UNIVERSITY OF CENTRAL FLORIDA

<u>UCF Senior Design I</u>

Temperature-Monitored Inkless Laser Engraver (T-MILE)

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Initial Project and Group Identification Document
Divide and Conquer, Version 2.0

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Project Narrative

Throughout history, printing has been an essential aspect of the world. Printing started with the use of stencils over 35,000 years ago. Over the generations, printing has evolved into laser printers and inkjet printers. Laser Inkless Printers are an upgrade to an ink printer in terms of resolution and sustainability. Ink is notoriously expensive, and has to be refilled manually. Most ink is petroleum-based, which means that ink contains inorganic compounds, heavy metals, and minerals, all of which are not biodegradable. As we look forward to a brighter and greener future, we must have a more environmentally friendly alternative to ink-based printing. Not only this, but ink bleeds away from the point of deployment by the printer itself. All of these factors are avoidable through the use of a laser for printing. By varying the power of a laser, you can create a laser that can print, engrave, burn or cut a variety of mediums such as paper, wood, or acrylic.

Groups in Senior Design have worked on this project before, and so our goal is to improve upon the performance of their design in two main categories. The primary goal is to move beyond a strictly braille printer into a continuous printing machine that operates just as a normal printer would. Our secondary goal is one of safety. Since we are dealing with paper and other flammable materials, the risk of a fire getting started is always looming. To combat this, we propose the use of a thermal sensor capable of reading the temperature in the printing area. Before printing, it would check for high temperatures to ensure no one is currently in the path of the laser, and then during printing, it can be used for quality control and to ensure that there are no active hazards within the printing area. Many laser engravers are also difficult to set up and operate, our group strives to create a user-friendly system that is simple and intuitive. Groups in the past have also used pre-built manufactured printing mechanisms for moving the laser around. We hope to be able to create our own to help increase the efficiency and lower the overall cost of our build.

We’d also like to look into varying the optical power of the laser to change the utility of the printer to do more than just print on paper, but also potentially cut paper, engrave on wood or acrylic, or even cut wood, depending on time and budgetary restrictions. As well, if we could vary power we could print more than just monotone color with the laser, but expand to grayscale. This will give the consumers who are interested in printing on wood or other materials be able to purchase one printer for all of their needs. We realize our solution may be more expensive upfront however, we are aiming to create a printer with little to no maintenance and replacement of parts for multiple years. Ideally, this printer could be upgraded in the future to include any aspects of printing that may be missed due to budgetary restrictions. This would give the consumer the option to upgrade the printer as they see fit.

Requirements

ID	Requirement
1.0	Engrave an image on an 8.27x 11.69 in. piece of paper (standard A4 size)
2.0	Fit on a 48 x 30 in. desk
3.0	No component of the system will exceed 200° C (400°F)
4.0	Laser will not remove more than 0.05mm-0.10mm of material
5.0	Laser dot will not exceed 12/72" (⅙inch) Diameter Spot Size
6.0	Have at least 8.3 MB of memory for data storage
7.0	Accept a supply voltage of 120V AC
8.0	The system will have an emergency stop switch
9.0	Thermal sensor to monitor laser heat and material.
10.0	300 Dots Per Inch Resolution for Motor Control

Table 1; Requirements

ID 1.0: A4 paper will be chosen in this project due to being the most common form of printer paper. If design specs allow, as a stretch goal, we could expand the scope of the papers allowed to other forms.
ID 2.0: This size was chosen to make the project a similar overall size to a standard home-use printer. Larger printer machines do exist, but they tend to be for companies and larger operations.
ID 3.0: No component can bypass 200° C for the operation of the parts themselves, and any parts which exceed a safe-to-touch temperature (38° C and up) will have warnings and safety measures in place to prevent accidental contact.
ID 4.0: A4 Paper Thickness is in the range of 0.05mm to 0.10mm, so we need to safely remove at least or at most that much in order to make a significant cut into paper. Alternatively, if we struggle with getting a full cut through paper, or the engraving is too shallow to be visible, we can apply a paint coating in that thickness range to add a color change to the engraved text.
ID 5.0: Size was chosen based on the standard pixel size of a 12 point font choice in Times new Roman. The minimum spot size would be desired at this level, but we are willing to bend on this size to achieve other parameters.
ID 6.0: The project should be able to accept data from a connected computer of images or PDF documents that have been converted into a series of drawn lines or dots, and prints based on that provided document, or to a more limited degree allow for direct input from the machine.

ID 7.0: The system will be powered by an AC adapter designed for a standard US 120V, 60Hz wall outlet. The AC adapter will output 15V (subject to change depending on power requirements), and this 15V output will be input into a PCB to power necessary components. A central motherboard PCB that is designed to consist of all of the power distribution for all components (motors, display, laser, sensors, etc.), as well as containing the necessary microcontrollers or microprocessors and their connections. This central PCB will be powered using the 15V AC adapter mentioned previously.
ID 8.0: Emergency stop for dealing with unforeseen events or user error, allowing for the laser process to cease. As well, there should be a non-emergency stop to serve as a pause on all events should the user need to step away from the printer for a time to ensure an emergency does not occur while no one is present.
ID 9.0: Thermal Sensor will monitor either the laser to ensure that its operating within normal parameters (as some lasers we have looked into and test have safety requirements based on this) and at the engraved medium to ensure that it is not exceeding expected thresholds and at risk of fire. The system will be able to monitor its temperature to prevent fires and overheating.
ID 10.0: A motor control system that will move the laser diode in order to print, or instead move the paper being printed, or a combination of the two. Using stepper motors to make the movements of the printing device, we want our motor movements to be precise enough to achieve a 300 dots per inch resolution, that being 300dpi vertically and 300dpi horizontally.

Design Options

Trade Offs	Main Drawbacks	Essential Requirement
Accuracy	Greater accuracy sets limits on the speed of the laser, and requires more quality parts which increase cost.	A priority to get out spot size requirements and maximum engraving depth values.
Speed	Being too slow would cause varied engravement depths along the medium, potential fire hazard if the laser is running too long, or too long in a given spot. Being too fast may result in uneven engravement, runs the risk of not being up to quality.	A priority to get our ease of use to be desirable and minimize the risk of hazards occuring or exceeding temperature controls.
Power	Increased Power Consumption increases the power demand of the system, could cause issues Increased power means greater risk of exceeding depth values or temperature restrictions.	A requirement for engraving within our spot size
Ease of Use	Increasing ease of use, i.e. creating a better interface or decreasing overall size puts more strain on the rest of the design.	A requirement to make the project viable, it needs to be at least as good as a typical printer in how it is to interface with.
Cost	Project is entirely out of pocket, so the higher cost of each component is a higher cost to each individual involved. Key parts may be paywalled behind an accessible price point, so a worse alternative may be needed.	A requirement to actually creating the project as parts are needed and certain features essential for function.

Table 2; Trade Offs for Design Options

Optical

- Laser Mounting: The laser can be mounted vertically and moved about the grid, but this limits us to a smaller, less heavy laser, or a much stronger x-y translation grid. Another option would be to couple the laser light into fiber optic cable, and then move the fiber output about the page. The downside to fiber would be finding fiber that can sustain higher input power without damage.
- Laser Power Control: We can start with a cheap, lower power laser and build an optical amplifier to increase the light output from miliwatts to watts, but this process would start

very cheap and enable easy mounting of the laser, but would result in a costly and complicated lens design system. Alternatively, we could get a laser with higher power output than is desired, say 10+ W, which would be far more expensive, and use either filters to cut power, or develop a system to monitor and decrease input power to the laser to cut the output power down to desired levels.

- Thermal Sensing: The scope of this can vary from existing solely as a gauge for the laser turning on, or off depending on what the sensor sees and if it determines if it's unsafe to operate. We can also expand the roll of this sensor into quality confirmation to check and see that the heat is isolated only to the desired printing area and of appropriate levels with respect to the resolution.
- Laser Choice: We can choose many different laser types, with different wavelengths and different optical power outputs, and the major deciding factor on the exact laser we buy will be based on economics as we have a limited budget and lasers can become very expensive. However, one other choice we have to consider is the beam profile, be it either a gaussian or a top hat. Ideally, we would use a top hat which would result in a spot size that has consistent power distribution, as opposed to Gaussian which would have a brighter center and fading edges.

Electrical

- Motors and Motor Controlling: Most likely we will settle on using stepper motors to control the movement of the laser on its rails. Stepper motors are able to be controlled quite easily with microcontroller data inputs, and a motor controller of some sort would be necessary to provide the appropriate power signals to the motors themselves. Our motors will have to be able to make precise enough movements to allow our laser to print and engrave in great detail.
- Power Distribution: As of now we believe the majority of our components will be using DC power, so it should be simple enough to buy a regular adapter to plug into a standard wall outlet to power our device. We need to distribute this power to quite a few components however, this includes: our laser, motor controllers (and by association the motors), a microcontroller or microprocessor, a display, a thermal sensor, and most likely other minor components. Ideally, most of this power distribution circuitry would be on a single PCB, allowing us to simply plug an AC adapter from a wall outlet to our device and everything that needs power will get power without needing any more connections.
- Printed Circuit Board: Our hope is to have one single, probably somewhat large PCB that houses all our power distributions to all necessary components, as well as containing whatever microcontroller or microprocessor we end up choosing to run most of our computations. Having a single PCB with as many components that can reasonably be on it will significantly reduce the size that electrical components will take, rather than having loose wires running about, or separate microcontroller development boards that take up too much extra room. Having many components on a PCB will most likely mean

we need a fan cooling system to cool all those components running at once on a single board.

Computational

- Image or Document Processing: To process images, a program can be written on an external computer that will then send data to the printer that can be directly interpreted into control signals. This way a multitude of different algorithms or preexisting software can be used to process the image without having to worry about microcontroller processing power.
- User Interface: A user interface can either be done using a GUI program on an external computer or using an onboard display and buttons. Using a GUI program will make it easier to add more complicated features and will most likely cut down on hardware development time, but will require a more robust communication protocol between the printer and the computer. Using an onboard display will decrease software development time, and will not be too expensive depending on the display model and information chosen to be displayed. However, an external computer will still be required for processing the image.

Block Diagram

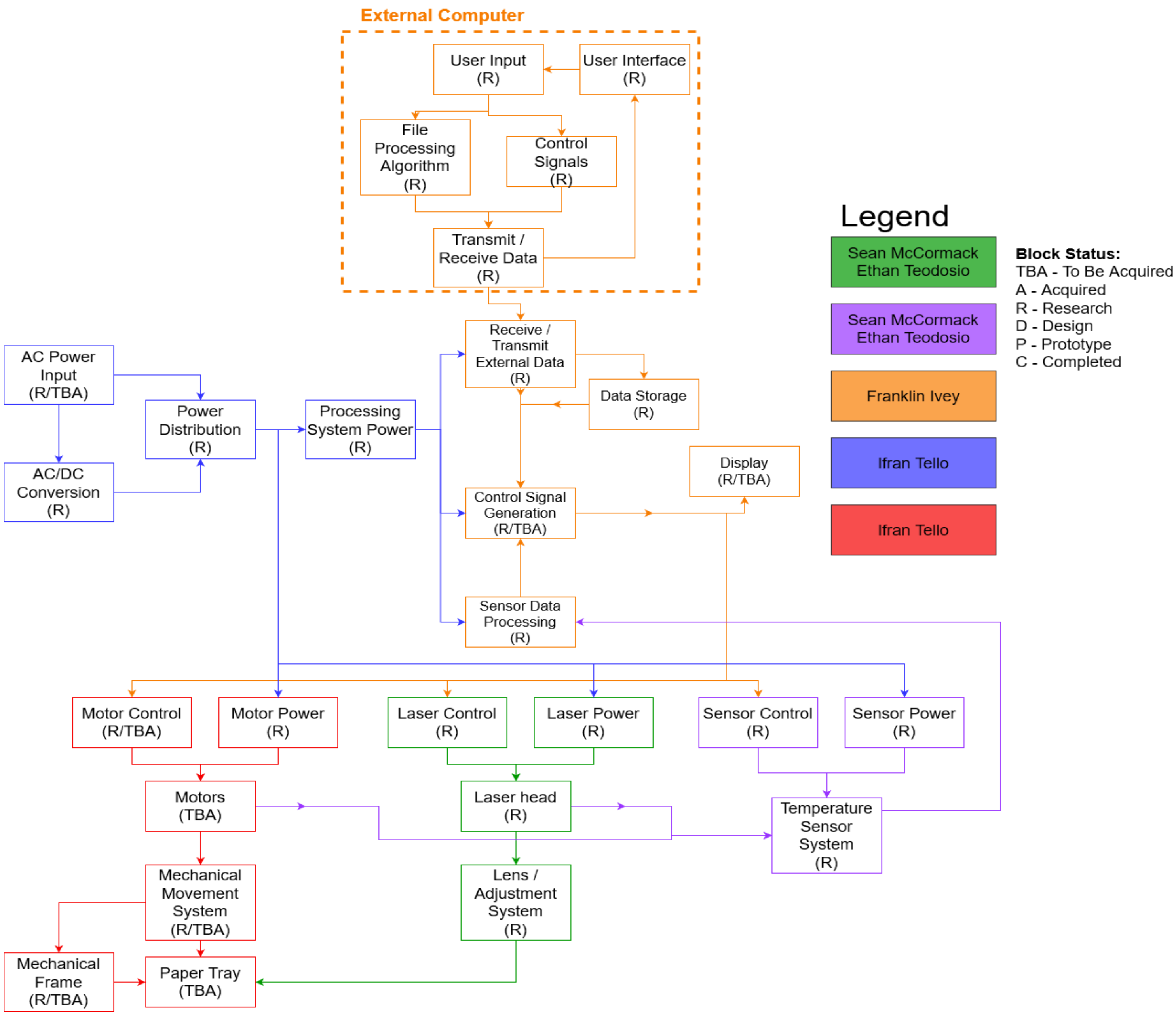
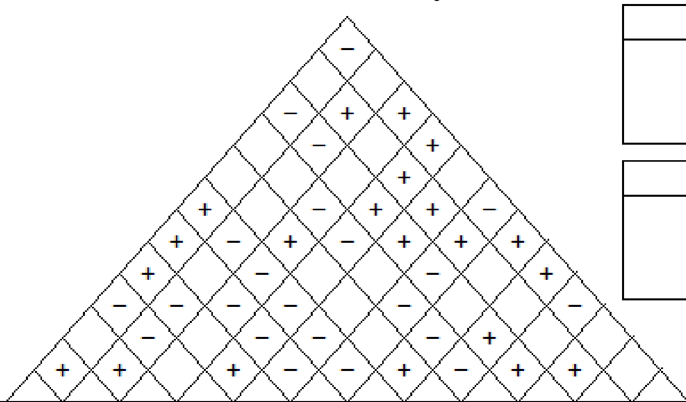


Figure 1; Block Diagram

House of Quality



Correlations	
Positive	+
Negative	–
No Correlation	

Relationships	
Strong	●
Moderate	○
Weak	▽

Column #	1	2	3	4	5	6	7	8	9	10	11	12
Engineering Requirements / Customer Requirements (Explicit and Implicit)	Size	Weight	Laser Power	Motors	Sensor	Cost	Power Consumption	Laser Wavelength	System Temperature	Energency Stop	Hardware Communication	Laser Dot
Printing Speed	▽	▽	●	○	▽	▽	●	●	○	○	●	▽
Resolution of Print	▽	▽	●	●	▽	●	●	●	▽	○	●	●
Power Efficiency	●	▽	●	●	○	●	●	▽	●	○	▽	●
Ease of Use	○	○	▽	▽	▽	▽	▽	○	▽	●	●	○
Appearance/Aesthetics	○	▽	▽	▽	▽	▽	○	○	○	▽	▽	○
Safety	▽	○	●	○	●	▽	▽	▽	●	●	●	○
Affordable	▽	○	○	○	○	●	●	○	○	▽	○	▽
UI Interface	▽	○	○	●	●	○	○	○	○	●	●	○
Runtime	●	○	●	●	●	○	○	●	▽	○	○	▽
Target	48 x 30 in. desk	TBD	~1W	TBD	TBD	<\$1000	120V AC	420 nm	>200°C	Safety	USB Cord	1/16" Diameter

Figure 2; House of Quality ver. 1

Project Budget

The prices below are estimated prices based on minimal research. The prices, quantity, and materials are subject to change once more research has been conducted. As of 10/08/22 there are no sponsors for the project and those involved will be financing the build.

Table 3; Budget Breakdown

Material	**Unit Cost**	**Quantity**	**Total Cost**
Optical Components			
Laser/Lasers	$150	1	$150
Laser Mount	$20	1	$20
Thermal Imaging sensor	$50	1	$50
Lenses	$40	3	$120
Mirrors	$50	2	$100
Electrical Components			
Stepper Motors	$30-$60	2	$60-$120
AC Adapter Power Supply	$20	1	$20
Motor Controller	$15	1	$15
Custom PCB	$20	1	$20
Miscellaneous PCB Components	$10-40	1	$10-$40
Display	$20	1	$20
DC Fans	$5	2	$10
Computer Components			
Microcontroller or Microprocessor	$30	1	$30
Building materials			
Aluminum rails	$10	10	$100
Aluminum corners	$5	15	$75
Paper	$4	1	$4
Miscellaneous	$30	1	$30
Total Cost Estimate			**$824-914**

Project Milestones

Table 4; Senior Design 1 Milestones

Milestone	Progress	Assigned To	Start Date	End Date
Form Group	Completed	All	8/23/22	8/25/22
Gather Ideas	Completed	All	8/23/22	9/2/22
Project Selection	Completed	All	9/2/22	9/13/22
Divide & Conquer 1.0	Completed	All	9/12/22	9/16/22
Divide & Conquer 2.0	In Progress	All	9/12/22	9/30/22
60 Page Draft	In Progress	All	9/12/22	11/4/22
100 Page Draft	In Progress	All	9/12/22	11/18/22
SD1 Final Document	In Progress	All	9/12/22	12/6/22
Image processing methods and algorithms	Researching	Franklin	9/20/22	10/3/22
Communication protocols	Researching	Franklin	9/20/22	10/3/22
On-board control data storage	Researching	Franklin	9/20/22	10/3/22
Mechanical movement methods	Researching	Ifran	9/20/22	10/3/22
Electrical motor control methods	Researching	Ifran	9/20/22	10/3/22
Laser head computation and research	Researching	Ethan	9/20/22	10/3/22
Laser intensity control	Researching	Ethan	9/20/22	10/3/22
Temperature sensor methods	Researching	Sean	9/20/22	10/3/22
Safety measures	Researching	All	9/20/22	10/3/22
Power conversion and distribution calculations	Researching	Ifran	9/20/22	10/3/22

Table 5; Senior Design 2 Milestones

Milestone	Progress	Assigned To	Start Date	End Date
Build Prototype	Not Started	All	1/9/23	1/30/23
Testing and Troubleshooting	Not Started	All	TBD	TBD
Finalize Design	Not Started	All	2/1/23	4/20/23
Build Finalized Design / Modify Prototype	Not Started	All	TBD	TBD
Peer Presentation	Not Started	All	TBD	TBD
Final Report	Not Started	All	TBD	TBD
Final Presentation	Not Started	All	TBD	TBD