Enhanced Driver Awareness Detection System

Critical Design Review
Group 5

Project is original without sponsors or external contributors.

Image: The Wide World of Off-Roading (caranddriver.com)

Team Overview

Gage Libby
B.S. Electrical Engineering
Interest: Off-road

Focus: Sensor Integration, Microcontroller Integration

Paul Ramos
B.S. Photonic Engineering
Interest: Autocross

Focus: Heads Up Display, Cameras

Josh Weed
B.S. Electrical Engineering
Interest: Off-road

Focus: Power Distribution, Circuit Protection

Scott Jokela
B.S. Computer Engineering
Interest: Motorcycles

Focus: Software, Video/Data Management, System Control

Motivation

Off-road travel has the potential to be challenging, mentally taxing, and dangerous.

Terrain can be misjudged leading to vehicles becoming stuck or damaged.

Though ill advised, many venture off-road alone.

Image: Lend a Hand: Off Road Hand Signals For Spotting On The Trail (4wheelparts.com)

Solution Vision

The objective of this project was to provide information to aid in driver decision making when navigating difficult terrain without the use of a spotter or leaving the vehicle.

System will provide live video feed for driver to assist in hazard identification and route selection.

System will have auxiliary sensors for vehicle and environmental awareness.

Designed as a retrofit to vehicles without existing systems.

Will not interfere with existing factory systems.

Project Prototype
Jeep Wrangler

Constraints and Standards Impact

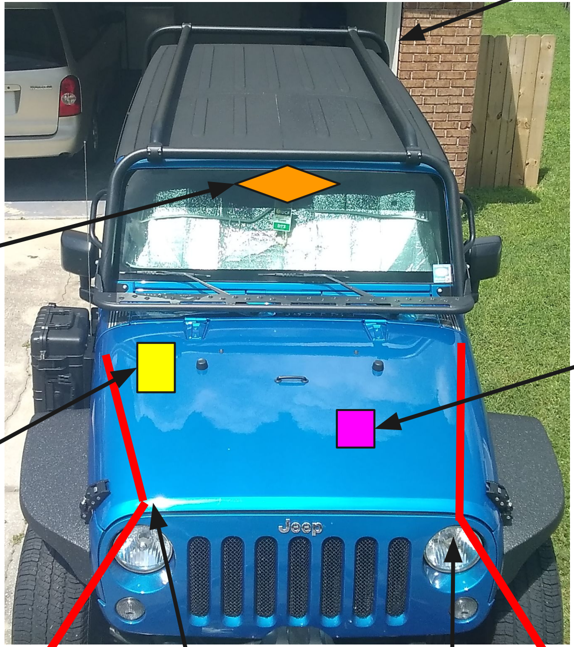
Our design decisions for potential solutions are dictated by the constraints we operate under.

Many standards covered aspects of our project but required purchase. In a commercial setting these could be purchased from groups such as the Society of Automotive Engineers (SAE), International Standards bodies, and the Federal Motor Vehicle Safety Standards (FMVSS) to be used as design resources.

Constraints Highlights				
Economic	Time	Environmental	Manufacturability	Health/Safety
Self-Funded, Not a commercial venture, limited investment	Competing priorities: Student course load, family, and work requirements	Legal and Responsible location to test system	Tools we have access to, lack thereof Team Experience	Inability to meet as a group
Tight Budget	Limited Amount	Harsh Environment Survivable	One-off, small scale production	COVID Restrictions

Highlighted Standards	
SAE J1292 Wiring	FMVSS #101 Controls and Displays
ISO 26262 Automotive Safety Assist	IEEE/ISO/IEC 29119 Software Testing Standard
IP Ratings IEC 60529	RoHS Hazardous Substance Exposure
SAE J17557-1, -2, -3 Vehicle Displays, HUD, Power	WEEE 2002/96/EC Waste Disposal

Solution Actual



Rear camera
Rear proximity sensors

In cabin main control, video display, heads up display

Engine bay temperature sensor

Inside engine bay battery, power distribution hub, circuit protection

Passenger side camera, 160 degree FOV

Driver side camera, 160 degree FOV

Requirements and Specifications

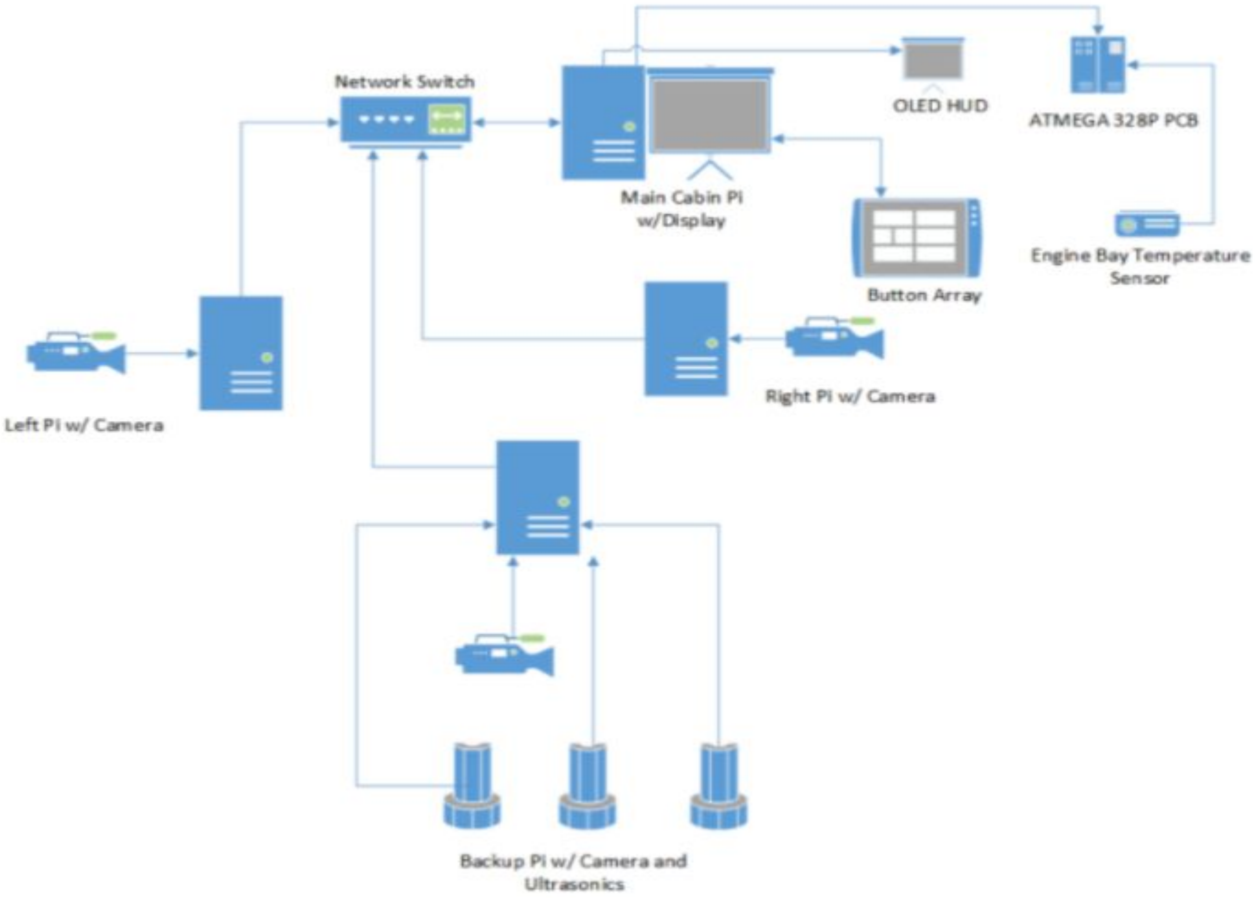
Table 1 Requirements and Specifications

Project Requirements and Specifications			
Requirement	**Specification**	**Verify**	**Result**
Remain in Budget	System Cost < $800	Track Receipts	$707.34
Compact Form Factor	System Weight < 10 kg	Weigh Unit	6.85 kg
Separated from Main Electrical System	Disconnect at 12.2 V	Perform Low Voltage Disconnect test	Y
Camera Coverage	1080 P Infared FOV > 180 degrees	Mark designated grid and measure angle of camera coverage	270 degrees
Video Display in Cabin	Real time view by driver, multiple feeds	Visual Inspection	Y
Sensor Function	Proximity alerts w/in 2', HUD warning, Camera full screen	Test according to designed procedure	Y
Sensor Function	Temperature sensor alerts via HUD if threshold is exceeded	Set temperature threshold, exceed, and examine HUD	Y
HUD Interaction	HUD is visible to Driver, Lens 2xs magnification	Visual Inspection, Measure object magnification	Y > 2xs

Above: Main Cabin

Above: Engine Bay

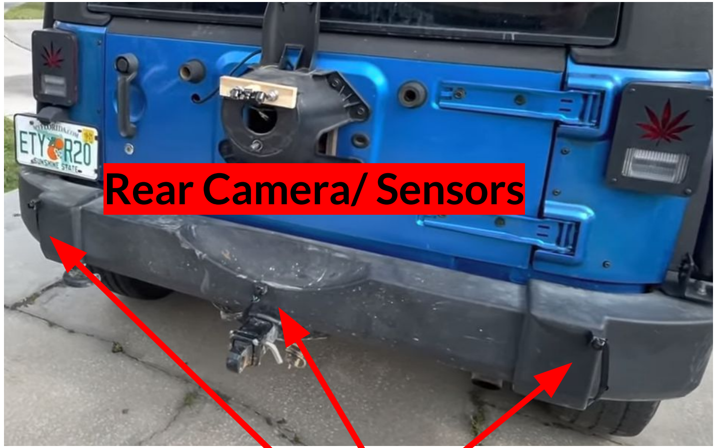
System Block Diagram

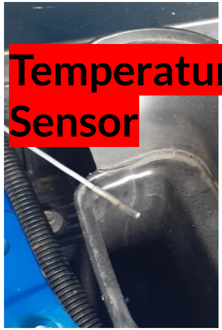


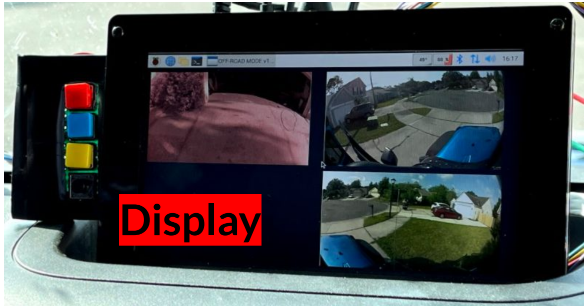

Driver Awareness Detection System - Senior Design Showcase
HUD


Front Cameras

Components


Rear Camera/ Sensors


Temperature Sensor


Display


Distribution HUB


Zoom, Proximity Sensor

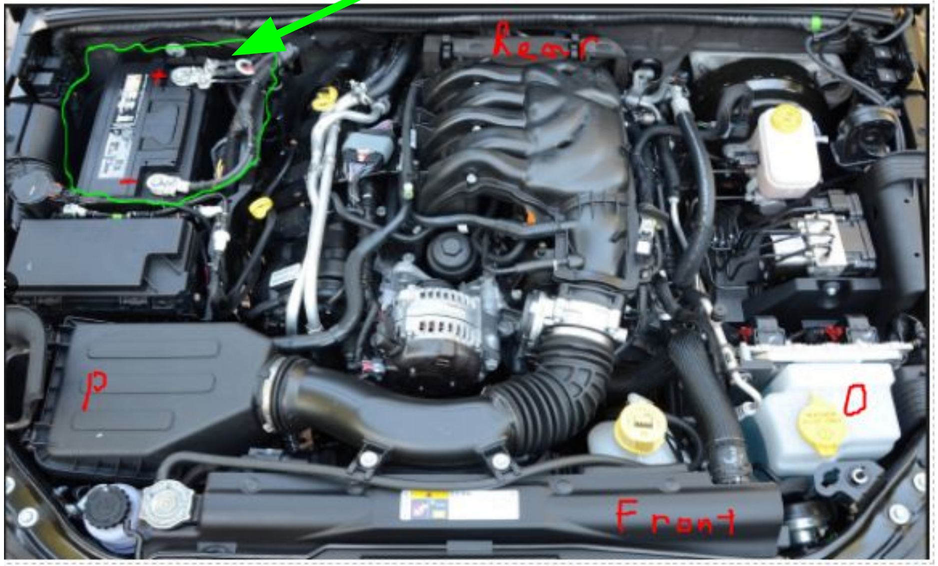
System Power Distribution

System Power Needs	
Demand	Item
5V DC @ 3 Amp Max (4)	Microcontrollers, Sensors
7V DC @ 1 Amp Max (1)	Microcontroller Integration
12V DC @ 3 Amp Max (1)	Main Cabin Display Unit
Use external batteries	Pro: Separate from main Con: Must be charged
Use main vehicle battery	Pro: Already present Con: Must be stepped down

The stock vehicle battery was selected to be used to power this project.

1. Charging infrastructure in place
2. Ample capacity for use when vehicle is on or off with 600 cold cranking amps, 120 minute reserve capacity and a 70 amp hour rating.
3. Less maintenance without a need to charge additional batteries.

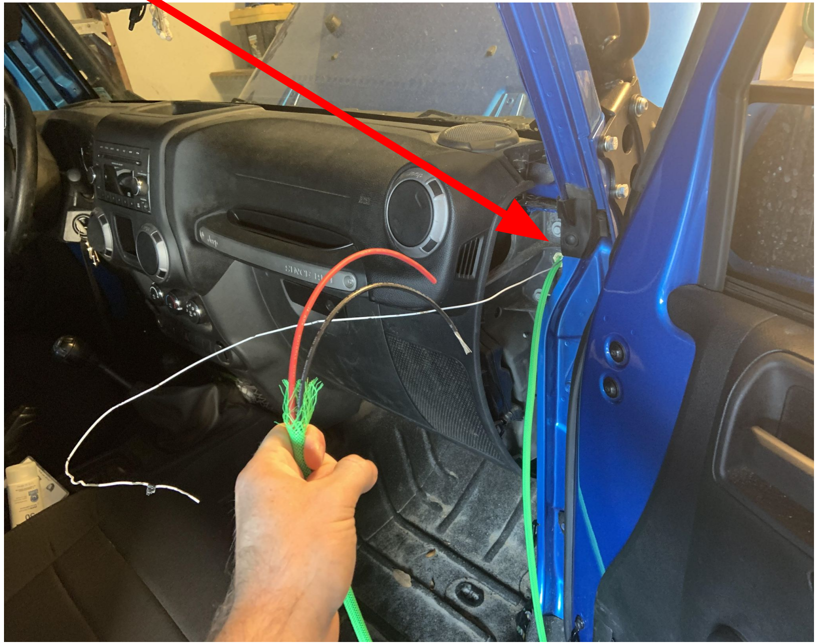
Vehicle Battery

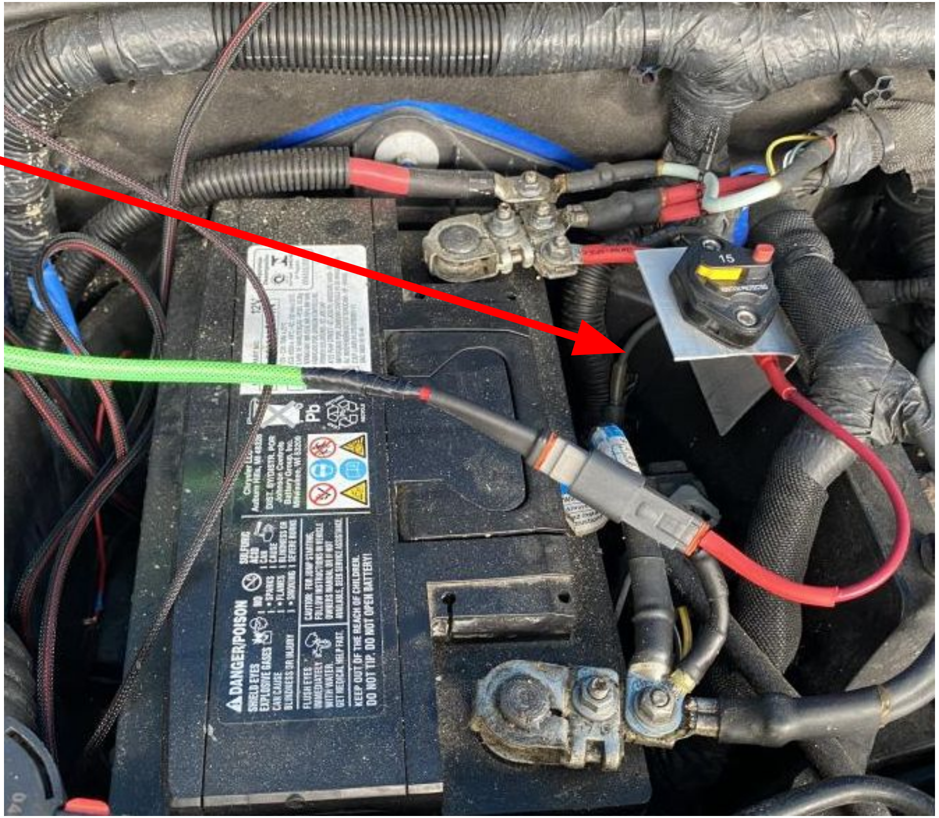


60" Wide x 22" Long

Implementation:

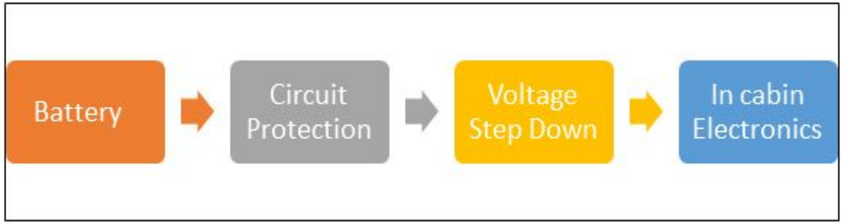
Firewall Pass through, Circuit Breaker





Circuit Protection and Power Distribution

Circuit Protection Considerations				
Item	Operating Condition	Realization	Location	Function
Fuse	20 Amp Fuse	Manual Reset Inline Fuse	Main Panel	Acts to prevent dangerous over current conditions
Low Voltage Cutoff	Isolate once battery drops below 12.2 V (50% charge)	Purchased Unit	Main Panel	To prevent draining the main vehicle starting battery
Reverse Bias Protection	If a reversed polarity is detected, isolate electronics from source	One-way connectors	Main Panel	To prevent damage to electronics in event battery is reversed
Brown Out	Prevent microcontroller operation during under voltage conditions	Built into Raspberry Pi Interface	In Cabin Center	Prevent faulty operating due to difficulty distinguishing between voltages

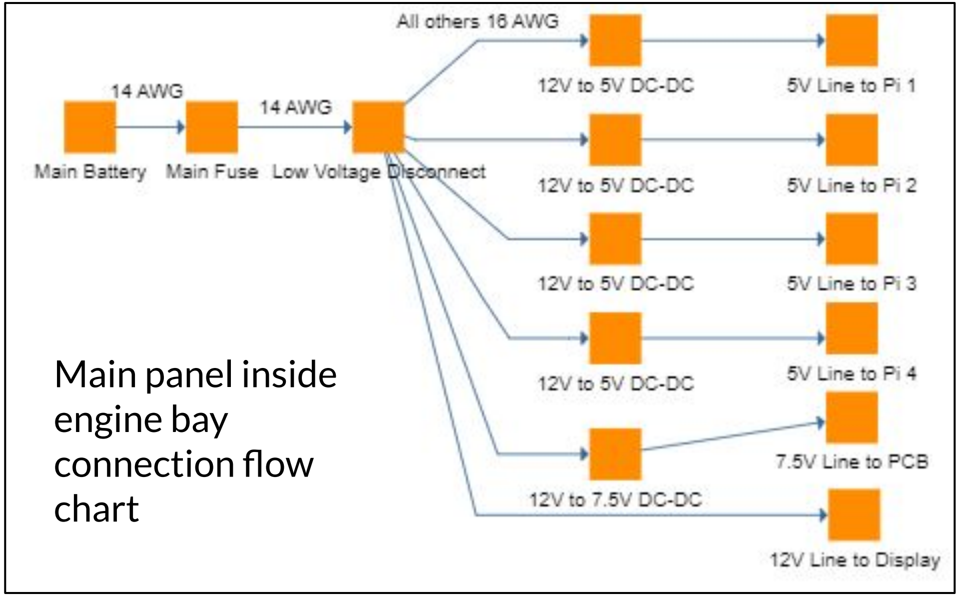


Purchase vs. Design

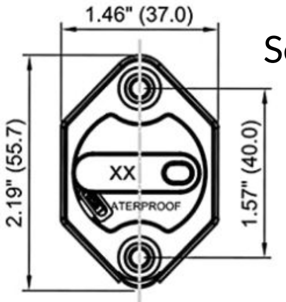
- Time
- Cost
- Efficiency
- Form Factor

Circuit Protection and Power Distribution

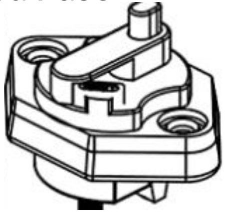
Fuse Selection		
Power Lines from Central Panel		Trip current > 16 Amp
Raspberry Pi max 3 Amp (x 4) = 12A		Resistive load- fast acting time
PCB max 1 Amp (x1) = 1 A		Manual reset
Display max 3 Amp (x1) = 3A		Compact Form Factor
Overall 16 Amp Max Load		Voltage and Interrupt Rating

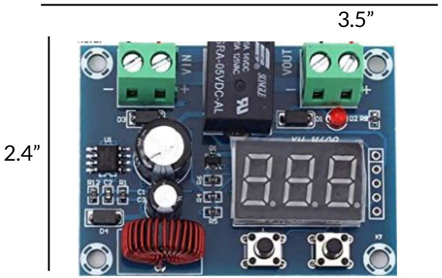


Main panel inside engine bay connection flow chart



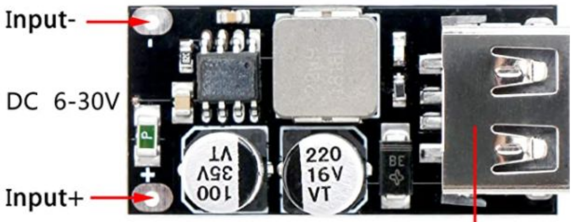
Selected Fuse



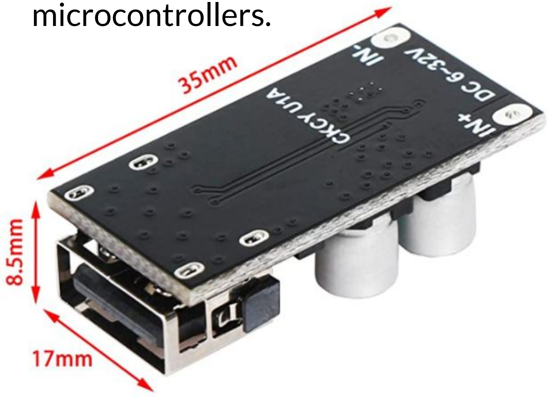


Low Voltage Cutoff @ <12.2 V

Circuit Protection and Power Distribution



Sample of DC-DC converter used to power microcontrollers.

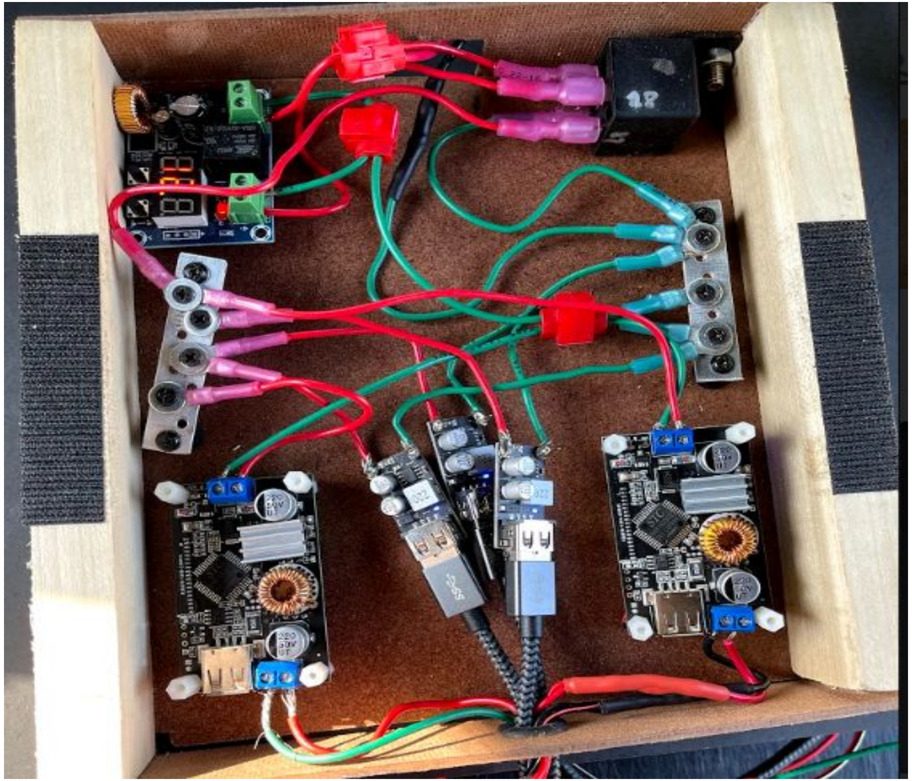


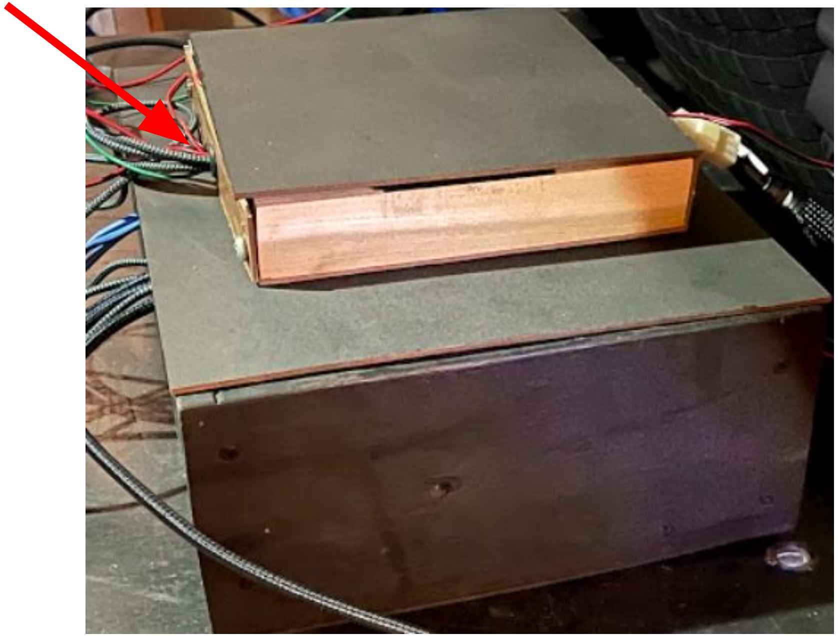
DC-DC Converters			
Item	**Specifications**	**Cost ($)**	**Comments**
DC Step Down			
DC Buck Module, DROK Adjustable Step Down Voltage Regulator	6V-32V 30V 24V 12V to 1.5-32V 5V 5A USB Port	13.99	1 pack Unit cost: 13.99 Supply PCB
USB Buck Converter, DROK 4pcs DC-DC Step Down Module	6-32V 12V 24V to 5V QC 3.0 USB Port	11.99	4 pack Unit cost: 3.00 Supply Microcontrollers

Selection Criteria:

- Adjust for 12-15V input to account for on and off states of vehicle battery
- Compact Form Factor
- Output regulated to desired voltage +/- 5% so 4.75-5.25 V for the 5V case
- USB output for downstream interface

System Implementation



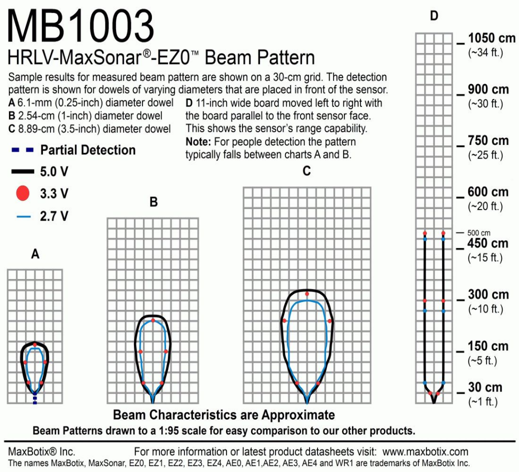


Sensor Types

- Types of sensors being used :
  - Ultrasonic
  - Resistive Temperature Detector (RTD)

Ultrasonic sensor

- Sensor being incorporated 3 x MB 1003 .
  - Cost: $37.95
  - Manufacturer: Maxbotix
  - Max detection range of the sensor is 16 feet.
  - Beam width is widest at 9 feet.
- Location: Rear bumper.
  - Spacing is about 24 inch between each sensor .
  - Placement considerations inside or outside bumper?
- Detect objects 2 feet from rear.
  - Objects ranging from 2’X2’ small end to human size and larger.
- Data from the sensor will be received via   3x different raspberry pi’s

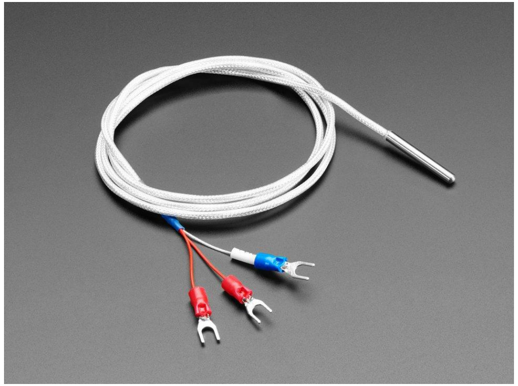


Mounting of the Ultrasonics

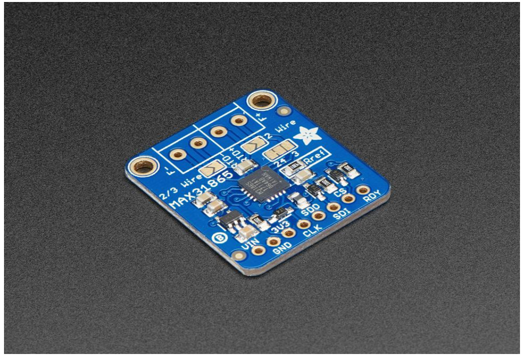
- The wire runs were made using a custom wire harness   to make the connections with the raspberry pi's located in side the vehicle.

Resistive Temperature Detector

- Placement in the Engine bay.
- Type of temperature sensor is a Resistive Temperature Detector (RTD).
  - Resistance changes with temperature so will the voltage.
- Our choice is the PT- 1000 3-wire.
  - Manufacturer: Adafruit .
  - Cost:$ 14.95.
  - Resistance at 0 C 1000 ohm.
  - Length: 1 Meter
- Adafruit PT-1000 amplifier Max31865.
  - Cost:$ 14.95



PT-1000



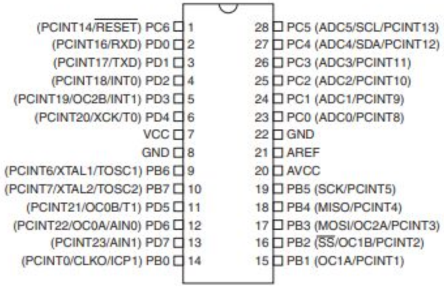
Max31865

Temperature Sensor mounting

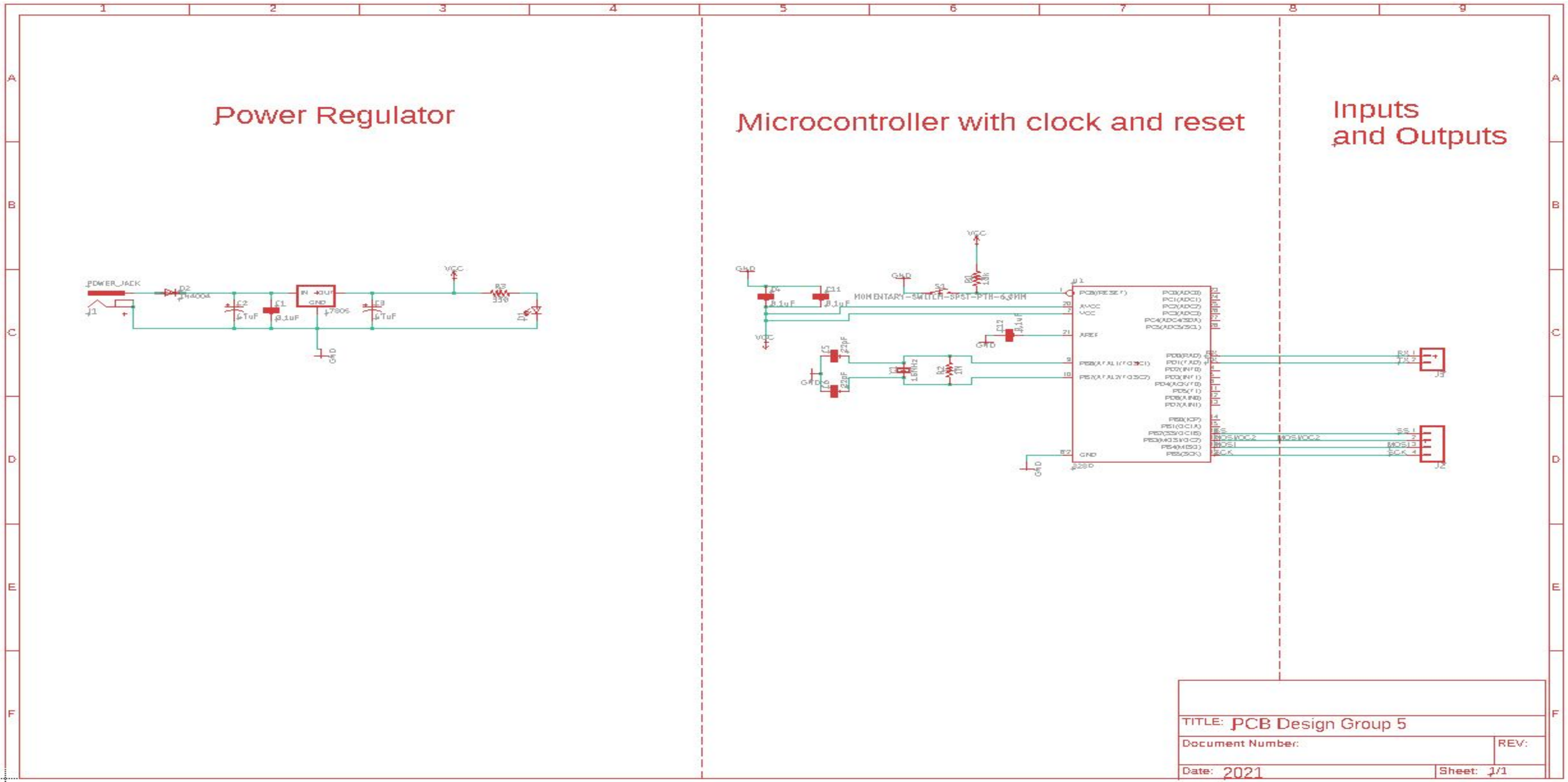
- The temperature sensor was mounted inside the engine bay being passed through a hole in the fire wall.

Microcontroller

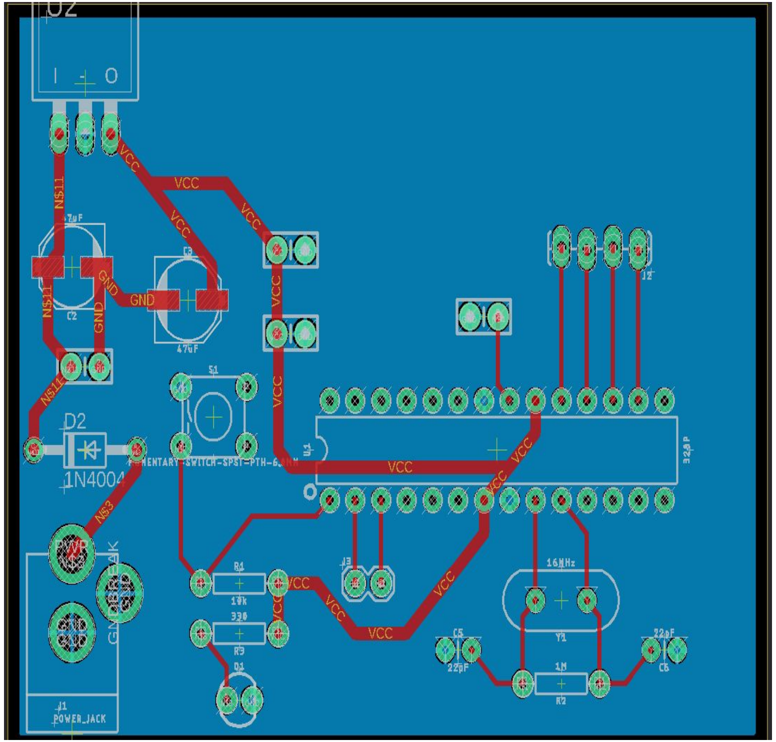
- The development board being used during testing is the Arduino UNO R3 .
  - Features 12 digital pins and 2 serial TX/RX and 6 ADC pins.
  - The microcontroller on the UNO is the ATMEGA328P-PU.
- Pins being used.
  - 1-Reset
  - 2-Tx
  - 3-Rx
  - 9&10 - Clock connection
  - 16-SS
  - 17-MOSI/OC2
  - 18-MOSI
  - 19-SCK



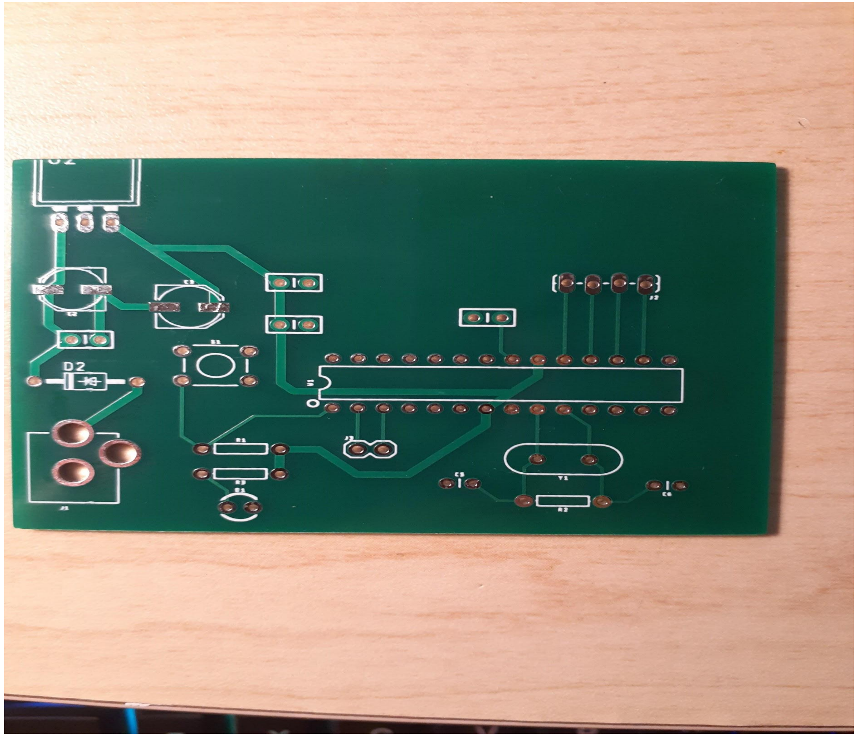
PCB Schematic



Board Layout



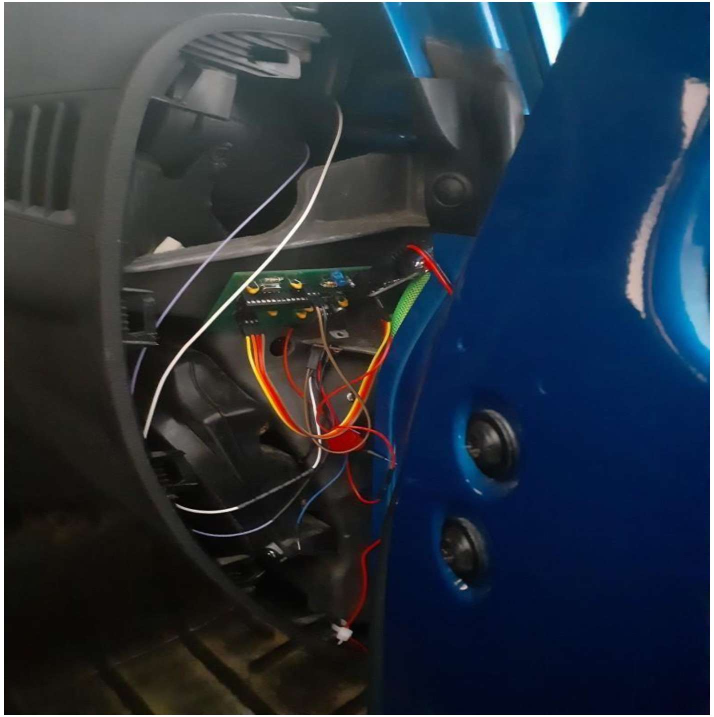
Eagle PCB board layout



Physical PCB

PCB Mounting

- The PCB was mounted inside the door frame next to the dashboard.

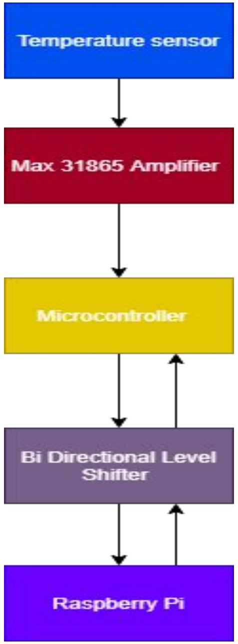


Compute Hardware Choice

- 4 x Raspberry Pi 4 Model B in server/client configuration
    - Each feature a CSI2 (Camera Serial Interface) port we will be taking advantage of
        - Then using CSI to HDMI conversions to extend the length and durability of the camera cable
    - Networking will allow the main cabin Pi to access video feed of client Pi’s
    - The Master/Server Pi will handle the logic and communication with the ATMEGA through serial communication, it will also be housed behind our main display
    - The Client Pis will handle connection to the cameras mounted nearby each Pi
    - The Master/Server Pi will be listening for rear Pi
- Sunfounder 7” display
    - Allows for mounting of our Master/Server Pi and connects via HDMI

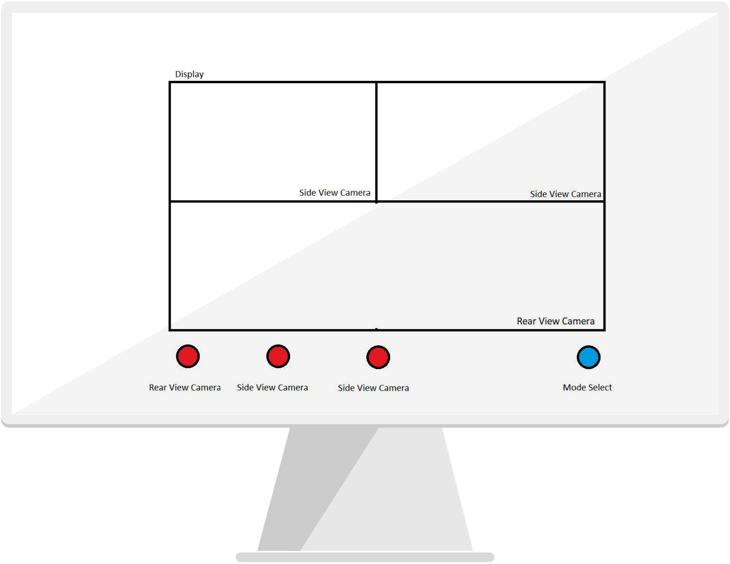
Bi directional Level Shifter

- ATMEGA 328P and Raspberry Pi incorporate different voltages for their logic
  - ATMEGA 328P uses 5 V
  - Raspberry Pi 3 Model B uses 3.3 V
- To allow for intercommunication between the 2 we needed a bi-directional level shifter that changed the logic voltage between 5 V and 3.3 V

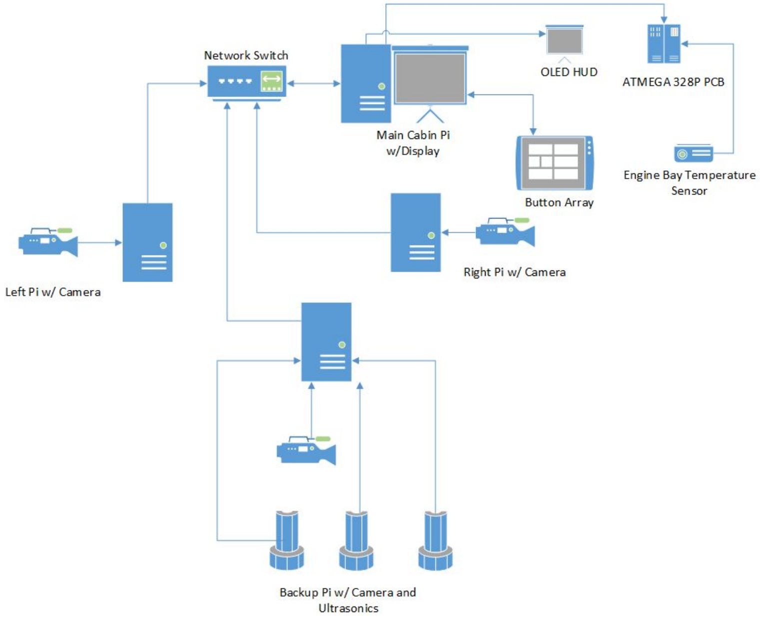


Software Design

- Simple controls - will make use of button controls
- 2 Modes - Street Mode/Off-Road Mode
- Most will be programmed in Python with C implemented for the Atmega

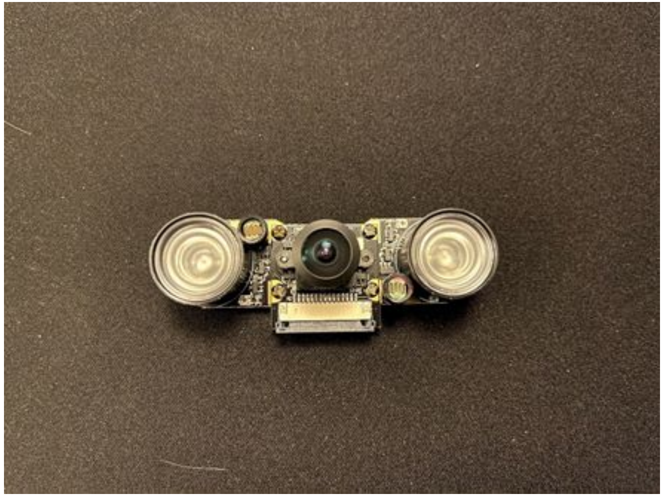


Software Design



Camera Hardware

- Camera being used 3 x RPi 4B
  - Resolution - 1080p
  - IR 850nm
  - Lens- Fisheye Adjustable 2.35 Aperture F
  - 160 degree FOV
  - 30$
- Mounting locations on the sides and rear of vehicle

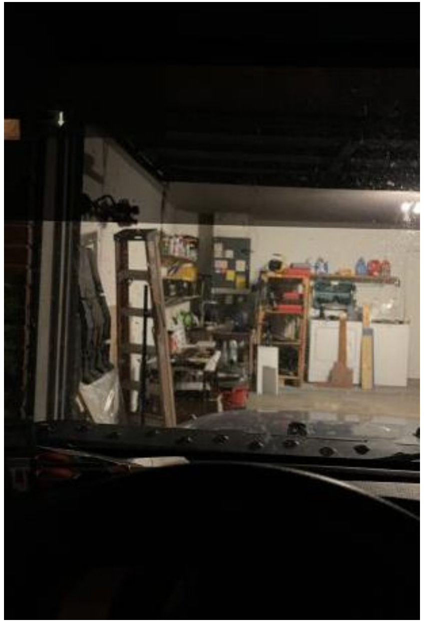


RPi Camera with attached infrared LEDs

Heads Up Display system

- Effective in catching driver attention
- Convenient
- Cost effective

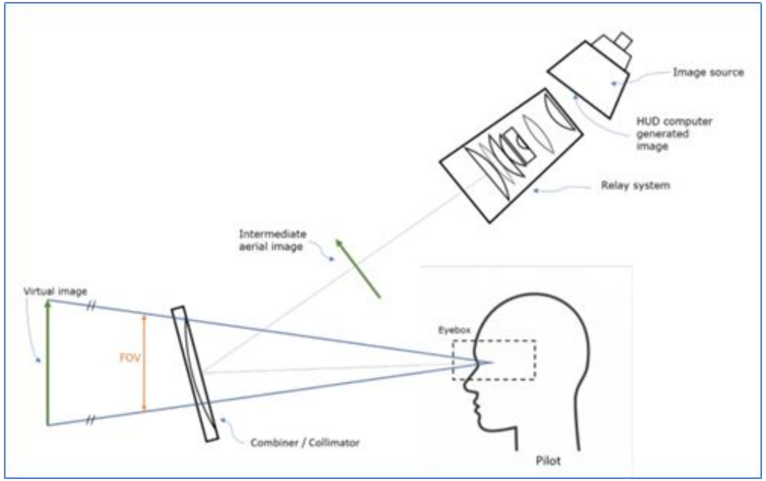
View of a HUD from inside an airplane from the perspective of a pilot



Full view example of our HUD unit

Heads up Display Parts

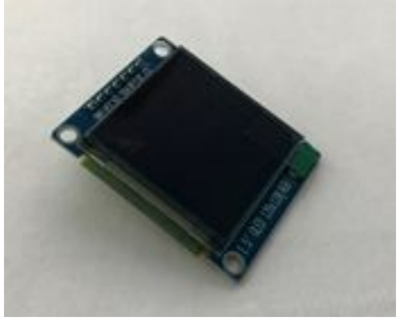
- Heads up display systems have 2 main parts
  - The Optics Display
  - The Combiner
    - Thin film



Labeled Heads Up Display System

Display for the HUD unit

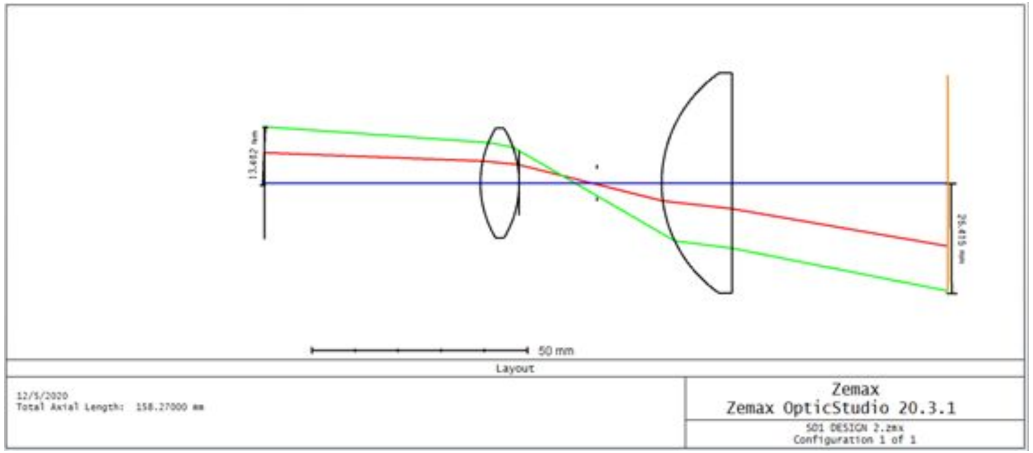
- **1 OLED DISPLAY ER-OLEDM015-1C-PSI**
    - Resolution - 128x128 rgb color
    - Contrast - 2000:1
    - Pixel size - 0.045mm x 0.194mm
    - Unit Size - 36mm x 44mm
    - Cost - $16
- Mounted in Heads up Display unit for image projection onto windshield



Full color display example from HUD unit

Optical Design

- Optics used to expand the image to desired size and project image
- Design based off of Keplerian beam expander
  - Lens 1 - LB1761
  - Lens 2 - LA1401



Zemax Design for HUD unit

Parts list /cost table

Parts List				
Part	Part Description	Quantity	Cost per unit	Total Cost
MLX90614 3V-5V Manufacturer- Melexis	IR Temperature sensor non-contact Works with I2C	1	$15.95	$15.95
Bi-Directional Logic Level Converter	Convert 5v to 3.3	1	$2.95	$2.95
MB 1003 HRLV	Ultrasonic sensor	3	$37.95	$113.85
PT 1000 3 Wire	Temperature sensor	1	$14.95	$14.95
Max 31865 RTD PT 1000 Amplifier	Amplifier	1	$14.95	$14.95
Raspberry Pi	Manage Video Feeds	4	$35	$140
Fuse	Prevent over current	2	$12.99	$25.98
Low Voltage Cutoff	Prevent draining vehicle battery	1	$22.33	$22.33
12-15V DC to 7.5 V DC	PCB	1	$13.99	$13.99
12-15V DC to 5V DC Step Down Conversion	Provide Power to Microcontrollers	4	$2.99	$11.96
Reverse Polarity Protection Circuit	Prevent damage in the event battery is hooked up incorrectly, one way connectors	1	3.99	$3.99
Wire	Electrical connections able to handle up to 3 amps over a 15-foot run, 16 amps 1-foot run	2 ft 14 AWG 60 ft 16 AWG	X	$20
Wire Sheathing	Prevent wire damage	70 ft	X	$40
Connectors	Allow easy assembly and disassembly	24	X	$35
Video Display	SunFounder 7	1	$60	$60

Enclosures	House PCB/ Main Panel/ Cameras/ HUD	6	X	$80
PCB	Microcontroller Integration	5	X	$17.40
HUD Display	Image display for HUD	1	$16	$16
Lenses	For HUD imaging	2	$30	$60

Total Budget spent $708.87 which is still under the $800 budget set!

Thank you!