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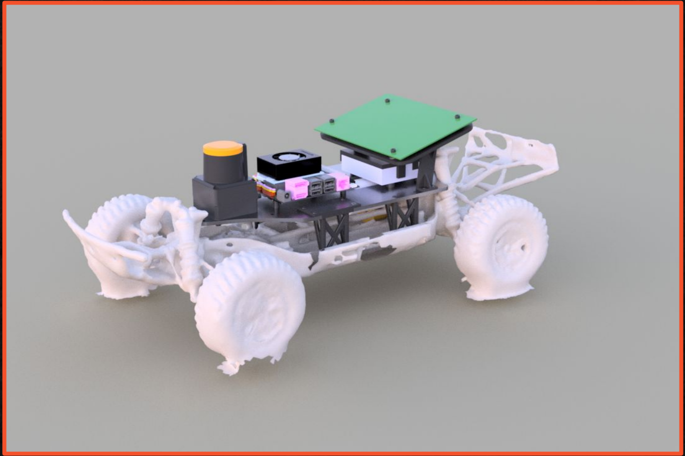


Small-Scale Autonomous Racing Vehicles

- Group 32 -

Critical Design and Review (CDR) Documentation

OUR TEAM

Israel Charles
Computer Engineer

Casey Jack
Electrical Engineer

Owen Burns
Computer Science

Asa Daboh
Computer Engineer

Tevin Mukudi
Mechanical Engineer

Background

- Autonomous navigation is advancing quickly, with small-scale vehicles serving as a critical testing platform.
- Research laboratories need robust, compact vehicles to research and test innovative autonomous driving technologies.
- The project blends computer vision, real-time decision-making, and control systems, requiring high precision and continuous innovation.
- The vehicle provides a controlled environment that simulates real-world challenges and advances scalable solutions.

Motivation

Our team has a passion for robotics, automation, and intelligent systems. We are motivated by several factors:

- Cutting-edge challenge that pushes the boundaries of current technical skills in autonomous navigation.
- Collaboration across various engineering disciplines fosters professional growth and innovative thinking.
- Mirrors real-world applications by integrating advanced technologies critical for future autonomous systems.
- Commitment to open-source sharing and thorough documentation aims to bridge knowledge gaps in autonomous vehicle technology.
- Prepares us for emerging trends in intelligent vehicle systems.

Goals

- Design and develop two small-scale autonomous vehicles capable of high-speed navigation on an indoor racetrack.
- Optimize the mechanical design of one vehicle to explore challenges related to control and performance, enabling comparative analysis.
- Refine both the hardware and algorithm to achieve competitive performance at an international level, with the goal of competing in elite autonomous racing events such as the RoboRacer competition.

Objectives

Software

Ensure cars are capable of perceiving, planning, and controlling their movement:

- Set up SLAM to map and localize vehicles in real time
- Compute optimal race line and avoid obstacles while pursuing it
- [Stretch goal] Use Model Predictive Control for physically grounded vehicle control
- [Stretch goal] Use State lattice planner to optimize race line following

Mechanical

Enhance physical performance characteristics of one of the vehicle:

- Optimize the suspension system to achieve a roll-angle reduction effectiveness greater than 1.25
- Optimize the weight distribution to allow the vehicle to have good handling characteristics
- Upgrade the motor and optimize weight to achieve a > 5% decrease in 0-14.5 mph acceleration times and a power to weight ratio of over 126.579 W/kg

Electrical

Ensure reliable power distribution and monitoring to the entire system:

- Design 2 Power Management Systems
- Develop and build a system status indicator board
- [Stretch goal] Write instruction manual for both systems

Engineering Specifications

Item	Parameter	Specification
Vehicle weight and weight distribution	Static weight distribution (front to rear)	50/50
Race line computation	Latency	< 10s
Race line following algorithm	Replanning time	< 0.5s
System Status Indicator module	Number of statistics on display	5
Power distribution board	Efficiency	> 60%
Odometry estimations	Accuracy	± 15cm
Battery	Runtime	> 10 minutes

To be demonstrated

Engineering Specifications

Item	Parameter	Specification
Vehicle Performance	0 - 14.5 mph time	> 5% decrease
Vehicle Suspension	Roll-angle reduction mechanism effectiveness	> 1.25
Vehicle weight and weight distribution	Power-to-weight ratio	> 126.579 W/kg
Battery	Capacity	> 5000mAh
Power distribution board PCB	Number of layers	2
Model Predictive Control Set-point tracking	Overshoot	< 20%
Model Predictive Control Set-point tracking	Rise-time	< 1 second

To be demonstrated

Comparison & Selection of Hardware

Vehicle Chassis

Model	Price (USD)	Scale	Size (L x W x H)	Weight	Manufacturer
HSP 94996	$460	1:8	20.5" x 15" x 9.8"	~3.5 kg	Hspacing Co., LTD
HSP 94118 PRO	$300	1:10	18.7" x 9.9" x 6.5"	~3 kg	Hspacing Co., LTD
Kyosho Inferno Buggy	$600	1:8	19.7" x 12.2" x 7.9"	~3.8 kg	Kyosho
Kyosho Fazer Mk2 FZ02L	$300	1:10	14.6" x 7.9" x 5.1"	~2.5 kg	Kyosho
Tamiya TT-02	$150	1:10	16.7" x 7.3" x 5.8"	~1.5 kg	Tamiya
Traxxas Slash 4x4 Ultimate	$550	1:10	22.4" x 11.7" x 7.6"	~2.9 kg	Traxxas
LaTrax Rally	$140	1:18	10" x 4.7" x 3.9"	~0.5 kg	Traxxas (LaTrax)
Traxxas X-Maxx	$1,000	1:6	30.7" x 21.3" x 13.8"	~8.6 kg	Traxxas

Computing Unit

Feature	UP Board	Raspberry Pi 4	Raspberry Pi 5	LattePanda	Intel NUC	NVIDIA Jetson Nano	NVIDIA Jetson Xavier NX	NVIDIA Jetson Orin NX
Price (USD)	~$150 - $200	~$35 - $75	~$75 - $100	~$200 - $400	~$300 – $1000+	~$100	~$400	~$600 – $800
CPU	Intel Atom x5-Z8350 quad-core (1.44–1.92GHz), x86	Quad-core Cortex-A72 @1.5GHz, ARM	Quad-core Cortex-A76 @2.4GHz, ARM	Intel Celeron N4100 quad-core (1.1–2.4GHz), x86	Intel Core i3/i5/i7 (varies), x86	Quad-core ARM Cortex-A57 @1.43GHz	6-core NVIDIA Carmel ARM v8.2	8-core ARM Cortex-A78AE
GPU	Integrated Intel HD Graphics	Broadcom VideoCore VI	Upgraded VideoCore-based GPU	Intel UHD Graphics (e.g., 600 series)	Intel UHD/Iris or optional discrete	128-core Maxwell GPU	384-core Volta GPU w/ 48 Tensor Cores	1024-core Ampere GPU w/ 32 Tensor Cores
Memory	4GB LPDDR4	2, 4, or 8GB LPDDR4	4 or 8GB LPDDR4X	4 or 8GB LPDDR4	4 – 64GB	4GB LPDDR4	8GB LPDDR4x	8GB or 16GB LPDDR5
Storage	64GB eMMC (expandable via microSD)	microSD card slot	microSD card slot	64GB eMMC (expandable via microSD/SSD)	2.5″ drive and/or M.2 SSD support	microSD slot	NVMe slot, (microSD slot in devkits)	NVMe slot, (microSD slot in devkits)
Specialized Hardware	x86 platform w/ GPIO for sensors	40-pin GPIO; CSI/DSI for cameras/displays	Enhanced GPIO & camera interfaces	Integrated Arduino co-processor; Windows 10 compatibility	x86 architecture for full OS support	AI acceleration (CUDA, TensorRT)	Advanced AI acceleration for vision/ML	Next-gen AI/deep learning optimization

Motor Controller

Feature	Motor Driver	ESC	VESC
Motor Type	Brushed DC, Stepper	Brushless DC (BLDC)	Brushless DC (BLDC)
Control Type	PWM, UART, SPI, I2C	PWM (servo signal)	PWM, UART, CAN, I2C
Telemetry	No	Limited	Yes (current, speed, temp, etc.)
Configurable	Limited	No (fixed settings)	Yes (via VESC Tool)
Regenerative Braking	No	Some models	Yes
Ideal For	Small robots, Arduino projects	RC cars, drones	Electric vehicles, robotics

Model	Price (USD)	Voltage Range	Continuous / Peak Current	Telemetry Sensors	Communication Interfaces
Flipsky FSESC 6.7	~$150–170	Up to ~60V (≈10S LiPo)	~70A / ~300A	Voltage, Current, Temperature	PWM, UART, CAN
Trampa VESC 6 MKVI	~$300–350	22–44V (6S–12S LiPo)	~80A / ~150A	Voltage, Current, Temperature, IMU	PWM, UART, CAN
MakerX Go-FOC HI200	~$250–300	3S–16S (up to ~75V)	~200A continuous (high peak)	Voltage, Current, Temperature	PWM, UART, CAN
Stormcore 60D	~$400–450	~36–75V (approx. 10S–18S)	~60A per channel (dual motor setup)	Voltage, Current, Temperature	PWM, UART, CAN
Makerbase M200 VESC	~$120–150	3S–12S (up to ~36V)	~50A / ~100A	Voltage, Current	PWM, UART

LiDAR

Sensor	Price (USD)	Size (in)	Weight (lbs)	Field of View	Range (m)	Refresh Rate (Hz)
Ouster OS0-32	~$1,850	~2.6 x 2.6 x 2.4	~0.9	360° horizontal / 90° vertical	~35	20
Velodyne Puck Lite	~$5,150	~2.8 x 3.5	~1.3	360° horizontal / 30° vertical	100	20
Slamtec RPLIDAR S2	~$500	~6 in (diameter)	~1.1	360° (2D scan)	30	20
Hokuyo UST-10LX	~$1,200	~2.0 x 2.0 x 2.8	~0.29	270° (2D scan)	10	40
Livox MID-360	~$749	~2.6 x 2.6 x 2.4	~0.58	360° horizontal / 59° vertical	40	20

Stereo/Depth Camera

Feature	Price	Size (in)	Weight (lbs)	FoV (H×V)	Range	Refresh Rate	Resolution	Additional Hardware
Intel RealSense D455	~$200	3.9 x 1.5 x 0.6	0.23	86°×57°	0.4–6 m	Up to 90 Hz	1280×720	IMU, Global Shutter
Intel RealSense D435i	~$130	3.5 x 1.4 x 0.6	0.18	85°×58°	0.2–10 m	Up to 90 Hz	1280×720	IMU, Global Shutter
ZED 2i	~$500	6.3 x 2.0 x 1.2	0.44	120°×70°	Up to 20 m	Up to 120 Hz	1280×720	IMU, AI accelerator
Intel RealSense L515	~$350	2.6 x 1.2 x 1.0	0.15	70°×55°	0.2–9 m	Up to 30 Hz	1024×768	LiDAR, RGB
Azure Kinect DK	~$500	4.9 x 2.7 x 1.3	0.88	120°×120°	0.5–5.46 m	30 Hz	1024×1024	7-mic, IMU

Vehicle Drivetrain Motor

Motor	Surpass Hobby 3650, 4350Kv	KingVal 3670, 2650Kv	KingVal 3650, 4300Kv
Power Rating (Watts, W)	900	1600	900
Operating Voltage (Volts, V)	11.1	11.1	11.1
Continuous Current (Amps, A)	60	86	60
Cost (Dollars, $)	71.89	37.68	53.68

Vehicle Drivetrain Belt

Belt Type	V-Belt	Flat Belt	Timing Belt
Short Distance Power Transmission	Good	Poor	Good
Slippage	Low (Good)	High (Bad)	None (Very Good)
Performance at High Speeds	Good	Good	Good
Mechanical Efficiency	Good	Poor	Good

3D Printing Material

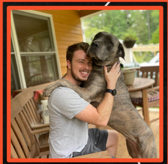
Materials	PLA	ABS	PETG	Polypropylene	ASA
Density (g/cm3)	1.24	1.04	1.27	0.9	1.05
Ultimate Tensile Strength (MPa)	65	40	53	40	40
Coefficient of Thermal Expansion (µm/m°C)	68	90	60	150	98
Average Cost/kg ($/kg)	25	25	40	90	39

Suspension System Optimization Method

Technology/Method	Anti-roll bars	CG and Raise roll center positioning	Suspension Spring Rates
Variability / Ease of Adjustment	Medium	High	Low
Ease of Integration	High	Medium	High
Average Cost (Dollars, $)	16.5	0	17

PMS Microcontroller

Microcontroller	Wireless Support	Multi-language support	Clock Rate	Price	Learning Overhead
MSP430FR6989	X	X	16 MHz	$10.05	Low
Raspberry Pi Zero W	√	√	1 GHz	$15.00	Medium
Arduino UNO R3	X	X	16MHz	$27.60	Low
Arduino RP2040 Connect	√	√	133 MHz	$29.40	Medium
ESP32	√	√	240 MHz	$10.00	Low



PMS 12V Regulator

Regulator	Input Voltage Range	Current Limit	Switching Type	efficiency	Protections	Price
LT3120	2.5V-26V	<9A	4-Switch (Buck-Boost)	High (>95%)	UVLO, OVP, Thermal Shutdown	Medium
LM2585	8V-40V	<3A	2-Switch (Boost)	Medium (85%)	Basic OVP	Low
LT3958	5V-58V	<4A	4-Switch (Buck-Boost)	High (>92%)	OVP, Thermal Shutdown	High
XL6009	5V-32V	<2.5A	2-Switch (Buck-Boost)	Medium (85%)	Basic OVP	Low

PMS Current Monitor

Sensor	Input Voltage Range	Current Limit	Package	Voltage Accuracy	Resolution	Price
INA219BIDR	0V-26V	3.2A (programmable)	SOIC-8	±1%	High (16-bit ADC)	Low
LTC2945	0V-80V	Wide	MSOP-16	±0.4%	Medium (12-bit ADC)	High
MAX40080	0V-36V	50mV shunt voltage	WLP-10	±0.1%	High (12-bit ADC w/ high speed)	Moderate
INA226	0V-36V	81.92mV shunt voltage	MSOP-10	±0.1%	High (16-bit ADC)	Moderate

SIS Microcontroller

MCU	Clock Speed	Flash Memory	ADC Channels	Operating Voltage	RAM	Price
MSP430FR2676	Up to 16 MHz	32 KB	16-bit ADC	1.8V to 3.6V	4 KB	$2 to $5
STM32	Up to 480 MHz (varies by model)	Up to 2 MB (varies by model)	Up to 24 channels, 12-bit ADC	1.8V to 3.6V	128 KB to 384 KB	$1 to $20+ (varies by model)
ESP32	Up to 240 MHz	448 KB ROM	18 channels, 12-bit ADC	2.2V to 3.6V	520 KB	$4 to $10
Arduino Uno	16 MHz	32 KB	6 channels, 10-bit ADC	5V	2KB	$20 to $25

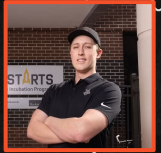
SIS 3.3V/5V Regulator

Regulator	Input Voltage Range	Output Voltage Range	Efficiency	Maximum Output Current	Switching Frequency	Size
TPS63060	2.5V – 12V	1.2V – 5.5V	Up to 93%	2.0A	2.4MHz	3.0 x 3.0mm
TPS552882	2.7V – 36V	0.8V – 22V	Up to 96%	4.0A	2.2MHz	3.0 x 2.5mm
TPS63070	2.0V – 16V	2.5V – 9V	Up to 95%	2.0A	2.4MHz	2.5 x 3.0mm

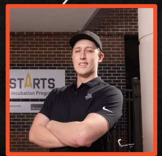
SIS Charger

Sensor	Input Voltage Range	Max Charge Current	Package	Charging Voltage	Price
TP4056	~4 V to 8 V	1.0 A	SOP-8/MSOP-8	4.2V	$0.04
MCP73831	~3.75 V to 6 V	500 mA	SOT-23-5/ 2x3 DFN	4.2V	$0.38
TP5100	5.0V–18.0V	2.0A	SOP-8	4.2V/8.4V	$0.55
CN3065	4.4V–6.0V	1.0A	SOP-8	4.2V	$1.23

Flight Controller Comparison



	# of IMUs	Microcontroller	PWM out	USB Port	Price	Integrated ESC
HolyBro PixHawk 6c	2	32 Bit Arm® Cortex®-M7, 480MHz, 2MB memory, 1MB SRAM	16	Yes	$212	No
ModalAI Flight Core v1	3	216MHz, 32-bit ARM M7 STM32F765II	8	No	$200	No
Sky-Drones AIRLink	3	STM32F7, ARM Cortex M7 with FPU, 216 MHz, 2MB Flash, 512 kB RAM	16	Yes	$2,790	No
Vesc 6 MkVI	1	N/A	N/A	Yes	$285	Yes



Software Architecture [Technology]

	Compatible with robot hardware out of the box	Compatible with simulation software out of the box	Work required	Difficulty to debug	Customizability
ROS	√	√	Moderate	Low	Universal
MAVLink	~	~	Low	High	None
Python	~	X	Extreme	Moderate	Universal
Python + Message Broker (Redis, RabbitMQ, etc.)	~	X	High	High	Universal

Comparison & Selection of Software

Motor Controller [Technology]

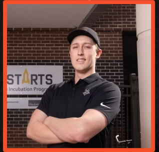
	Native support for vehicle systems	ROS Integration
Microcontroller	No	No
Flight controller	Yes	Yes

ROS Version Comparison

	Ubuntu Version	Compatible with Gmapping	Compatible with Slam Toolbox	Compatible with NAV2	Degree of forum support
ROS1 Melodic	18	√	√	X	High
ROS1 Noetic	20	√	√	X	Low
ROS2 Foxy	20-22	~	√	√	High
ROS2 Jazzy	20-22	~	√	√	Low

Mapping [Technology]

	Enables raceline optimization	Works indoors	Ease of Implementation
SLAM	√	√	Moderate
GPS	√	X	Easy
None	X	√	N/A



SLAM Package Comparison

	Works with live sensor data	Pose estimate stable when vehicle isn't moving	Clean loop closure	Loop closure detection	Works with Nav2
Cartographer	√	√	√	√	X
SLAM Toolbox	√	√	√	√	√
Hector	√	√	X	N/A	X
Gmapping	√	~	√	X	X

Controller [Technology]

	Requires vehicle model	Handles steering and velocity	Designed for ackermann vehicles	Difficulty to configure
PID	X	√	X	low
Stanley	X	X	√	moderate
Pure Pursuit	X	√	√	low
Model Predictive Control	√	√	√	high

Pure Pursuit Implementation Comparison

	Ease of implementation	Customizable to vehicle dimensions
Write our own	Hard	√
Python Control Systems Library	Moderate	~
ROS2 controller library	Easy	~
NAV2 Plugin	Easy	√

Planner [Technology]

	Fast online	Can compute optimal path
RRT	√	X
Clothoid Sampler	X	√
Lattice based planner	√	√

Lattice Planner Implementation Comparison

	Difficulty to implement	ROS2 compatible
Write our own	Hard	√
ROS Navigation	Moderate	X
Nav2 Plugin	Moderate	√

Test Environment [Technology]

	Ease of setup	Speed of iteration
Simulation	Hard	High
Hardware	Moderate	Slow

Simulator Comparison

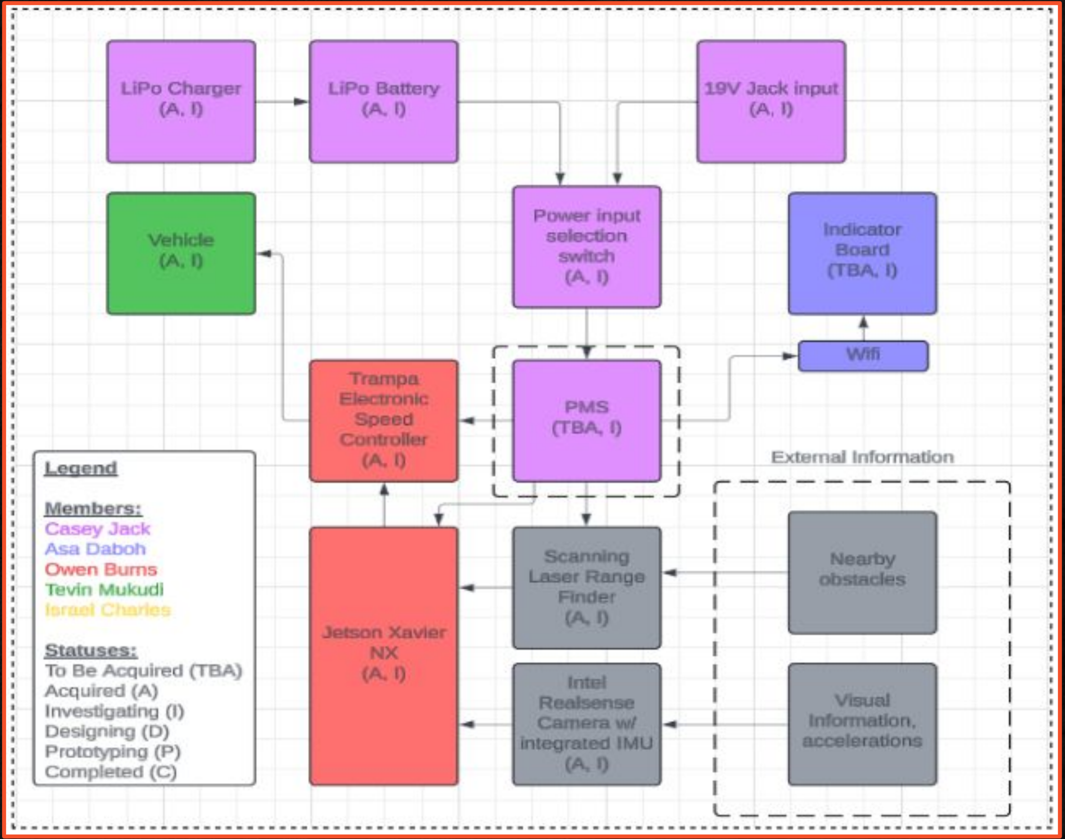
	3D Physics	1/10th scale vehicles	Mac compatible	Supports map->odom->base_link tf tree
F1Tenth simulator	X	√	X	X
F1Tenth Gym	X	√	√	X
CARLA	√	X	X	X
F1Tenth Gazebo	√	√	X	X
AutoDRIVE	√	√	√	X
Write our own	√	√	√	√

SIS Communication Protocol

	Range	Speed	Power Consumption	Ease of Integration	Use Case
ESP-NOW	200 m LOS	2 Mbps	Low	Moderate	P2P Communication
Wi-Fi (TCP/IP)	50m indoors, 100m LOS	11 Mbps	High	Easy	Reliable Data transfer, Large
Bluetooth Classic	10m indoors, 100m LOS	2.1 Mbps	Moderate	Moderate	Audio, moderate data transfer
Bluetooth Low Energy (BLE)	30m indoors, 100m LOS	1 Mbps	Very Low	Easy	Low power IoT devices

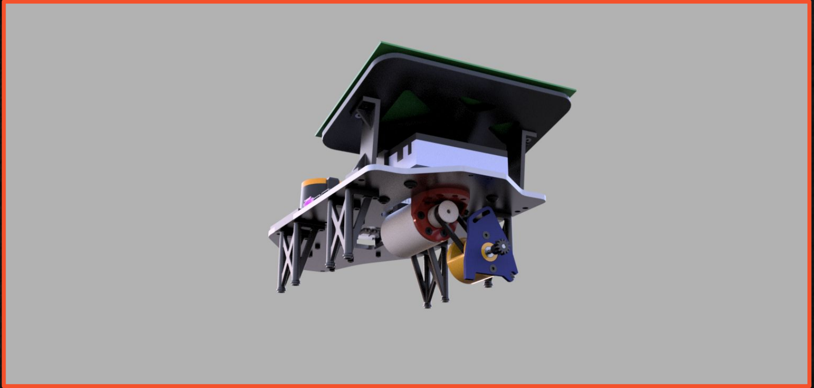
Hardware Design

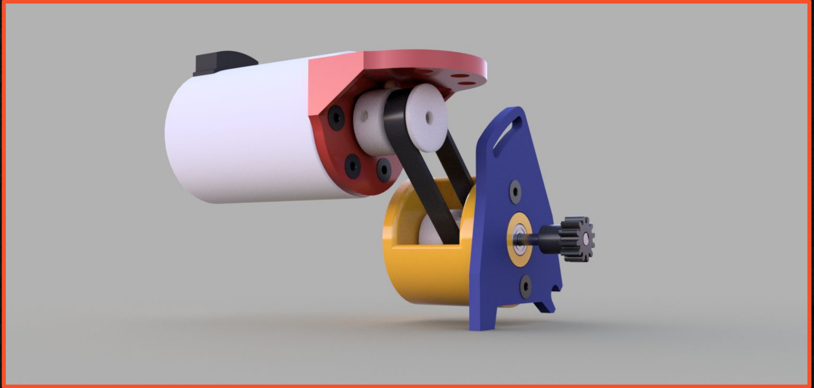
Hardware Block Diagram

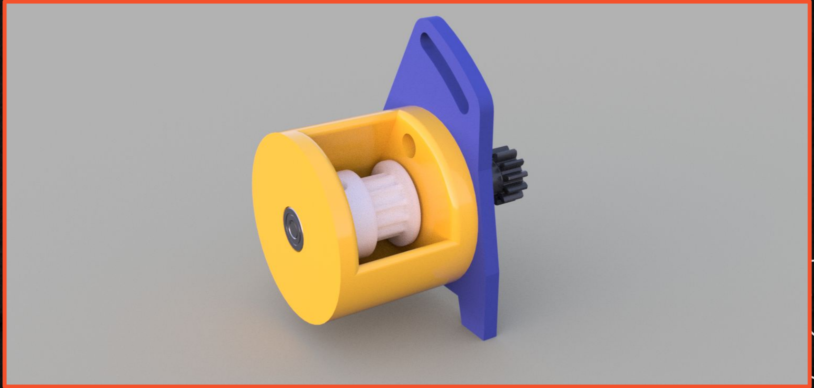


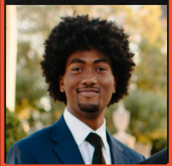
Belt Drive Design

- 900W Motor
- GT2 timing belt and gears
- 3mm motor and transfer shafts
- Bearings for transfer shaft
- Stock output gear

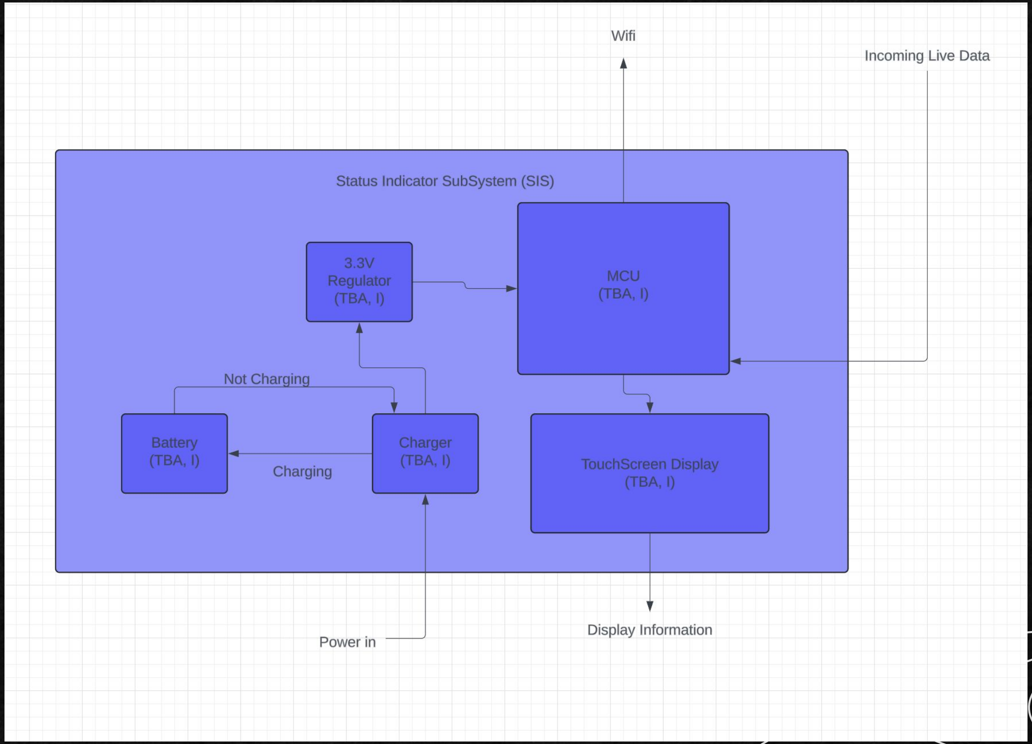


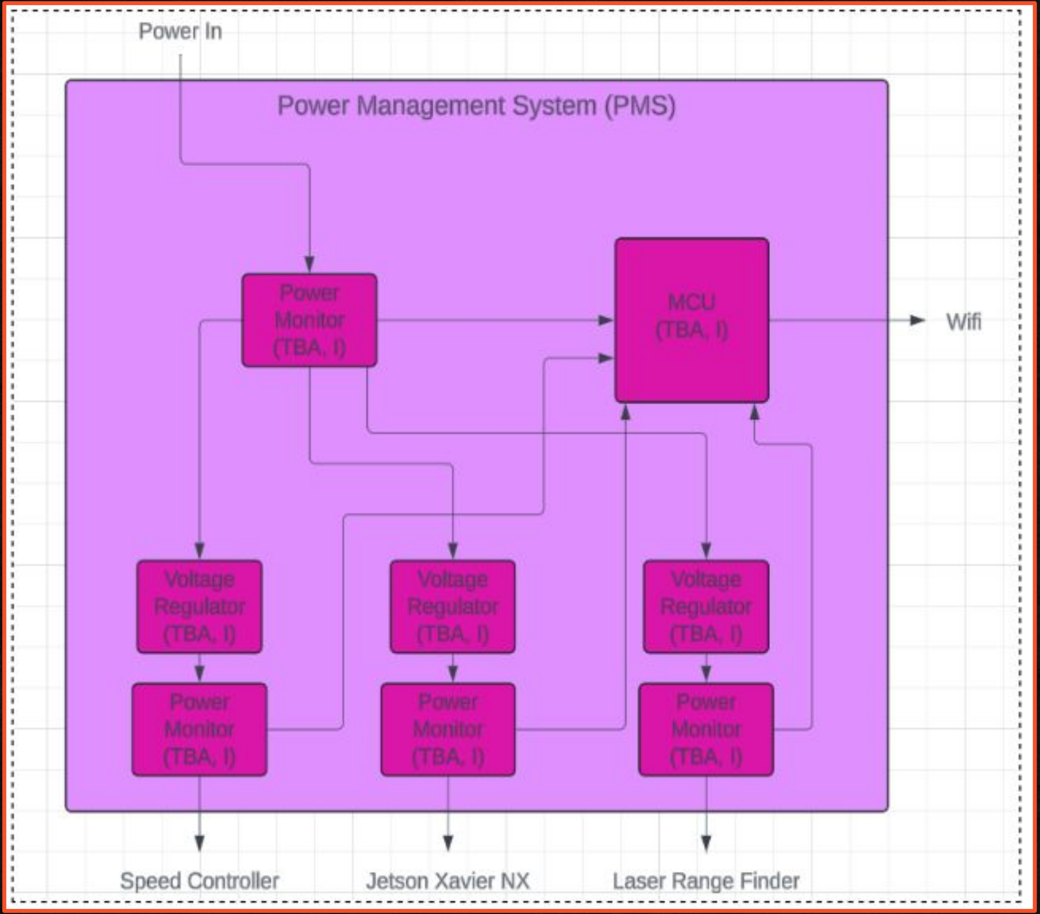


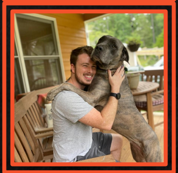




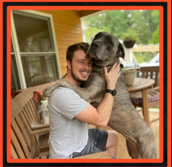
Status Indicator System (SIS) Block Diagram



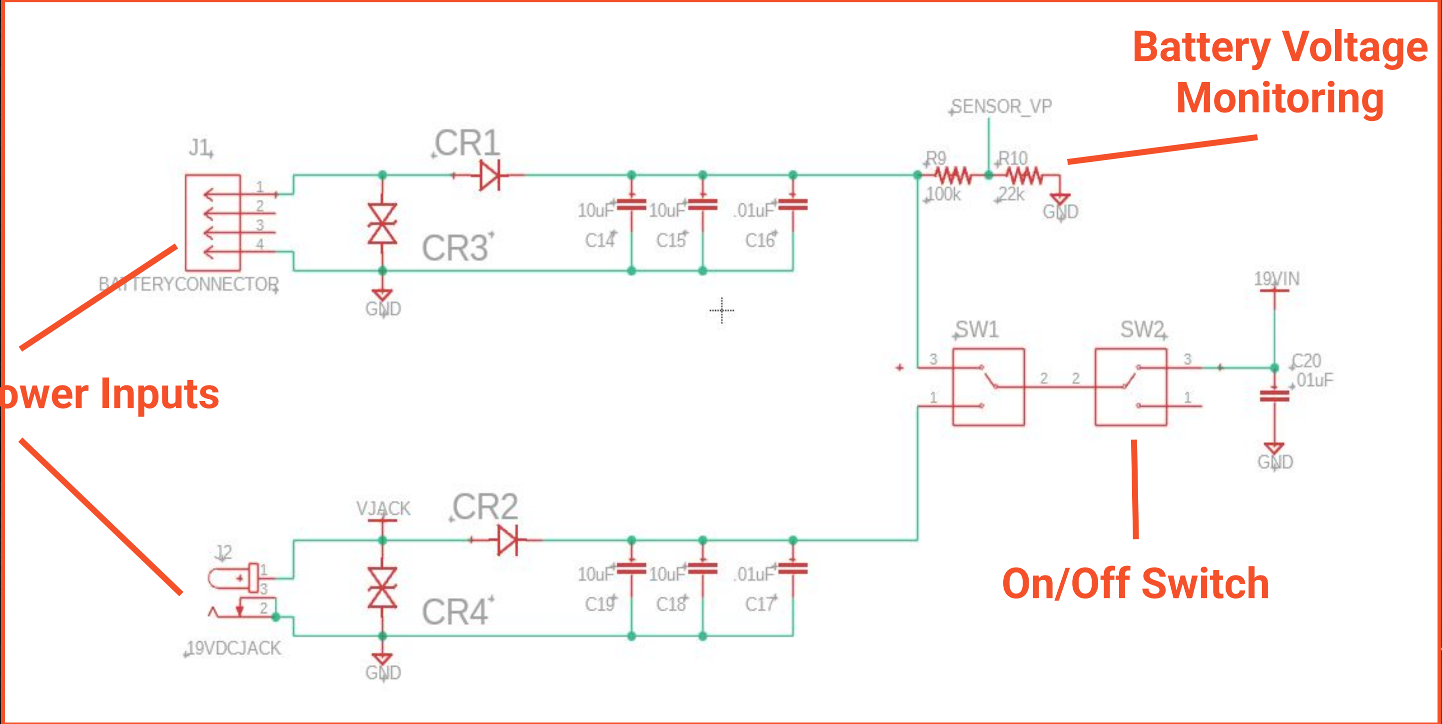




Power Management System (PMS) Block Diagram

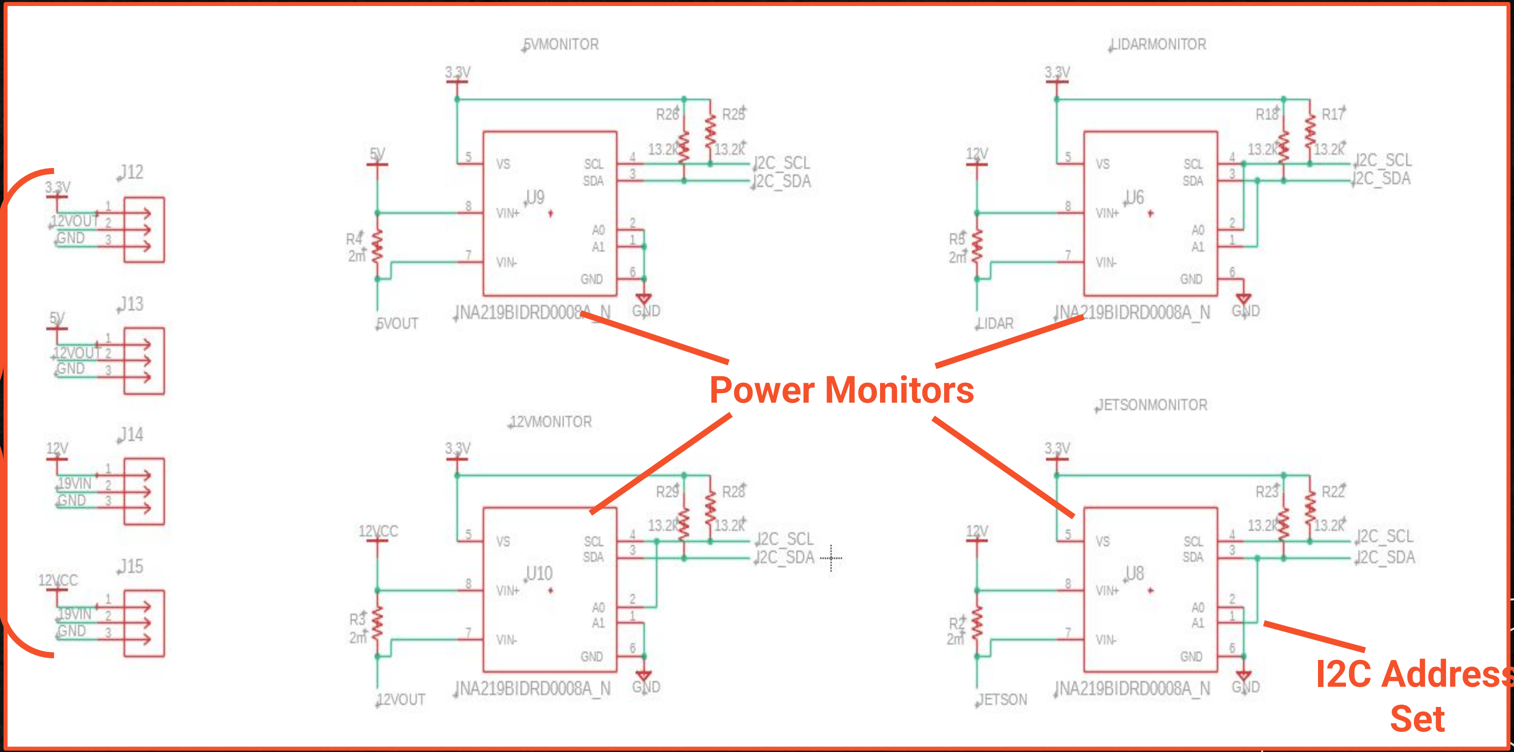


PMS Schematics: Motherboard



PMS Schematics: Motherboard

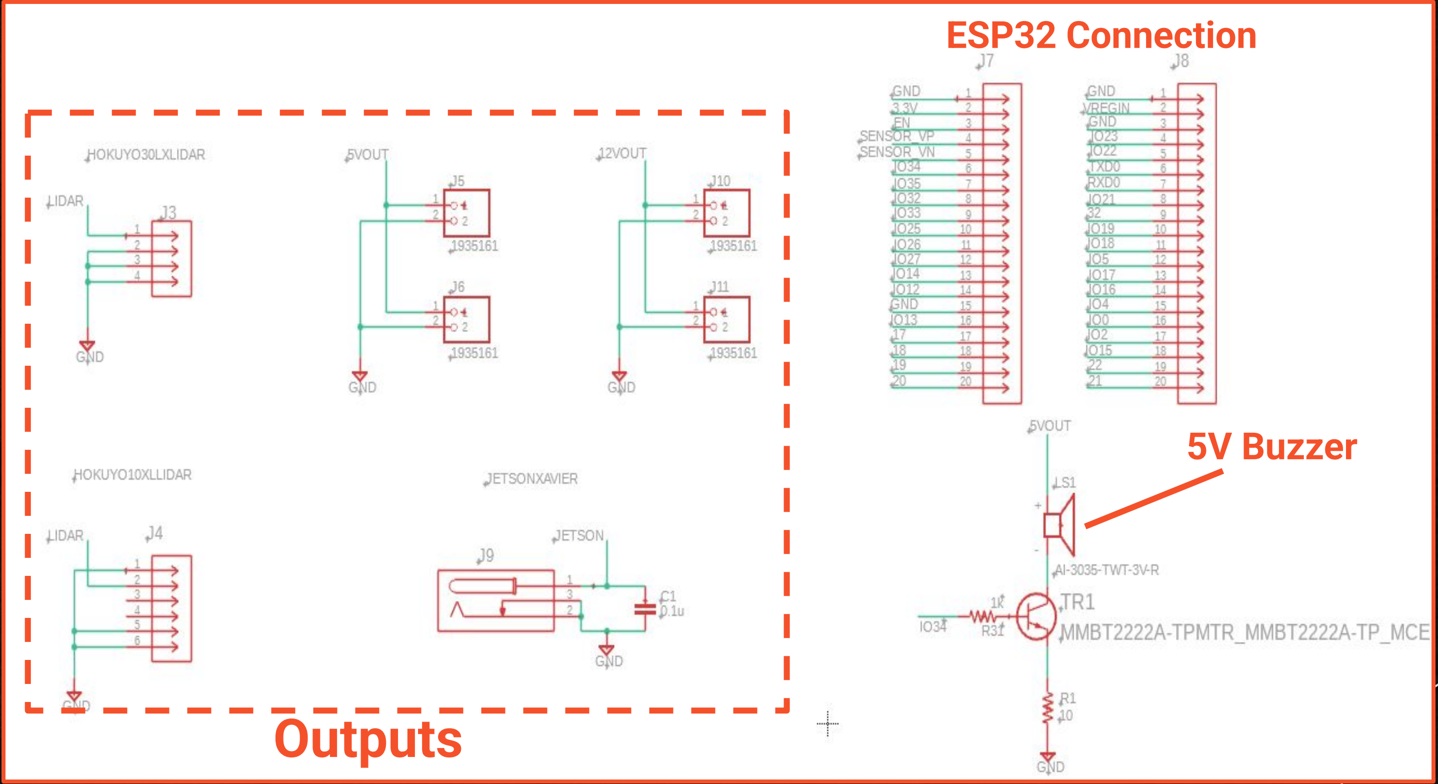
Voltage Regulators



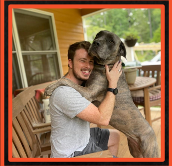
Power Monitors

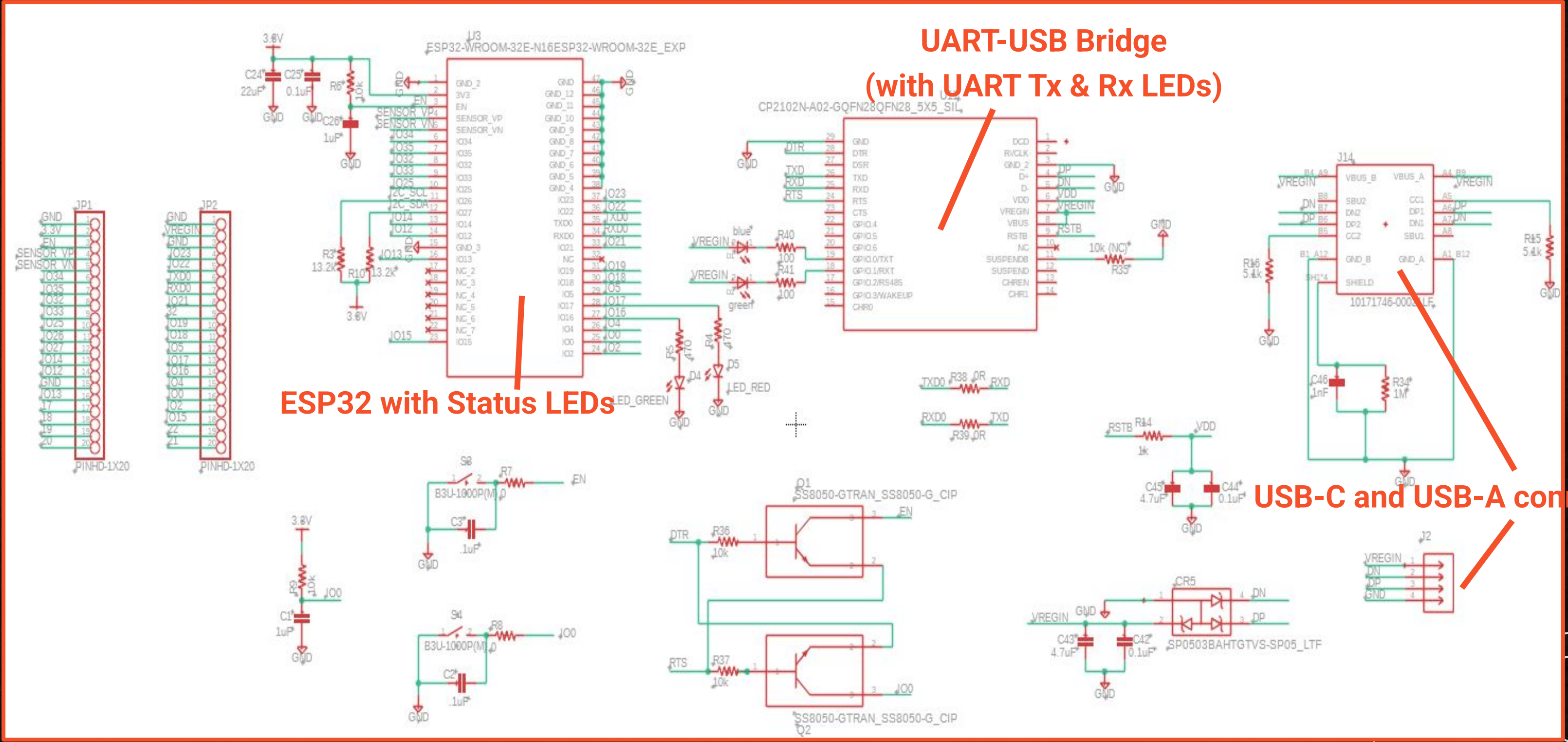
I2C Address Set

PMS Schematics: Motherboard

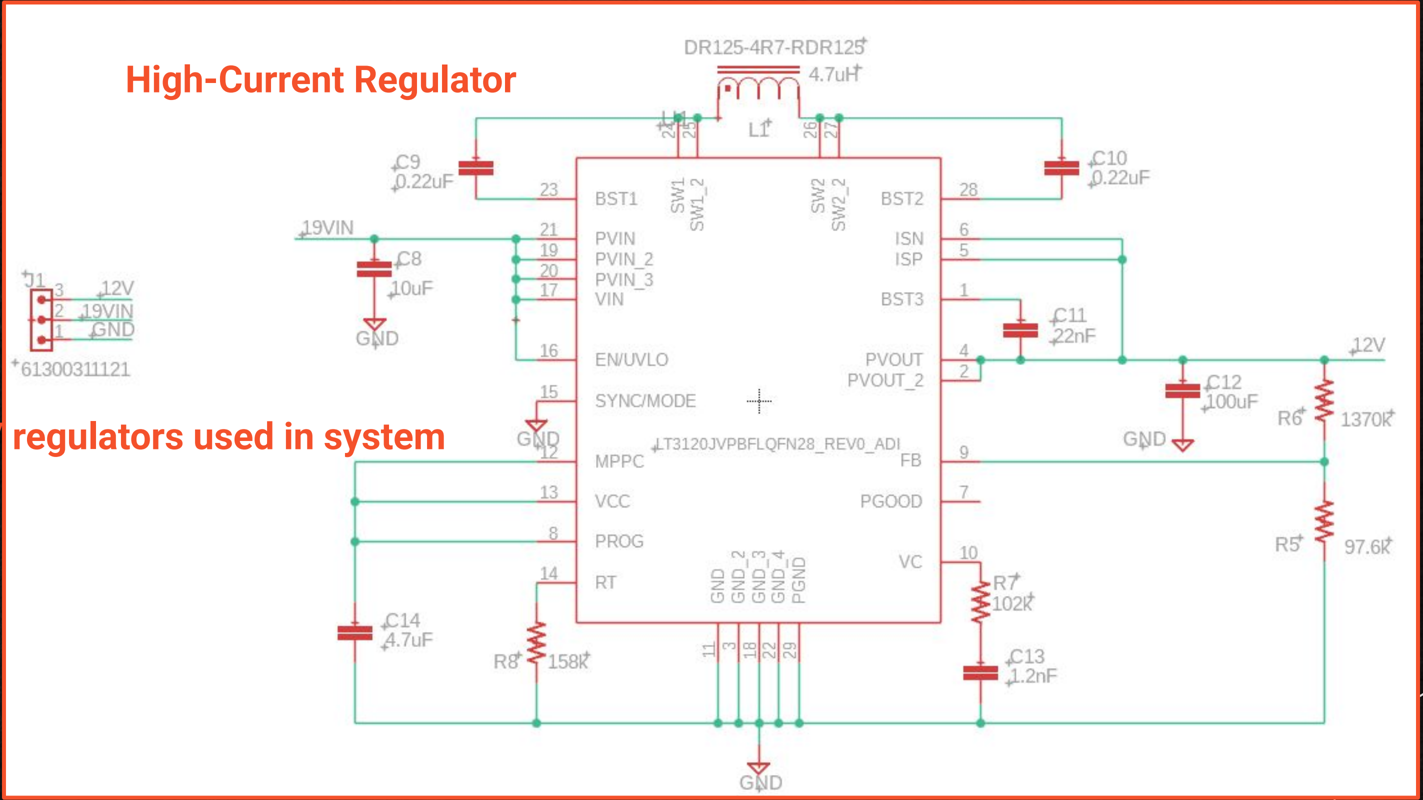


PMS Schematics: Brain Board



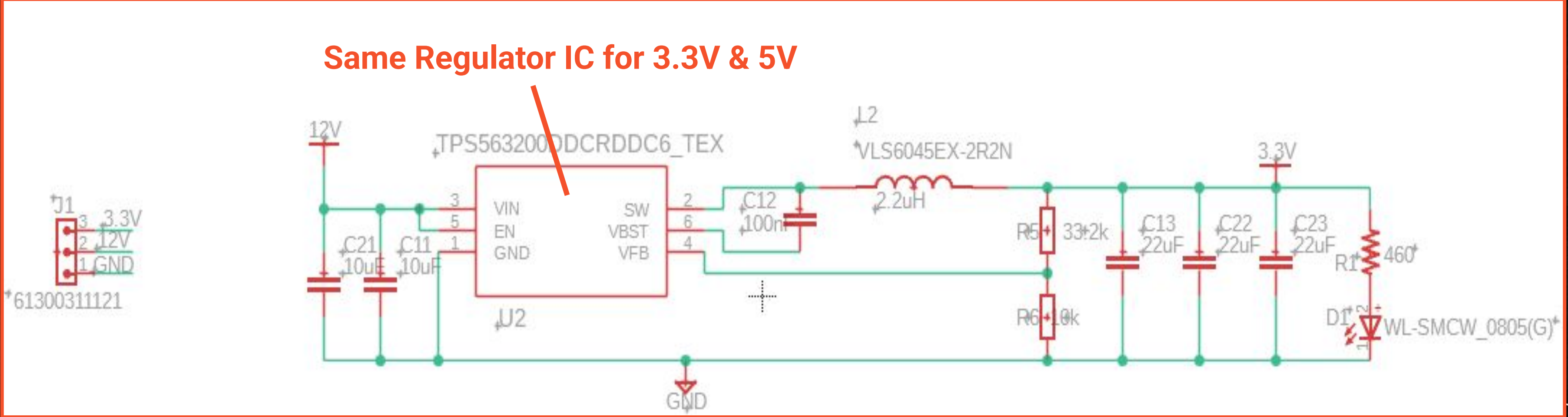


PMS Schematics: 12V Regulator



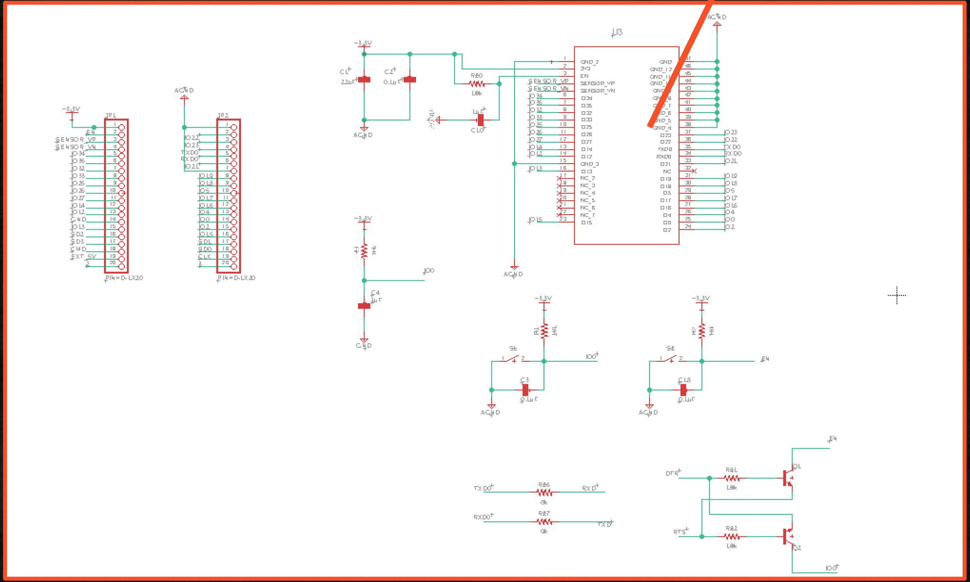
2x 12V regulators used in system

PMS Schematics:
3.3V & 5V Regulators

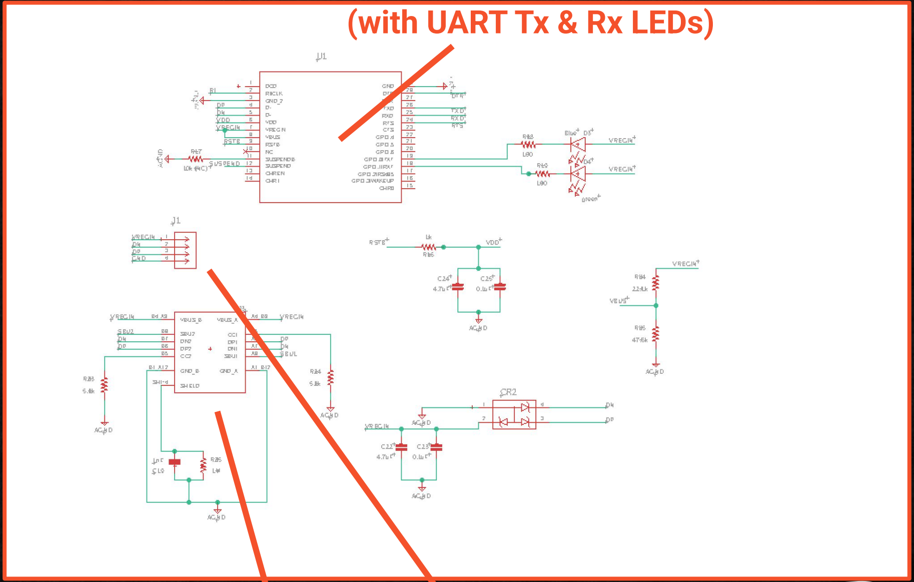


SIS Schematics: Control Board

ESP32 with Status LEDs

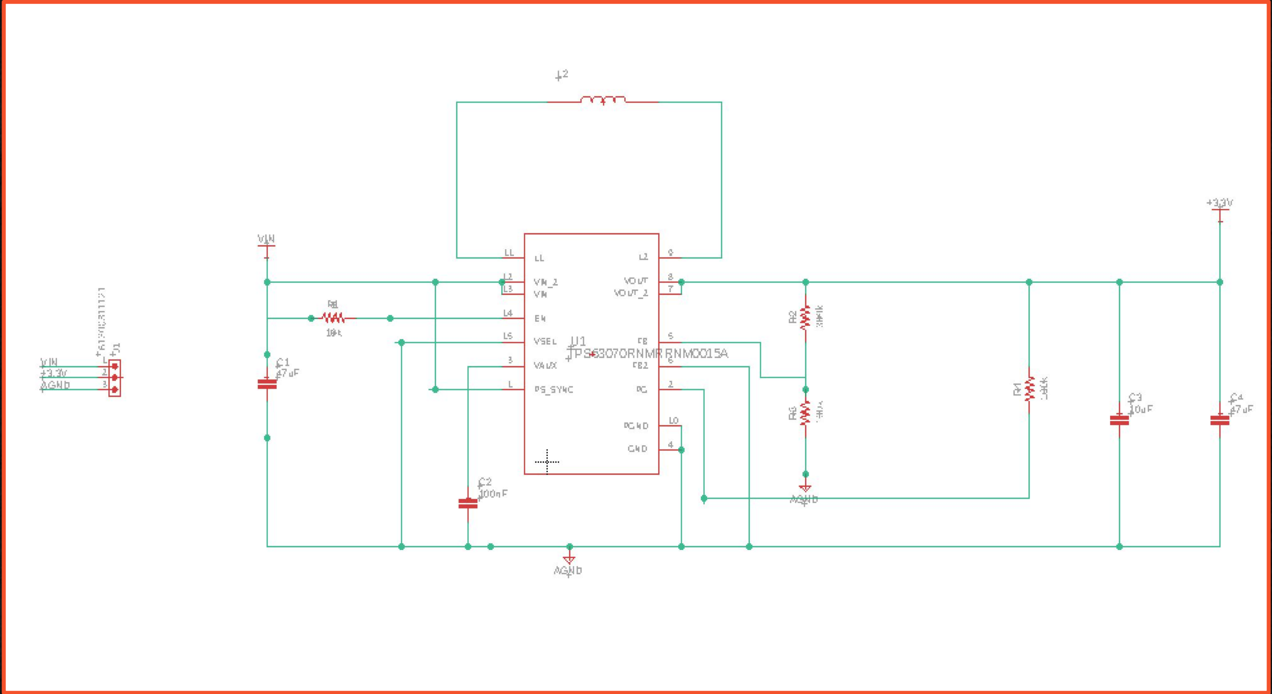


UART-USB Bridge
(with UART Tx & Rx LEDs)

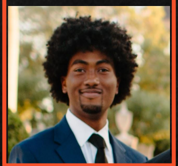


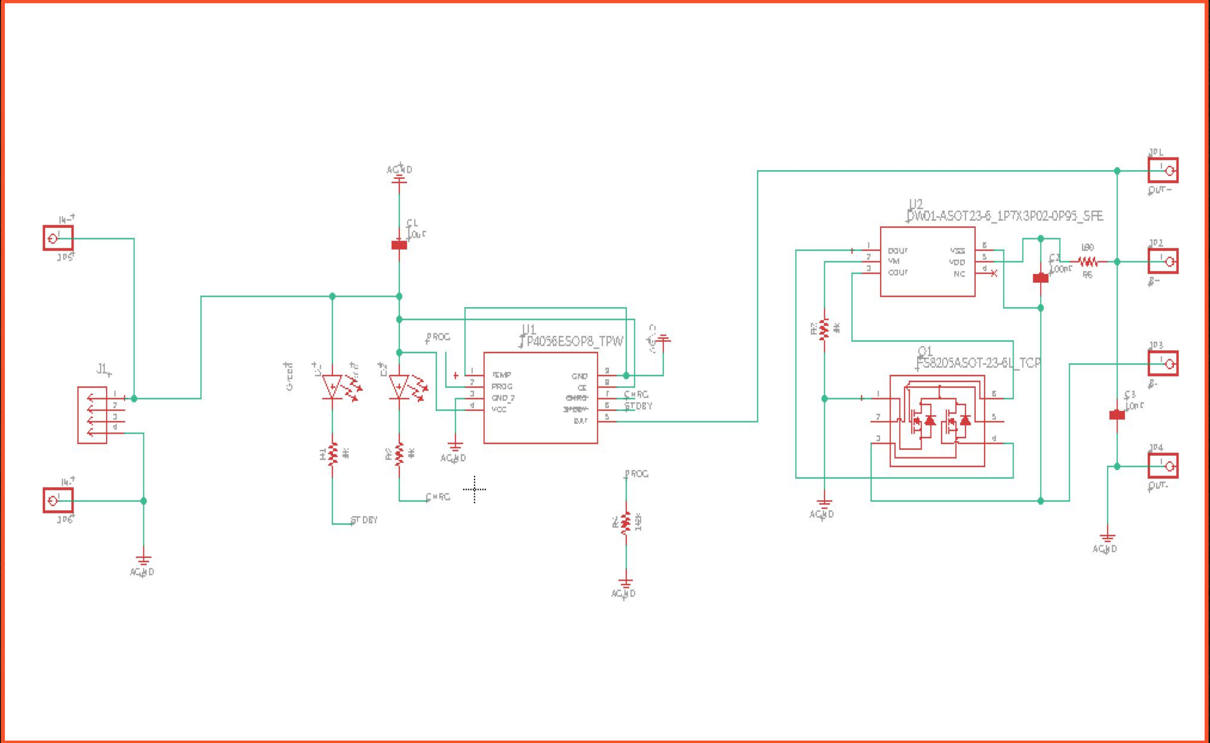
USB-C and USB-A connectors

SIS Schematics: 3.3V/5V Regulator

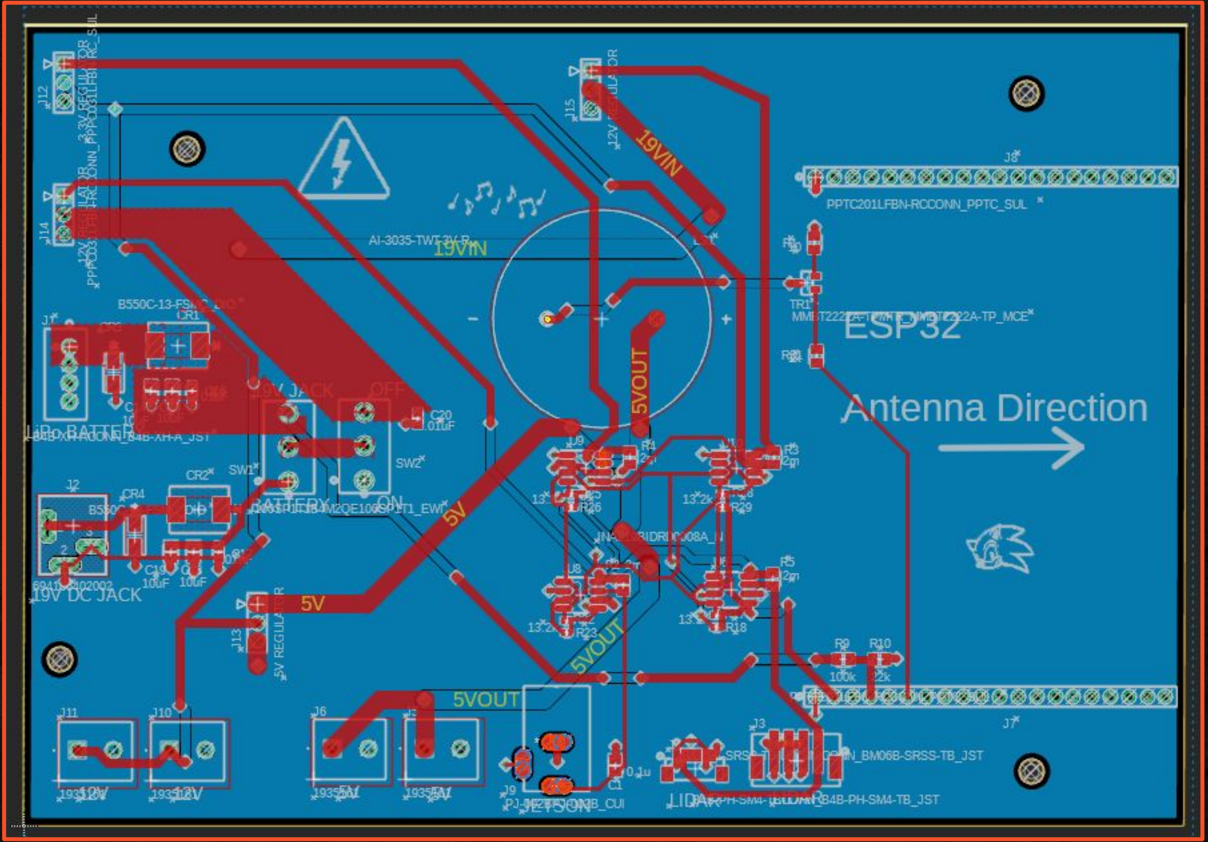


SIS Schematics: Charger





PMS PCB Layout: Motherboard

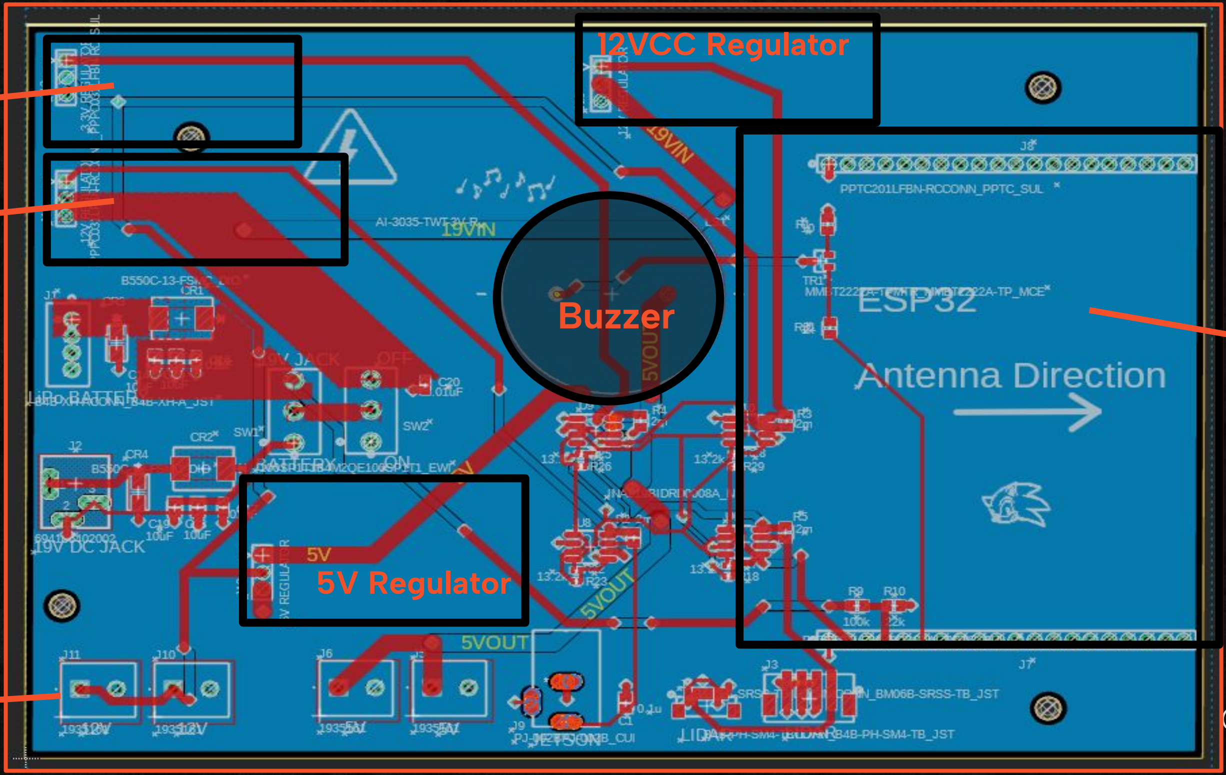


- 2-layer board
- Blue is ground plane (bottom layer)
- The “glue” of the PMS; connects all other boards together
- Screw holes for mounting on vehicle
- Silkscreen features include: Sonic head, high voltage symbol, and music notes for buzzer

PMS PCB Layout: Motherboard

3.3V Regulator

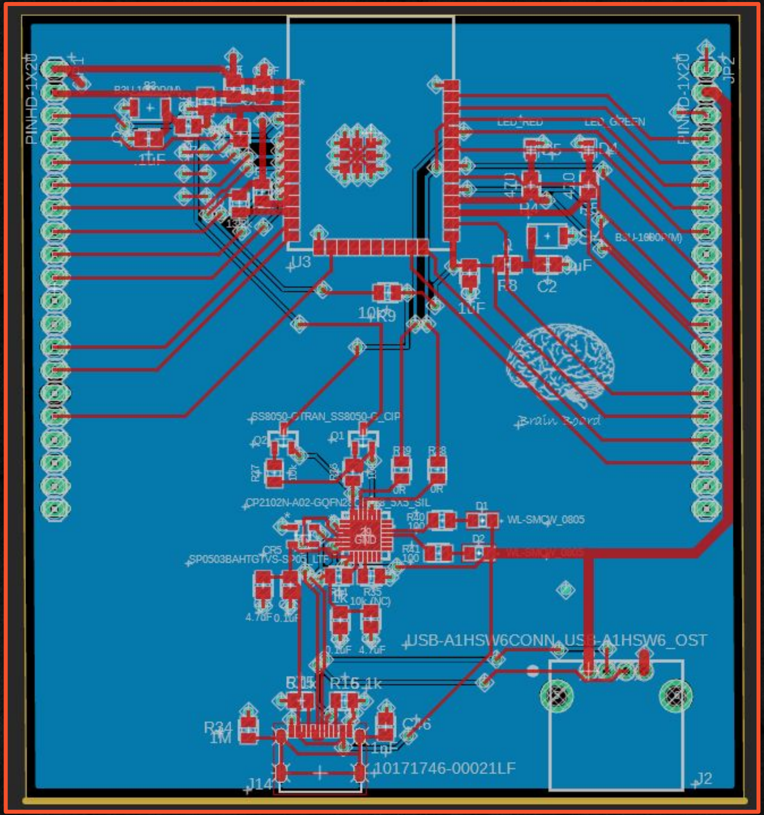
12V Regulator



ESP32

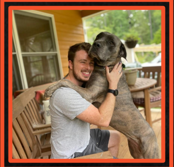
Outputs

PMS PCB Layout: Brain Board (ESP32 Daughter Board)

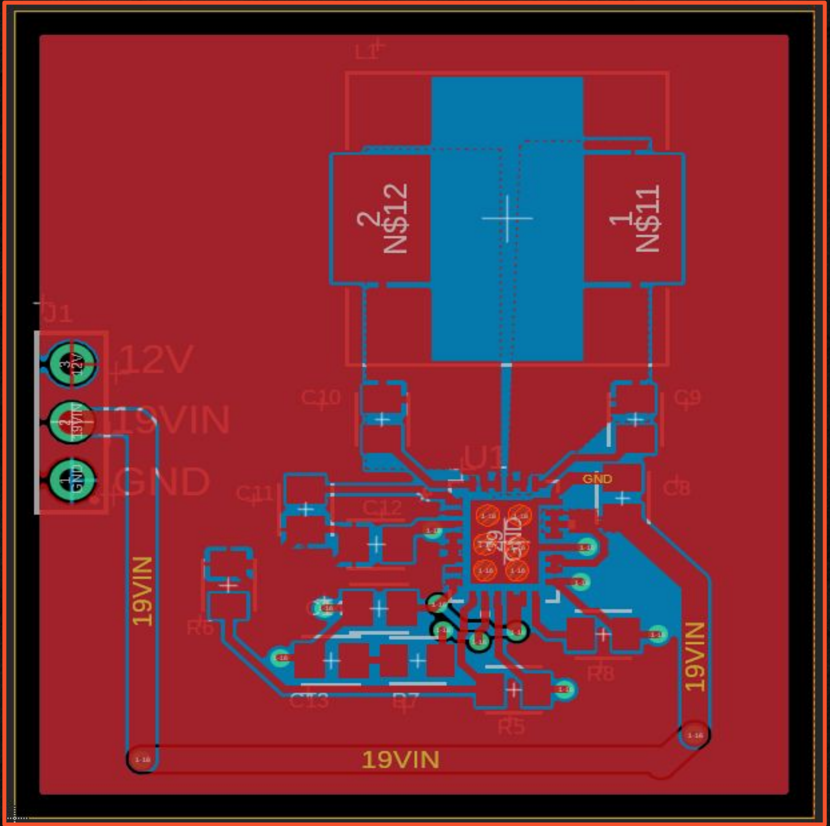


- 2-layer board
- Blue is ground plane (bottom layer)
- Features USB-C and USB-A connections
- Dubbed the “*Brain Board*” (hence the brain in the silkscreen)

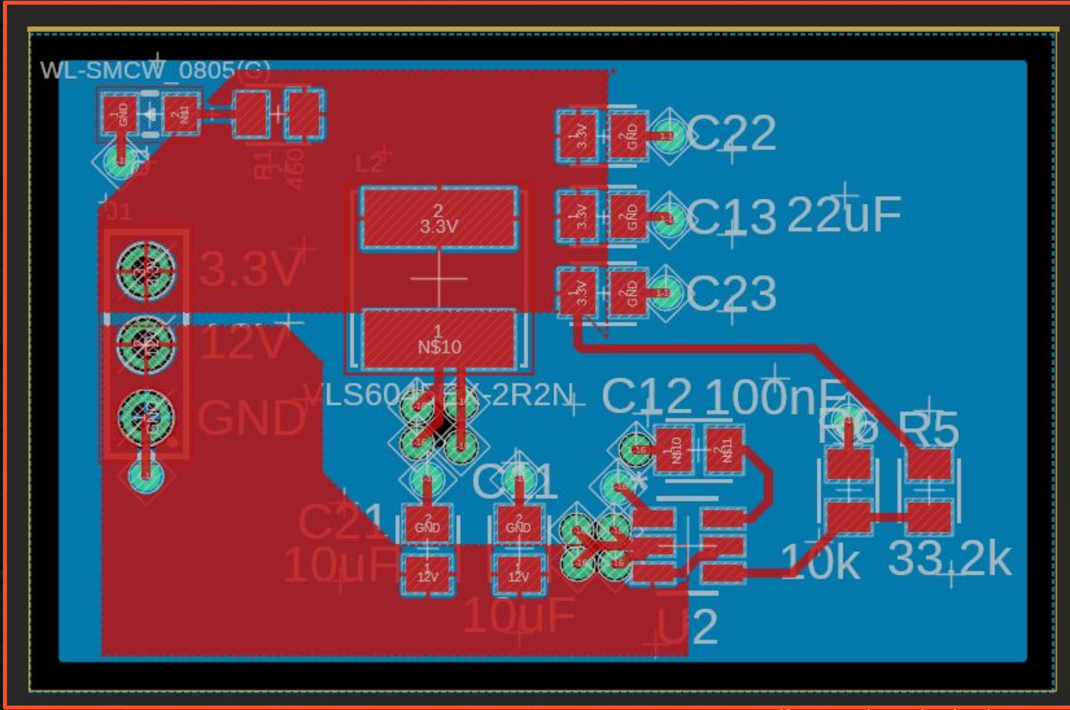
PMS PCB Layout: Regulators



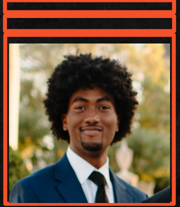
12V Regulator



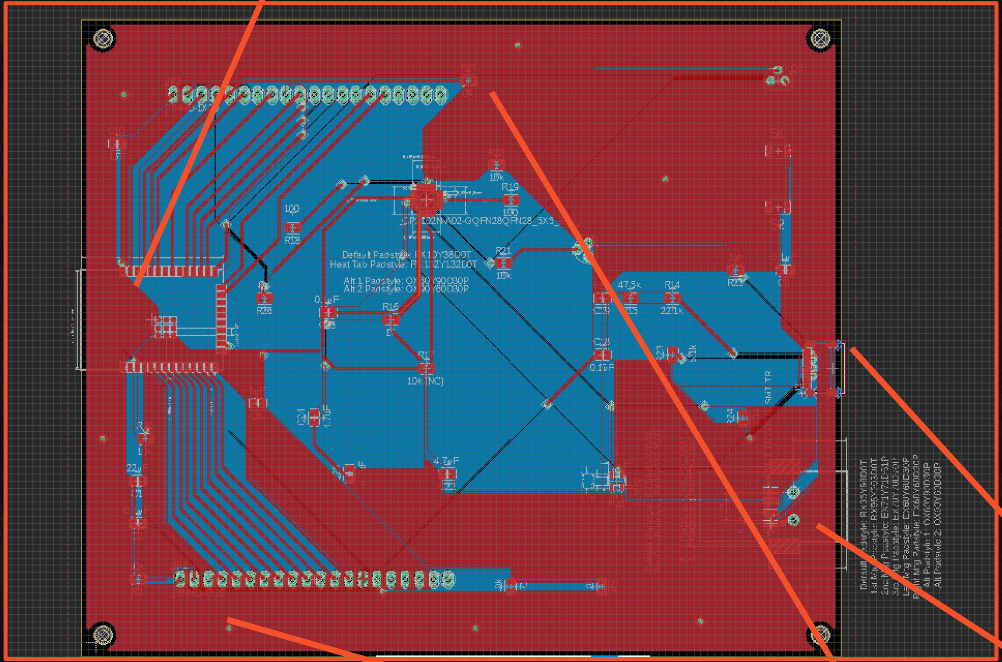
3.3V/5V Regulator

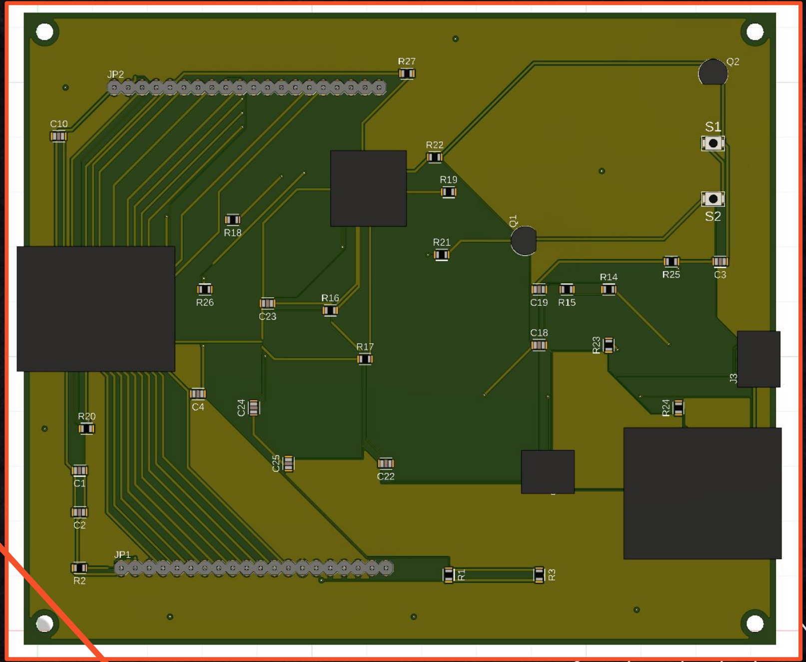


SIS PCB Layout: Control Board



ESP32

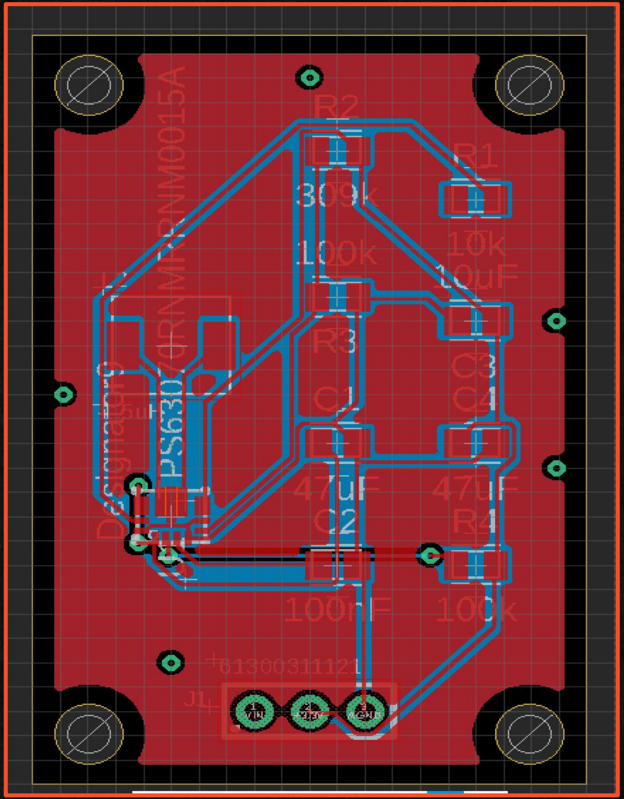


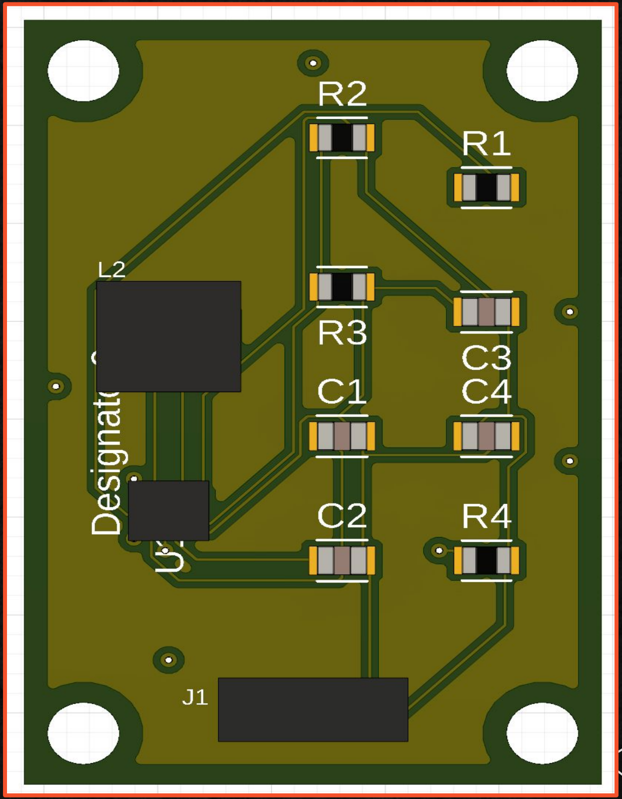


Screen Display Output

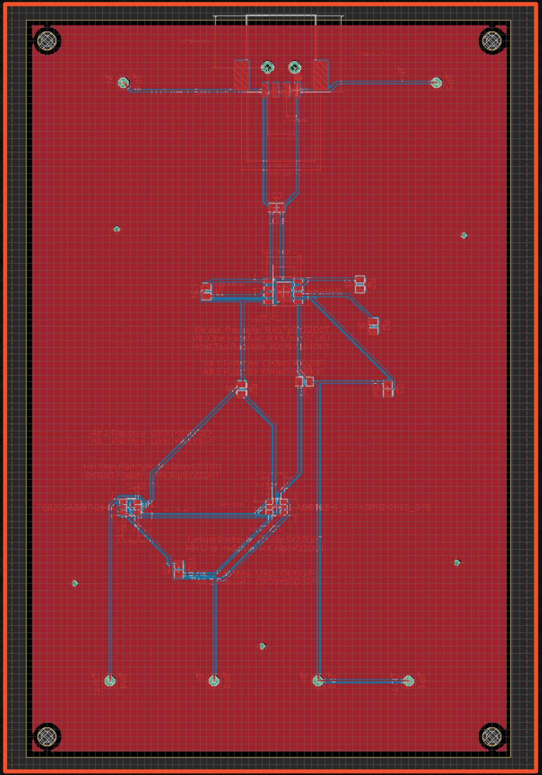
Input

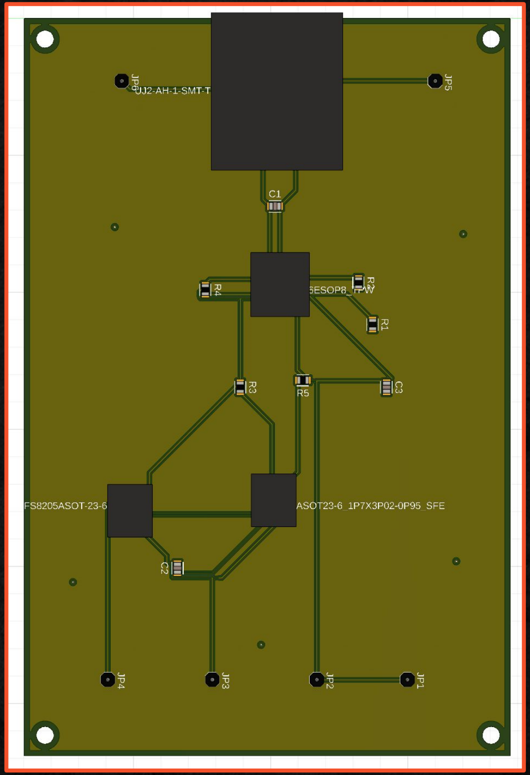
SIS PCB Layout: 3.3V/5V Regulator

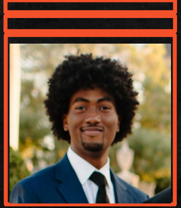




SIS PCB Layout: Charger

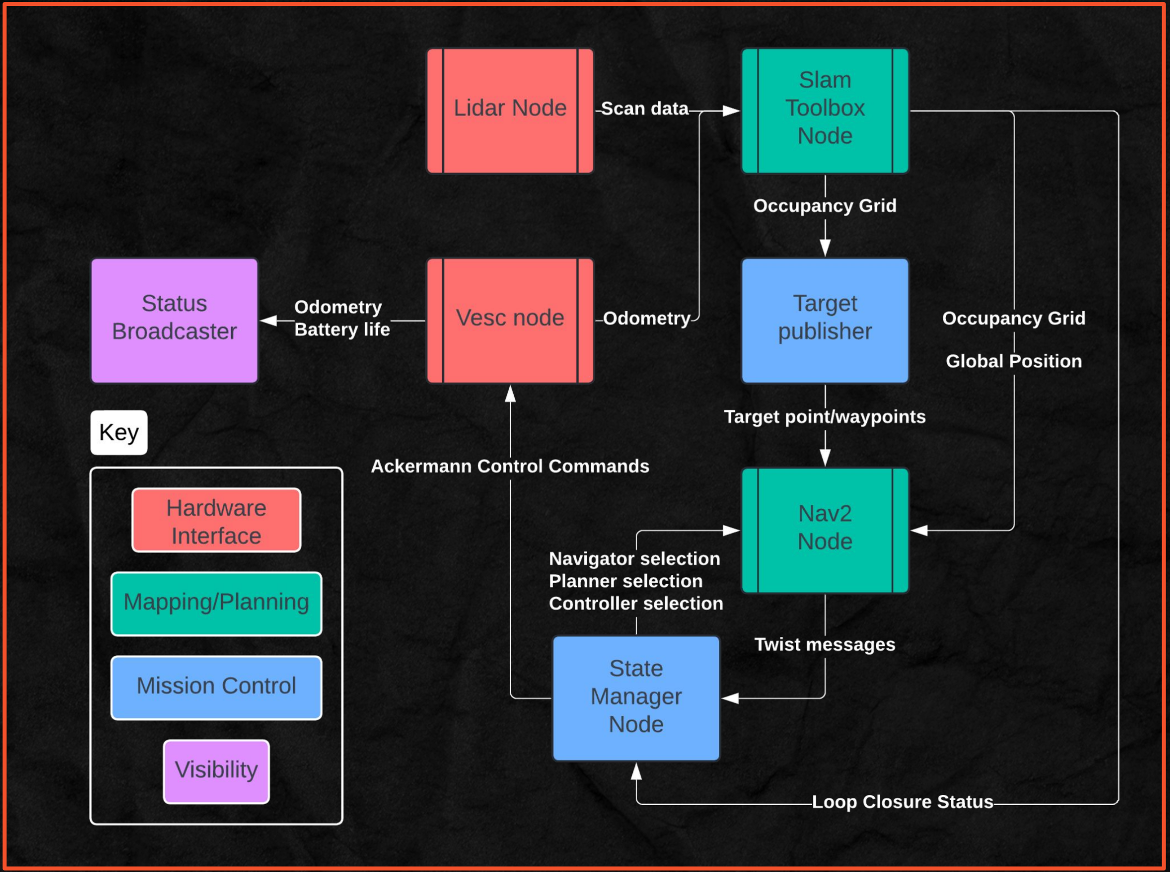






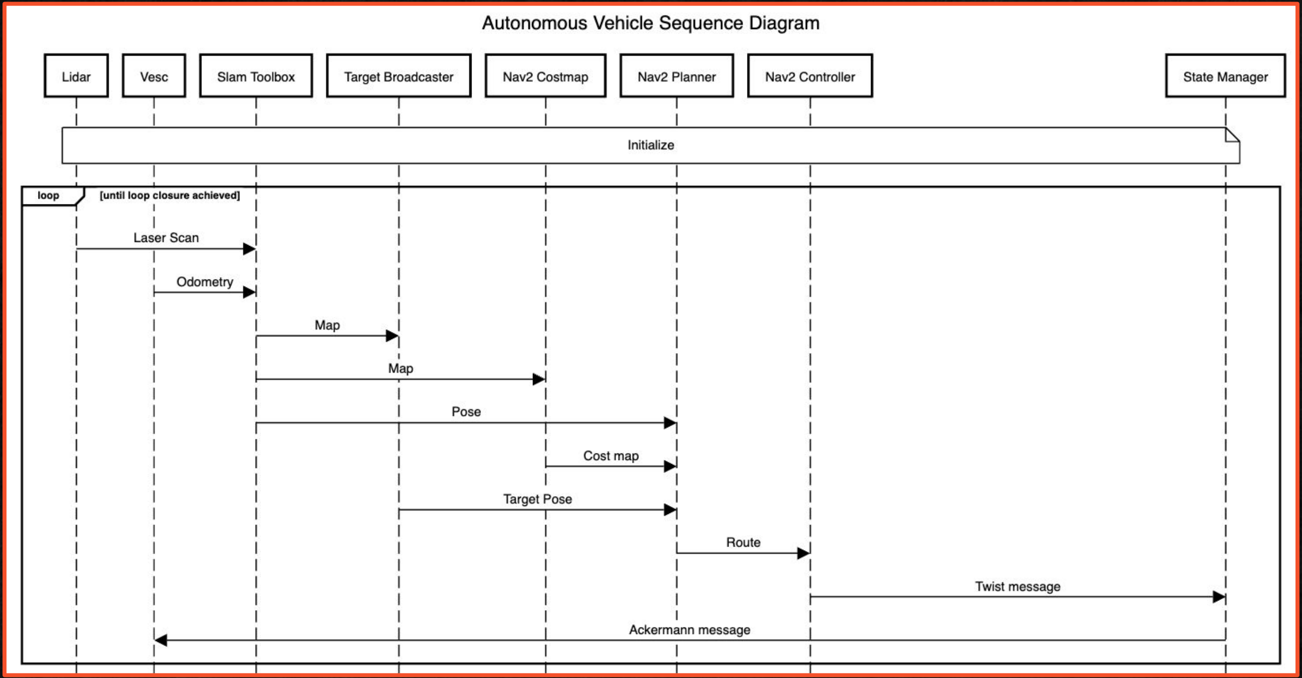
Software Design

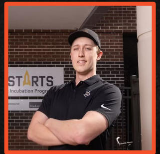
Flowchart



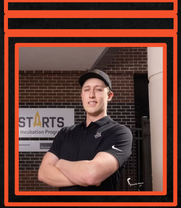
Lidar Node
Scan data
Slam Toolbox Node
Occupancy Grid
Status Broadcaster
Odometry
Battery life
Vesc node
Odometry
Target publisher
Occupancy Grid
Global Position
Target point/waypoints
Key
Ackermann Control Commands
Hardware Interface
Mapping/Planning
Mission Control
Visibility
Nav2 Node
Navigator selection
Planner selection
Controller selection
Twist messages
State Manager Node
Loop Closure Status

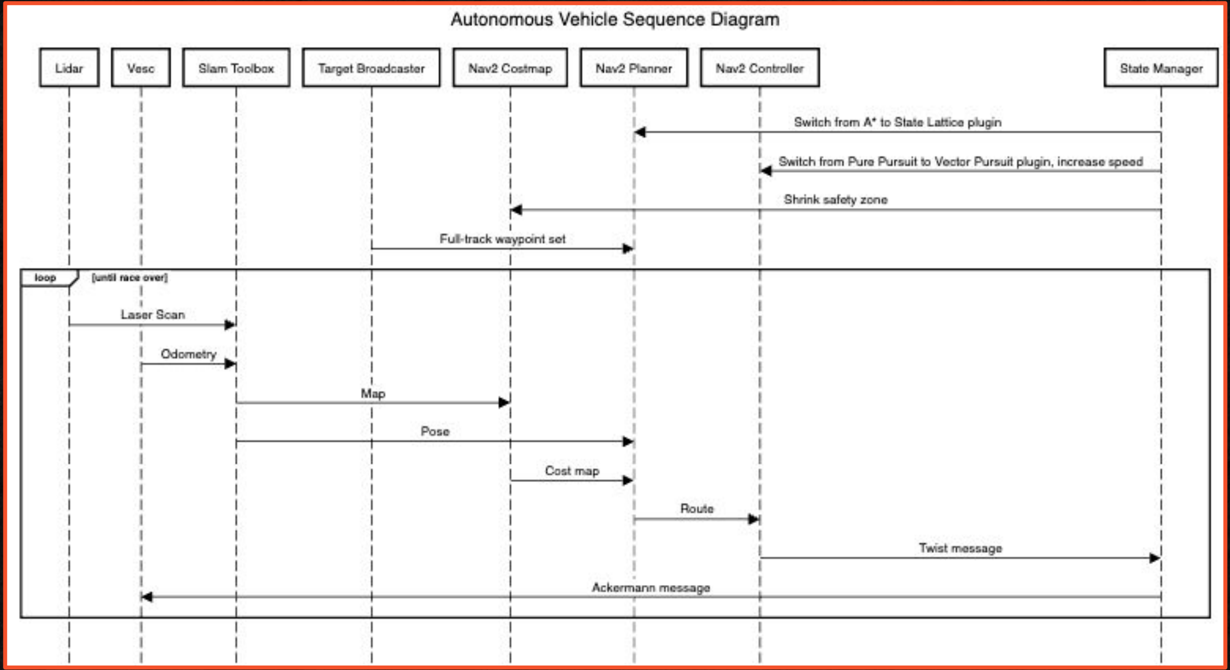
Sequence Diagram (pt. 1)



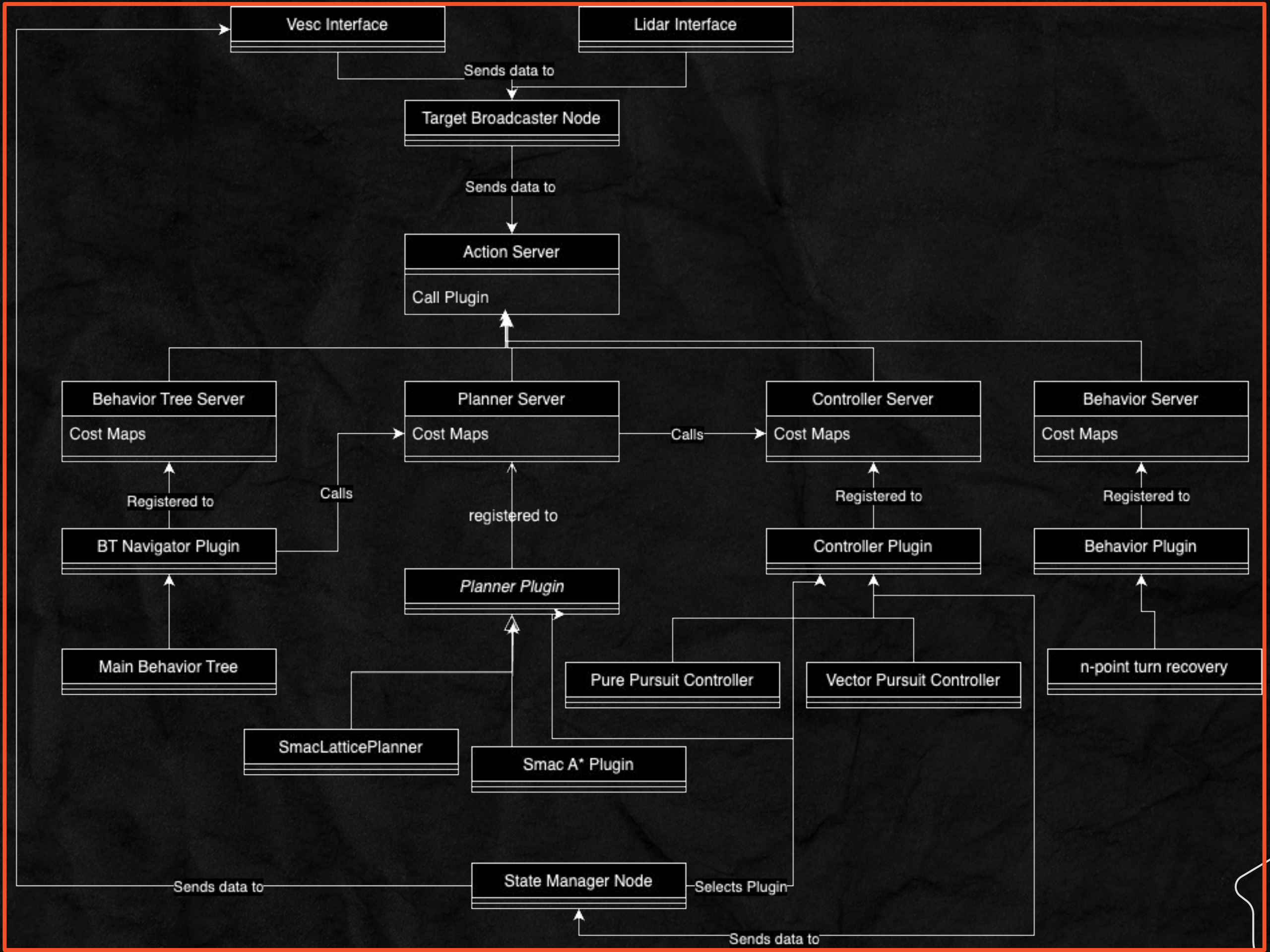


Sequence Diagram (pt. 2)





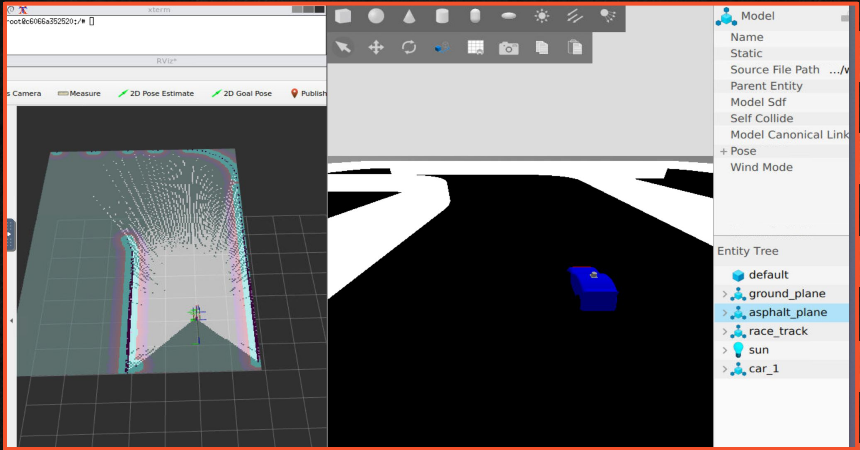
Class Diagram



Prototyping and Testing

Software Testing

Software testing is performed in our proprietary Gazebo-based simulator.



Successes:

- Fully integrated Nav2 and Slam Toolbox
- Developed target publisher node

Difficulties:

- Physics issues impact movement of simulated car, limiting what can be simulated; lots of time devoted to trying alternative simulators proved fruitless for our use case

Hardware Testing

Hardware testing is on our racetrack in our advisor’s lab

Successes:

- Ported simulated code to hardware
- Exploration phase runs successfully

Difficulties:

- Had to re-flash car’s computer to install the correct operating system
- PixHawk had to be abandoned in favor of just Vesc due to complications with non-GPS navigation

Administration

Project Cost Estimate

Vehicle Components			
Component	**Unit Cost**	**Quantity**	**Total Cost**
Chassis	$500	2	$1,000
Computing Unit	$800	2	$1,600
High-Speed LiDAR	$1800	2	$3,600
Depth Camera	$300	2	$600
9 Axis IMU	$150	2	$300
Batteries	$100	4	$400
Electronic Speed Controller	$100	2	$200
Display Board	$50	1	$50
Printed Circuit Board (PCB)	*~ Varies*	*~ Varies*	$150

Miscellaneous	
Component	**Total Cost**
Mechanical Improvement Components	$400
Microcontrollers	$50
Communication Modules	$50
Printed Circuit Board Components	$50
Battery Charger	$100
Electrical Wiring and Connectors	$100
Peripherals Mounting Platform	$50
Racetrack Wall Material	$200
Unexpected Expenses	$500

Grand Total	$9,400

Project Expenses

Vehicle Components				Miscellaneous			
Component	Unit Cost	Quantity	Total Cost	Component	Unit Cost	Quantity	Total Cost
Traxxas Slash 4X4 Ultimate	2	$500	$1,000	TRX to XT90 Adapter Pack	2	$10	$20
2 LiPo Batteries and Charger Combo	2	$240	$480	TRX ID Connector Converter Pack	2	$6	$ 12
VESC 6 MkV	2	$258	$516	LiPo Safety Bag	2	$10	$20
Jetson Xavier NX	2	$659	$1,318	Barrel Jack to Pigtail Pack	2	$5	$10
Hokuyo UST-10LX Scanning Laser Rangefinder	2	$1,670	$3,340	Bullet Adapter 4mm Male 3.5mm Female Pack	2	$9	$18
Intel RealSense D435i	2	$234	$468	VESC 3S ppm cable	2	$5	$10
Sony DUALSHOCK 4 Wireless Controller	2	$58	$116	Short (~1 ft) A USB-to-micro USB cable - Pack	2	$8	$16
Wifi Antenna	2	$9	$18	M2 - M5 Socket Head Assortment Kit	1	$25	$25
Micro SD Card 32 GB	2	$14	$28	M2 - M4 Standoff Kit	1	$23	$23
NVMe SSD Card 250 Gb	2	$46	$92	Header Pins Pack	1	$9	$9
HDMI emulator	2	$14	$28	Air Duct Material (for creating a race Track)	8	$32	$256
Printed Circuit Board (PCB)	Many	N/A	$450	Printed Circuit Board Components	Many	N/A	$150
Grand Total							$8,423

Work Distribution

Task	Primary	Secondary
Vehicle Mechanical System Design & Assembly	Tevin	Israel
Power Distribution System	Casey	Asa
Design & Development of Status Indicator PCB	Asa	Casey
Electrical Safety Monitoring System	Casey	Asa
Program Status Indicator Module & Data Fusion	Asa	Casey
High-Level Computing Unit Programming	Owen	Israel
Vehicle Steering & Control System	Israel	Owen
Race Line Computation	Owen	Israel
Follow-the-Gap Algorithm Implementation	Israel	Owen
SLAM (Simultaneous Localization and Mapping)	Owen	Israel
Project Administration & Website Development	Israel	Owen
Comprehensive Testing of Physical System	Tevin	Israel
Project Management & Coordination	Israel	Owen

Project Progress and Completion Plan

Tasks	Status	Progress Bar
Initial Research & Planning	Completed	100%
Initial Hardware & PCB Design	Completed	100%
Algorithm Design	Completed	100%
Initial Project Report	Completed	100%
Hardware & PCB Acquisition	Completed	100%
Testbed Prototype V0	Completed	100%
Algorithm Development	In Progress	50%
Subsystem Testing and Assembly	In Progress	40%
Overall System Testing and Optimization	In Progress	30%
Prototype Live Demo	Not Started	
Presentation & Project Final Report	In Progress	20%

THANK YOU

For Watching

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