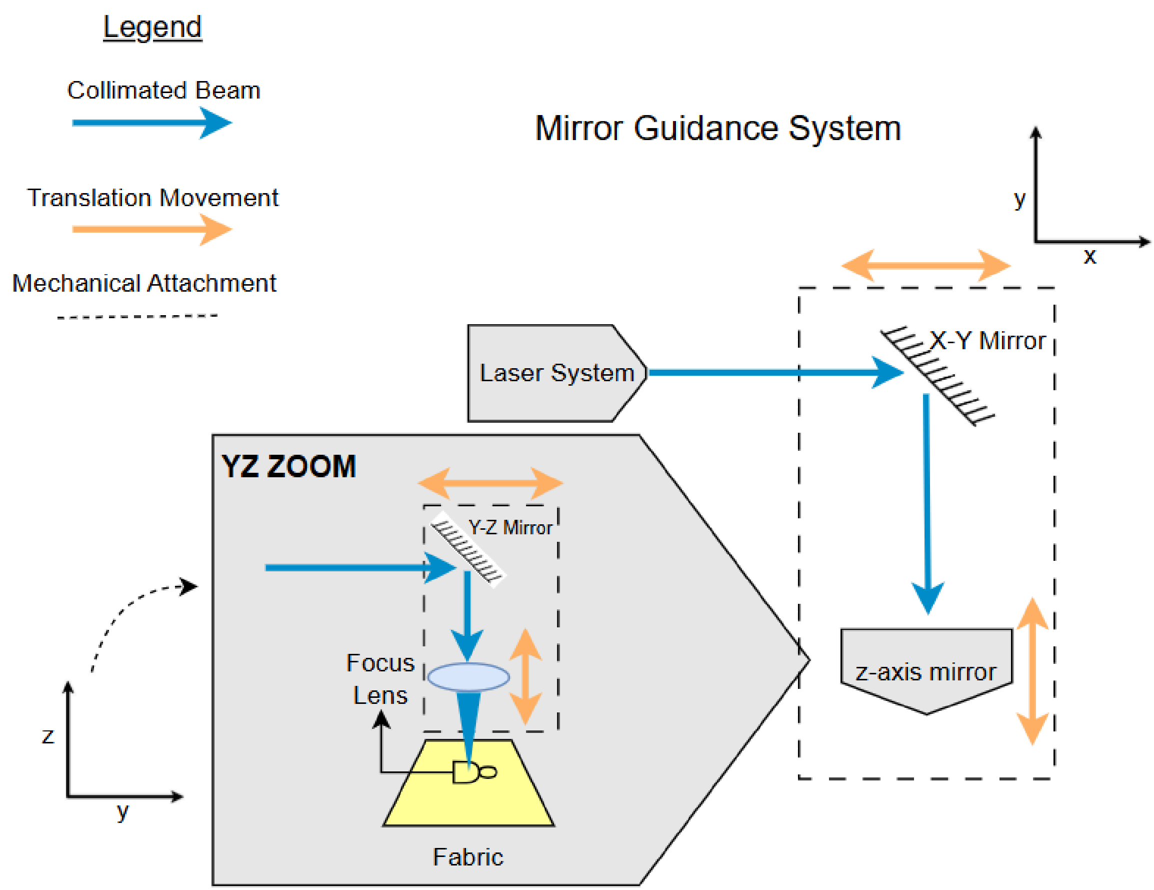

Figure 2: Beam Guidance Optical Design

The laser diode system shown in Figure 1 uses three lenses, secured by 3D printed mounts, to keep the laser diode beam collimated and enlarged as it approaches the mirror guidance system with the focusing lens. Collimation of the beam is essential because it minimizes divergence, or widening, of the beam as it travels. The initial lens of the system is aspheric which will also assist in lowering divergence. Followed by the beam expander system composed of two lenses, expanding the beam size incident on the mirrors. The beam expander in this system ensures the beam spot size on fabric will be small.

To best guide this beam with the least amount of divergence and distortion possible, a moving XY gantry mirror system (Figure 2) will be implemented for scanning the entire 350 x 350 mm field. Both mirrors will move in the x-direction together on a shiftable crane component above the fabric, dictating the x-position of the beam. A second downward-facing mirror will move independently in the y-direction along the crane component itself, dictating the y-position of the beam and directing the beam onto the fabric. This makes it possible for the beam to reach any x-y position on the fabric canvas.

At this stage, the beam is still large and collimated with low intensity. Mounted on the same unit as the second mirror, directly under it, is a convex lens to focus this beam to get the final small beam spot and high optical intensity on the desired line to be cut. Since the thickness of the fabrics may differ, the focus lens will be able to translate up and down in the z-direction, ensuring uniform focus spot of high intensity and high precision cutting on a multitude of fabrics.

To be able to detect and locate the lines, a camera mounted overhead will capture an image of the entire fabric canvas in bright ambient lighting before the job is initiated. To avoid distortion at the edges of the image, a narrow FOV camera will be used over a foot above the fabric. Once the image is captured, it is analyzed, the lines are confidently discerned from the fabric, and the pixels will be mapped into coordinates for the beam guiding system to follow.

2.5 Engineering Specifications

Component	Parameter	Specification	Unit
Housing			
Honeycomb Base	Dimensions	350 x 350	Millimeters
Laser Safety Window	Dimensions	250 x 250	Millimeters
Laser Diode System			
Laser Diode	a) Wavelength b) Optical Power Output c) Beam Diameter	a) 445-465 b) 3500 c) .1-.3	a) Nanometers b) Milliwatts c) Millimeters
Laser Diode Driver	a) Current Delivered b) Max Voltage c) Operating Temperature	a) TBD b) TBD c) TBD	a) Amps b) Volts c) Celsius
Aspheric Lens	a) Focal Length b) Diameter c) Coating	a) TBD b) TBD c) TBD	a) TBD b) TBD c) TBD
Beam Expander Lens A	a) Focal Length b) Diameter c) Coating	a) TBD b) TBD c) TBD	a) TBD b) TBD c) TBD
Beam Expander Lens B	a) Focal Length b) Diameter c) Coating	a) TBD b) TBD c) TBD	a) TBD b) TBD c) TBD
Focusing Lens	a) Focal Length b) Diameter c) Coating d) Beam Size	a) TBD b) TBD c) TBD d) TBD	a) TBD b) TBD c) TBD d) TBD

Mirror Guiding System			
Mirror A	a) Reflectivity b) Dimensions c) Wavelength	a) >99% b) TBD c) 445-465	a) N/A b) Millimeters c) Nanometers
Mirror B	a) Reflectivity b) Dimensions c) Wavelength	a) >99% b) TBD c) 445-465	a) N/A b) Millimeters c) Nanometers
Camera-Tracking System			
Camera	a) Resolution b) Field of View c) Shutter Speed d) Aperture	a) 1920×1080 b) ~40-60 c) 1/100 d) TBD	a) Pixels b) Degrees c) Seconds d) f/#
Touchscreen System			
Screen	a) Touch b) Brightness c) Input latency d) Resolution e) Viewing Angle f) Size	a) Five-touch capabilities b) ≥500 c) ≤100 d) 720 x 1280 e) ≥80 f) 7	a) Pressure Points b) Nits c) Milliseconds d) Pixels e) Degrees f) Inches
Controller/Processor	a) CPU Speed b) RAM c) Power Draw d) Boot Time	a) 1.5 b) 4GB c) ~3.4 - 7 d) ~25	a) Gigahertz b) Gigabytes c) Watts d) Seconds
Storage	a) Type b) Size c) Read speed d) Write speed	a) High Endurance b) 256 c) 100 d) 40	a) Class b) GB c) Megabytes per second
Buzzer	a) Frequency b) Trigger Latency	a) 2000 - 4000 b) <1	a) Hertz b) Millisecond
Power System			
Power Supply	a) Efficiency b) Load Regulation	a) ≥74 b) ≤8	a) Percentage b) Percentage

Table 1: Component Specifications

Engineering Requirement	Requirement Specification	Unit
Housing System		
Overall Dimensions	≤50x50x30	Centimeters
Laser Diode System		
Optical power required to burn through fabric	>3	Watts
Max voltage delivered to LD	<5.2	Volts
Mirror Guiding System		
Mirrors direct laser beam	>10	Millimeters per second
Camera-Tracking System		
Camera able to reliably filter out light at	~455	Nanometers
Touchscreen System		
The system shall boot within and show the system UI within a reasonable amount of time	≤30	Seconds
The system shall show clear images from the camera system and clearly show written text.	720 x 1280	Pixels
The system shall provide user feedback on errors and job progression	≥90% of error states produce an onscreen message	Percentage
The system shall provide audio feedback on job completion and errors	≥70	dB

Table 2: Engineering and Performance Specifications

2.6 Hardware Block Diagram

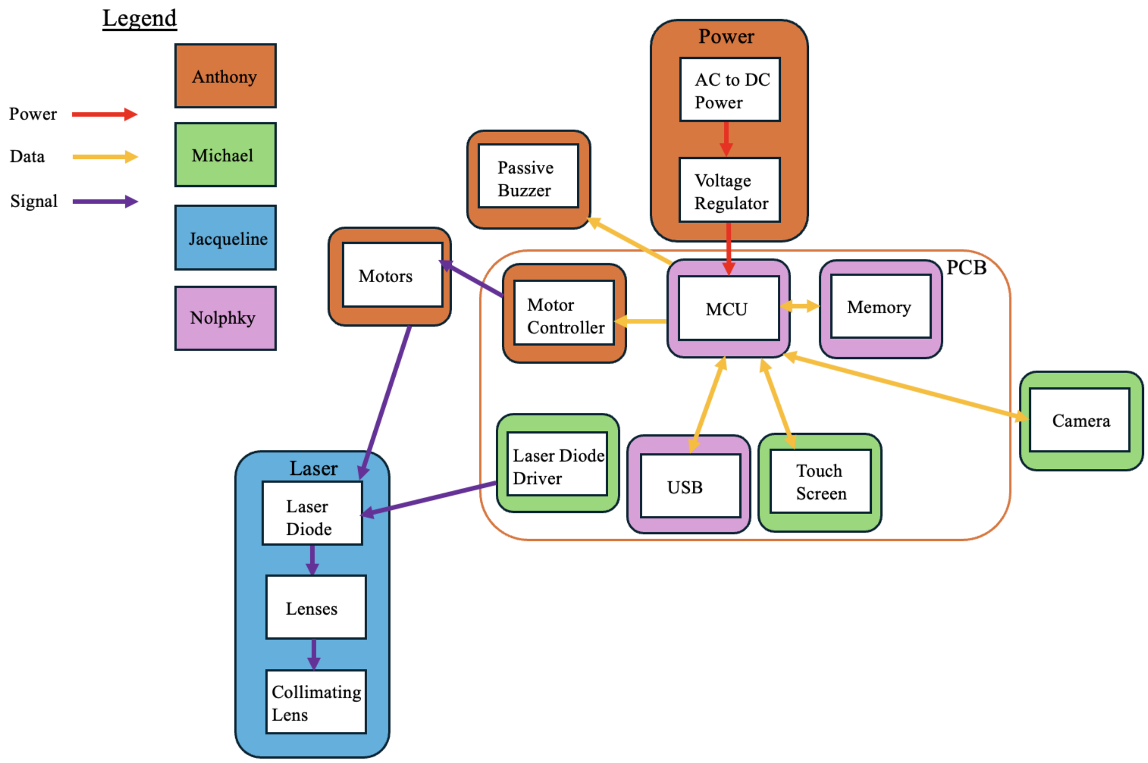

Figure 3: Hardware Block Diagram

The hardware block diagram involves three main subsystems: the power supply unit, the optical module and the date module. All the subsystems work in tandem with the microcontroller to deliver a product that closely resembles what the user asked for.

2.7 Software Diagram

2.7.1 Touchscreen Flowchart & Description

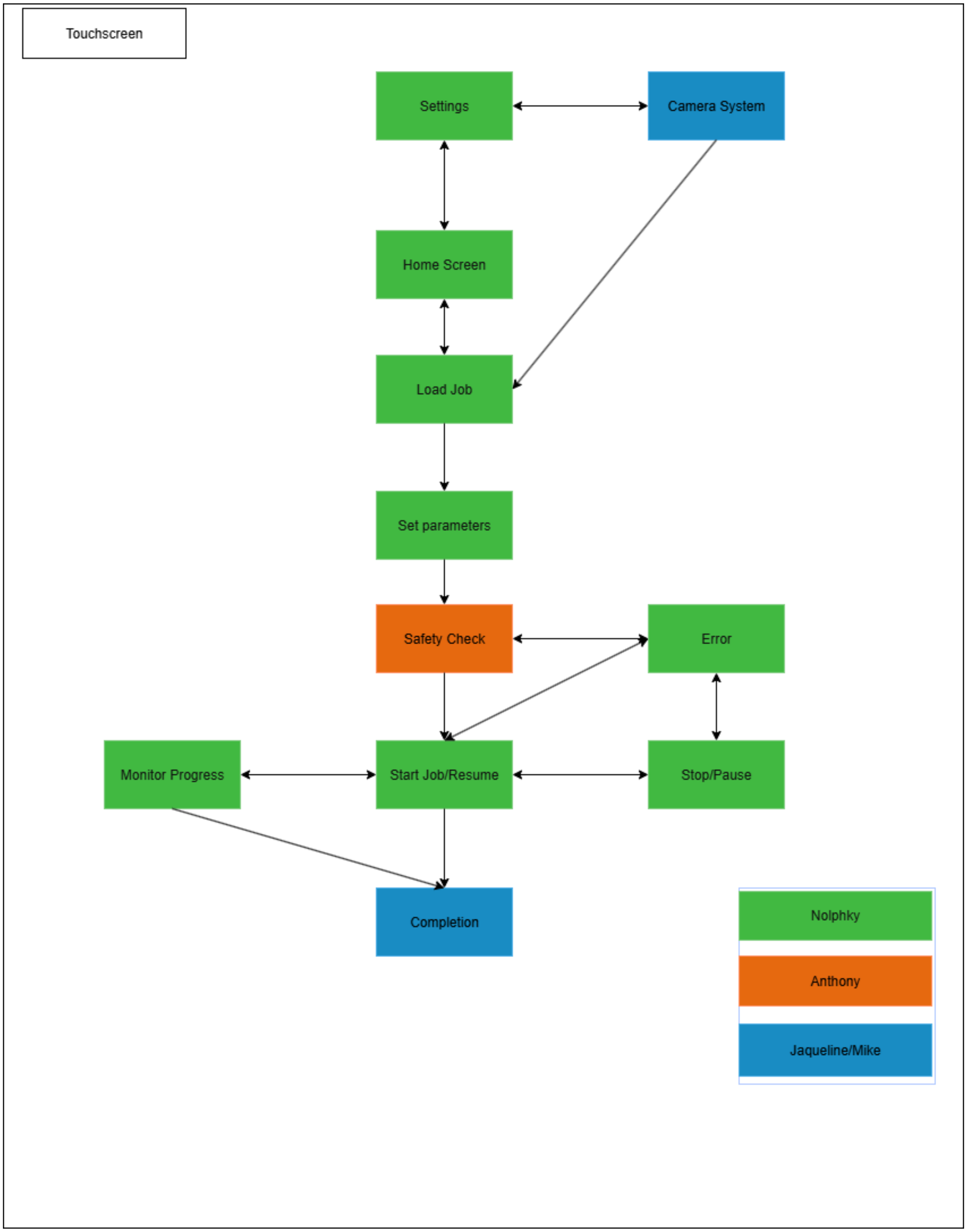

Figure 4: Touchscreen Flowchart

- **Home Screen**
    - Access Settings
        - Control over system preferences

        - Configure camera system (alignment, job preview, calibration)
    - Load job – Selects a cutting job from the camera system or, as a stretch goal, via USB drive or Bluetooth file transfer
- **Load Job**
    - **Captured by the camera system (preview image available)**
- **Set Parameters**
    - Allows for users to configure power, speed, and number of passes
    - Includes material presets for common fabrics
- **Safety Check**
    - The software verifies critical safety check
    - Any failures will lead to an error screen
- **Error Handling**
    - Displays descriptive warnings
    - Prevents the system from starting until conditions are corrected
- **Start Job/Resume**
    - Sends job parameters and cutting commands to the controller
    - Initializes job timer and enables real-time monitoring
- **Monitor Progress**
    - Displays percent completed, estimated time remaining, and live status
    - Emergency stop and pause options are also available on this screen
- **Stop/Pause**
    - User can halt or pause the cutter mid-operation
    - Software ensures the laser powers down safely
- **Completion**
    - Once a job is finished, a confirmation message is displayed. The software logs the job and returns the user to the home screen
    - Provides an option to review job statistics

2.8 Prototype Illustration/Blueprint

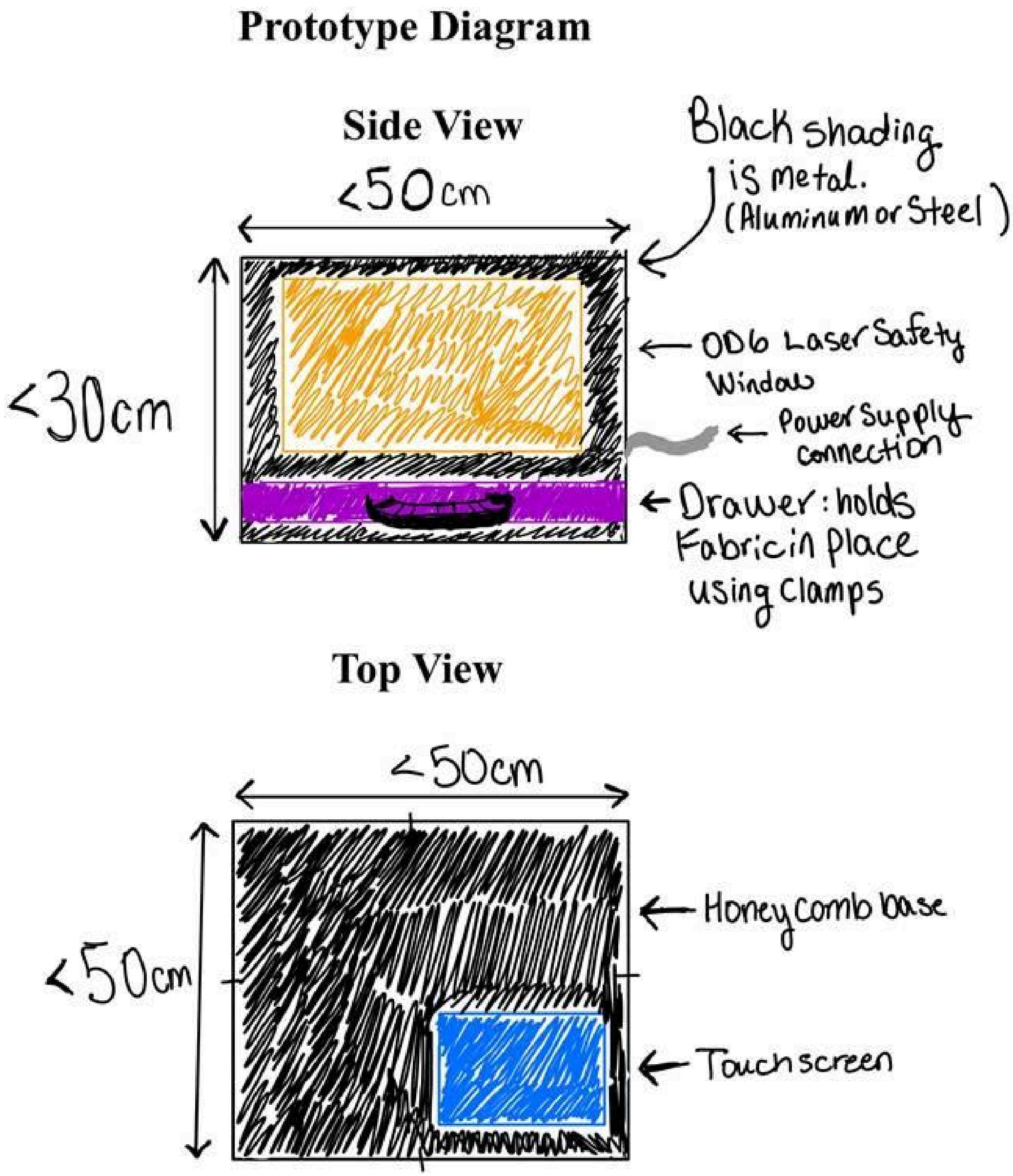

Figure 5: Prototype Diagram

Figure 5 is a visual representation of our final prototype. It will be rectangular from the side and square from the top due to the dimensions of available honeycomb beds. The honeycomb bed is often utilized for laser cutters because its design allows for air flow underneath the fabric and for minimal contact area between the base and the laser as the beam heats the fabric.

2.8 House of Quality

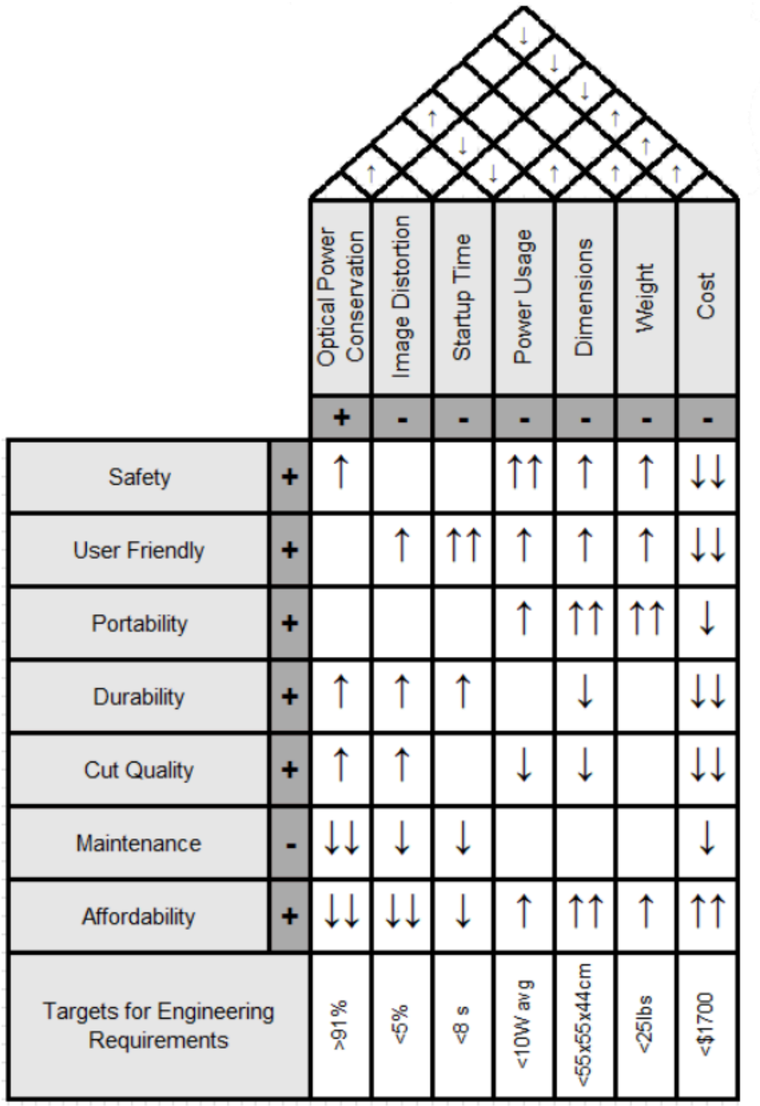

Figure 6: House of Quality

Chapter 10: Administrative Content

10.1 Budget and Financing

This project is not sponsored and is funded by the students who complete each subsystem. The budget sets a target to keep costs below a certain price while not compromising on quality. Total cost is kept in mind to make the final product affordable to a common customer. The budget could change due to design changes or economical factors such as a tax on imported goods.

10.2 Bill of Materials

The table below shows the components that make up the bill of materials.

Item	Details	QTY	Price (USD)
Raspberry Pi 4/4GB	Main processor for touchscreen HMI	1	55.00
Raspberry Pi Touch Display 2	Main touchscreen	1	72.50
Pi Bezel for 7" Pi touchscreen	Frame for the touchscreen (optional, 3d printing)	1	9.99
Samsung PRO Endurance (256GB)	Internal storage for the touchscreen	1	29.99
Passive Buzzer	Provides feedback for user actions and errors	1	0.95
standoffs and screws	Standoffs, screws, etc	1	14.95
Touchscreen power (TBD)	Powers the touchscreen (integrated into system PSU)	TBD	TBD
Laser diode	Cuts fabric	1	25.00
Aspheric Collimating Lens	Collimates beam from LD	1	40.00
Pair of Lenses (Beam Expander)	Expands beam	1	TBD
Focusing Lens	Focuses laser beam	1	TBD
Lens Holders and Mounts	3D Printed	TBD	Free! (TBC)
Fume Extraction System	Safety Precaution	TBD	20.00

Table 3: Tentative Budget

10.3 Project Milestones

Below are two tables that outline timeframes for tasks to be completed in Senior Design 1 and Senior Design 2. The project is broken into several parts that will come together to realize a final product. Breaking down the project into smaller parts allows for weekly progress to be made by a certain timeframe.

Senior Design 1 (Fall 2025)					
Week(s)	**Milestone:**	**Assigned to:**	**Start Date:**	**End Date:**	**Progress:**
1	Form Project Idea	Everyone	8-19-25	8-25-25	DONE
2	Form Group	Everyone	8-26-25	8-28-25	DONE
2/3	Reach Out to Reviewers	J. Harper, A. Martinez-Garcia, N. Nicolas	8-29-25	9-4-25	DONE

3	Complete Divide & Conquer Initial Draft (Submit)	Everyone (M. Rodriguez)	9-2-25	9-5-25 (noon)	DONE
4	Senior Design Bootcamp	Everyone	9-9-25	9-12-25	In Progress
4	Create Project Website	N. Nicolas	9-8-25	9-28-25	In Progress
4	Equipment Loan (if needed)	Everyone	9-8-25	9-12-25	In Progress
5	Divide & Conquer Final Revision (Submission)	Everyone (A. Martinez-Garcia)	9-8-25	9-12-25 (noon)	In Progress
7	Email D&C to Reviewers (add to Website)	A. Martinez-Garcia, (N. Nicolas)	9-12-25	9-19-25	TBD
7	Engineering Standards Assignment	Everyone (Individual sub.)	9-8-25	10-3-25 (noon)	TBD
8	Optical Demo	J. Harper, M. Rodriguez, (Everyone Present)	9-27-25	10-7-25 (10AM SHARP)	TBD
9	15 Pages Completed (per person)	Everyone	9-2-25	10-25-25	In Progress
11	(Submit) Midterm Report First Draft	Everyone (A. Martinez-Garcia)	9-2-25	10-31-25 (noon)	In Progress
12	Midterm Report Meeting	Everyone	11-3-25	11-5-25	TBD
12	(Submit) Midterm Report Revision	Everyone (A. Martinez-Garcia)	11-3-25	11-7-25 (noon)	TBD
14	Upload report and video (YT Link) to website + email for Reviewer Feedback	(N. Nicolas) A. Martinez-Garcia	11-17-25	11-21-25	TBD
16	(Submit) 120-page Final Report	Everyone (A. Martinez-Garcia)	9-2-25	11-25-25 (noon)	In Progress
16	(Upload) Demo Video	Everyone (A. Martinez-Garcia)	11-17-25	11-25-25 (noon)	TBD
17	Upload Demo to Website and Email to Committee	N. Nicolas	11-17-25	11-25-25	TBD
17	Submit Evaluations	N. Nicolas	11-17-25	11-25-25	TBD

Table 4: Senior Design 1 Project Milestones

Senior Design 2 (Spring 2026)					
Week(s)	Milestone:	Assigned to:	Start Date:	End Date:	Progress:
1	Purchase Components	Everyone	TBD	2/25	TBD
TBD	Test Experimental Setup, Adjust	Everyone	TBD	2/25	TBD
TBD	Assemble Housing	Everyone	TBD	3/25	TBD
TBD	CDR Video Submission	Everyone	1/25	1/25	TBD
TBD	CDR Video on Website and Sent to Committee	N. Nicolas	1/25	2/25	TBD
TBD	Review Final Submission Documents with Committee	Everyone	TBD	3/25	TBD
TBD	Upload all Documents to Project Website	N. Nicolas	3/25	Final Exam Date	TBD

Table 5: Senior Design 2 Tentative Project Milestones

Appendices

Appendix A - References

[1] "Buildlog.net 2.x Laser". *Buildlog.Net Blog*, https://www.buildlog.net/blog/2011/02/buildlog-net-2-x-laser/. Accessed 1 Sep. 2025.

[2] "Epilog Fusion Pro Lasers". *Innovative Cutting Systems*, https://www.innovativecuttingsystems.com/epilog-laser/fusion-pro-laser-series.ht m. Accessed 1 Sep. 2025.

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