Proximity-Based Hazard Detection System for Older Vehicles

CDR Presentation

Group 7

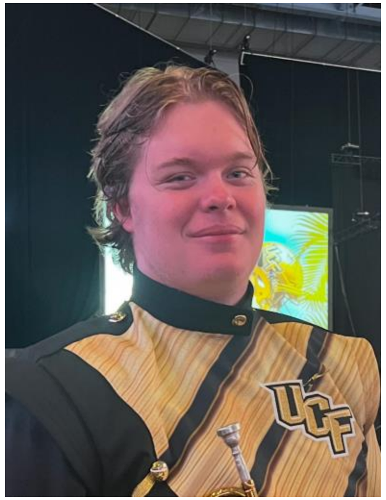
04/09/2025

Meet the Team

Michael Nelson
EE

Sebastien St. Hilaire
EE

Allison Oehmann
PSE



Patrik Regan
CpE

Jonathan Joslin
CpE

Motivation/Background


Michael (EE)

- Over 40,000 traffic accident-related fatalities in 2023 alone.
- While car manufacturers have made advanced technological improvements for car safety features in the last 5 years (since 2020).
  - Average price of new car is $47,000. Average salary is $59,000.
  - Over 62% of cars on the road today are from 2014 or older.
- Project is aimed to give a less expensive option of vehicular safety to the average consumer.
- Include as many similar safety features as new cars on the market today.

Motivation/Background

Allison (PSE)

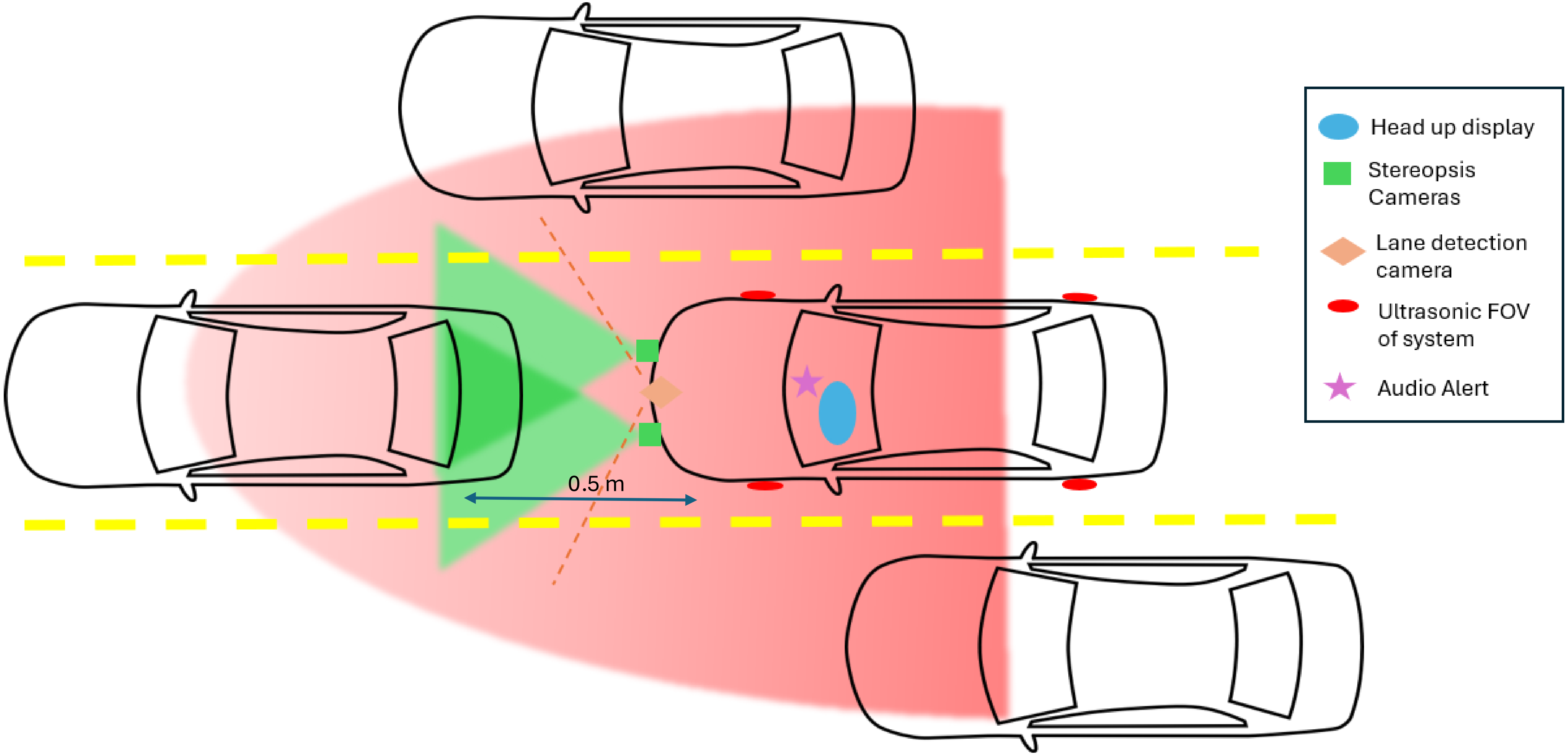
- Upgrade safety features for older vehicles
  - Lane detection
  - Blindspot detection
  - Tailing distance monitoring
- Incorporate audio and visual warnings

Applications:

- Upgrading old cars for cheaper than buying a new car
- Drivers with audio/visual impairments
- Young drivers

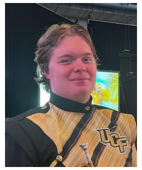
Project Visualization

Allison (PSE)



Goals and Objectives

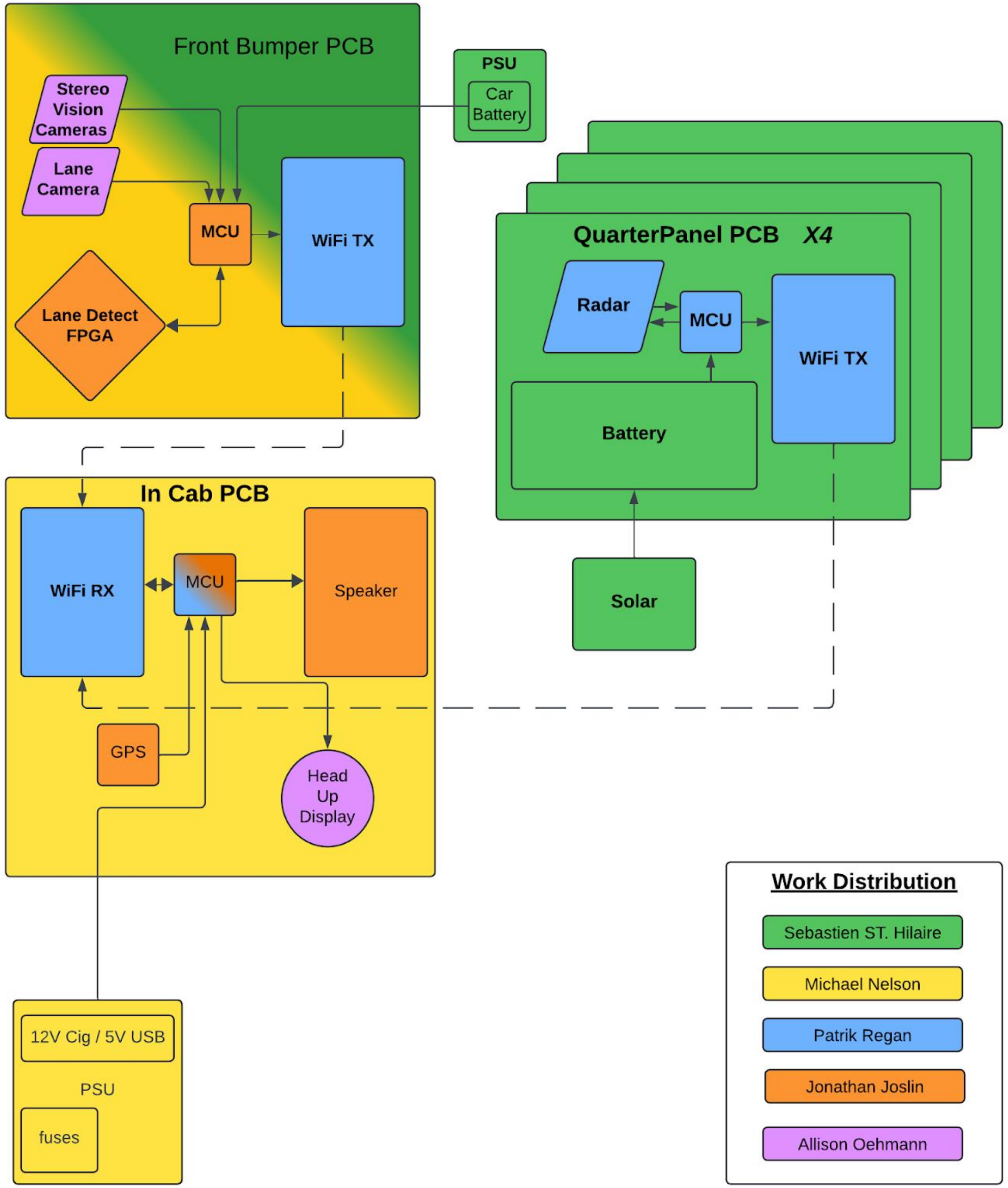
Allison (PSE)

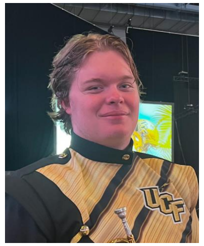


Patrik (CpE)

Basic Goals	Basic Objectives	Advanced Goals	Advanced Objectives	Stretch Goals	Stretch Objectives
Alert driver of hazards such as adjacent vehicles with multiple sensory feedbacks.	Implement a buzzer or speaker to sound when a sensor has detected a hazard, or hazardous situation.	Provide a visual interface for operator accessibility that allows users to keep eyes on the road while receiving feedback from the device	Design and implement Head Up Display that projects on windshield in front of driver's point of view.	Provide more contextual and varied visual output based on hazard type.	Implement multiple changeable stencils for the Head Up Display system. Use a motor to change between stencils based on the hazard being communicated.
Provide blind spot detection for multiple vantage points of the vehicle.	Integrate 2 low power LiDAR sensors into two external peripheries placed on the front quarter panel of the vehicle.	Provide 180 degrees (relative to the direction of the travel) of data for potential hazards	Implement a low power LiDAR on each quarter panel to detect hazardous objects.	Provide a system that stays on for extended periods of time.	Use a combination of solar power and power management to ensure peripheries that are not attached to the vehicle battery maintain operation. Even in low light and throughout the night.
Real time communication of hazards between wireless peripheries and UI.	Implement a closed WiFi network between the radar boards and the alarm producing boards with a 2.4GHz WiFi signal.	Provide tailing distance (distance between operator's front bumper and the vehicle in front of them).	Use two cameras is a stereovision system to calculate depth and distance from camera to object using lens equations.	Design with weather rating.	Design enclosures with IP69 weather casing for practical outdoor use.
Provide lane keeping assistance.	Use a 1280 X 720 RGB output camera to collect roadway visual data. Process images with the Jetson nano to detect road lanes and send feedback to the driver if needed.	Provide dynamic tailing distance adjusted for rad speed.	Use a GPS to calculate road speed. Use calculated road speed with stereovision data with the convention of 2 feet per mph to give operator tailing distance feedback.		
		Reduce power consumption and performance of the front module by optimizing the device for lane detection.	Implement lane detection algorithms via logic on FPGA dedicated to lane detection. Paralleling algorithms to reduce computation time and optimizing unused components.		

Overall Block Diagram





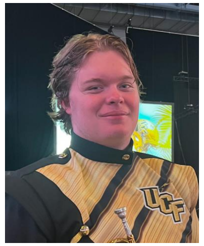
Patrik (CpE)

Engineering Specifications of the System

Allison (PSE)

System Requirement	Requirement Specification	Unit
The system shall alert the user of hazards detected within the specified range.	0.5	meters
The system shall detect objects with the specified level of accuracy.	4	centimeters
The system shall draw no more than the specified power.	20	watts
The system shall produce a visible alert within the specified time from detection.	1	second
The system shall produce an audible alert within the specified time from detection.	1	second
The system shall provide front facing sensing region about the center of the rear axle.	180	degrees

Comparison of Technologies



Patrik (CpE)

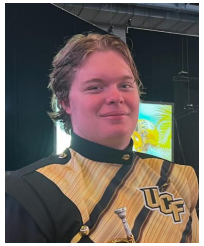
Blind Spot Detection

Key:

- selected
- purchased
- not considered

Technology	Price	Light sensitivity	Weather sensitive	Distance	FOV (typical)
Lidar	$5	Yes	moderate	2 - 60 m	39.6 degree
UltraSonic	$3	no	high	2cm - 5m	120 degree
Camera	$ 34+	yes	high	2 cm - 20 m	Lens specific
Radar	$20	no	moderate	50 cm-100 m	80 degree

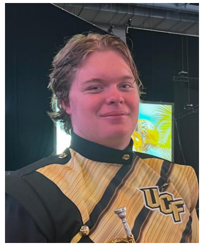
Comparison of Parts – LiDAR



Patrik (CpE)

Part	VL53L1CBV0FY-1	VL53L1CXV0FY/1	DF-Robot SEN0524
Price	$5.77	$5.77	$42.90
Range	8 m ~ 26.25 ft	4 m ~ 13.12 ft	15 m
FOV	36.5	36.6	4

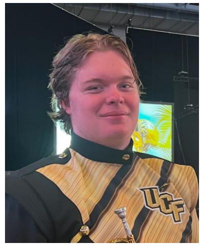
Selection of Part – LiDAR



Patrik (CpE)

- VL53L1CBV0FY-1 was selected
- Best price point for range and FOV
- Acceptable range

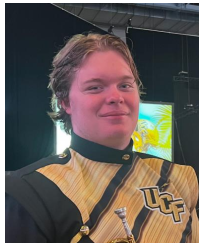
Comparison of Parts - Ultrasonic



Patrik (CpE)

Part	HC-SR04	JSN-SR04T	RCWL-1670
Price	$2	$7	$8
Range	5 m	6 m	4 m
FOV	~21°	~75°	~21°

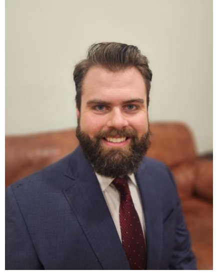
Selection of Part - Ultrasonic



Patrik (CpE)

- HC-SR04 was selected
- Best price point for FOV
- More than acceptable range

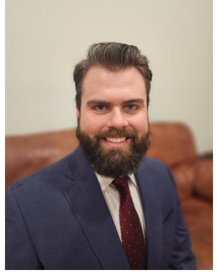
Comparison of Parts – GPS module



Jonathan (CpE)

Module	TESEO-LIV4FTR	YIC31612EBGG	STA8089GADTR
Price	$16.19	$5.98	$5000 (only bulk)
Communication protocol	I2C UART	UART	I2C UART
Baud Rate	115200	9600	115200
Passive/Active (internal LNA)	Active	Active	Active
Automotive Grade	No	No	Yes

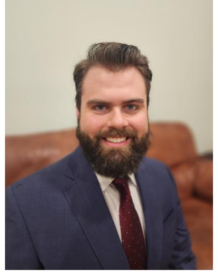
Selection of Part – GPS Module



Jonathan (CpE)

- Part selected: TESEO-LIV4FTR
- Better Baud Rate than similarly priced options
- Had LNA to amplify RF signal built in
- Had simplest interface as detailed by data sheet

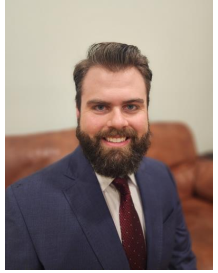
Comparison GPS Antenna



Jonathan (CpE)

Model	ASGPDF254.A	2042860001	2066400001
Return Loss	-10dB	-10dB	-8dB
Active	yes	No	yes
Type	Ceramic Patch	Ceramic Patch	Ceramic Patch
Termination	SMD	Through hole	SMD
Noise @ 3V	N/A	1.0dB	<2.0dB
Price	$27.49	$3.65	$10.98

Part Selectin GPS Antenna



Jonathan (CpE)

- Part Selected: ASGPDF254.A
- Lowest noise LNA for active antenna
- SMD with no extra rods or patches

Sebastien (EE)

Comparison of Parts – Voltage Regulator Module

Part	D36V50F5	LM2596S	D36V28F5
Voltage Input Range	5.5V to 50V	3.5V to 40V	5.3V to 50V
Output Voltage	5V	1.5V to 35V	5V
Output Current	5.5 A	2A	3.2A
Cost	$24.95	$10	$15.95

Sebastien (EE)

Selection of Parts – Voltage Regulator Module

- D36V50F5 Module was selected.
- Provide a wide voltage Input Range.
- Meets the voltage and current requirement for the Jetson Nano.

Comparison of Parts – Audio Amplifiers

Michael (EE)

Regulator Model	MAX98357	MAX98306	PAM8302A	TPA3116D2
Supply Voltage Range	2.5-5.5V	2.7-5.5V	2.5-5.5V	4.5-26V
Output Power	3.2W	3.2W	2.5W	50W
Output Configuration	Mono	Stereo	Mono	Stereo
Input Type	I2S Digital	Analog	Analog	Analog
Efficiency	>90%	>90%	>85%	>90%
Cost	$2.91	$2.50	$1.70	$1.84

Selection of Parts – Audio Amplifiers

Michael (EE)

- MAX98357 audio amplifier was selected.
- Only investigated amplifier capable of I2S Digital.
- Output configuration did not play a factor.
- Power output and input voltage ranges were sufficient.

Comparison of Parts - Speakers

Michael (EE)

Speaker Model	CS40-01P60-05-3X	CS23-01P100-03-1X	CVS-1708	CVS-1508	AS01808A
Power Consumption	1W	1.5W	0.5W	0.5W	2.2W
Sound Pressure Level (SPL)	95dB	95dB	84dB	84dB	99dB
Operating Temperature Range	-20 – 70 C	-20 – 60 C	-20 – 55 C	-20 – 55 C	-20 – 70 C
Cost	$3.55	$3.03	$3.07	$3.12	$3.93

Selection of Parts - Speakers


Michael (EE)

- Selected the AS01808A speaker.
- Utilizes the available power.
- Slightly higher sound pressure level output.
- Cost difference inconsequential.

Comparison of Technologies- Light Sources

Allison (PSE)

Technology	HeNe Laser	Laser Diode (red)	Laser Diode (green)	Argon Ion Laser
PN	HNL020RB	VLM-650-01-LPT-ND	VLM-520-03LPT-ND	38-1005-ND
Type	HeNe	Laser diode	Laser diode	Argon ion
Manufacturer	Thorlabs	Quarton	Quarton	US-Lasers
Wavelength	632.8 nm	650 nm	520 nm	808 nm
Package size	44.2 x 271.78 mm	10.4 x 18.4 mm	7 x 21 mm	10.4 mm
Drive current	6.5 MA	35 mA	80 mA	25 mA
Output intensity	2 mW	1 mW	1 mW	5 mW
Class	Class IIIa	Class II	Class II	Not listed
Cost	$1767.15	$17.64	$19.70	$54.32

Allison (PSE)

Comparison of Parts- Laser Diodes

PN	1528-2100-ND	VLM-650-01-LPT-ND	38-1003-ND
Manufacturer	Adafruit	Quarton	US Lasers
Wavelength	650 nm	650 nm	655 nm
Package size	10.11 mm D x 32.82 mm L	10.4 mm D x 18.4 mm L	10.4 mm D x 17 mm L
Drive current	35 mA	35 mA	25 mA
Voltage input	4.8 - 5.2 V	2.6 - 5.0 V	3.0 - 6.0 V
Output intensity	5 mW	1 mW	5 mW
Class	Class IIIa	Class II	Class IIIa
Cost	$18.95	$17.76	$30.81

Comparison of Parts - Lenses


Allison (PSE)

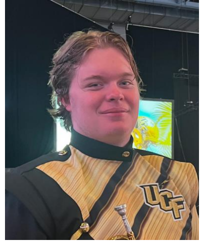
PN	#49-847	#29-094	LA1805	LA1401
Manufacturer	Edmund Optics	Edmund Optics	Thorlabs	Thorlabs
Diameter	25.4 mm	50.8 mm	1 in	2 in
EFL	25.4 mm	50.8 mm	30 mm	60 mm
Glass type	N-SF11	N-SF11	N-BK7	N-BK7
Lens shape	Plano-Convex	Plano-Convex	Plano-Convex	Plano-Convex
Cost	$31.00	$47.50	$26.50	$42.18

Selection of Parts- Lenses

Allison (PSE)

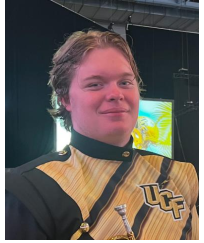
- Optimal focal length
- Reasonably priced
- Personal preference
- Calculations:
    - System length (max)= Laser + Microscope Objective + working distance + 4f
    - 32.82mm + 160mm + 0.66mm + 4f <= 304.8mm
    - F <= 31.435 mm
    - Decision: f = 25.4mm, diameter = 25.4 mm
    - System length = 295 mm = 11.6 in

Comparison of Technologies – Wireless



Patrik (CpE)

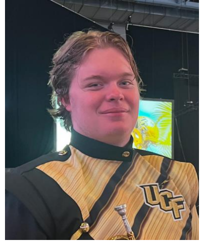
Wireless Methodology	Wi-Fi	Bluetooth Classic	Bluetooth Low Energy	Zigbee
Bandwidth	20 MHz, 40 MHz, 80 MHz, 160 MHz	1 MHz	2 MHz	2 MHz
Data Rate	Up to 9.6 Gb/s	Up to 3 Mb/s	Up to 2 Mb/s	250 Kb/s
Number of Devices	255	7	Unlimited	65,000
Range	45 meters	30 meters	50 meters	300 meters
Latency	0.90 ms	100 ms	6 ms	130 ms


Patrik (CpE)

Selection of Technologies – Wireless

- Wi-Fi was selected
- Allows for high bandwidth
- Lowest latency out of all wireless methodologies

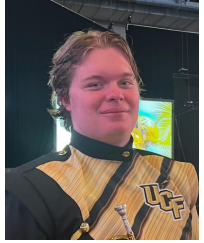
Comparison of Parts – Wireless



Patrik (CpE)

Part	ESP32-WROOM-32E-N4	ESP8266EX	ESP32-MINI-1U
Type	Module	SoC	Module
Wi-Fi Protocol	IEEE 802.11 b/g/n	IEEE 802.11 b/g/n	IEEE 802.11 b/g/n
Temperature	-40 ~ 80 ºC	-40 ~ 125 ºC	-40 ~ 85 ºC
GPIO	26	17	28
SRAM	520 KB	160 KB	520 KB
Frequency	240 MHz	160 MHz	240 MHz
Size	18*25.5*31 mm	QFN32 (5*5) mm	13.2*13.5*2.4 mm
Voltage	3.0 ~ 3.6 V	2.5 ~ 3.6 V	3.0 ~ 3.6 V

Selection of Parts – Wireless

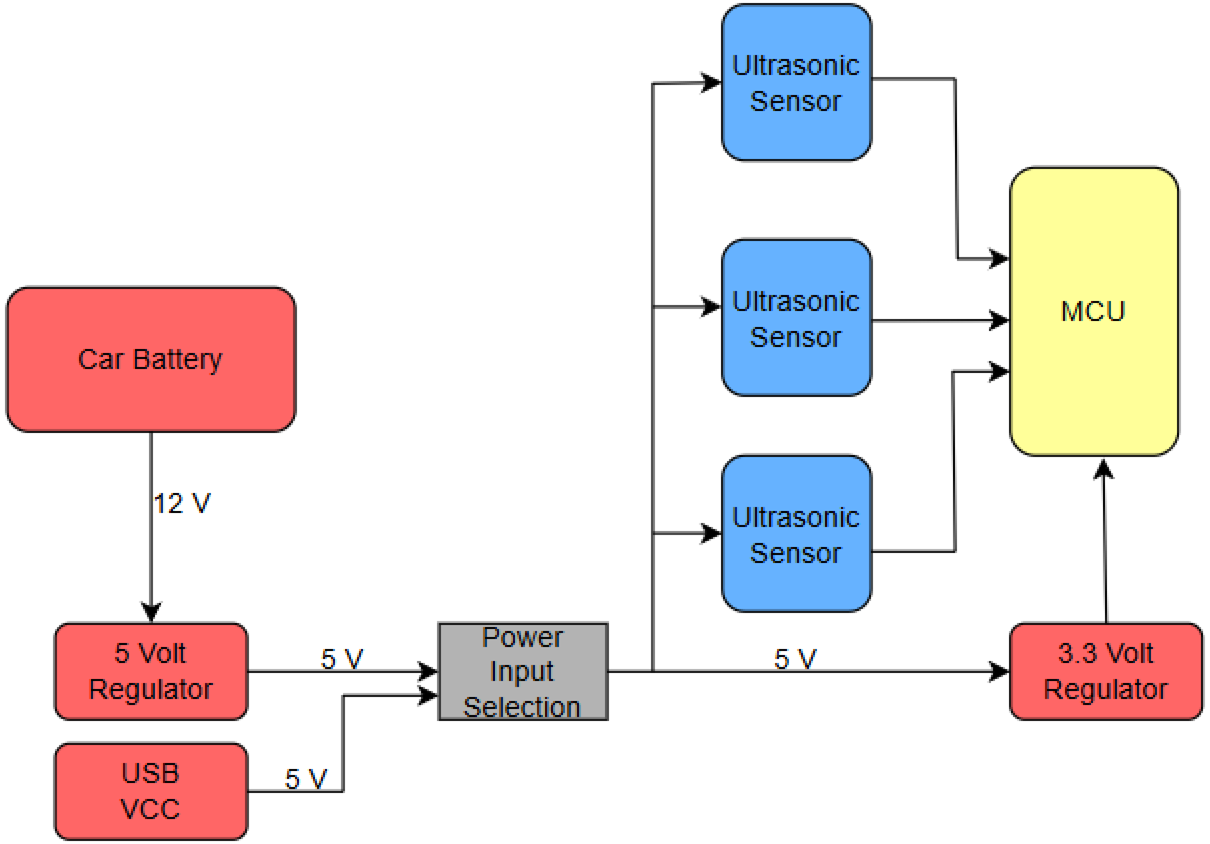


Patrik (CpE)

- ESP32-WROOM-32E-N4 was selected
- 26 GPIO pins provides enough pins to work with
- Allows for a good frequency to work with, being 240 MHz

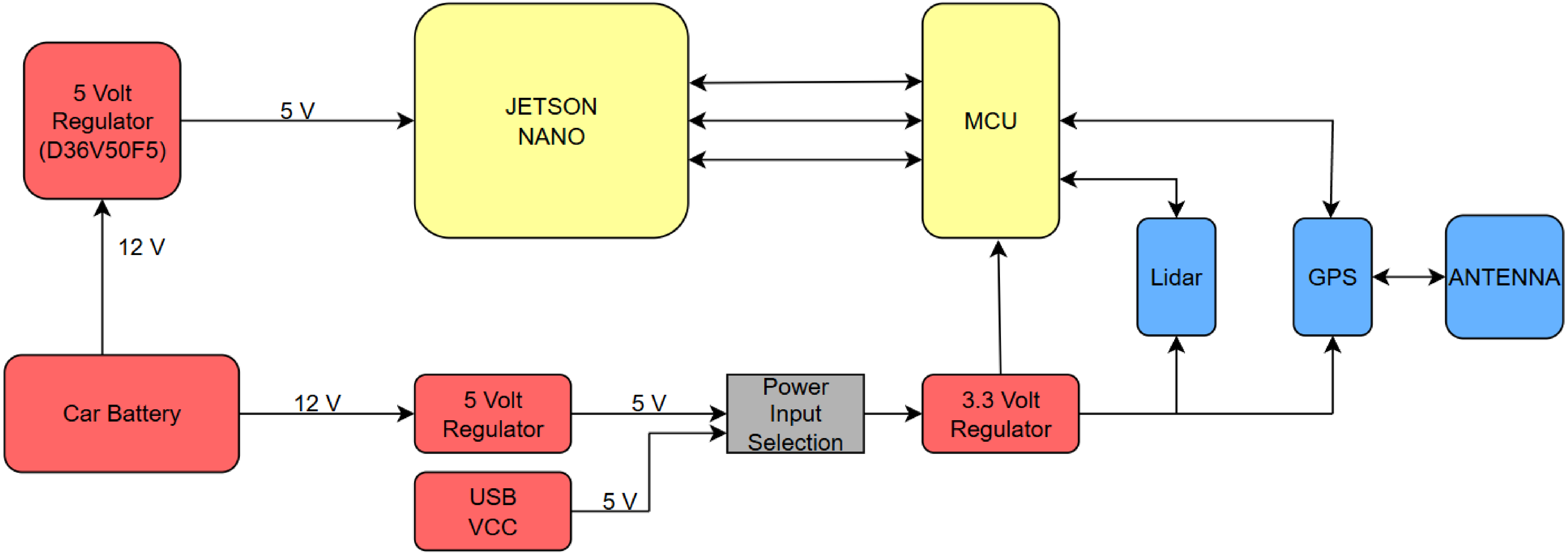
Quarter Panel Block Diagram

Sebastien (EE)



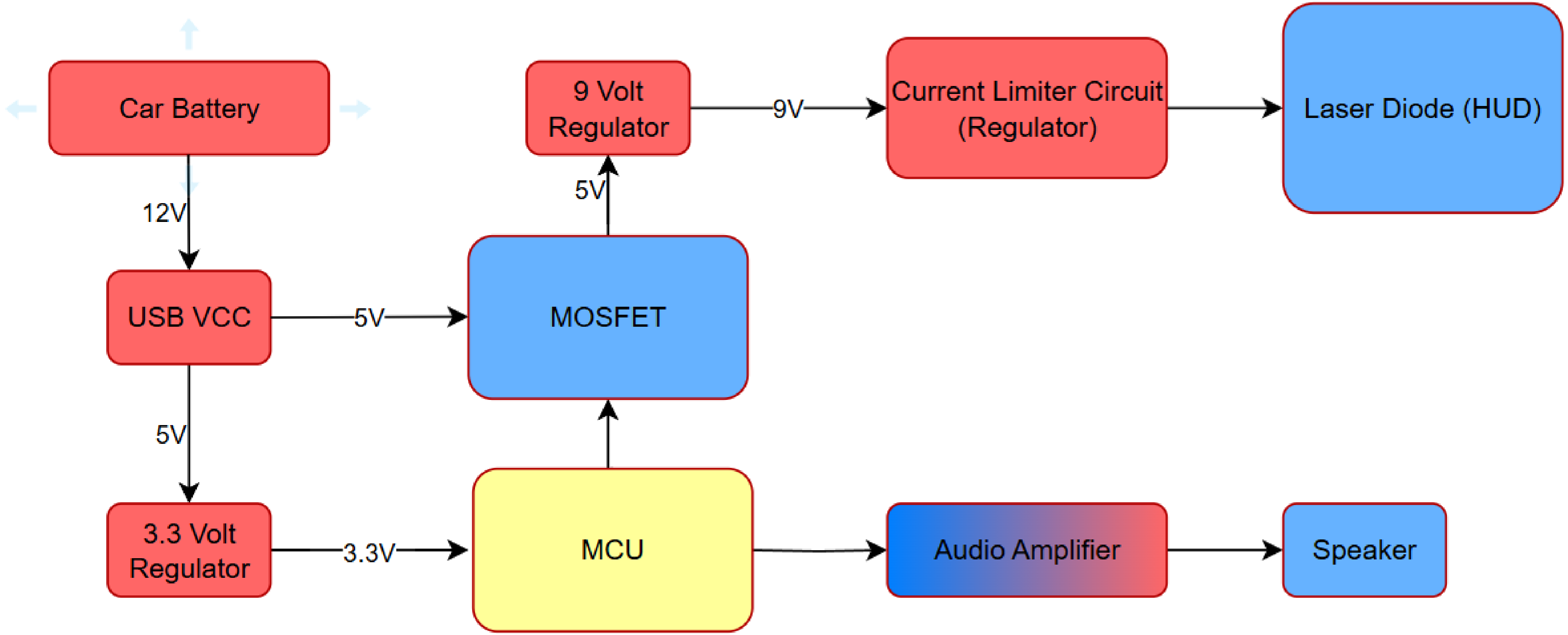
Front Bumper Block Diagram

Sebastien (EE)



Internal Cabin Block Diagram

Michael (EE)



Optical Layout– Heads Up Display

Allison (PSE)

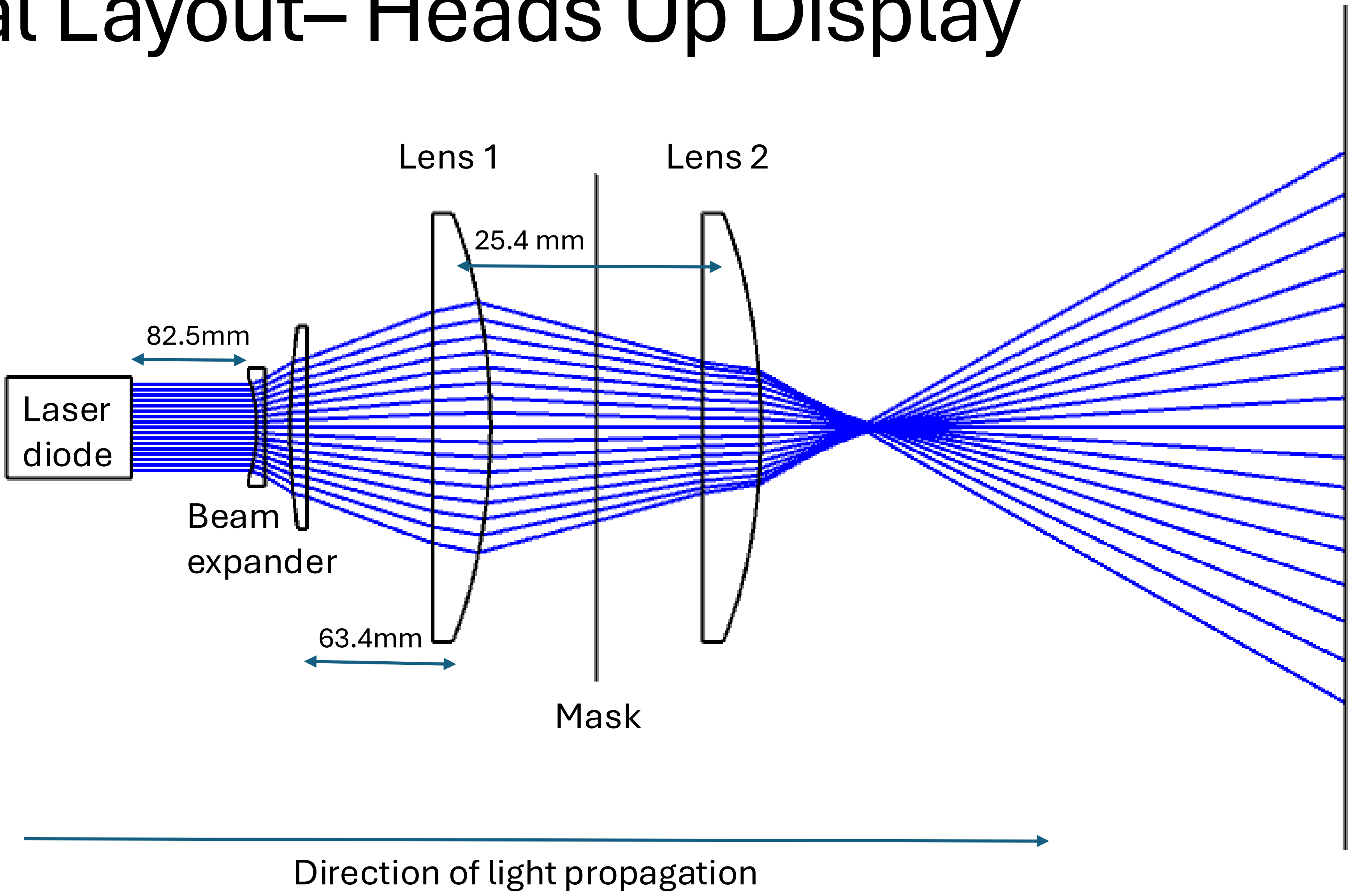
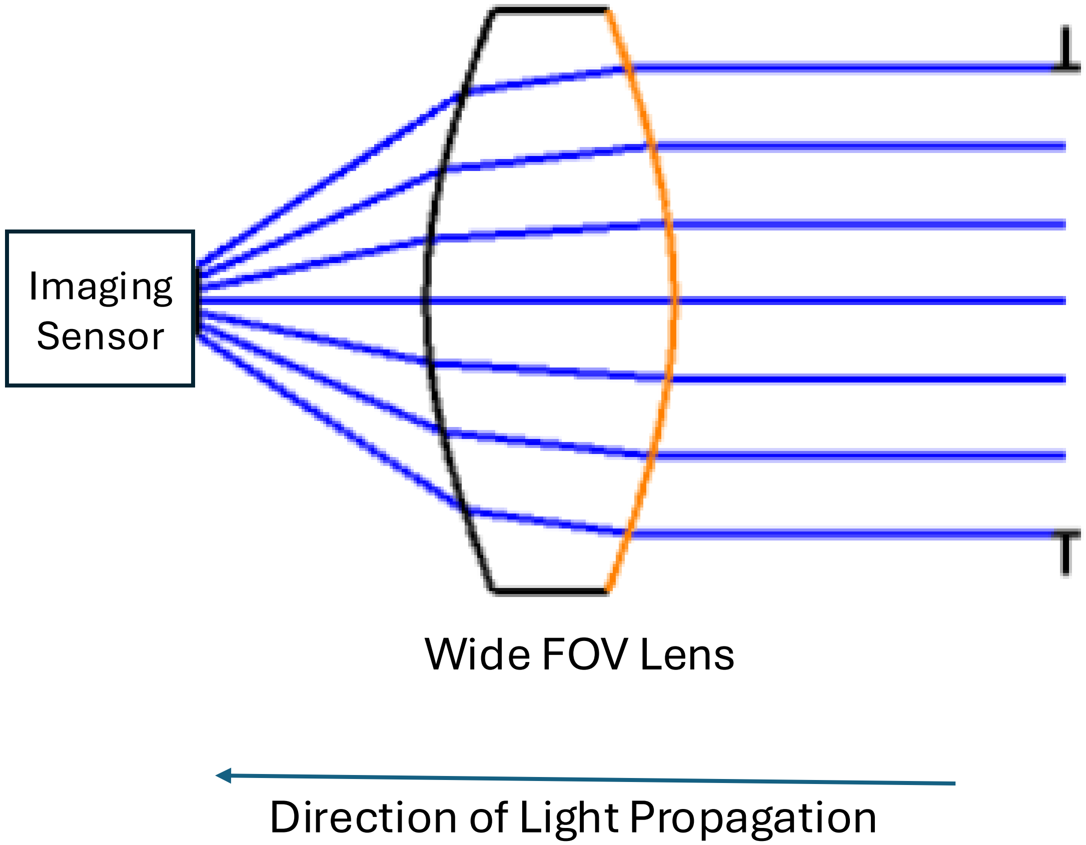


*Image not to scale

Optical Block Diagram – Front Imaging Systems

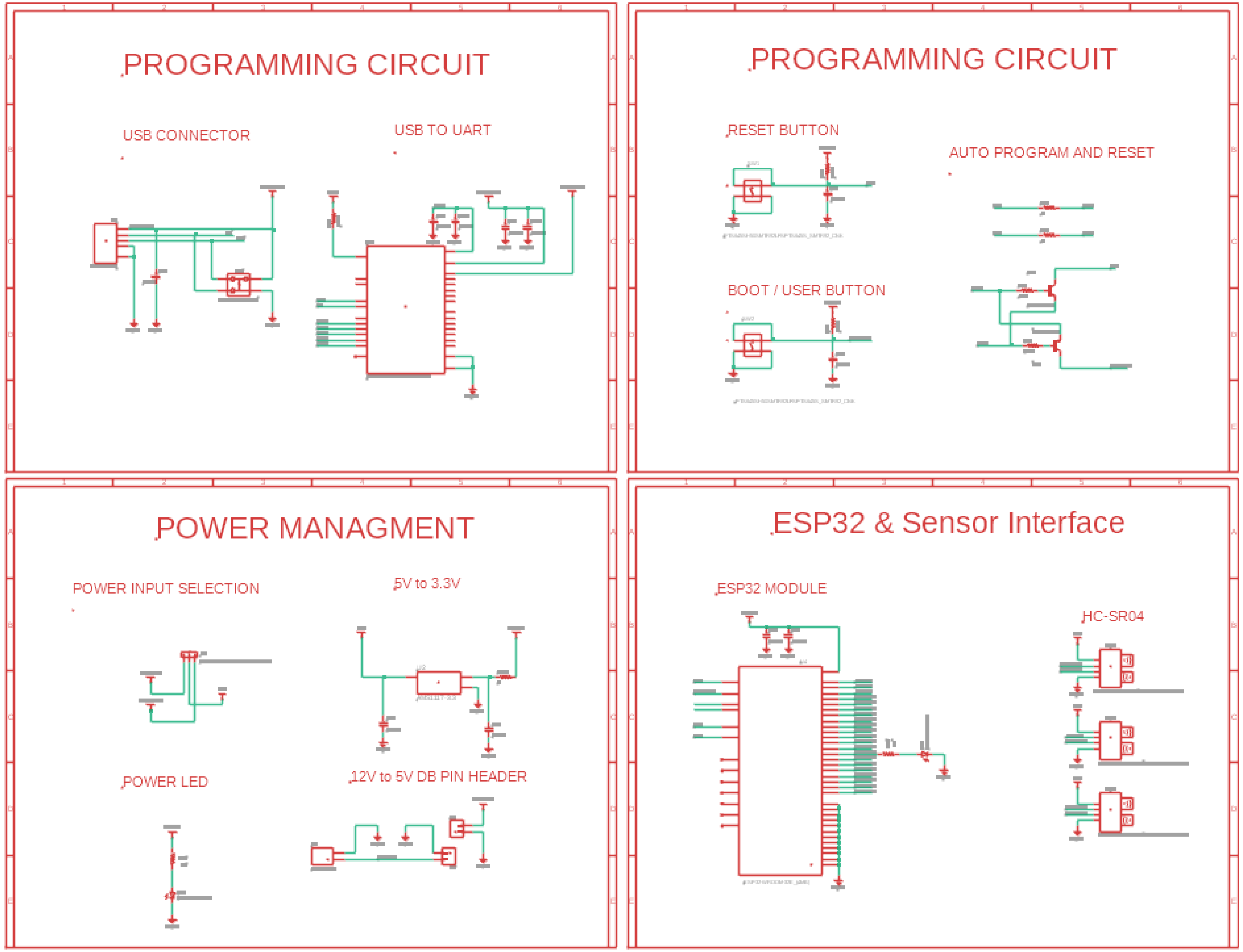
Allison (PSE)

Stereovision Camera Design



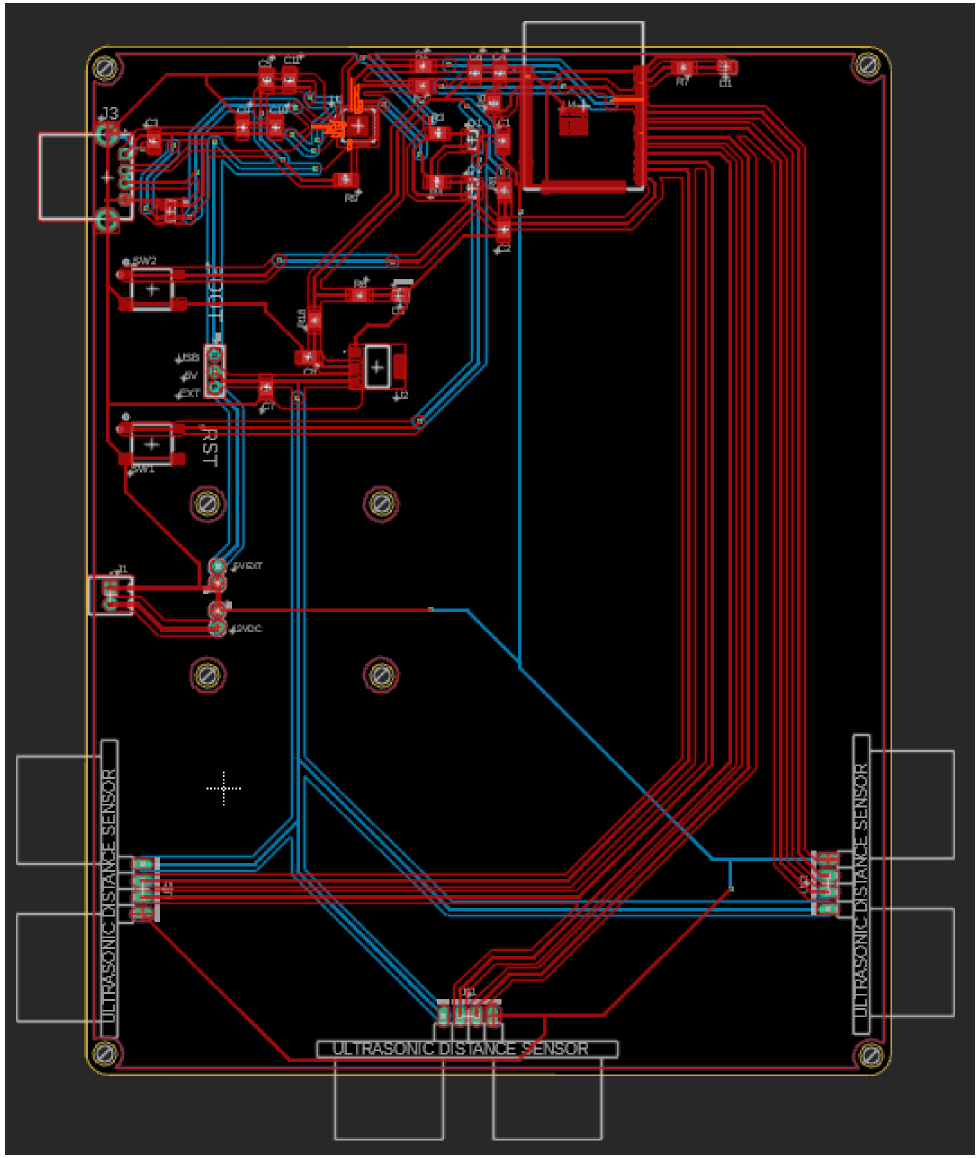
Overall Schematic – Quarter Panel

Sebastien (EE)

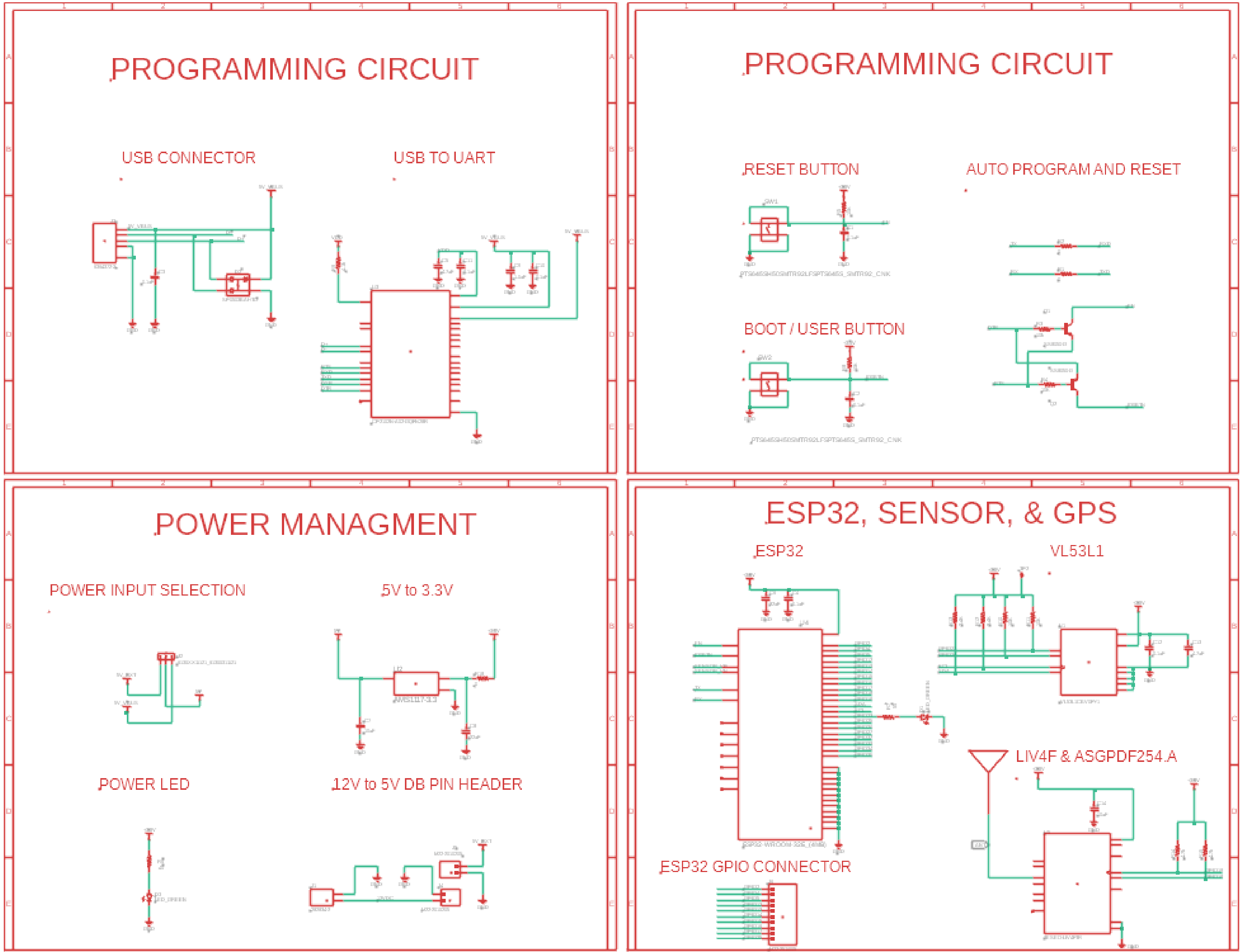


PCB Layout – Quarter Panel

Sebastien (EE)

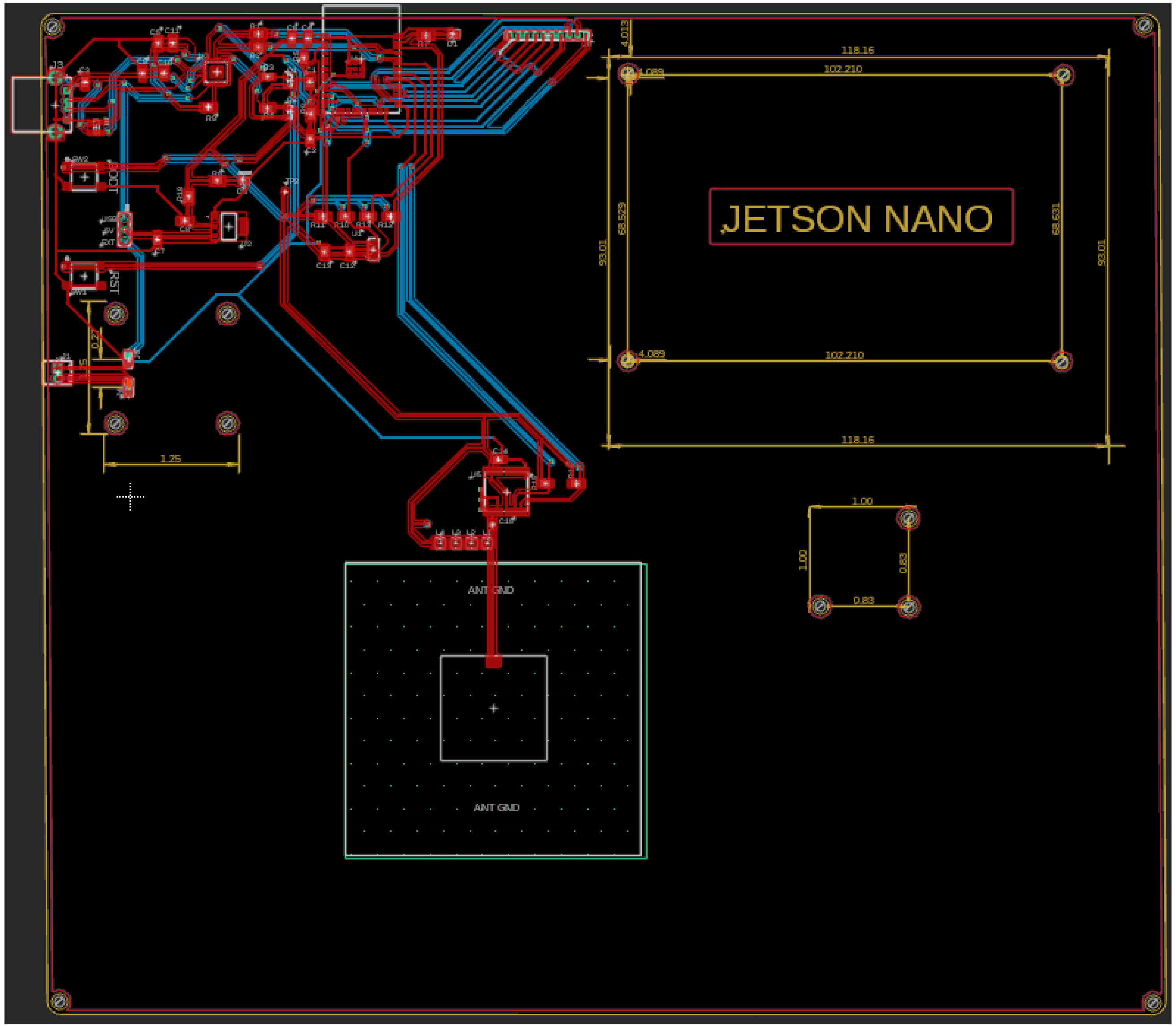


Overall Schematic – Front Bumper



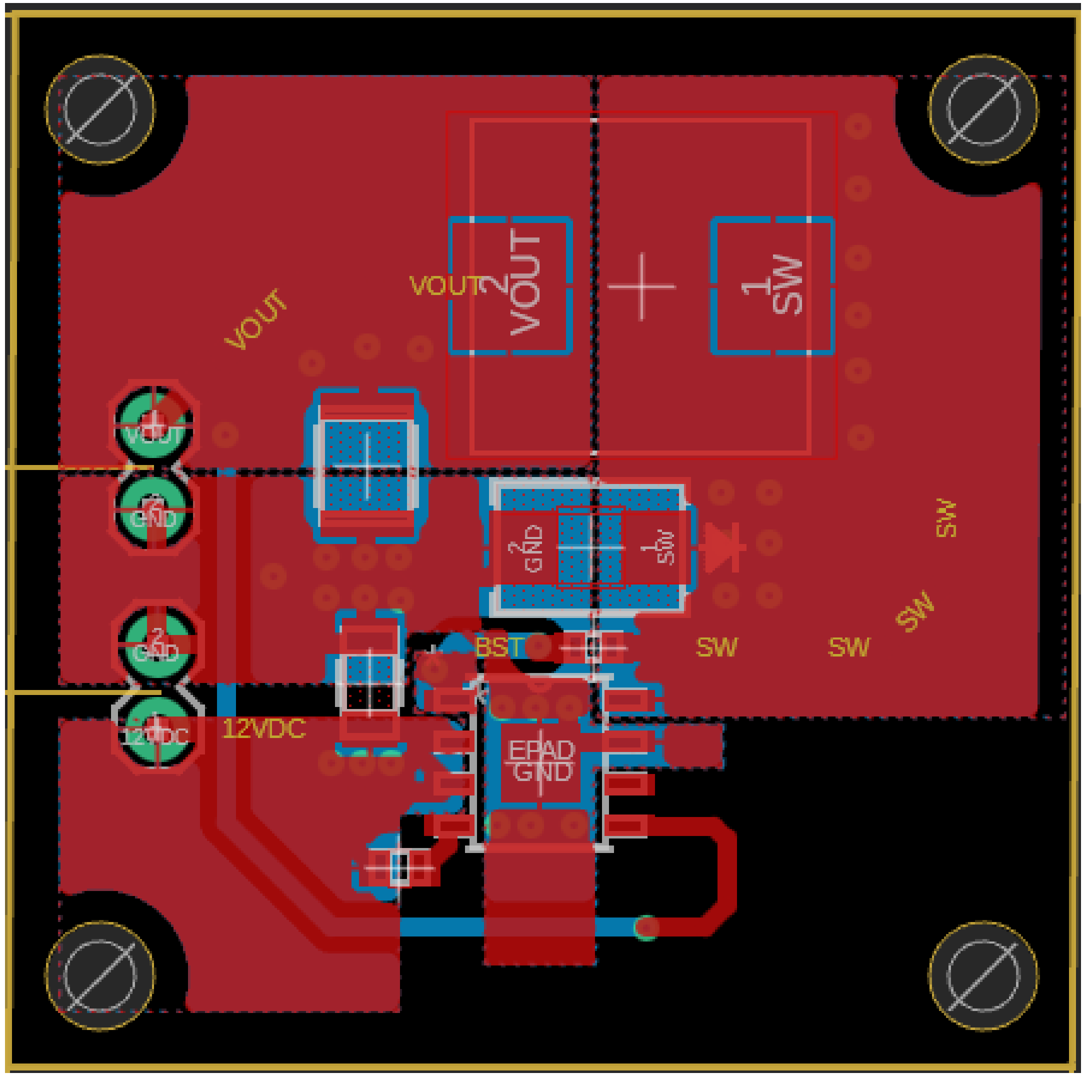
Sebastien (EE)

PCB Layout – Front Bumper



Sebastien (EE)

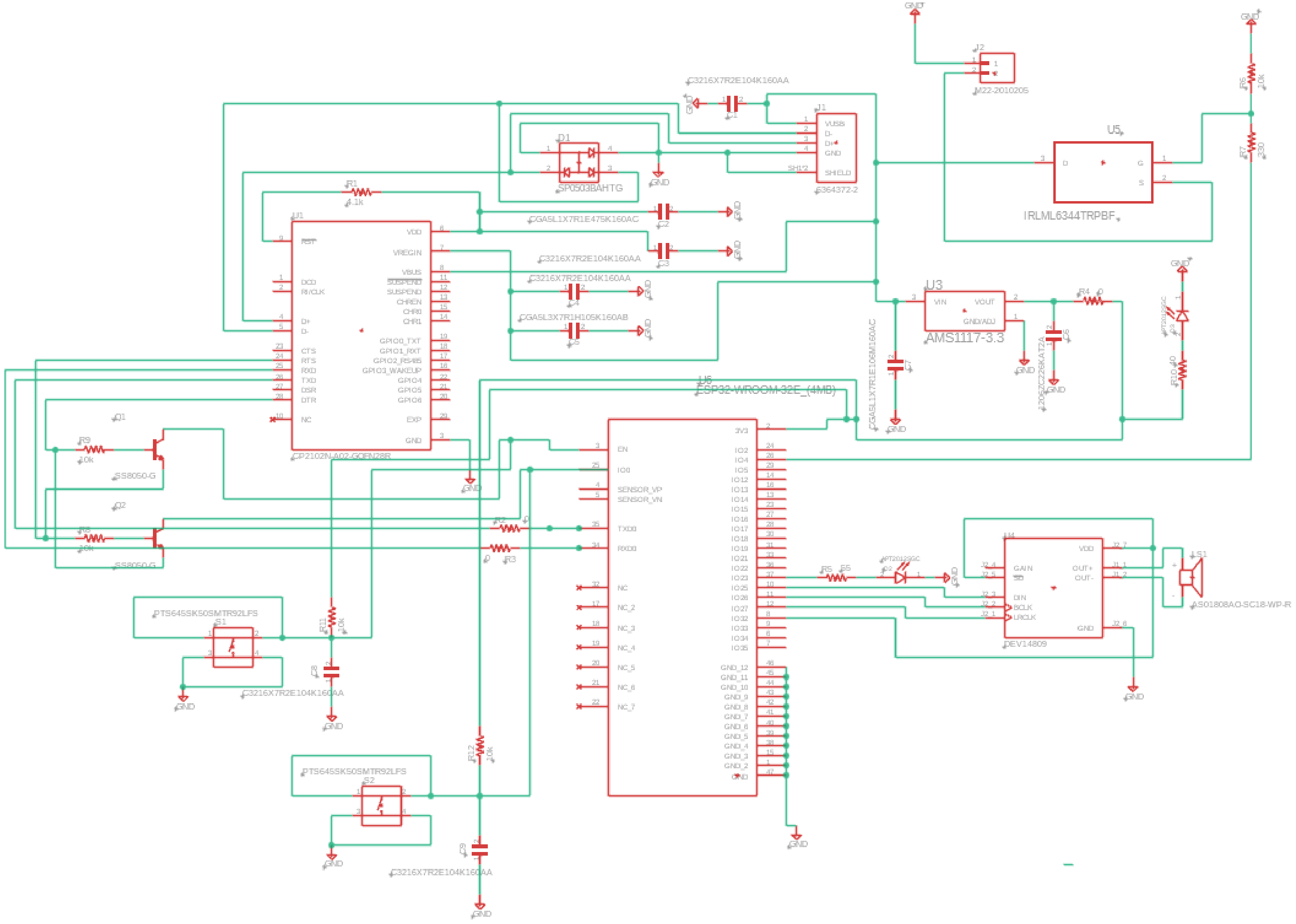
PCB Layout – 12V to 5V Voltage Regulator



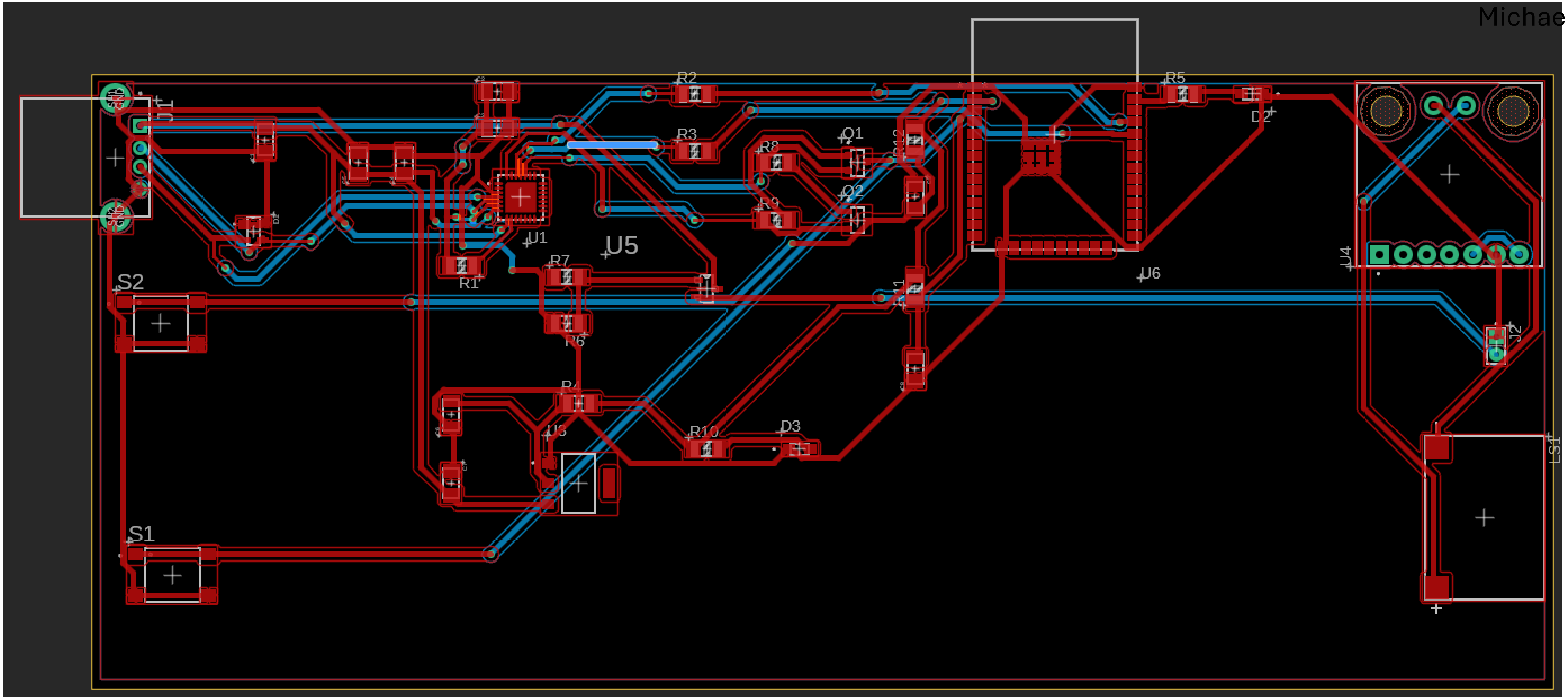
Sebastien (EE)

Overall Schematic – Main Internal Cabin

Michael (EE)



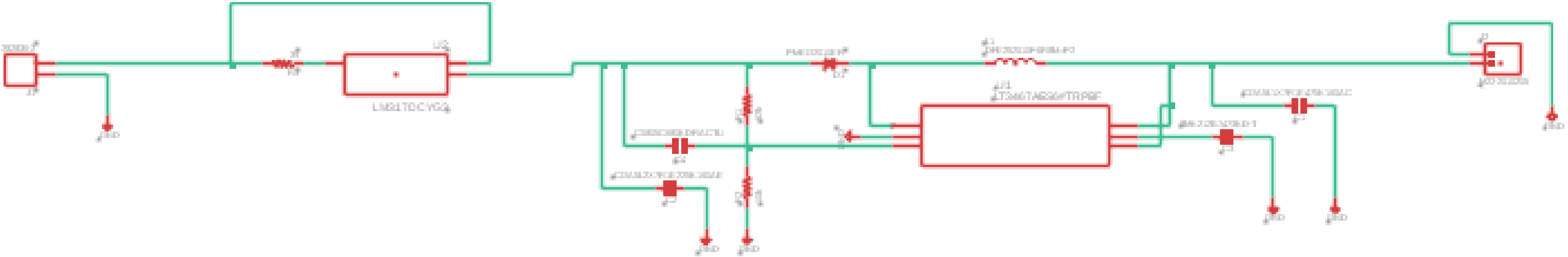
PCB Layout – Main Internal Cabin



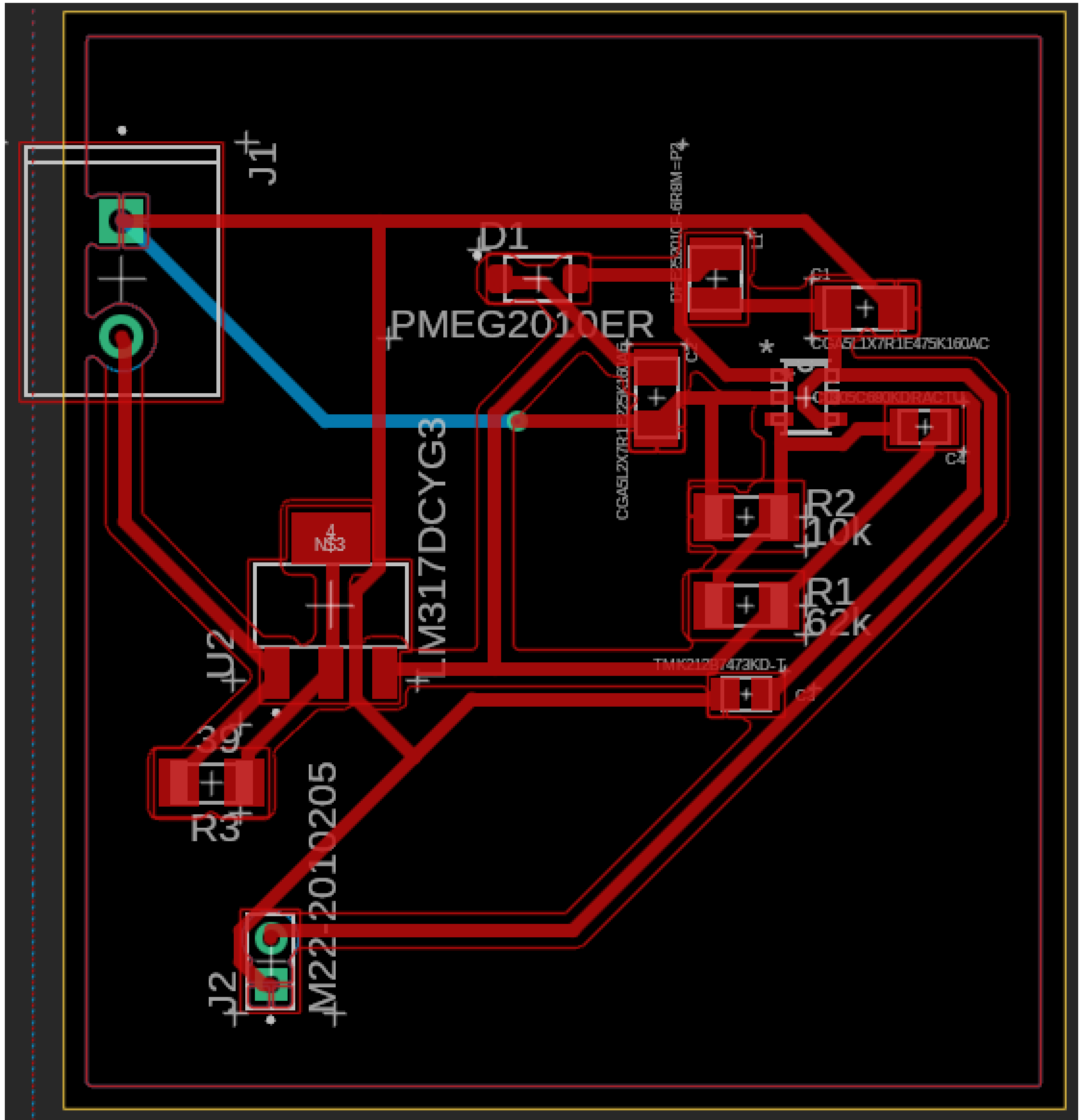
Michael (EE)

Overall Schematic – Internal Breakout Board


Michael (EE)

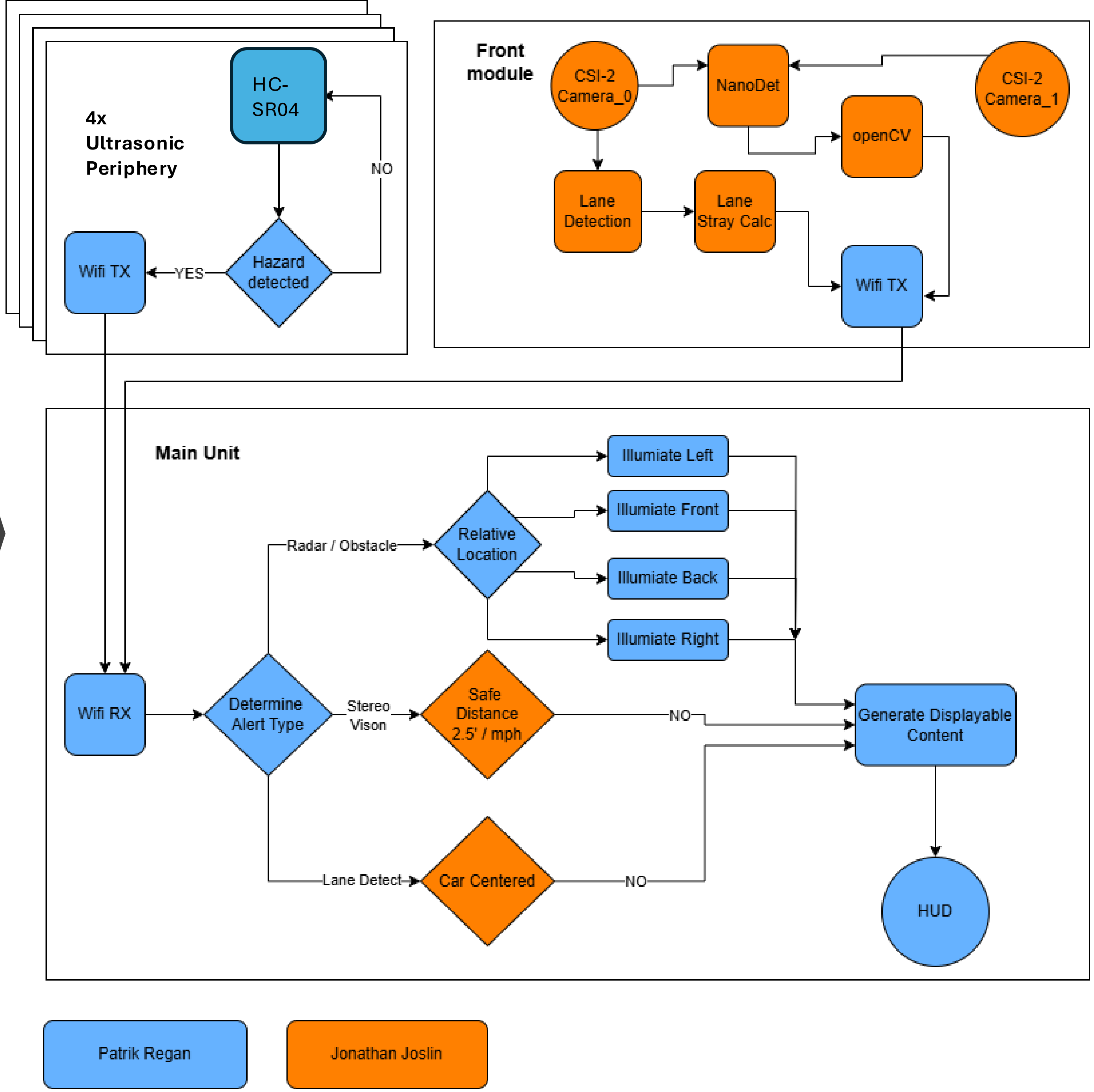


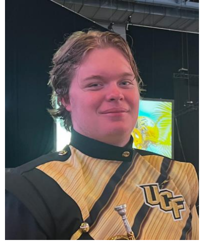
PCB Layout – Internal Breakout Board



Michael (EE)

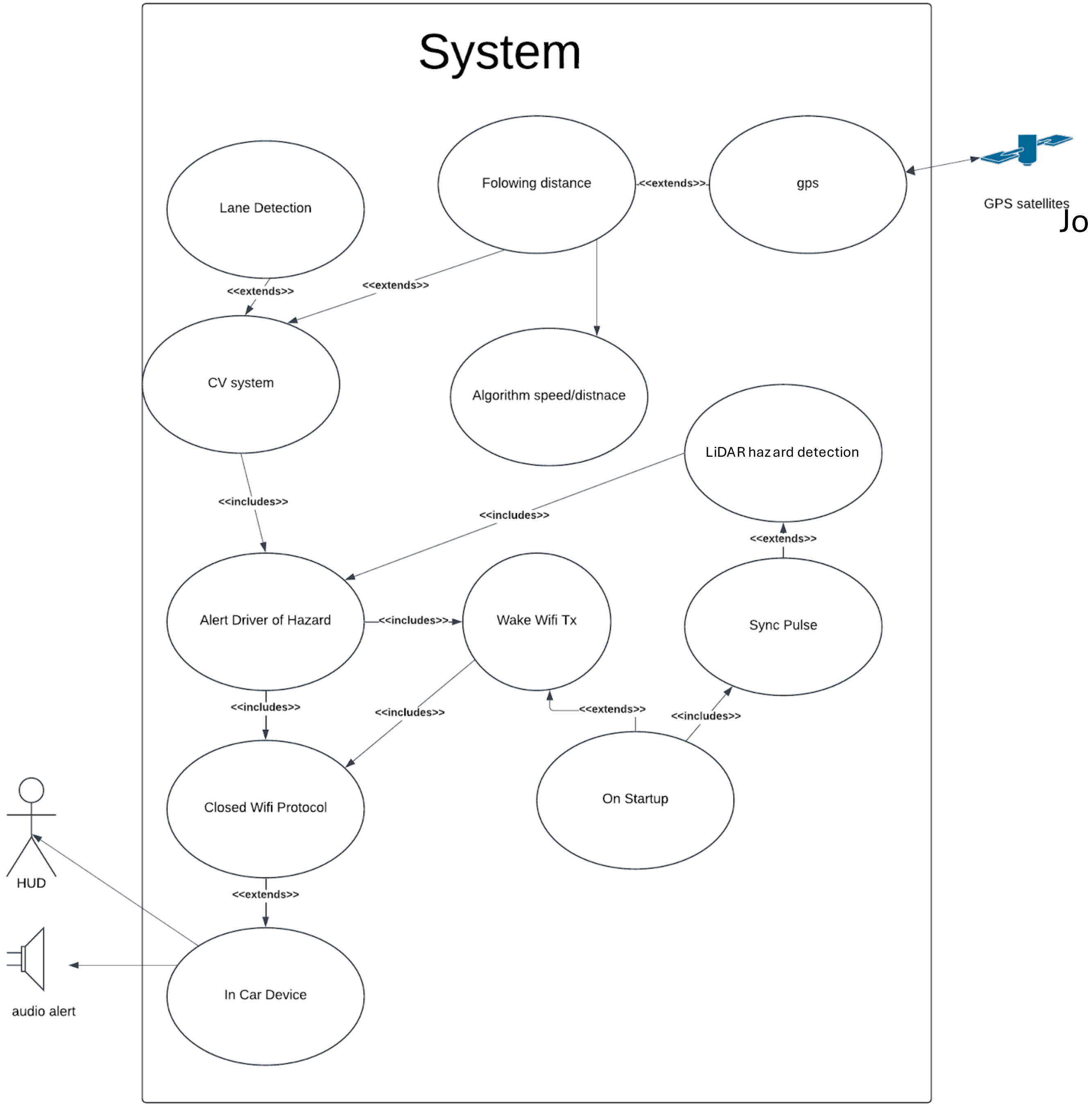
Software Flowchart

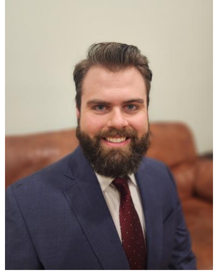




Patrik (CpE)

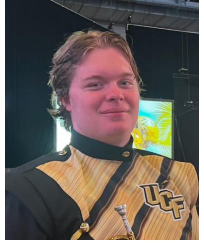
Software Case Diagram





Jonathan (CpE)

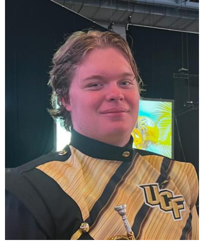
Wireless System Design – ESPNOW



Patrik (CpE)

- Implemented the wireless communication procedure with ESP-NOW
- ESP-NOW is an adaption of Wi-Fi by reducing the standard OSI model into three layers
  - Layers: ESP-NOW, data link layer, physical layer
- Built for the ESP32 family, allowing for lower latency communications
- Designed for short packet transmissions, ideal for our project

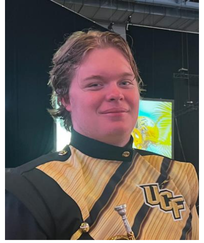
Wireless System Design – Receiver



Patrik (CpE)

- Receiver board will establish connection with transmitters using its MAC address
- Located on the in-cab PCB
- When signal is received, receiver will process the information and send out necessary alerts
- Will be in control of turning on heads-up display and sending audio alert

Wireless System Design - Transmitter



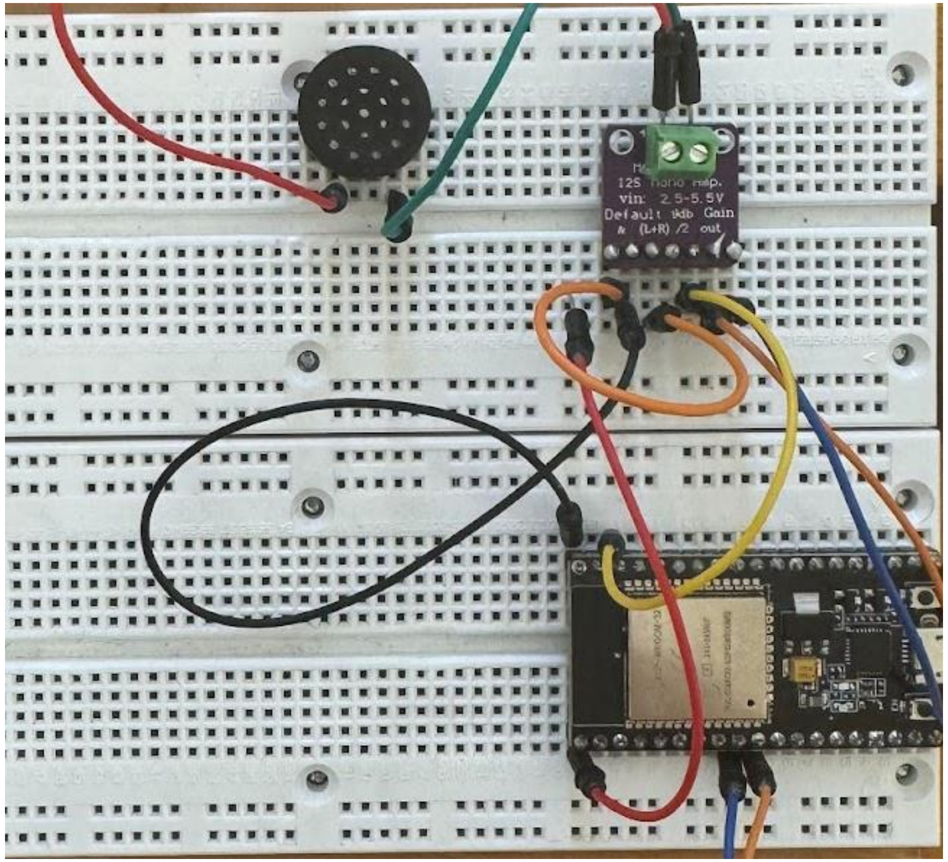
Patrik (CpE)

- Transmitter located on quarter panel and front bumper PCB
- Contains receiver MAC address to connect easily
- Will constantly monitor any input from the LiDAR units
- When LiDAR picks something up, transmitter will process the data
- When processed, flag will be sent to receiver to be handled accordingly

Hardware Testing – Audio Amplifier/Speaker

Michael (EE)

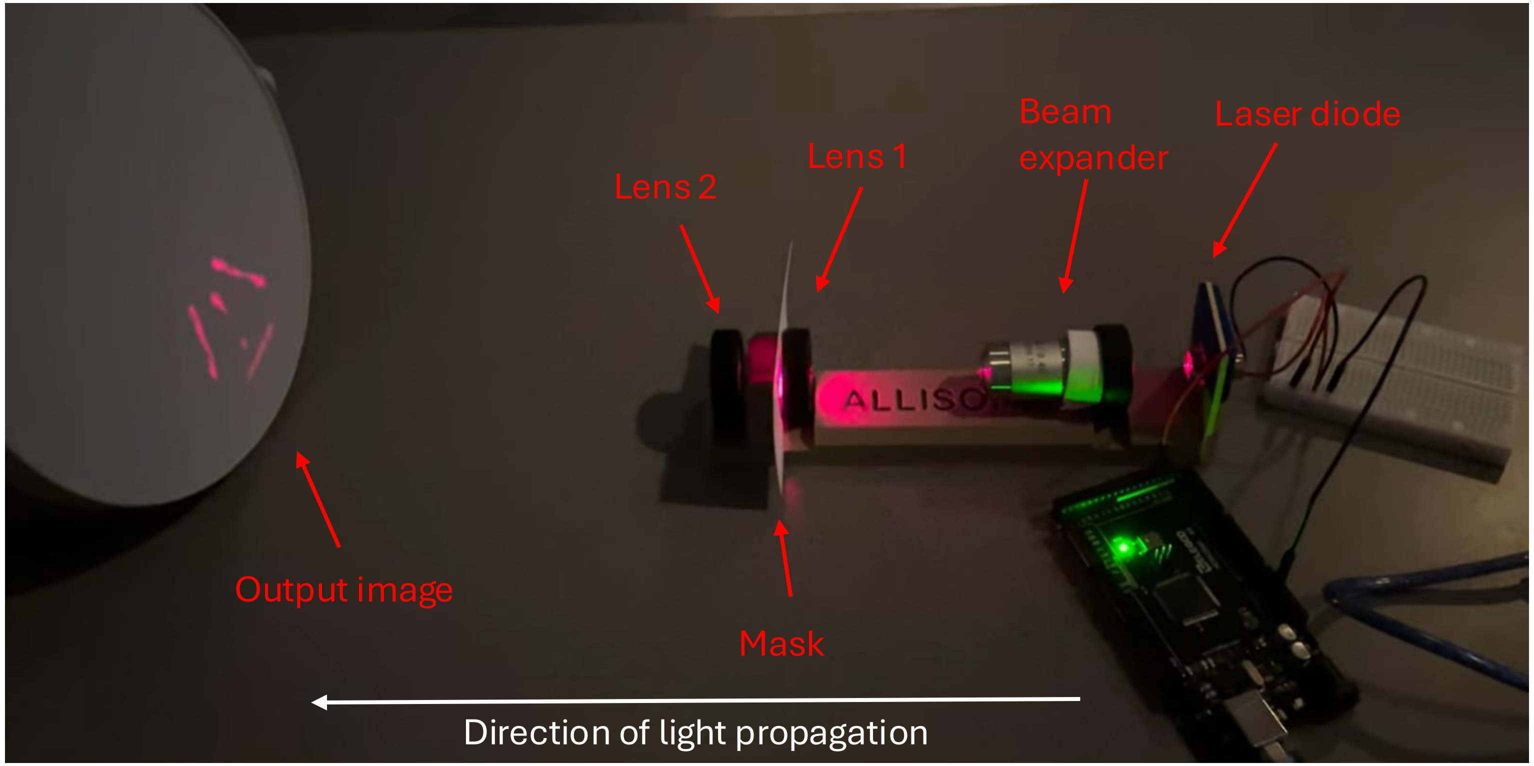
- Audio amplifier and speaker are on main internal cabin PCB.
- ESP32 is utilized as MCU.



Allison (PSE)

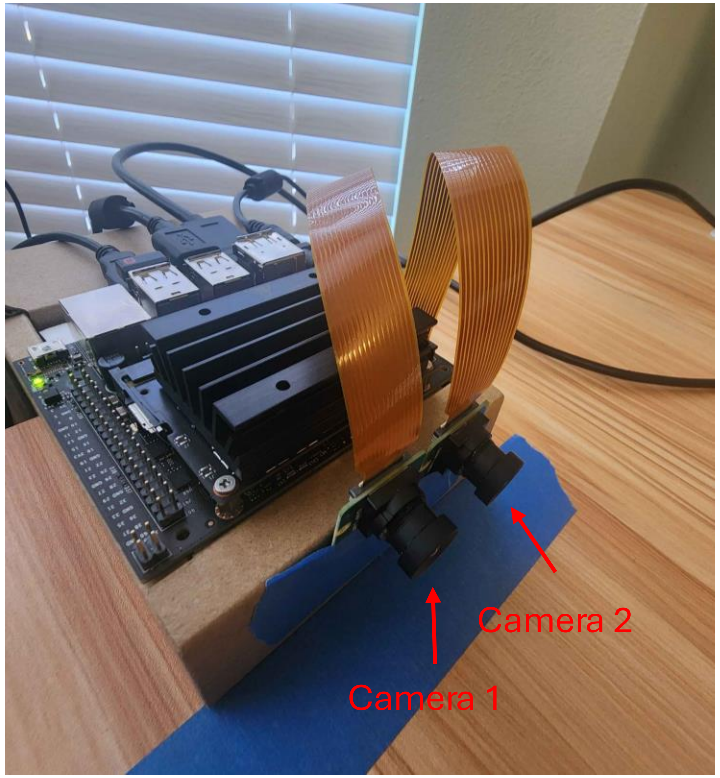
Optical Concept Testing

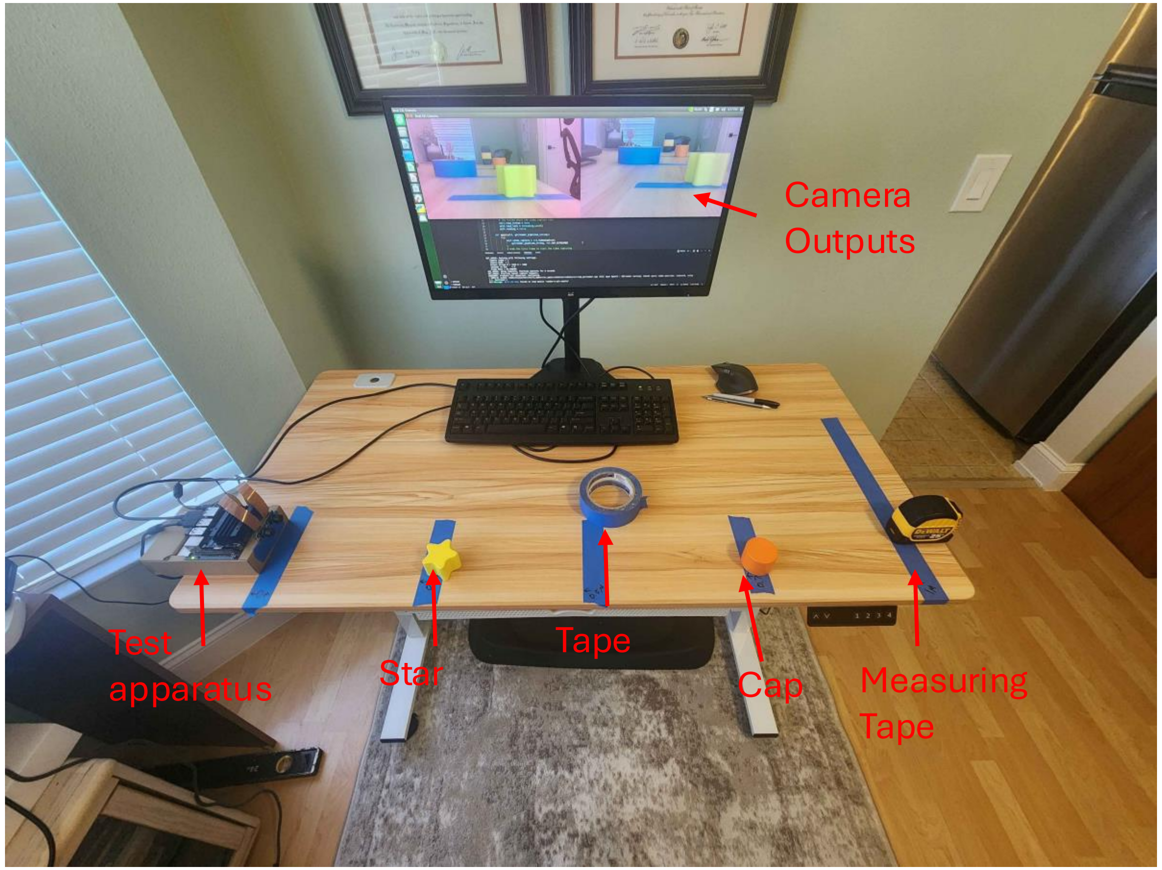
- 3D printed housing design
- Lenses, and beam expander worked as expected
- Improvements:
  - Higher intensity diode
  - Stronger objective mount
  - More rigid structure
  - Add enclosed housing
  - Incorporate combiner screen for windshield



Stereovision Concept Testing 1/3

Allison (PSE)





- Test setup, including the camera setup to be used in the final product.

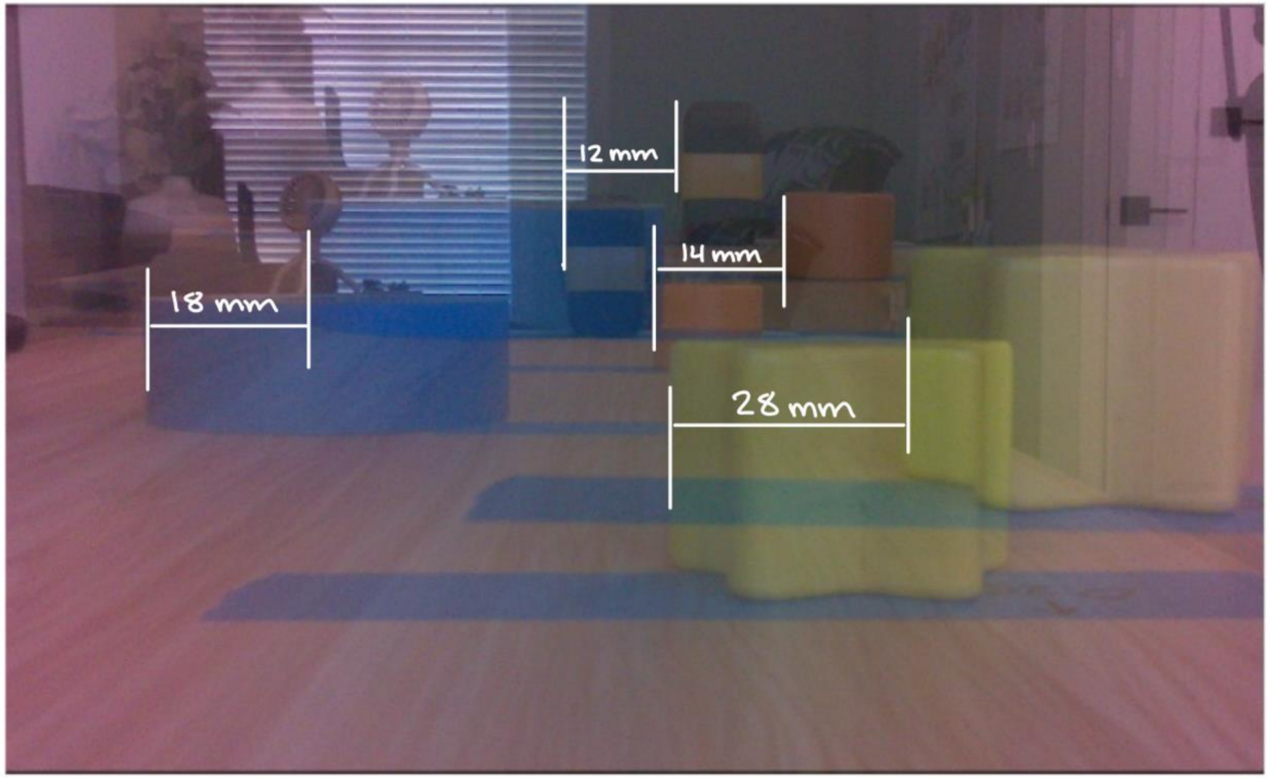
Stereovision Concept Testing 2/3

Allison (PSE)

Camera 1 POV

Camera 2 POV

Overlay of camera outputs for image processing



- Proof of concept and formulas for stereovision design to be used on the front panel for object distance detection

Stereovision Concept Testing 3/3

Allison (PSE)

$$Z = \frac{f \cdot B}{d}$$

Z : depth (distance from object)
f : focal length of camera
B : distance between cameras
d : disparity (displacement)

- Now to translate this test for our final equipment
- Distances obtained from the formula were proven to be close to real-life distances, with room for improvement.

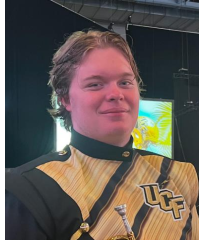
Focal length of camera: 2.8 mm
Distance between cameras: 27 mm
Scaling Factor: 138

Object 1 (star):
Edge displacement: 28 mm
Distance from viewer:
$Z = \frac{2.8 \cdot 27}{28} \cdot 138 = 372$ mm
Real distance: 250 mm

Object 2 (tape):
Edge displacement: 18 mm
Distance from viewer:
$Z = \frac{2.8 \cdot 27}{18} \cdot 138 = 579$ mm
Real distance: 500 mm

Object 3 (cap):
Edge displacement: 14 mm
Distance from viewer:
$Z = \frac{2.8 \cdot 27}{14} \cdot 138 = 745$ mm
Real distance: 750 mm

Object 4 (measuring tape):
Edge displacement: 12 mm
Distance from viewer:
$Z = \frac{2.8 \cdot 27}{12} \cdot 138 = 870$ mm
Real distance: 1000 mm

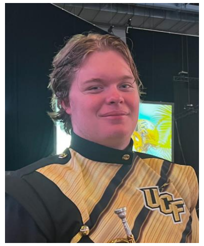


Patrik (CpE)

Software Testing – Wireless Connections

- Three devices connected wirelessly
- One host, two clients
- Clients send data wirelessly
- Host outputs data to terminal

Additional Testing

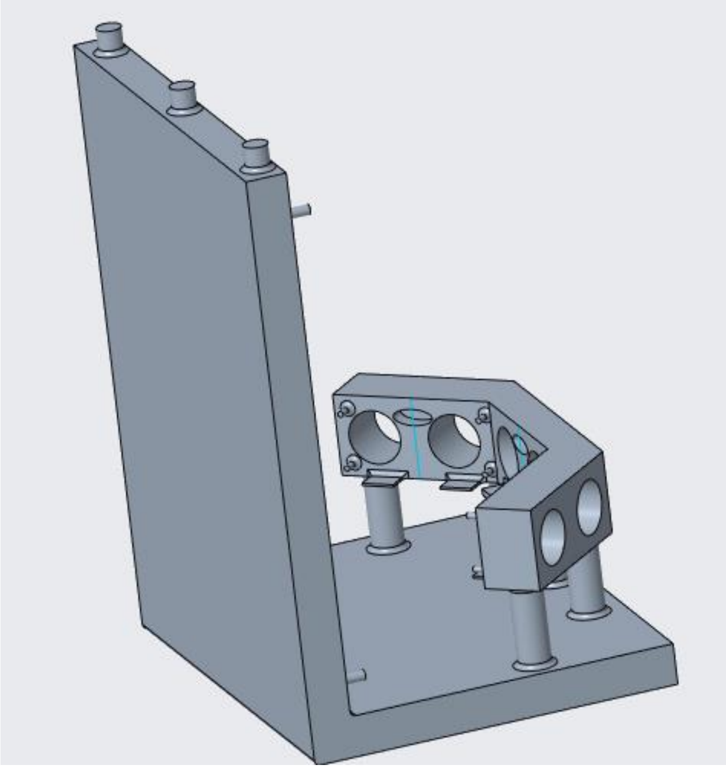


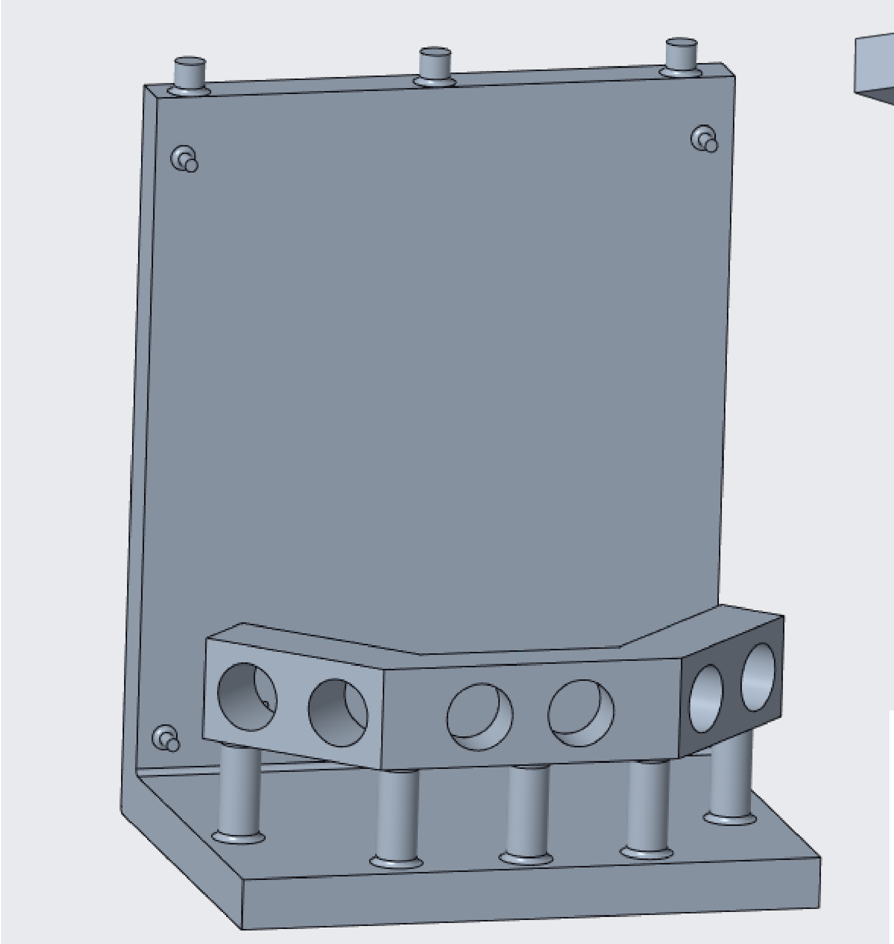
Patrik (CpE)

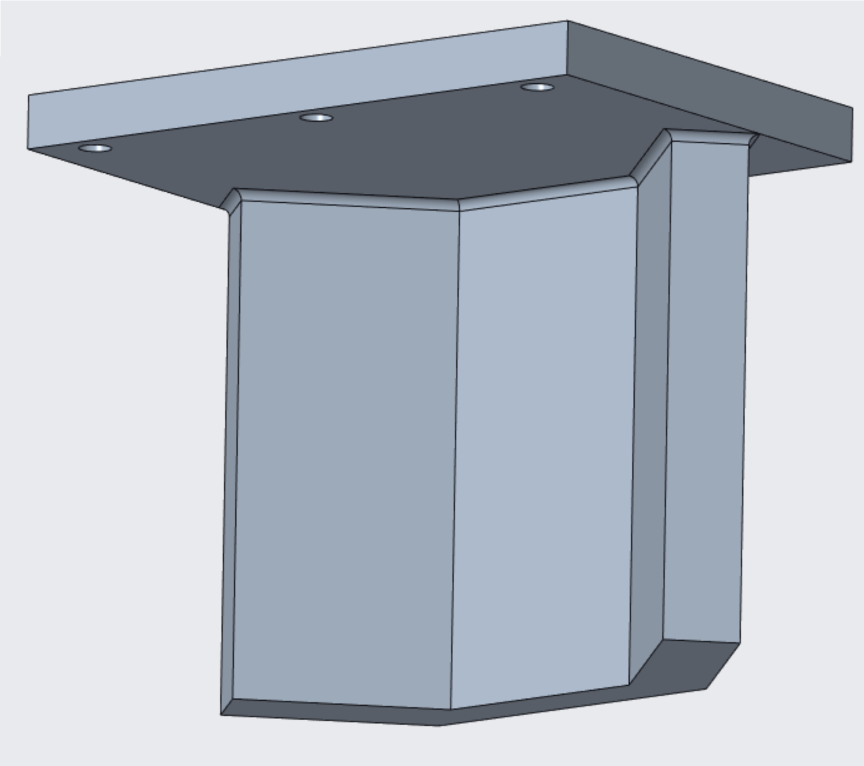
- Test integration of parts
  - Ultrasonics picking up data and send alerts wirelessly
- Integrate Jetson Nano
  - Lane and obstacle detection sending proper alerts
- Final testing
  - Testing the system on a vehicle

3D Modeling- Quarter Panels

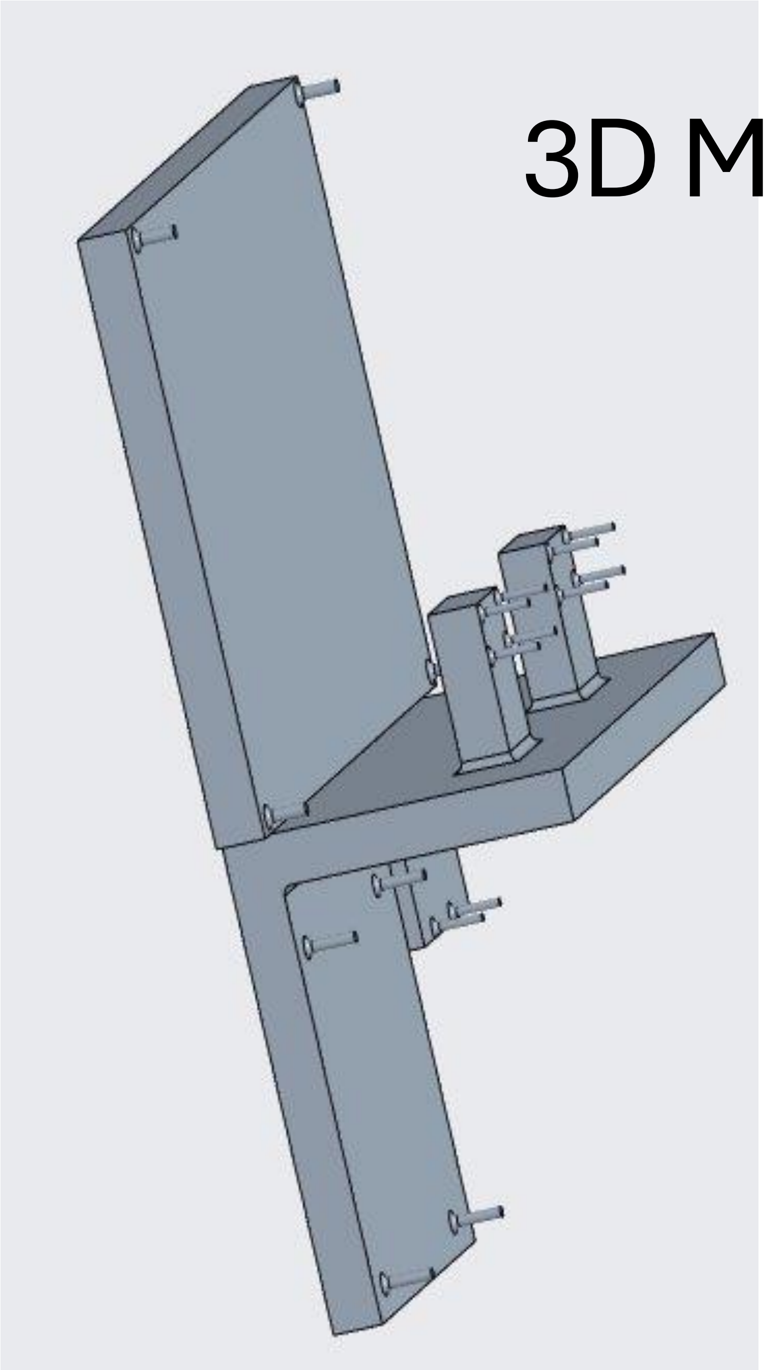
Allison (PSE)

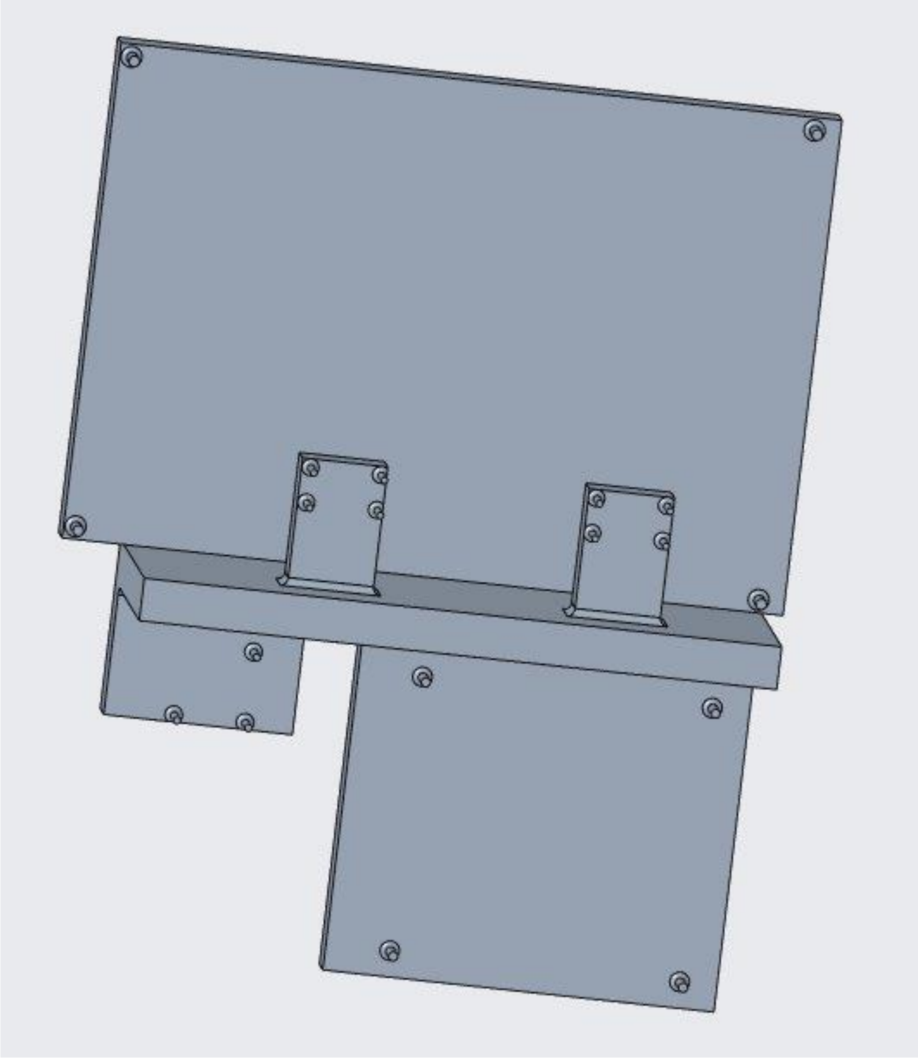






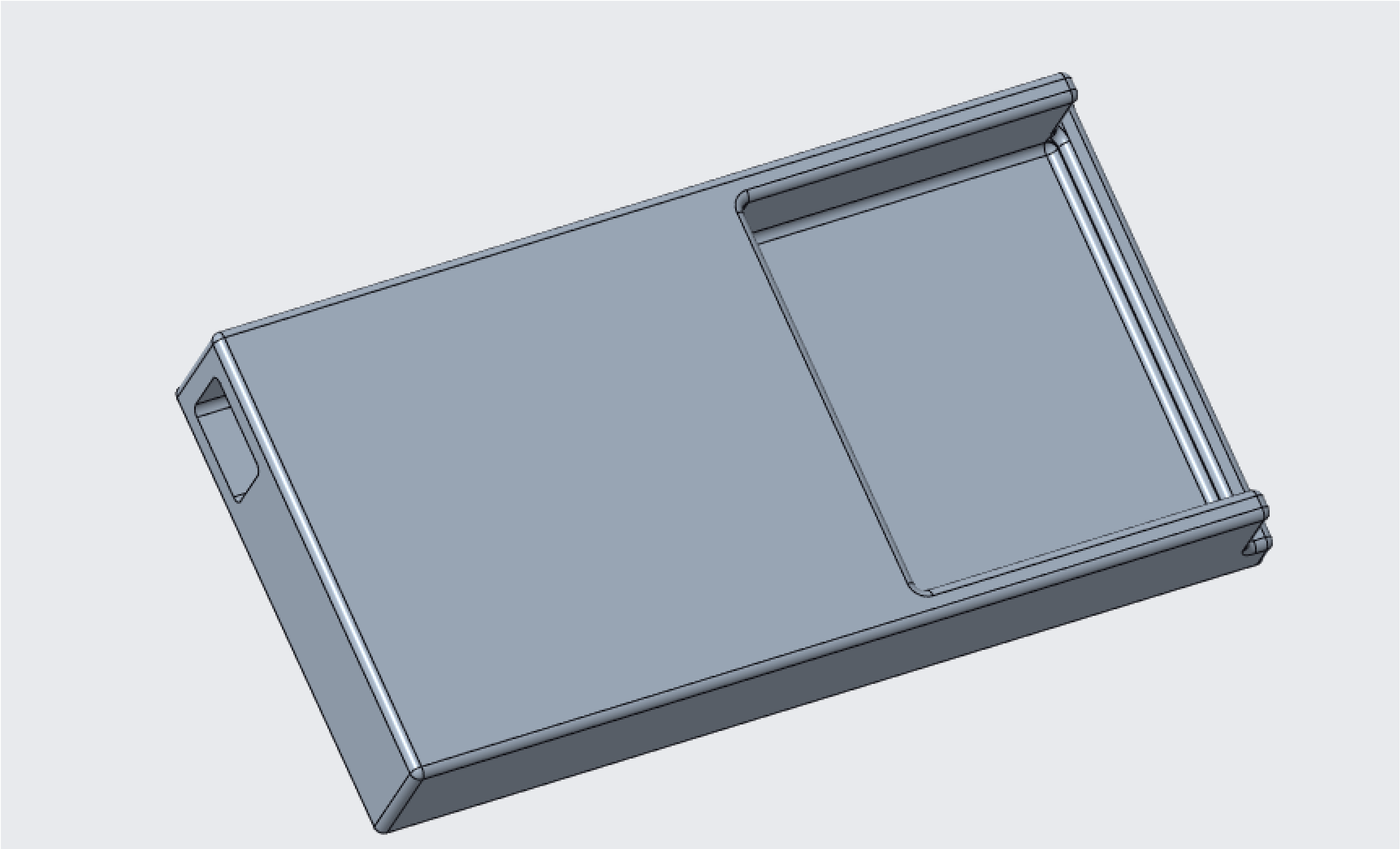
3D Modeling – Front Bumper





Allison (PSE)

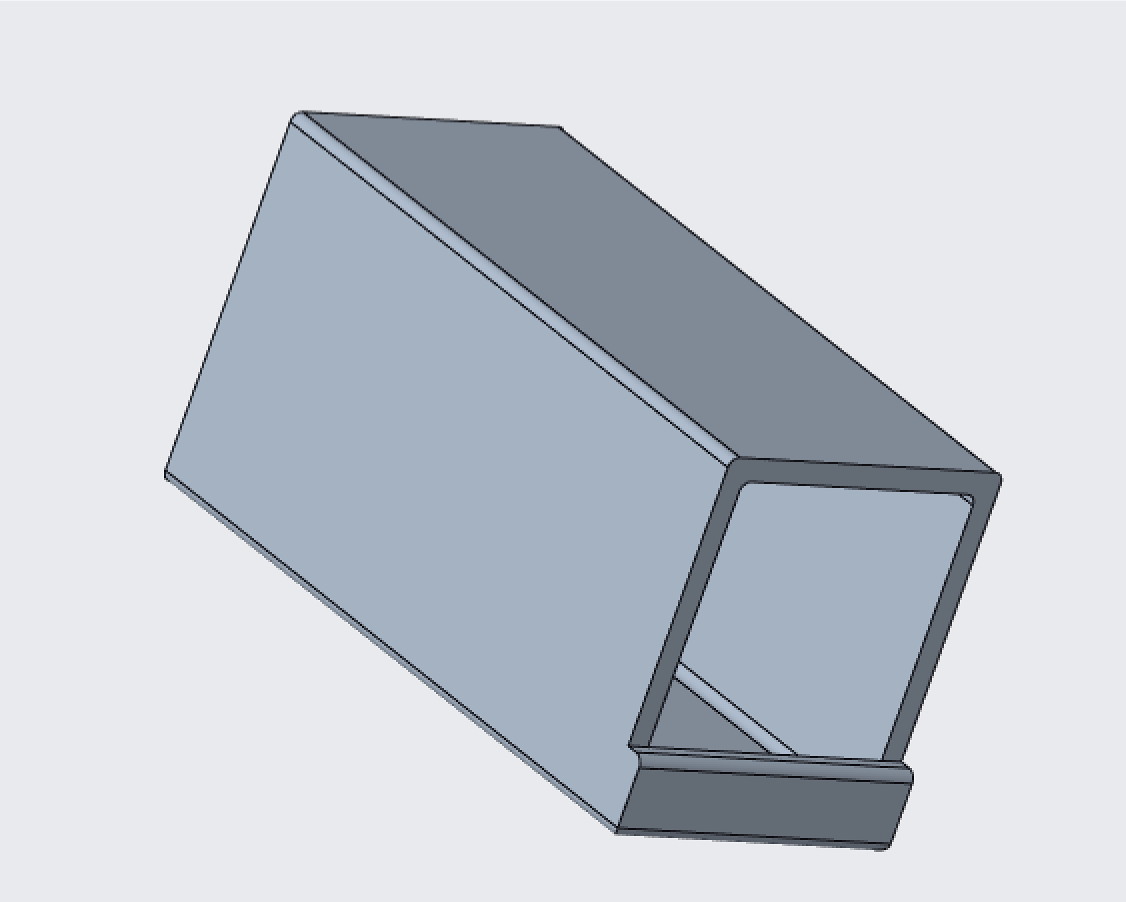
3D Modeling – Interior PCB Housing

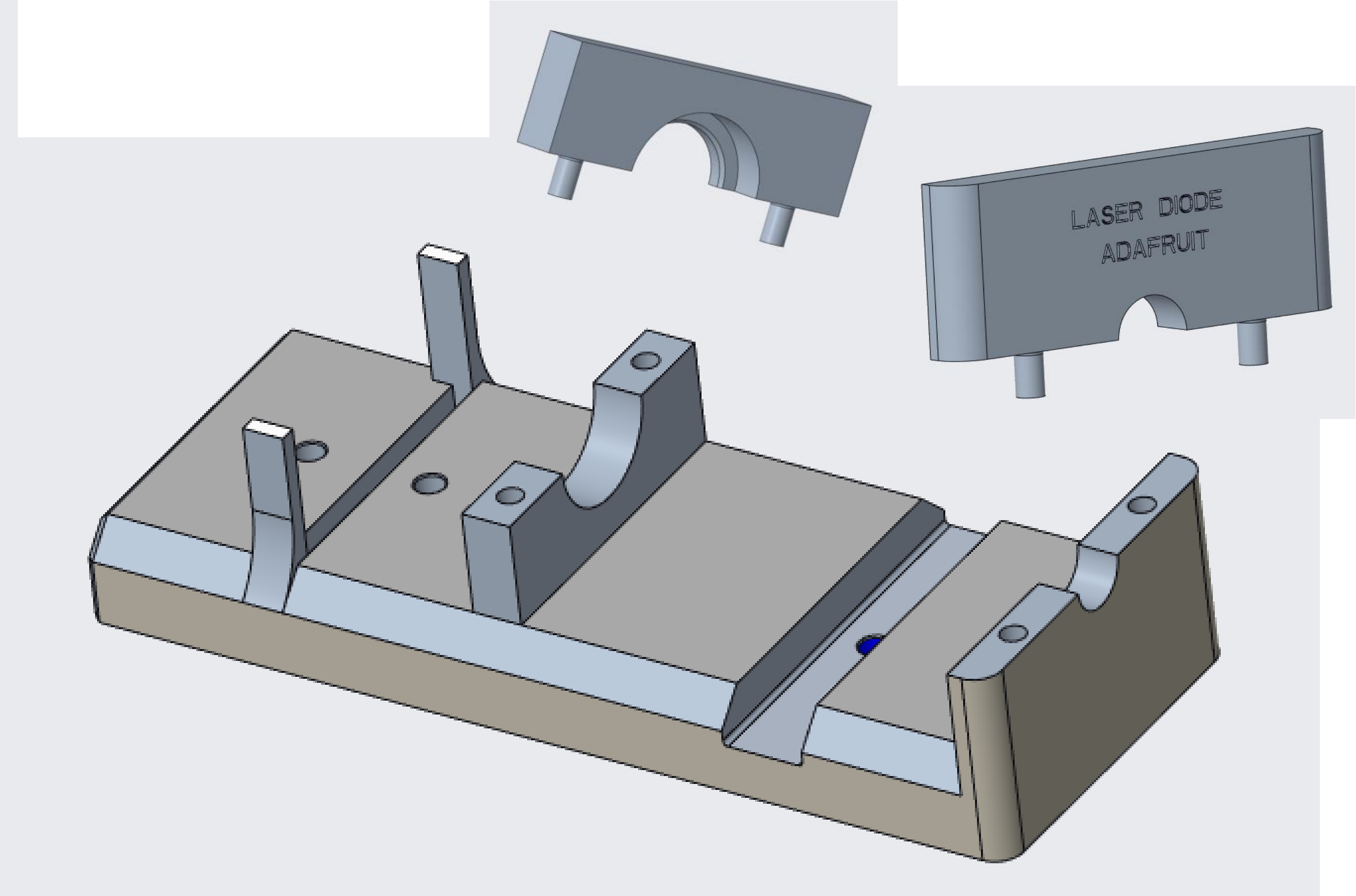


Allison (PSE)

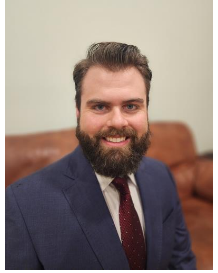
3D Modeling – Head Up Display

Allison (PSE)





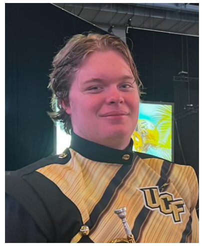
Difficulties, problems &proposed solutions



Jonathan (CpE)

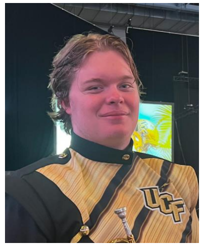
- Selecting an accessible technology for our lab facilities and personal skill levels
  - Problems
    - Radar in GHz range is difficult and expensive to design for. Initial move to ultrasonic found DSP can be power hungry and provide underwhelming short range on battery supply for our use case
    - Real time image processing on originally proposed raspberry pi would only supple .5 FPS, severely underperforming
  - Solutions
    - Move to TOF lidar with a comparable FOV communicates in I2C and DSP is handled by unit simplifying incorporation into product.
    - Use a Jetson Nano with tensor acceleration

Problems and Solutions (cont'd)



Patrik (CpE)

Problem	Solution
LiDAR sensors were lacking in range and had issues when dealing with sunlight	Switched to primarily Ultrasonic sensors to deal with excess sunlight problems
Ultrasonics would struggle to properly set up when blocking setup statements separately	Created a for loop to deal with the sensing of them individual, rather than all at the same time.
Proper positioning of our sensors for our system deemed challenging to set up	3D housings allowed for proper positioning of our sensors for maximum FOV
Not enough power was getting to the laser diode to activate when an object is detected	Rewired internal to allow adequate power for laser diode by having source power dictate voltage



Patrik (CpE)

Successes and Performance Evaluation

- System was successfully implemented as intended
- ESP-NOW proved to be as effective as planned
- Using higher intensity laser diode gave us a desired effect of more visible output
- Ultrasonic sensors deemed to be more effective than LiDAR when redesigning

Budget and BOM

Allison (PSE)

Part	Quantity	Budget	BOM
Camera	2	70	100
MCU + WiFi	6	120	30
Jetson Nano	1	55	200
GPS Module	1	10	20
Head Up Display	1	200	500
Speaker	1	5	5
PCB Boards	6	195	400
Total		655	1255

Work Distribution

Allison (PSE)

- Optical Engineering
  - Allison O
    - Head Up Display design and implementation
    - Stereovision design
    - Front Imaging System lens selection
- Electrical Engineering
  - Michael
    - Internal PCB and warning system design
    - Front PCB power regulation
  - Sebastien
    - Blind Spot PCB design
    - Front PCB TOF and Jetson Nano interfacing
- Computer Engineering
  - Jonathan Joslin
    - Jetson Nano image processing
    - Audio alert interfacing
    - TOF sensor interfacing
    - Team Lead / Project Management
  - Patrik Regan
    - Wireless communication protocols and programming
    - Head Up Display signal programming
    - Alert signal processing

Questions?