Light Saver

Pedestrian Safety Smart Sign

Senior Design 2: Critical Design Review

Group 15

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Motivation

- Pedestrian safety is a paramount concern for the National Highway Traffic Safety Administration (NHTSA).

- NHTSA reported 6283 pedestrian fatalities in 2018 (17.2% of traffic deaths annually).

- According to the Insurance Institute for Highway Safety, adoption of Right-Turn-On-Red (RTOR) laws contributed to 60% increase in pedestrian crashes.

- Pedestrians have a right-of-way at crosswalks, regardless of RTOR laws.

- As pedestrians ourselves, we have encountered hazardous right-turn intersection conditions.

- We want to improve pedestrian safety at crosswalks and signalized intersections.

Solution

- We propose a smart device integrated signalized sign to send both In-Vehicle and Roadside alerts to pedestrian presence.

- Features include embedded LEDs for visual alert, computer vision analysis of crosswalk conditions, motion sensor for pedestrian presence, etc.

- Installation at high-risk intersections with frequent pedestrian traffic.

- Integrates with existing measures such as crosswalk timers and pedestrian signs.
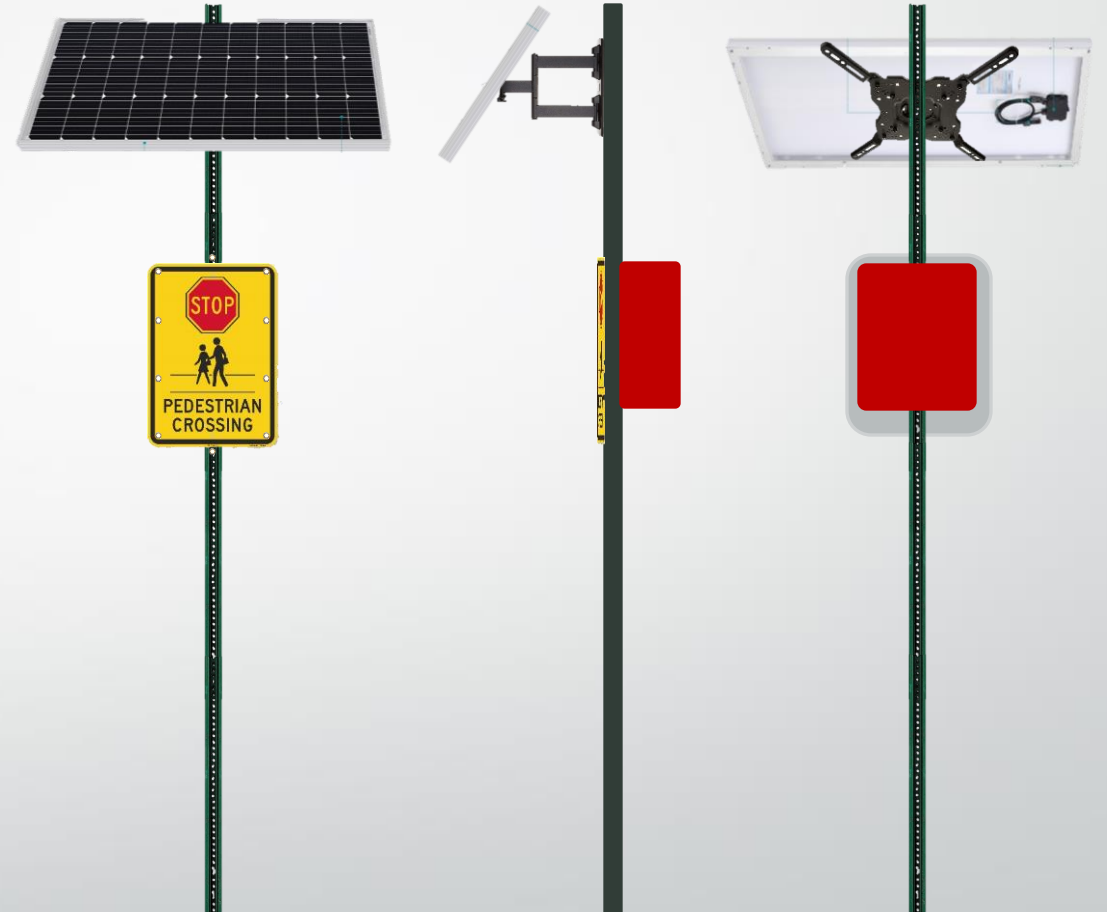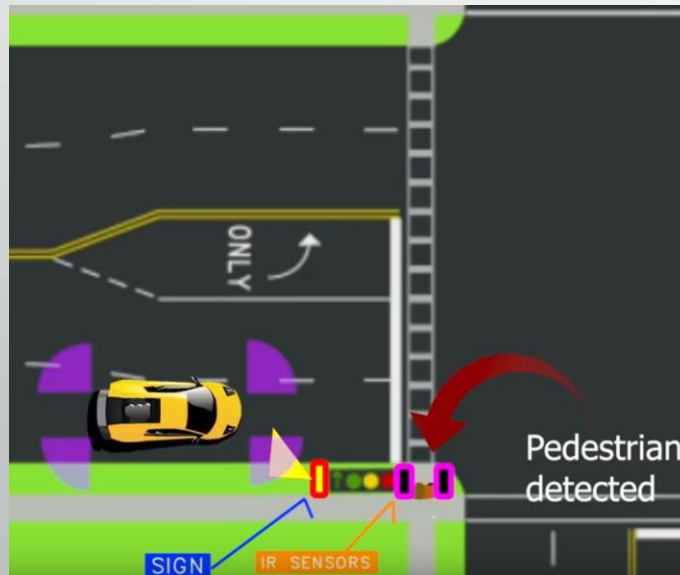
Goals and Objectives

To alert vehicles to the presence of pedestrians at crosswalk and create safer conditions for pedestrians at intersections.

To raise awareness to the right-of-way of pedestrians, where there is RTOR scenario.

To be portable and power self-sufficient, allowing for integration at existing locations.

To be an active alert system, analyzing real-time conditions for engagement.

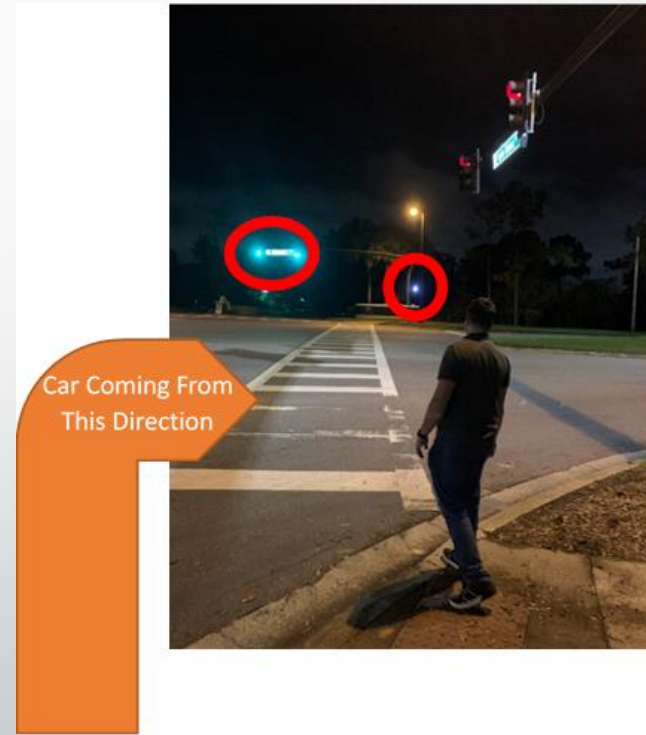Comply with NHTSA rules and standards.

Real World Scenarios

Scenario 1

Scenario 2

Car Coming From This Direction

Car Coming From This Direction

System Specifications

|	System Specifications	Units
1.1	The Light Saver will detect pedestrians approaching the crosswalk with IR Sensors.	> 3 ft
1.2	The Light Saver will alert vehicles of the presence of pedestrians using mounted lights, flashing at rate compliant with MUTCD guidelines.	40-60 times per minute
1.3	The Light Saver will be powered off-grid with specified operational time.	24 hours
1.4	The Light Saver will detect pedestrian presence on crosswalk video feed with specified range of operation.	0-25 feet
1.5	The Light Saver shall engage alerts if conditions met within specified time.	2 seconds
1.6	The Light Saver shall engage vehicle-side alert with specified range of operation.	0-60 feet
1.7	The device shall disengage after passing of pedestrians within specified time.	5 seconds

Block Diagram
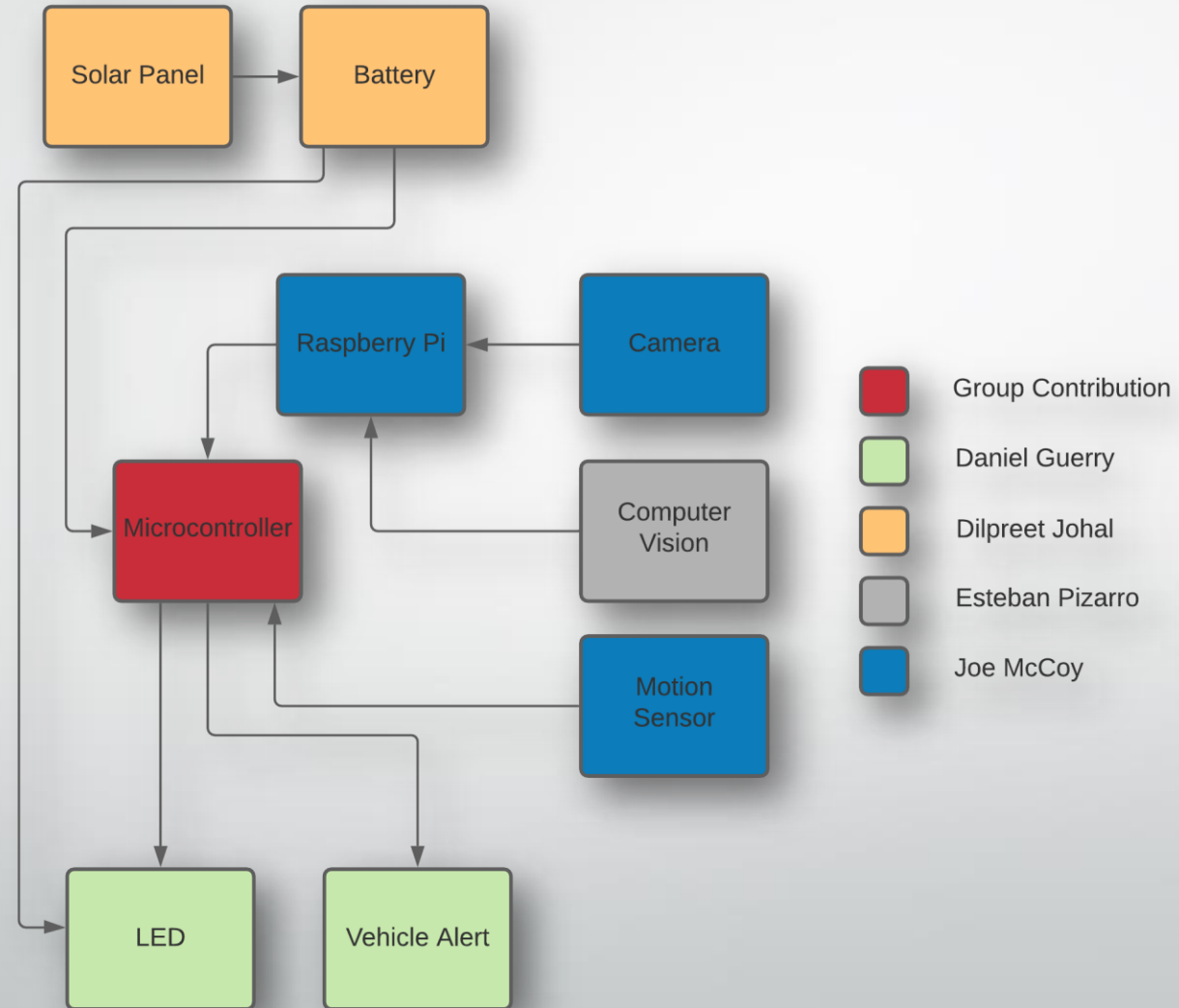
Hardware Block Diagram

- Optimize power efficiency, to prolong operation time on battery

- Require multiple power rails for different voltage inputs, 12V, 5V, 3.3V

- Minimize power distribution through Pi 3 to prevent damage
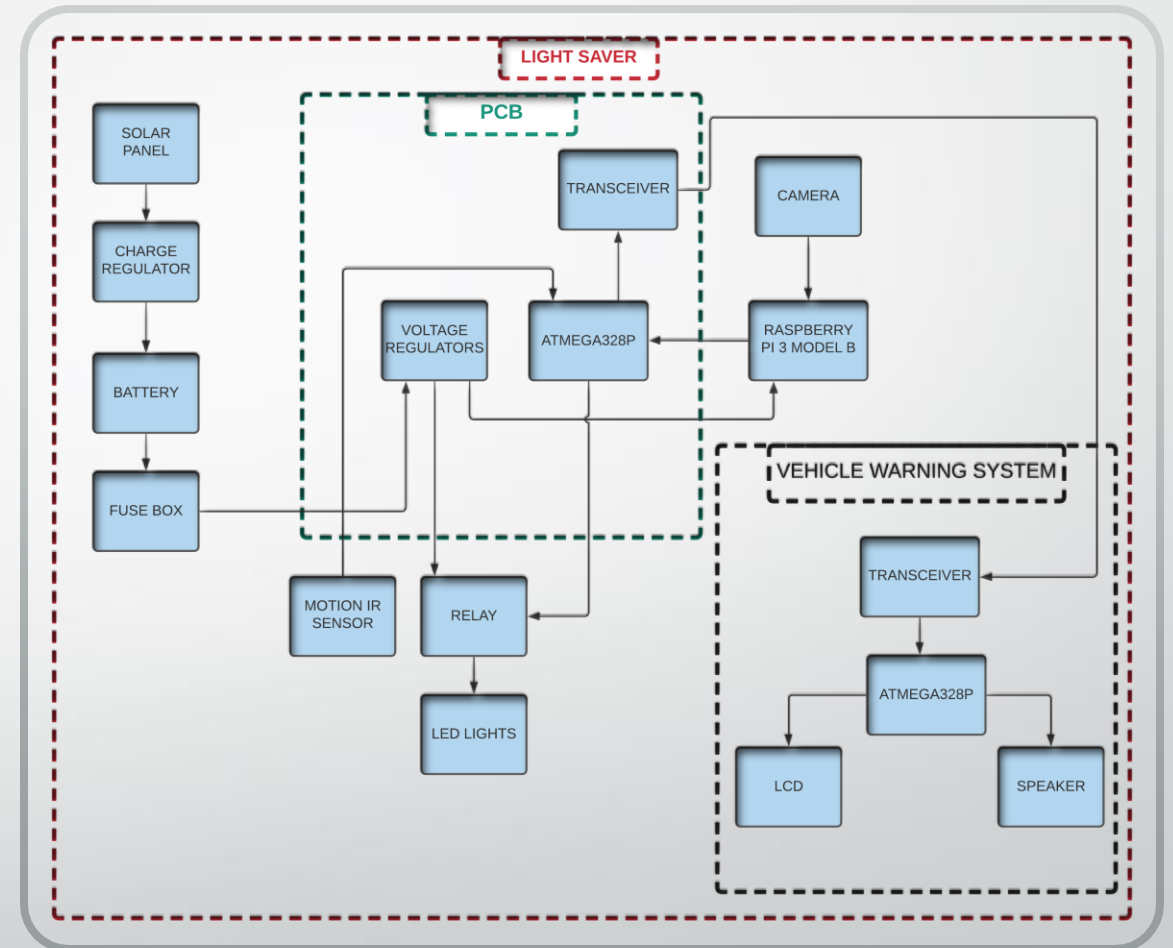
Power System Design

- **Off Grid (Portable)**
- **Power Storage**
- **Charging System**
- **Three power rails - 12V, 5V, 3.3V**
- **24-hour operation time**

Power Supply Requirements

|	Input Voltage	Input Current	Total Power	Supply Method
Raspberry Pi 3	5 V	0.72A	3.6W	PCB
ATMEGA328P Microcontroller	5V	12mA	0.06W	PCB
IR Sensor	12V	300mA	3.6W	Fuse Box
nRF24L01 Module	3.3V	12mA	0.04W	PCB
Camera	5V	0.25A	1.25W	Pi 3 Board
LED (x8)	12V	0.07A	6.72W	Fuse Box
Relay	3.3V	0.07A	0.231W	PCB
Total Power			15.501W	
(24 Hours)			372.02W	

Power Systems Implementation

- The PCB will take 12V from battery through the fuse box and convert into 5V and 3.3V to power the Microcontroller, Pi 3, Transceiver, and Relay.

- Pi Board will supply the camera

- LEDs and IR sensor will receive 12V power via fuse box
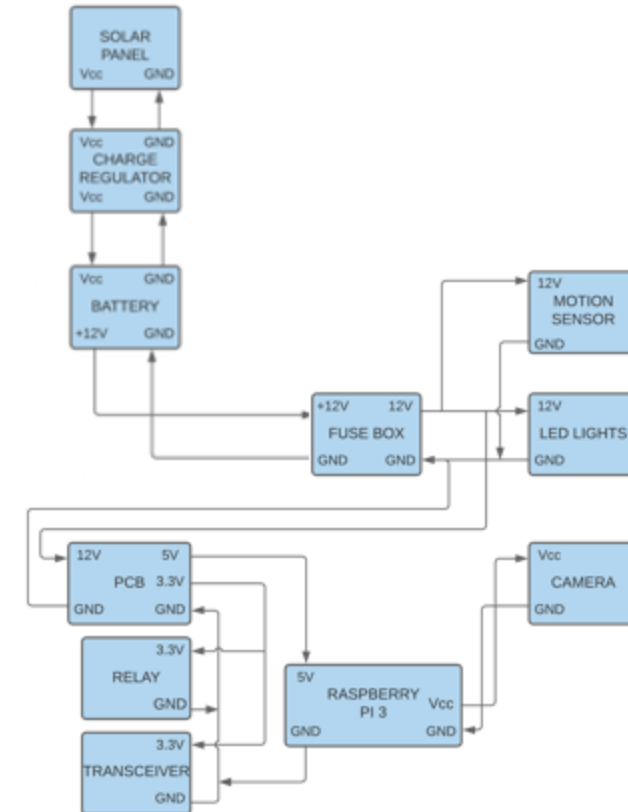
Solar Panel

Part #	Kw1210	GS-100	B087213FLB	B07GF5JY35
Manufacturer	Umi-Motor	Rich Solar	Weize	Renogy
Power Rating (Watts)	180	100	100	100
Voltage Rating (volts)	20	12	12	12
Dimensions (inches)	56.53 by 21.02	39.6 by 26.4	36.4 by 26.8	42.2 by 19.6
Weight (lbs.)	23.05	17.5	15.8	16.5
Includes-Charge Controller	Yes, PWM	No	No	No
Material	Polycrystalline Silicon	Polycrystalline Silicon	Monocrystalline Silicon	Monocrystalline Silicon
Price	$225	$80	$100	$100

RNG-100D Characteristics Versus Voltage
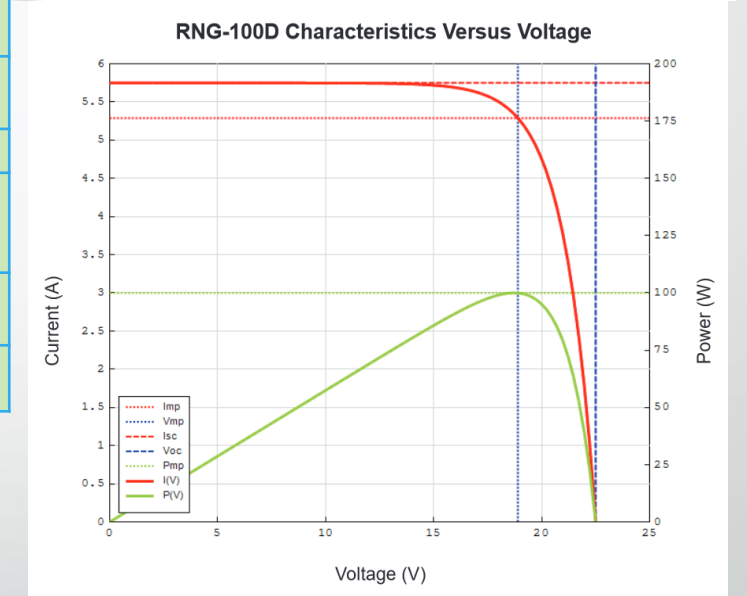
Pros of Monocrystalline vs Polycrystalline Solar Panels
- Efficiency is ~20% vs ~15%
- Better performance in low light conditions
- Longer lifespan >25 years

Con:
- Higher cost per KwH(~$1.00 vs $0.78)

- Different parameters to consider are capacity, power density, longevity.

- Rechargeable vs Non-Rechargeable

- Lead-Acid, Nickel- Cadmium, Nickel Metal Hydride, Lithium Ion

- Advantages of Lead Acid

  - Lower cost per AH ($2 per Ah, vs $9 per Ah of comparable Li-Ion battery)

  - Long shelf life (Discharge rate ~40% per year),

  - Long Battery Life (~8+ years) safer operating conditions and

  - No memory effect

  - More safe and stable vs Li-Ion

- Advantage of AGM vs Flooded or Gelled (Lead Acid Batteries)

  - No maintenance

  - Non-hazardous, no toxic spill if container broken

  - Sealed against toxic fumes

Choosing the Right Battery

Battery Specifications

| Part #	ML50-12SLA	LFP12100	RNG-AGM12	EP12100
Manufacturer	Mighty Max	Weize	Renogy	Expert Power
Voltage Rating (volts)	12	12	12	12
Dimensions (inches)	7.76 by 6.50 by 6.89	12.8 by 6.8 by 8.5	13 by 6.8 by 9	7.7 by 6.5 by 6
Weight (lbs.)	30.02	67	66	13
Amp Hour Rating	50	100	100	50
Composition	SLA AGM	SLA GEL	SLA AGM	LiFePO4
Price	$99.90	$199	$210	$450

Charge Controller

- Necessary to maintain correct charging voltage output to battery

- Direct connection between solar panels and battery will result in damage

- Parameters to consider are conversion efficiency, cost, battery type, etc.

| Part #	RCC20VOYP-G1	GS-100	Tracer2210AN
Manufacturer	Renogy	GHB	EPEVER
Voltage Rating (Volts)	12	12	12
Current Rating (amps)	20	20	20
Max Input Power (watts)	260	240	260
Weight (lbs.)	0.37	0.65	2.07
Discharge Stop (volts)	10.7	10.5	10.5
Charge Controller Type	4-stage PWM	PWM/WPC	4-stage MPPT
Suitable Battery Type	Lead acid	Lead acid	Lead-acid or Lithium
Price	$20	$30	$84

Schematic: Light Saver PCB
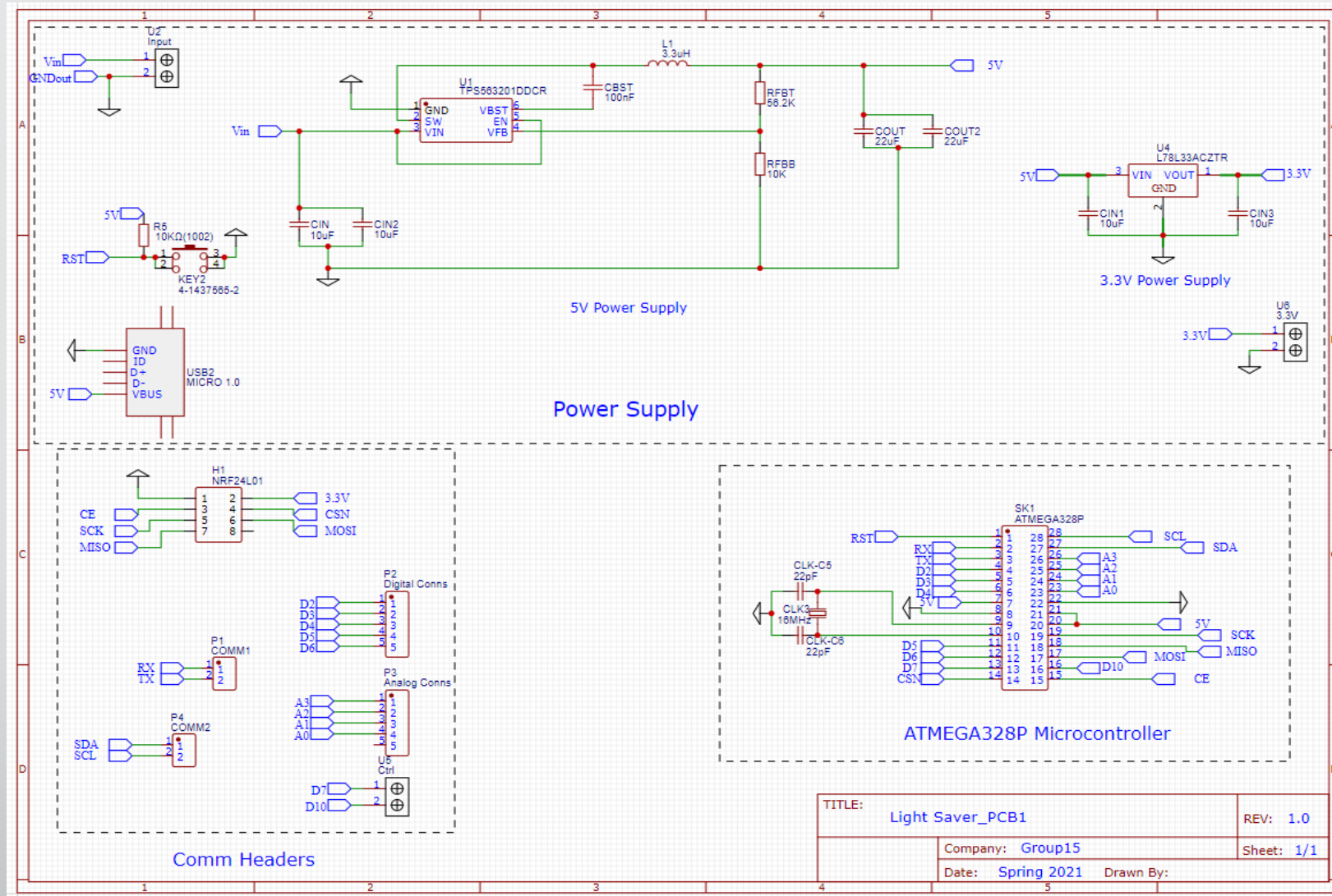
- Voltage regulation 12V to 5V, 3.3V

- Designed using TPS563201DDCR Buck convertor and TI Webench program

- Terminal block connectors and USB to provide output connections
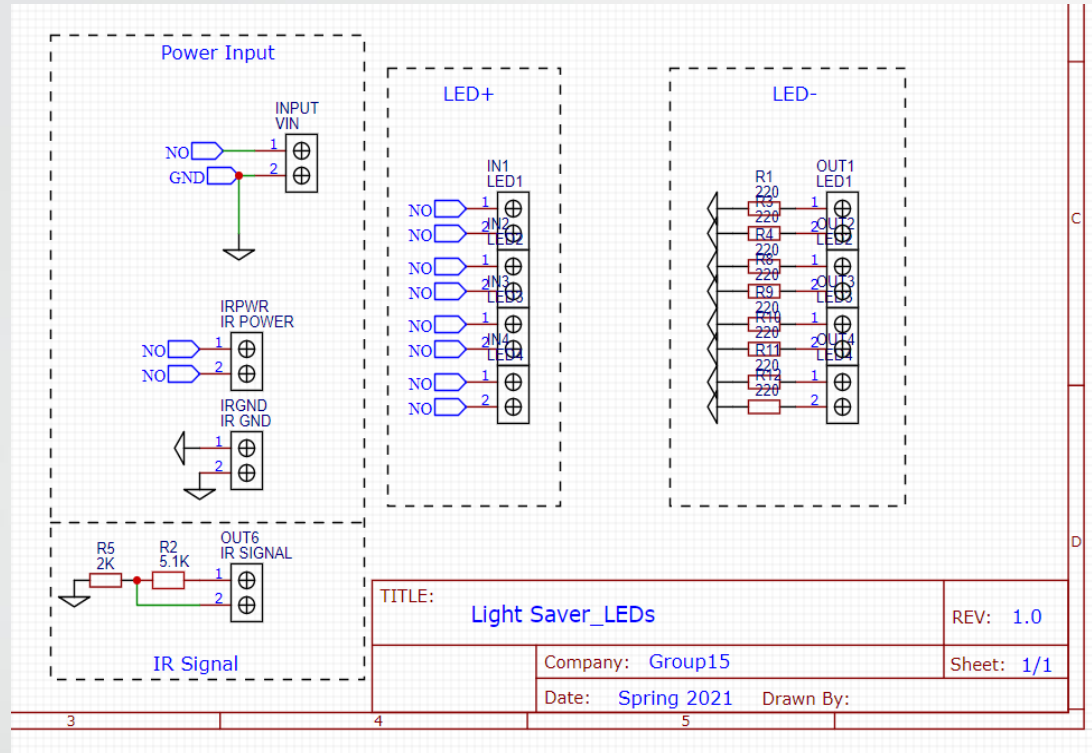
- Efficiency 90.2%, an important consideration

Schematic: Vehicle Alert PCB
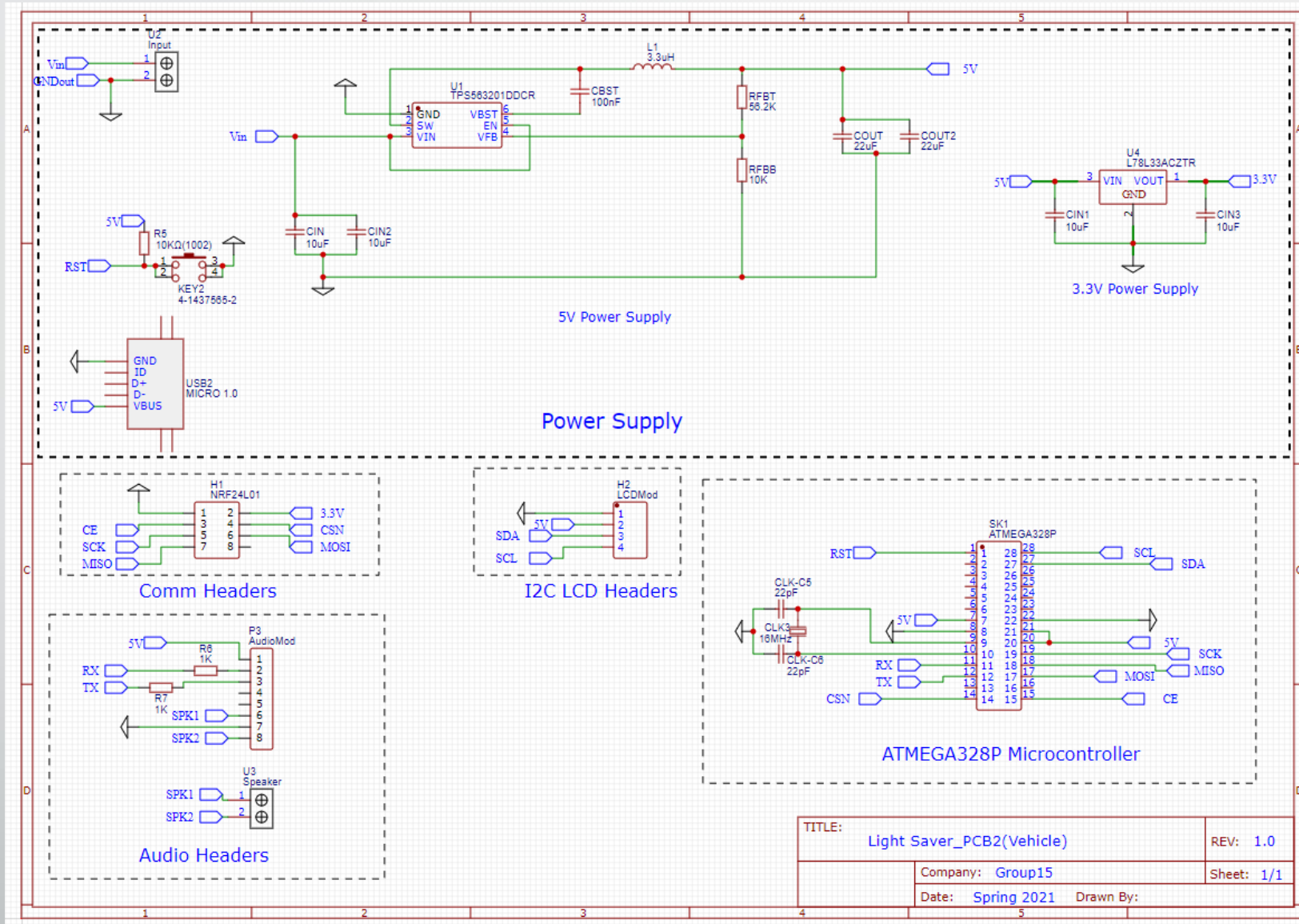
- Voltage regulation 12V to 5V, 3.3V
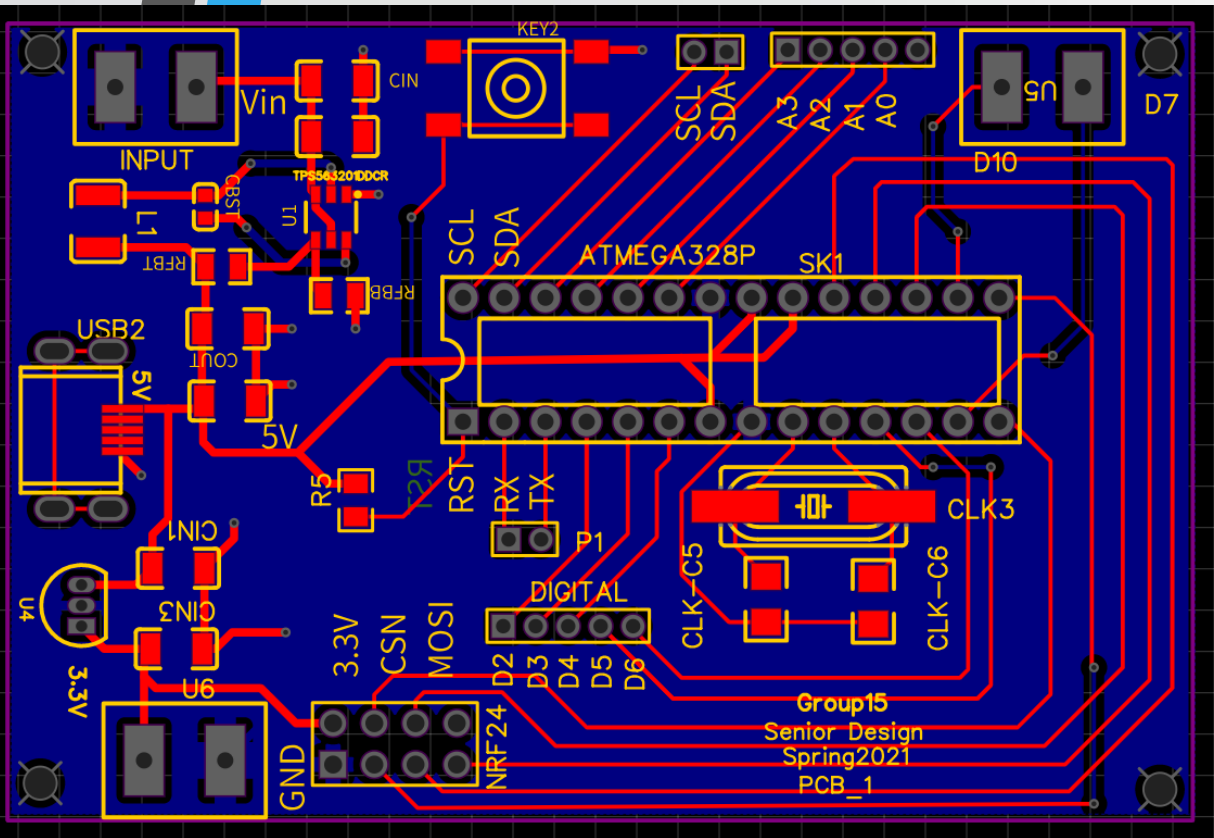- Terminal block connectors and pin headers for peripheral connections
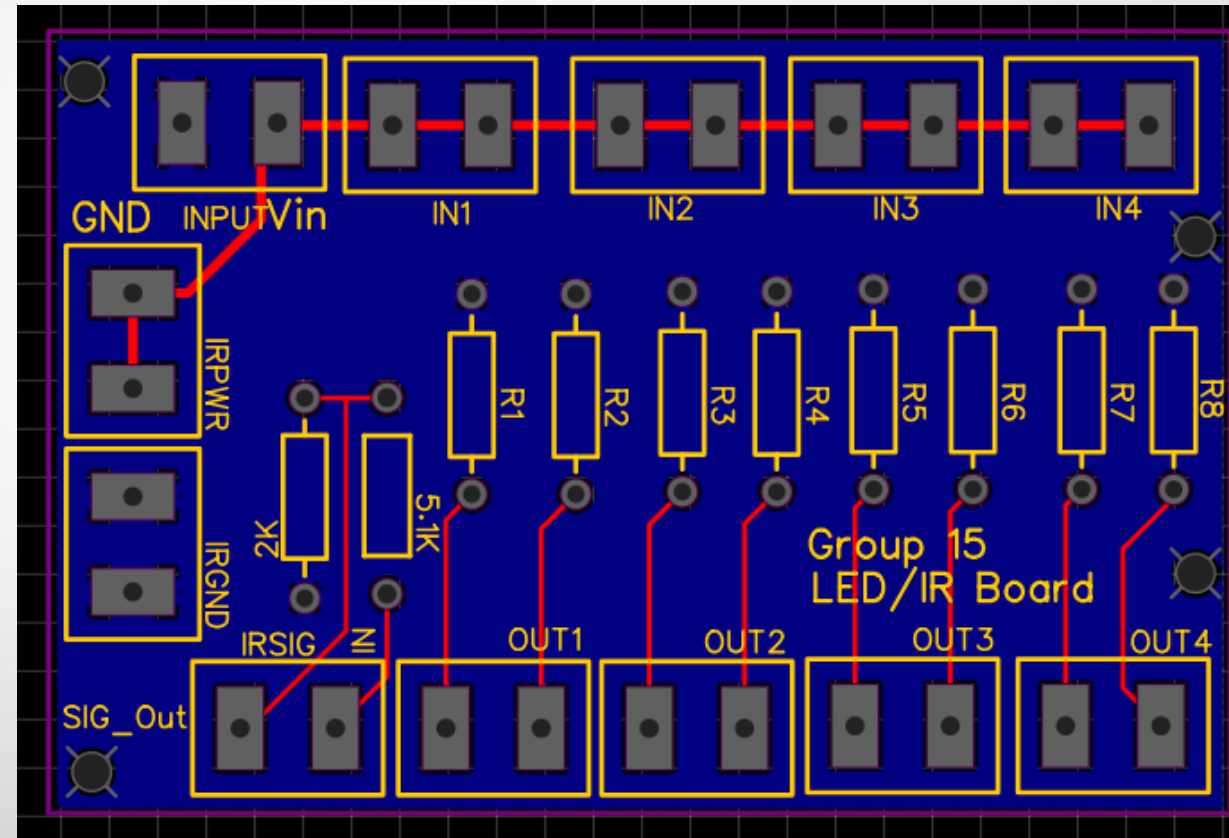
LED/IR Implementation

- Require method to avoid power surge through microcontroller
- Solution is to toggle LEDs through software utilizing relay
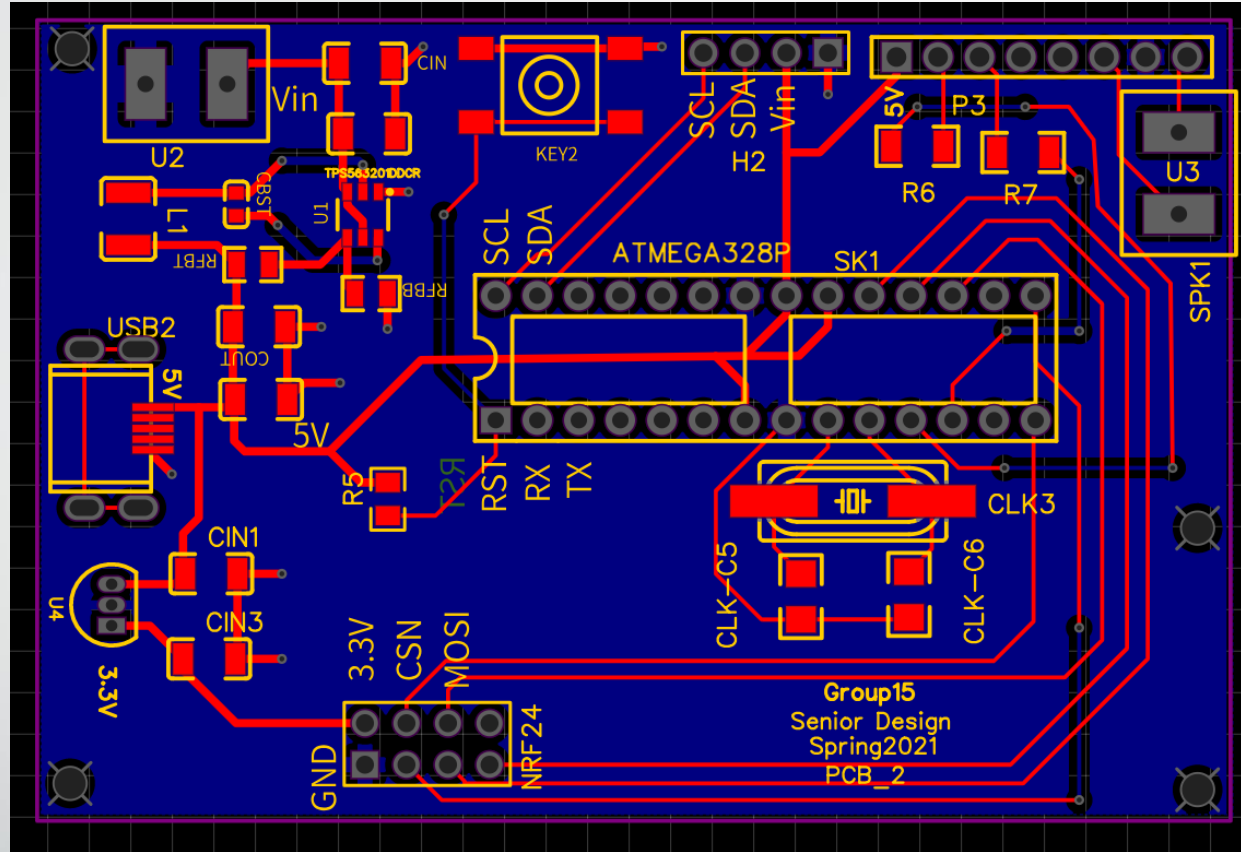- IR motion sensor connections for power and control signal
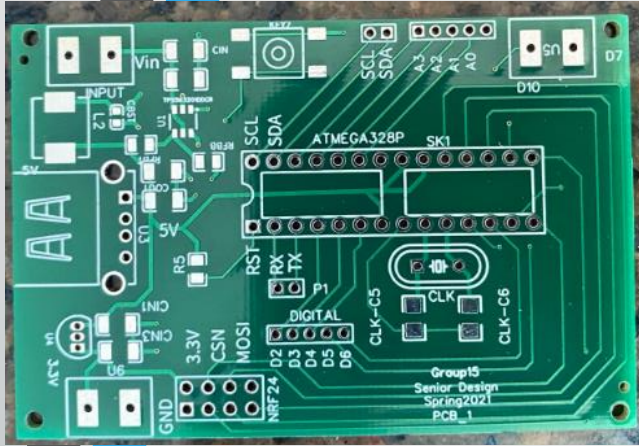
PCB Layout

Light Saver Board
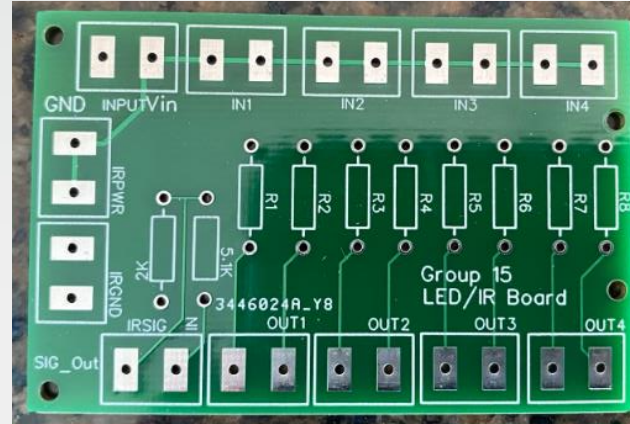
LED/IR Board

PCB Layout
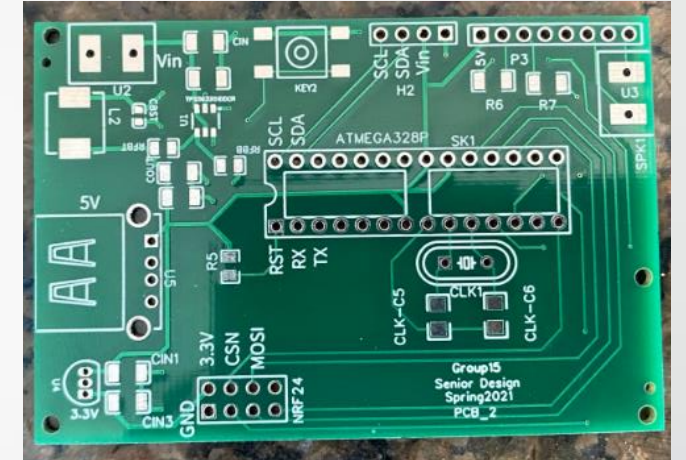

Vehicle Alert Board

PCB Board

Light Saver Board

LED/IR Board

Vehicle Alert Board
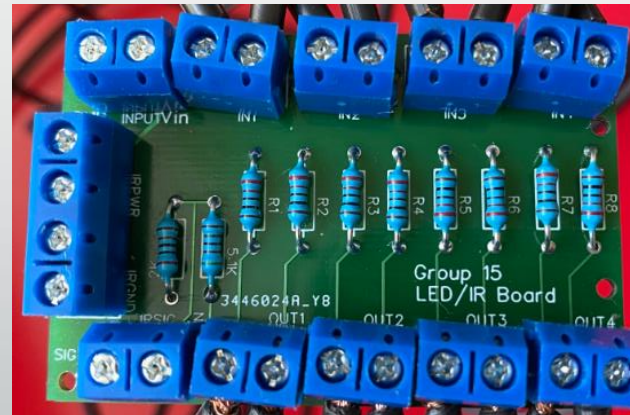
Microcontroller

- Balancing power efficiency, potential features
- Selected the ATmega328P
- Low power consumption
- Built in timers, counters
- High performance 8-bit MCU

Feature	MSP430G2553	ATmega328P	SAMD21 Cortex
Operating Voltage	1.8-3.6V	5V	5V
Temperature Range	-40℃ to 85℃	-40℃ to 125℃	-40℃ to 85℃
Memory	16 KB Flash, 0.5 KB SRAM	32 KB Flash, 2KB SRAM	256 KB Flash, 32 KB SRAM
Max Clock Frequency	16 MHz	16 MHz	48 MHz
GPIO Pin Count	20	23	16
Comms	SPI, I2C, UART	SPI, I2C, USART	SPI, I2C, UART
Power Consumption Active mode	1.14mW	7.5mW	280mW
Camera Port	No	No	No, but has LoRa protocol
Board Price	~$0.93	~$2.09	~$2

Raspberry Pi 3

- Need video processing capability (MIPI CSI)

- Fast processing to run real-time analysis of video feed (1.2 GHz)

- Efficient power consumption(~3.6 W)

- Wide operating temperature range (0-50 degrees Celsius)
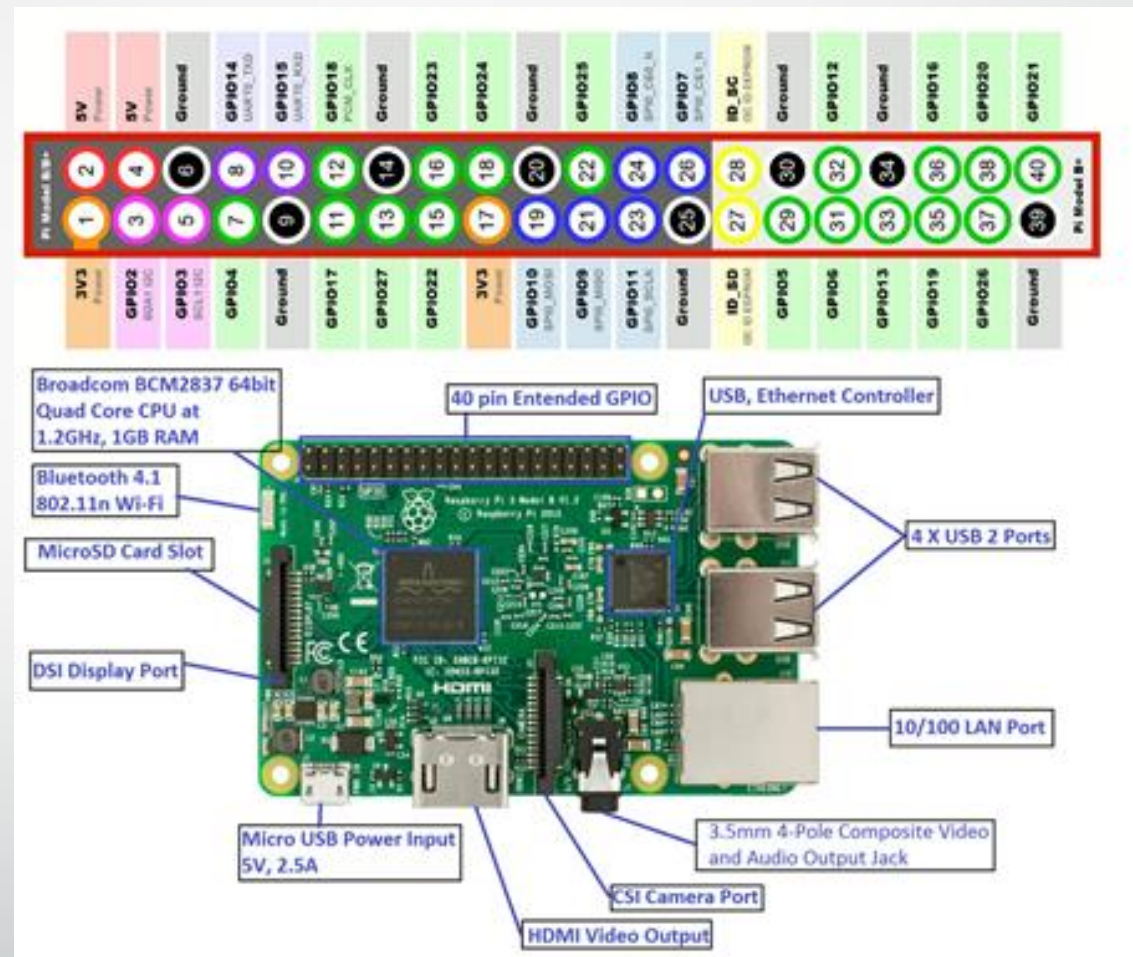
Camera

- Many different parameters, i.e., Color, scan, semiconductor type, resolution

- Compared 3 color cameras, CMOS semiconductor chips

- Selected Arducam OV5647

- Good video capturing day/night

- Cost effective
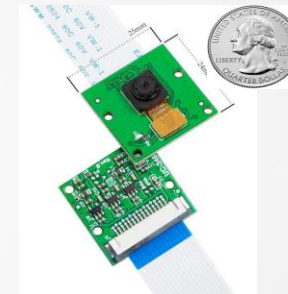
	OV5647	C920	Pi HQ Cam
Brand	Arducam	Logitech	Raspberry Pi
Resolution	5MP	2.07MP	12.3MP
Size	34mm x 24mm	43mm x 94mm	38mm x 38mm
Weight	20 gm	162 gm	53 gm
Cost	$9.99	$79.99	$50.00

Motion Sensor

- Ultrasonic, Tomographic, Microwave, Infrared
- Infrared Sensors commonly used in control systems
- IR preferred due to accuracy
- Range 0-5 meters
- Prefer Break Beam for accuracy

Receiving End   Transmitting End

Part #	M18	E3Z-R61	HC-SR501	EP12100
Manufacturer	Taiss	IKSACE	Low Voltage Labs	Jcheng Security
Voltage Rating (volts)	6-36	6-26	4.5	3.6
Dimensions (inches)	2.3 by 2.7 by 0.9	1.22 by 1 by 1.8	1.33 by 1.18 by 0.94	5.82 by 2.95 by 2.12
Weight (lbs.)	0.10	0.08	0.10	0.12
Range (meters)	0-5	0-3	3-7	0-12
Angle (degrees)	N/A (Break-Beam)	N/A (Break-Beam)	100	100
Technology	IR	IR	PIR	MW/PIR
Price	$19.99	$15.98	$6	$30

Communication Module

- Many different methods, Bluetooth, Wifi, Radio protocols such as LORA, nRF24, etc.

- Compared range, speed, data transmission

- Selected nRF24L01

- Good range and transmission ability

- Cost effective

| Type	nRF24L01	433 MHz	LoRaWAN
Range	~250 meters	~100 meters	~48000 meters
Power	0.04W	0.02W	0.01W
Transmission	GFSK	ASK	LoRa
Max Rate	2 Mbps	1 Mbps	0.61 Kbps
Cost	$1.28	$2.80	$11

LEDs

- We want Low power consumption <1 W

- Durability to weather elements

- Meets standards according to NHTSA guidelines for light-embedded signalized signs

Part #	12B-R-B	194-xHP5-CAR	20-LED
Manufacturer	SuperBrightLEDs	SuperBrightLEDs	Yifengshun
Current-Rating (Amps)	0.05	0.05	0.25
Voltage-Rating (volts)	9-14.5	10-30	12-24
Power-Rating (Watts)	0.45-0.725	0.5-1.5	3-6
Diameter (inches)	0.45	0.42	4.4-by-1.61 (Rectangular)
Wire-Length (inches)	7.5	Pin out	18
Intensity (Lumens)	55	85	100
Wavelength (nanometers)	590	630	590
Beam-Angle (Degrees)	110	360	360
Price	$2.95	$4.95	$7.22
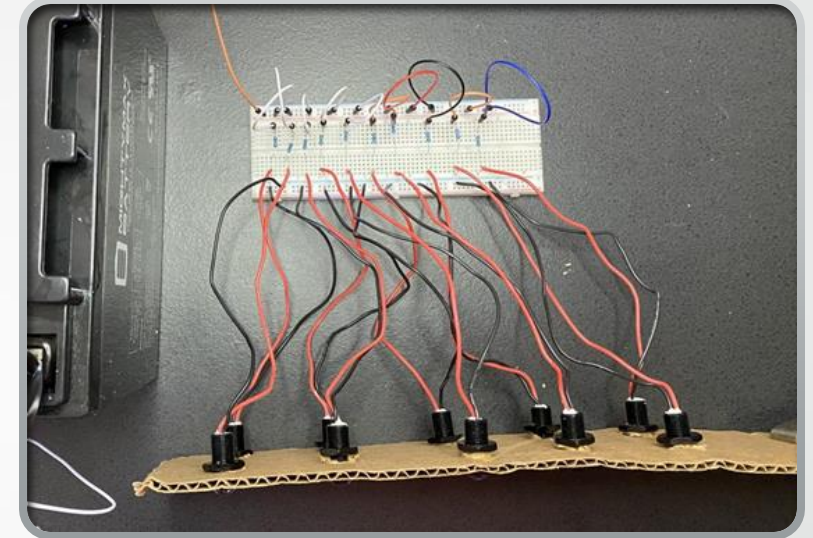
Software Flow Chart

- YOLO software to use Computer Vision algorithms to analyze video feed

- Software code written in Python

- Engage LED notification only if conditions met
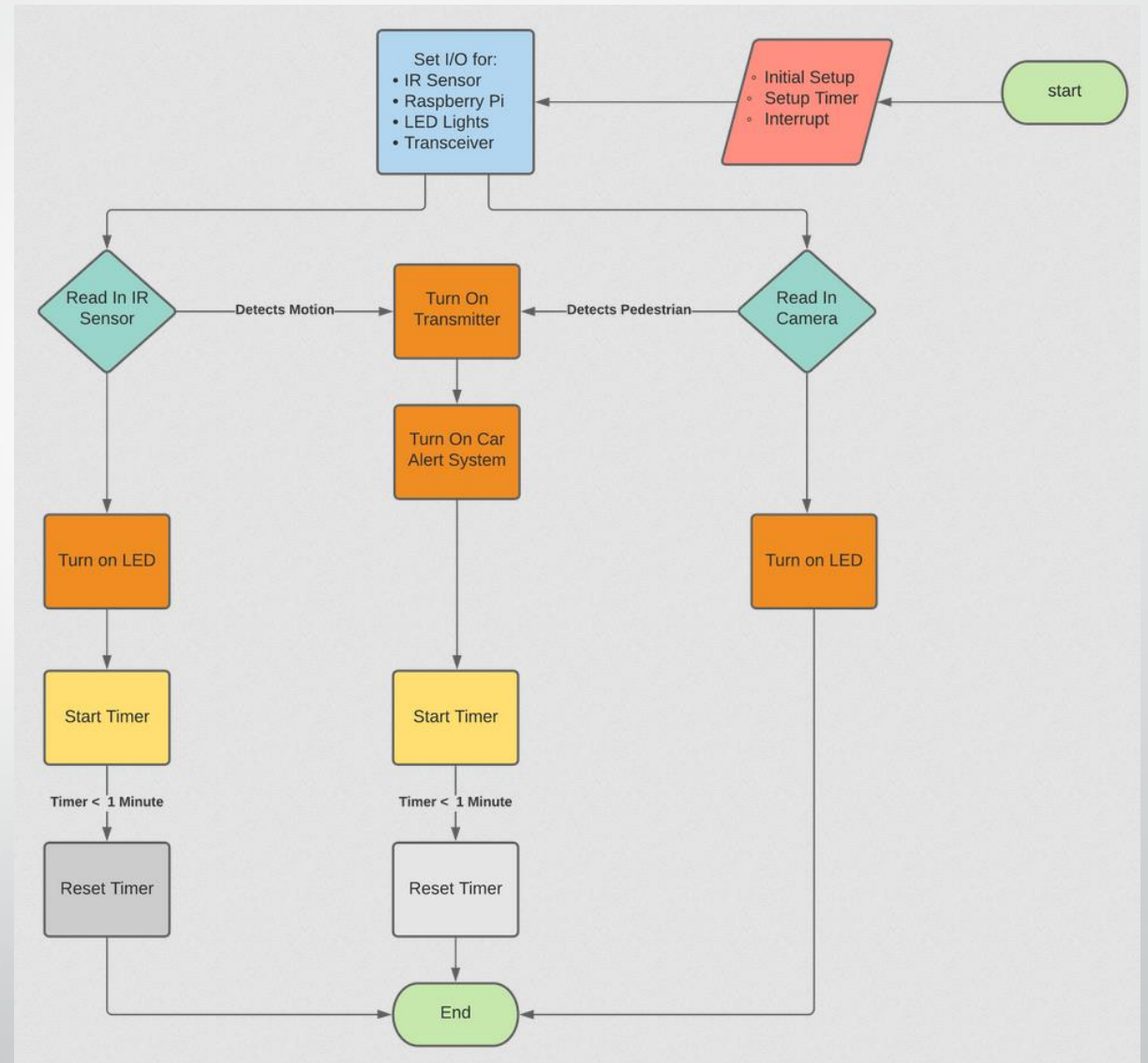
Computer Vision

- We need real-time analysis of crosswalk conditions

- Video feed analysis will help determine parameter- Pedestrian presence on crosswalk

Input Image	→	Feature Extraction	→	Convolutional Layers	→	Bounding Box Prediction	→	Result

- How can we analyze video?

- Utilize open-source computer vision techniques of deep learning, YOLO

- Supports various operating systems, such as Raspbian (Pi Board OS)

OpenCV Software

- Library of programming functions useful for real-time computer vision applications

- ~200 MB library size

- Cross-platformed, free to use under Apache 2 License

- Written in C++, but interfaced with Python, Java, MATLAB, etc.

Raspberry Pi 3 Implementation

- We download and compile OpenCV (~2.5 hours)

- We will use Python 2.7

- Utilize virtual environment to operate Python

- Utilize various functions, i.e., object detection, bounding box, tracking, etc.

Computer Vision Testing

- Detect presence of Pedestrian

- Based on given input, provide state condition to microcontroller

- Training data to enable person detection

- Track across multiple lanes of traffic

Mounting and Enclosure

- Need a secure method to mount solar panel, sign, enclosure
- Consider weather conditions, structural integrity, etc.

Mounting Pole Specifications:

- Brand: Smart Sign
- Model: K-153-8-2
- Parameters: U-Channel signpost
- Type: Steel w/Enamel Coating
- Compatibility: NCHRP 350 compliant
- Price: $70.95

8cm

413cm

Enclosure Box

- Need weatherproof enclosure to house components such as PCB, battery, etc.

- Require adequate space for components, durability for protection

- Considered various enclosures, metal, PVC, etc.

- For Light Saver, we chose clear panel box to allow visual analysis of component housing during presentation

Enclosure Specifications:

- Brand: Seropac

- Model: 1632HLTCVR

- Type: UV-stabilized Polycarbonate

- Dimensions: 43.5 x 38.5 x 21 cm

- Compatibility: >IP67

- Price: $128.52
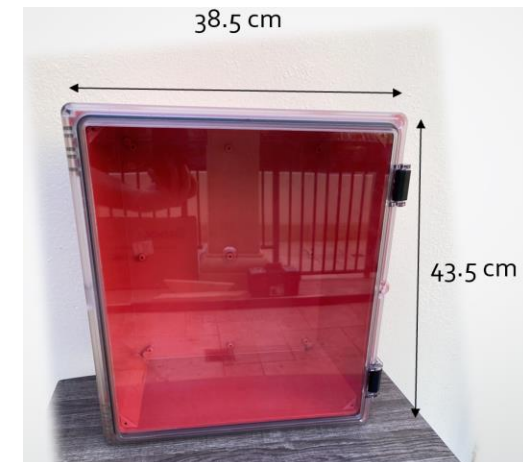
Sign with Embedded LEDs

- Require sign to be MUTCD compliant
- Appropriate symbols and conveyance

Sign Specifications:

- Brand: SmartSign
- Model: K-2845-EG
- Type: 3M High Intensity Grade Reflective Aluminum
- Dimensions: 61 x 46 x 0.23 cm
- Compatibility: >IP67, Meets DOT FP-85
- Price: $42.36

LED Specification

- We drilled & mounted w/18cm spacing
- Column width 40cm
- Color Yellow/Amber (matches base color of sign)

Assembly and Solar Panel

- Distance of Sign Base from Ground: 206.5cm

- Total Height of Pole: 413cm

- Distance of Box Base from Ground: 226cm

- Solar panel angle/orientation based on optimum incident peak sunlight

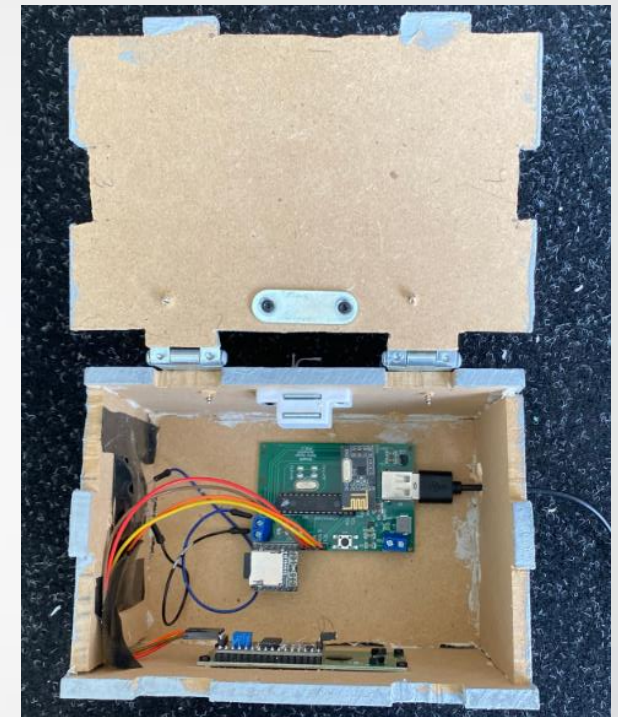- Initially mounted solar panel to the lower end of pole for demonstration

Final Testing

- Assembled and tested at crosswalk at Valencia College (West Campus)

- Used plexiglass inside enclosure box to mount components and route wires behind

- Constructed enclosure box for vehicle alert components

- Results displayed on next slide

Demo Results

	System Specifications	Units	Actual
1.4	The Light Saver will detect pedestrian presence on crosswalk video feed with specified range of operation.	0-25 feet	37 ft
1.5	The Light Saver shall engage alerts if conditions met within specified time.	2 seconds	1.65 seconds
1.6	The Light Saver shall engage vehicle-side alert with specified range of operation.	0-60 feet	131 ft

Design Constraints

- Lower budget, self-funded, limit the dispersion of money around different parts
- Shipping & Manufacturing delays due to COVID-19
- Durability to weather conditions
- Energy efficient and sustainable
- Pedestrians and drivers obeying traffic laws
- Ensuring Sign meets all NHTSA guidelines and conveys the correct message
- Computer vision: Concern with people being recorded
- Protection and Safety of the pedestrian
- Device reliability

Current Progress

- Prototype and Testing Complete
- Final PCB assembled and installed
- Light Saver field operation complete

Upcoming Goals

- Finalize website
- Submit all documentation
- Committee Review

Administrative Content

Work Distribution

	Power System/ PCB Design	Sign & LEDs	Mounting & Casing Design	Camera Selection	Computer Vision Processing	Peripheral Integration	Software Coding
Dilpreet	P	P					
Daniel		S	P				
Esteban					S	P	P
Joe				P	P		S

Project Timeline

The Week of	The Objective
2/4/2021	CDR due on 2/11. Assemble prototype and start testing
2/26/2021	Project Summary Due 2/26
3/5/2021	Ordering all additional parts
3/12/2021	V2 PCB ordered
3/19/2021	V2 PCB assembly
3/26/2021	Housing and waterproofing
4/9/2021	8-page Conference Paper and Committee Form due 4/9
4/20/2021	Final presentation due 4/18, presenting 4/20
4/27/2021	Final document due 4/27

Project Budget

ITEM	QUANTITY	Vendor	PRICE
Aluminum Sign K-2845-EG	1	SuperSign	$42.36
Mounting Pole	2	Smart Sign	$70.95
Mounting Hardware	1	Lowes	$25
LED mounted lights 12B-R-B	8	Super Bright LED's Inc.	$16.76
Solar Panel (12V) 100W-12V	1	Renogy	$103.02
SLA-AGM Battery L50-12	1	Mighty Max (Walmart)	$99.99
IR Motion Sensors	1	Taiss	$19.99
Raspberry Pi 3 Model B	1	Adafruit (Amazon)	$35.00
Atmega328P Microcontrollers	2	Atmel	$4.18
Charge Controller PWM	1	Renogy	$38.24
Camera for CV OV5647	1	Arducam (Amazon)	$9.99
nRF24L01 modules	2	Makerfire	$2.56
I2C LCD1602 module	1	GeeekPi	$5.99
Audio Module	1	KeeYees	$7.99
Custom Enclosure	1	Amazon	$128.52
PCB Fabrication	5	JLCPCB	$124.94
TOTAL			~$735.48
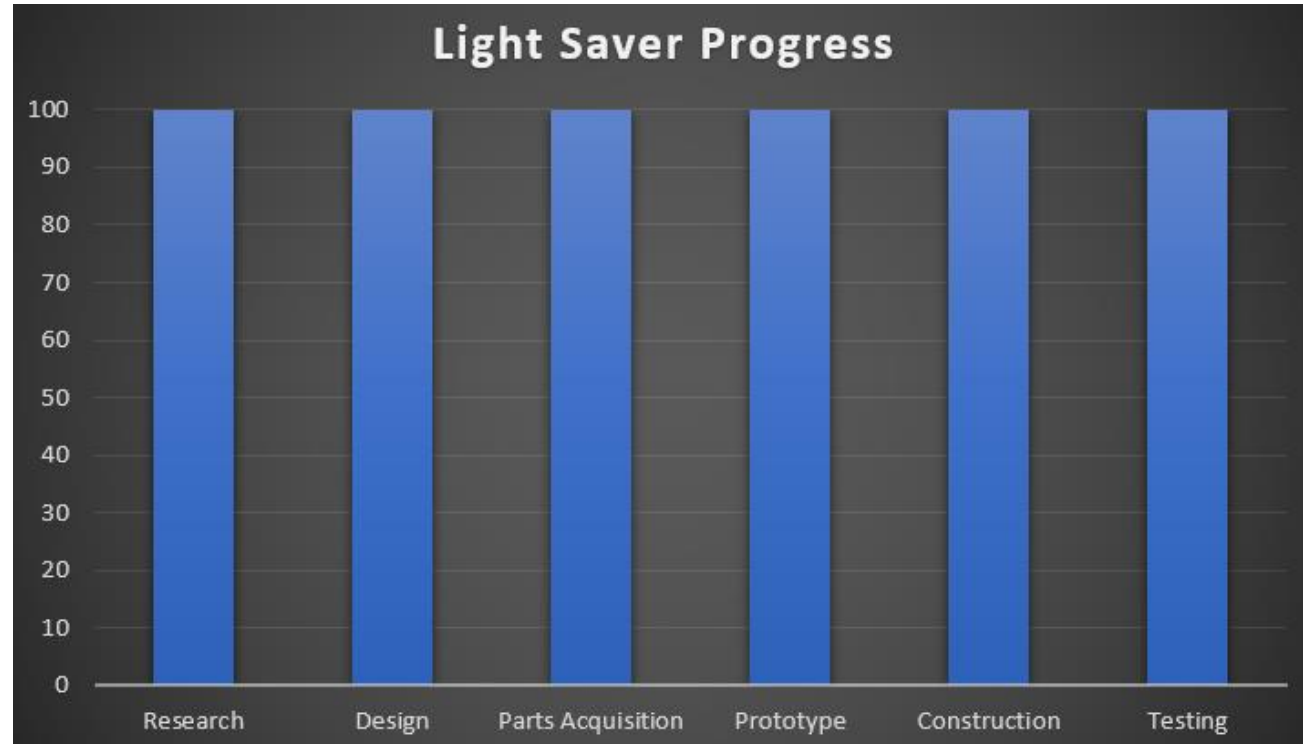
Light Saver Progress

Thank You

Questions?