Light Technology in Medical Devices

Alicia Corona, Claire Mitchell, Norma Munoz

Project Description

- Utilize photo biomodulation (PBM) technology
- Red LED lights, infrared sensors, & rechargeable battery
- Design a cutting-edge tool that monitors blood flow & oxygen circulation
- Offers a non-invasive solution for cardiovascular health monitoring

- Enhances cellular function, promotes tissue repair, and reduces inflammation
- Applicable to medical institutions, rehab centers, military, and sports teams
- Partnering with EE & CS Capstone to enhance teamwork skills
- Jesslynn Armstrong, President, Light Matter Solutions, LLC

QFD

		Power Output	Battery Life	Unit Cost	Wavelength (Infrared light)	Wavelength (Red LEDs)	Treatment duration
1	Power Output						
2	Battery Life	9					
4	Unit Cost						
5	Wavelength (Infrared light)		9				
6	Wavelength (Red LEDs)		9				
7	Treatment duration		3		3	3	

Legend	
A	LOVTRAVEL LED Light Therapy Pad
B	Garmin HRM-Dual Heart Rate Monitor
C	Innovo iP900BP-B Finger Pulse Oximeter

			Technical Requirements						Customer Opinion Survey				
	Customer Needs	Customer Weights	Power Output	Battery Life	Unit Cost	Wavelength (Infrared light)	Wavelength (Red LEDs)	Treatment Duration	1 *Poor*	2	3 *Acceptable*	4	5 *Excellent*
1	Disinfectable	4						1		A	B		C
2	Rechargeable	3	9	9							C	A	
3	Light Exposure	4				9	9	9	AC				B
4	Time Duration	3	3	3		3	9	9			AC		B
5	Automatic shut down	1	3	9				3	BC		AC		
6	Cost effective	3			9					A		BC	
	Technical Requirements Units		W	min	$(USD)	nm	nm	min					
	Technical Requirements Target		20-50	120	290	850-880	650-670	20					
	Absolute Technical Importance		39	45	27	45	63	70					
	Relative Technical Importance (%)		13.49	15.57	9.34	15.57	21.80	24.22					

CR/ER Discussion

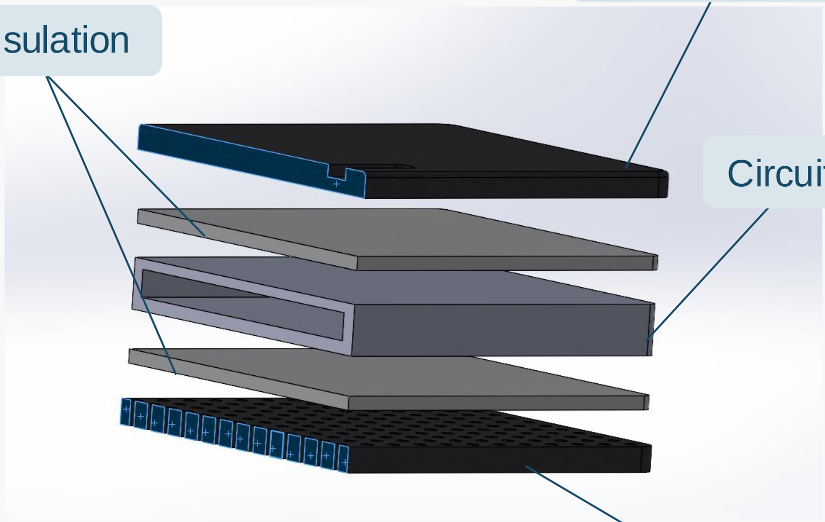
Customer Requirements

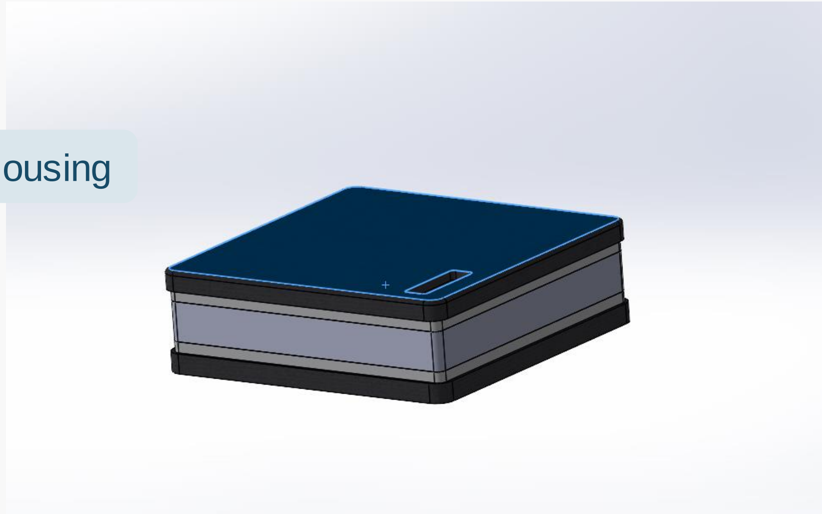
- Disinfect-able
- Rechargeable
- Light Exposure
- Time Duration
- Automatic shut off
- Cost effective

Engineering Requirements

- Power Output (20-50W)
- Battery Life (120 min)
- Unit Cost (Around $290)
- Wavelength IR (850-880)
- Wavelength Red (650-670)
- Treatment time (20min)

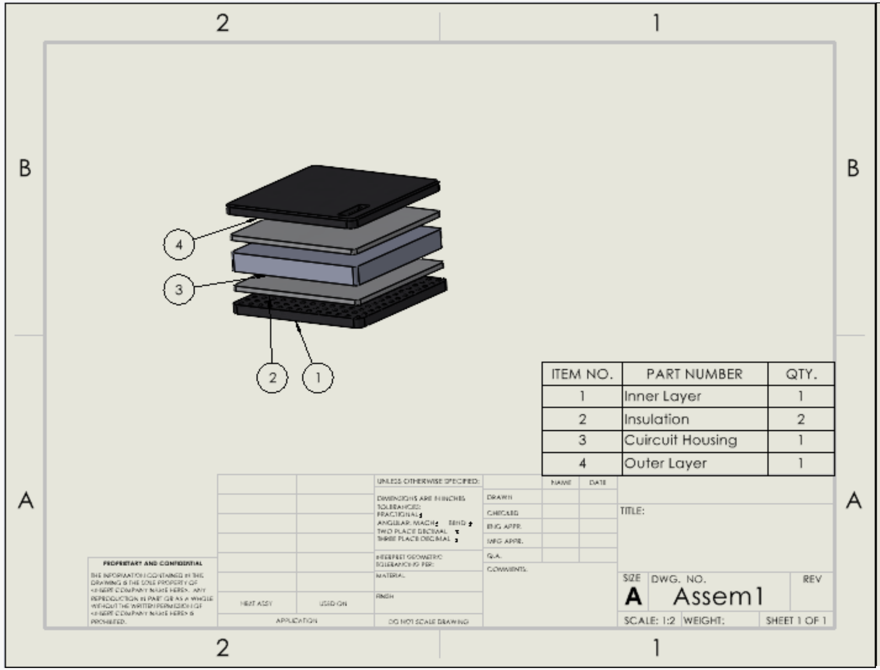
CAD Model

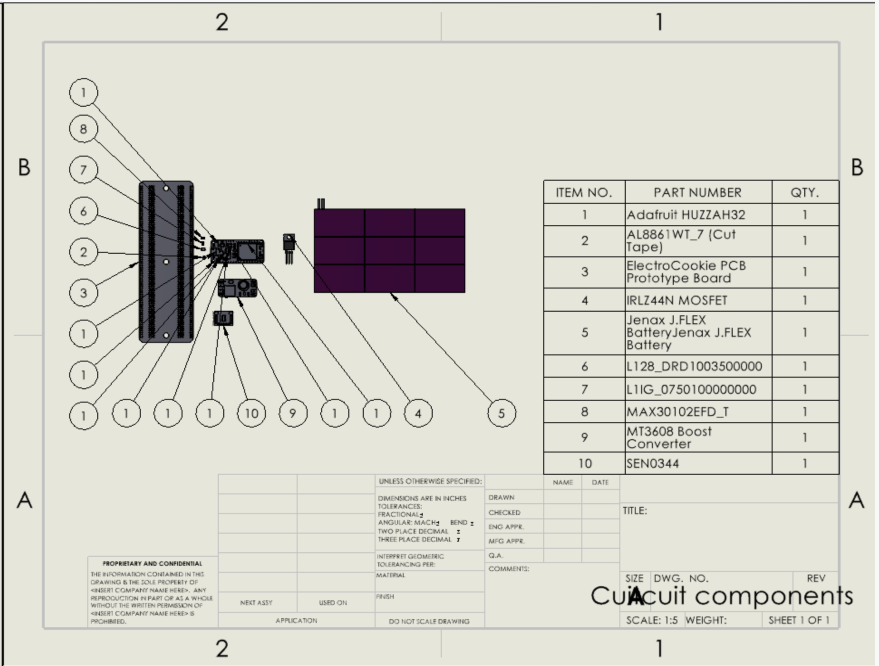




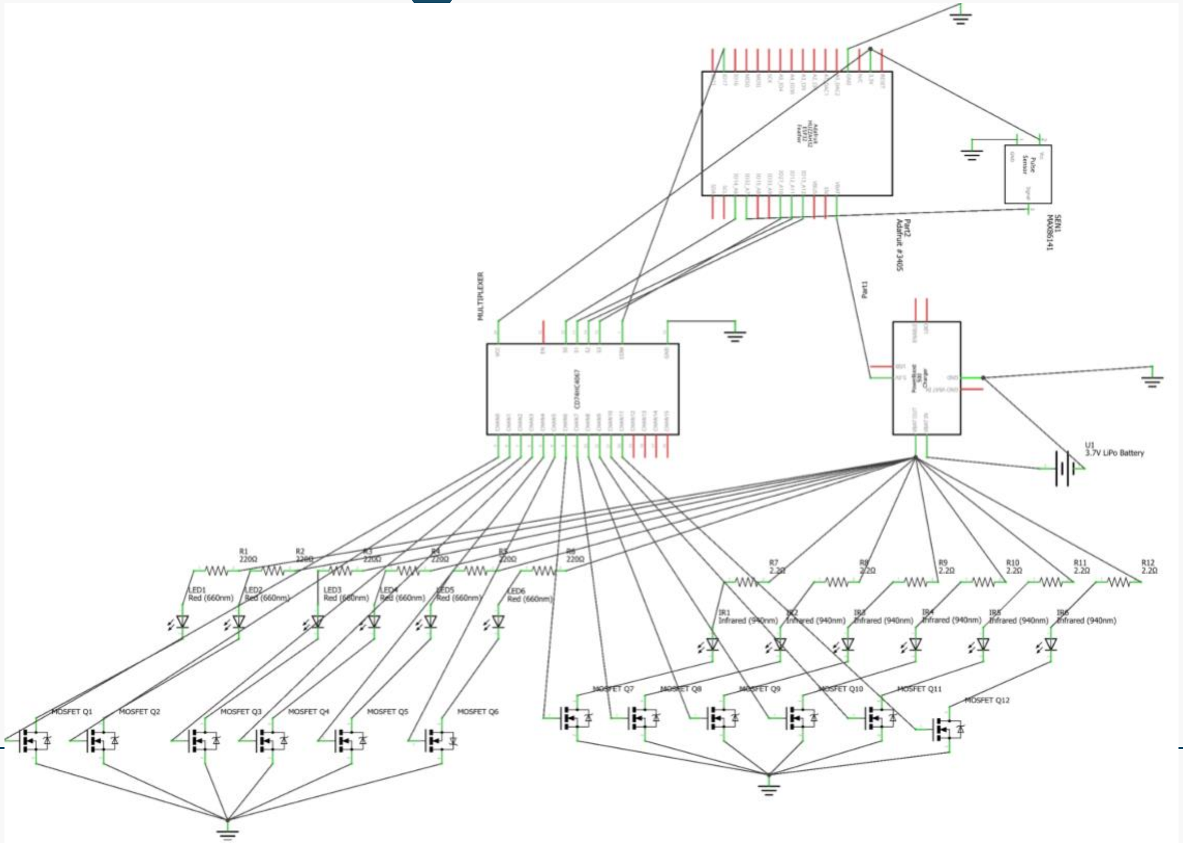
*Houses the LEDs and sensor

CAD Drawings





Circuit Planning



Engineering Calculation

Alicia Corona 1

$$Q = -kA\frac{\Delta T}{L} \Rightarrow \Delta T = \frac{Q * L}{k * A}$$

$$Q_{electrical} = heat\ transfer\ rate\ of\ electrical\ components\ (W)$$

$$k_{TPU} = thermal\ conductivity\ of\ TPU\ (\frac{W}{mK})$$

$$L = thickness\ of\ material\ (m)$$

$$A = cross\ sectional\ area\ (m^2)$$

$$\Delta T = temperature\ difference\ (Kelvin)$$

Temperature Difference
Temperature difference of the electronic components.

Software
Desmos Scientific Calculator

Engineering Calculation

Alicia Corona 2

$$Q_{electrical} = 9\ W$$

$$k_{TPU} = 0.15 \frac{W}{mK}$$

$$L = 0.0127\ m$$

$$A = 0.0097125\ m^2$$

$$\Delta T = \frac{(9\ W) * (0.0127\ m)}{\left(0.15 \frac{W}{mK}\right) * (0.0097125\ m^2)}$$

$$\Delta T = 78.5\ K$$

Temperature Difference
Temperature difference of the electronic components.

Software
Desmos Scientific Calculator

Engineering Calculation

Claire Mitchell

$$P_{\text{total}} = N \times P_{\text{LED}}$$

P_{total} is the total power consumption in watts (W),

N is the number of LEDs or light sources,

P_{LED} is the power consumption of a single LED or light source in watts.

$$I = \frac{P}{A}$$

I is the irradiance (light intensity) in watts per square meter (W/m^2),

P is the total power emitted by the light source in watts (W),

A is the area the light is covering in square meters (m^2).

$$E = I \times t$$

E is the **energy exposure** in joules per square centimeter (J/cm^2),

I is the **irradiance** (intensity of light) in watts per square centimeter (W/cm^2),

t is the **exposure time** in seconds (s).

1. Total power Calculation
2. Irradiance Calculation
3. Energy Exposure

Engineering Calculation

Claire Mitchell

$$Red\ LED-\ N:16\ ,\ P:0.11W$$

$$IR\ LED-\ N:32\ ,\ P:0.05W$$

$$P_{total}=N\cdot P_{LED}$$

$$P_{total}=(16\cdot 0.11W)+(32\cdot 0.05W)$$

$$P_{total}=3.36W$$

$$4in=0.1016m$$

$$I=\frac{P_{total}}{A}$$

$$I=\frac{3.36W}{(0.1016m\cdot 0.1016m)}$$

$$I=325.5\frac{W}{m^2}$$

$$325.5\frac{W}{m^2}=0.03255\frac{W}{cm^2}$$

$$E=I\cdot t$$

$$E=\left(0.03255\frac{W}{cm^2}\right)(20\,\mathrm{min})\left(\frac{60sec}{1min}\right)$$

$$E=39.06\frac{J}{cm^2}$$

1. Total power Calculation
2. Irradiance Calculation
3. Energy Exposure

Engineering Calculation

Norma Munoz

$$A = \frac{\pi D^2}{4}$$

- Cross sectional area of the channel

$$\mathrm{Re} = \frac{\rho v D}{\mu}$$

- Reynolds number (Re) for the flow
  - Re>4000, flow is turbulent

$$\Delta P = f \cdot \frac{L}{D} \cdot \frac{\rho v^2}{2}$$

- Darcy-Weisbach equation for pressure drop
  - *f= 0.03*

Pressure Variations in TPU

Pressure drop

Engineering Calculation

Norma Munoz

Coolant: Water (density $\rho = 998\,\mathrm{kg/m^3}$, dynamic viscosity $\mu = 0.001\,\mathrm{Pa \cdot s}$)

TPU Channel Inner Diameter (D) = 0.005 m (5 mm)

Channel Length (L) = 1 m

Flow Rate (Q) = 1 liter per minute = $1.67 \times 10^{-5}\,\mathrm{m^3/s}$

Tensile Strength: ~30 MPa

Elastic Modulus: ~10-30 MPa (depends on TPU grade)

$$A = \frac{\pi(0.005)^2}{4} = 1.9635 \times 10^{-5}\,\mathrm{m^2}$$

$$v = \frac{1.67 \times 10^{-5}}{1.9635 \times 10^{-5}} = 0.85\,\mathrm{m/s}$$

$$\mathrm{Re} = \frac{998 \times 0.85 \times 0.005}{0.001} = 4241.5$$

$$\Delta P = 0.03 \cdot 200 \cdot \frac{998 \times 0.7225}{2}$$

$$\Delta P = 0.03 \cdot 200 \cdot 360.615 = 2163.69\,\mathrm{Pa} = 2.16\,\mathrm{kPa}$$

Fluid Dynamics for pressure variations in cooling mechanisms:

Bernoulli's Equation

FMEA

	Part # and Functions	Failure Mode	Potential Effect(s) of Failure	Severity (S)	Potential Causes of Failure	Occurance (O)	Current Design Controls Test	Detection (D)	RPN	Recommended Action
1	Red LED	Electrical	Could start an electrical fire resulting in damage to the device as well as potential burning of the patient	10	Short Circuit	3	Overload and Short-Circuit Testing, IEC Standards	3	90	Allow for breatheable material as insulation, and make sure the wiring isnt too stacked on top of eachother to casue a short circuit
2	IR LED	Electrical	Could start an electrical fire resulting in damage to the device as well as potential burning of the patient	10	Short Circuit	3	Overload and Short-Circuit Testing, IEC Standards	2	60	Allow for breatheable material as insulation, and make sure the wiring isnt too stacked on top of eachother to casue a short circuit
3	Battery	Electrical	Battery could loose its ability to charge propperly	6	Over use / too long left on charger	6	Overcharge/ Overdischarge Testing, Charge Cycle Testing	1	36	Have warnings on the product that give instructions on teh propper use and charging requirements
4	Featherboard	Bending Strain Fracture	Becasue the device needs to be felxable, the device might bend but the fetherboard could break under the bending stress	3	Bending/Breaking	2	Insulation Packing	5	30	Position the board in a way that would be best suited for the use of the devise, as well as providing instructions for best use

FMEA (Part2)

5	Arduino	Failed Circuitry	Wires could disconnect from the arduino to the featherboard	4	Mistreatment/ movement of product	5	Circuit Testing	2	40	Have propper chackes during the manufacturing process to make sure parts dont come loose
6	Holding shell/component	High-cycle Fatigue	Could bend so much that it yields and breaks becasue of too much use	2	Bending/Breaking	6	Stress testing our material (TPU)	3	36	Use a material that is both flexable and resistant to benging fracture
7	Insulation	Impact Deformation	The weight of the components on top of the insulation could casue it to deform or break out of place	1	Material stress testing	3	Stress testing our material (TPE)	2	6	Use a material that is both flexable and resistant to benging fracture
8	Sticker Adhesive	Adhesive Wear	Could loose its stickability after multiple uses	4	Loose Stick	8	Adhesive Strength Testing	5	160	Find a material that is reuseable while also being able to keep its stick

Testing Procedures

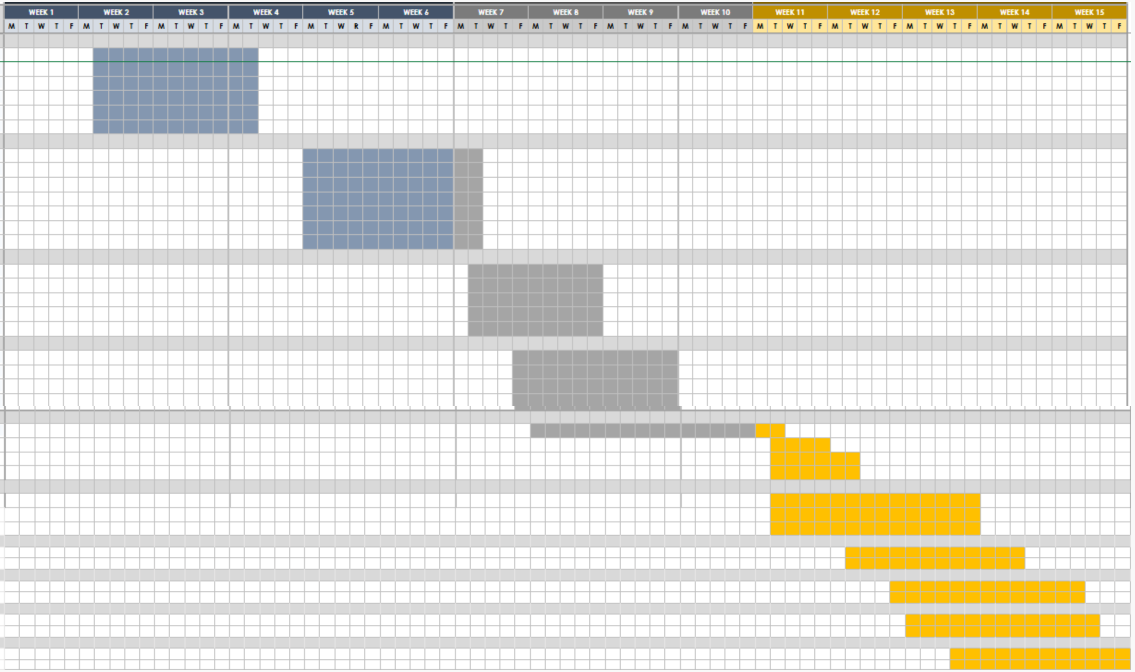
- For our second semester testing: dog testing

- In our prototyping stage, we have decided to create two different devices,
    - one we could test on dogs
    - other we would be able to test on humans in the future

- The innerworkings of the second device will not be any different, we are just planning on including a harness on the 'dog version' so that it would stay in place during use/testing

Gantt Chart

TASK ID	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION IN DAYS	PCT OF TASK COMPLETE
1	Presentation 1					
1.1	QFD	Alicia	09/03/24	09/17/24	14	100%
1.2	Literature Review	All	09/03/24	09/17/24	14	100%
1.3	Mathematical Modeling	All	09/03/24	09/17/24	14	100%
1.4	Budget	Norma	09/03/24	09/17/24	14	100%
1.5	Project Description	Claire	09/03/24	09/17/24	14	100%
1.6	Benchmarking	All	09/03/24	09/17/24	14	100%
2	Presentation 2					
2.1	Black Box Model	All	09/23/24	10/07/24	14	100%
2.2	Concept Generation & Selection	Alicia	09/23/24	10/07/24	14	100%
2.3	Calculations	All	09/23/24	10/07/24	14	100%
2,4	BOM	All	09/23/24	10/07/24	14	100%
2.5	Budget	All	09/23/24	10/07/24	14	100%
2.6	CAD Model	Norma	09/23/24	10/07/24	14	100%
2.7	Specification Table	Claire	09/23/24	10/07/24	14	100%
3	Report 1					
3.1	Background	Norma	10/08/24	10/18/24	10	100%
3.2	Requirements	Alicia	10/08/24	10/18/24	10	100%
3.3	Research within your design space	All	10/08/24	10/18/24	10	100%
3.4	Design Concepts	All	10/08/24	10/18/24	10	100%
3.5	Appendix	Claire	10/08/24	10/18/24	10	100%
4	Website Development					
4.1	Project Description	Claire	10/11/24	10/25/24	14	100%
4.2	About the team	Alicia	10/11/24	10/25/24	14	100%
4.3	Gallery	All	10/11/24	10/25/24	14	100%
4.4	Documents	All	10/11/24	10/25/24	14	100%
4	Prototype Demo 1					
4.1	Order Prototype Materials	All	10/14/24	11/05/24	22	100%
4.2	Meet with team to discuss prototyping	All	11/05/24	11/08/24	3	25%
4.2.1	Virtual Prototype	TBD	11/05/24	11/12/24	7	10%
4.2.2	Physical Prototype	TBD	11/05/24	11/12/24	7	10%
5	Homework 4					
5.1	Heat Calculations	Alicia	11/05/24	11/22/24	17	0%
5.2	Circuit Analysis	Claire	11/05/24	11/22/24	17	0%
5.3	Material Analysis	Norma	11/05/24	11/22/24	17	0%
6	Report 2					
6.1			11/12/24	11/27/24	15	0%
6.2			11/12/24	11/27/24	15	0%
7	Final CAD Design					
			11/15/24	12/03/24	18	0%
			11/15/24	12/03/24	18	0%
8	Prototype Demo 2					
			11/18/24	12/04/24	16	0%
			11/18/24	12/04/24	16	0%
9	Website Check 2					
			11/21/24	12/07/24	16	0%
			11/21/24	12/07/24	16	0%



Budget: Pricing Strategy

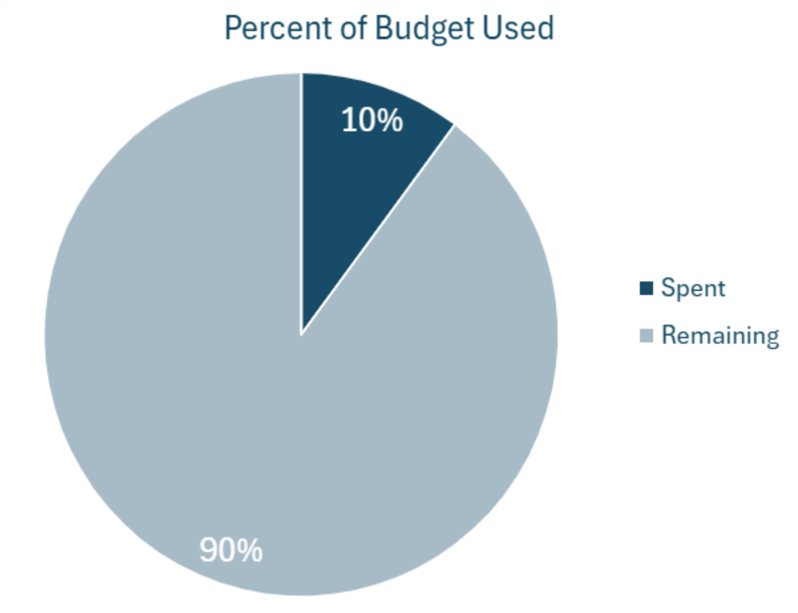
Up to $5000; additional funding subject to the disbursement within each capstone group involved

- One unit is about $290
- Making 5 units; comes out to $1450
- Product parts in next slide

Project budget	$5K
Anticipated Expenses (estimated)	$3K
Actual Expenses (to date)	$1450
Resulting Balance (to date)	$5K

Budget: Current Spending

Budget Spending	
Budget	$5,000
Prototyping Materials	$510
Total Budget Left	$4,490



Thank You, Questions?