N.A.V.I.S.
NAVIGATIONAL ASSISTANCE FOR VISUALLY IMPAIRED SHOPPERS

Final Presentation

Spring 2025 / Summer 2025 – Group 10

Meet the team

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Motivation, Background, and Overview

- According to the WHO, over **2.2 billion people** worldwide are affected by visual impairment.
  - *Some conditions are **uncorrectable** by glasses, medicine, or surgery, often caused by **age-related disorders** (e.g., macular degeneration, glaucoma).*
  - *These are classified as **'low vision'** by the NIH.*
- The CDC predicts that, in the U.S., **low vision among adults 40+ is expected to double by 2050**.
- This project focuses on individuals with **visual acuity from 6/18 to 3/60**, who may struggle with recognizing objects beyond **arm's length**.
- Daily activities often require **caregiver assistance**, which can reduce **independence and quality of life.**
- Our goal: develop a **portable assistive device** to help users **navigate grocery stores**, **locate items** (within 0.5m), and **avoid obstacles.**

Goals

Basic Goals

- Create a portable navigation device that users can mount onto a shopping cart
- Guide visually impaired users to within **0.5 meter** of the items in the users shopping list
- **Detect obstacles** in front of the shopping cart to warn users of potential collisions

Advanced Goals

- Create an **optimized route** through the grocery store after the user provides the item list
- Assist users with locating the position of the object on the shelf
- Incorporate additional **feedback systems** to avoid collisions with other shoppers, walls, and obstacles

Stretch Goals

- Extend application to more severe visual impairments (total blindness)
- Expand to other locations (different store types such as libraries, hardware stores,
- etc.)
- **Modulate light** for depth camera system in order to be unaffected by different light sources

Objectives

Basic Objectives

- Lightweight – for easy setup and teardown
- Rechargeable and long lasting battery
- Integrate **Inertial Measurement Unit** (IMU) data
- Detect obstacles with **active stereovision depth camera system**
- Provide directions through **audio commands**

Advanced Objectives

- **Path planning** - localization and user item list
- Provide directions through **haptic commands.**
- Active stereovision depth camera system capable of at least **60° FOV** and **2m object detection**

Stretch Objectives

- Integrate a camera to identify and indicate shelf level upon reaching the requested object
- Incorporate **real-time updates** if users change the item list or obstacles require route changes
- Track the user's **hand position** to provide additional precise audio commands
- Expand the store map database to support **multiple locations**
- Ensure the optical system can **filter** out diverse light interferences

Engineering Requirements and Specifications

Specification	Target Value
Distance User Guided from Product	Within 0.5 meter
Success Rate	At least 90%
Collision Avoidance Latency	<300 ms
Size	Approx. 50x50x30 cm^3
Weight	2.5 - 5 lbs
Battery Life	At least 1 hour
Setup/Teardown Time	Within 5 minutes

Component	Parameter	Target Value & Unit(s)
Camera Focus length	Range	1 - 6 meters
Cameras	Field of View	30°(V) x 60°(H)
Light Emitter	Field of View	30°(V) x 60°(H)
Haptic Motors	Signal Discretion	3+ distinct vibration patterns
Speaker	Output Volume	At least 60dB SPL at 0.5m

Engineering Requirements and Specifications

Specification	Target Value
Distance User Guided from Product	**Within 0.5 meter**
Success Rate	**At least 90%**
Collision Avoidance Latency	**<300 ms at roughly 2m**
Size	Approx. 50x50x30 cm^3
Weight	2.5 - 5 lbs
Battery Life	At least 1 hour
Setup/Teardown Time	Within 5 minutes

Component	Parameter	Target Value & Unit(s)
Camera Focus length	Range	1 - 6 meters
Cameras	Field of View	30°(V) x 60°(H)
Light Emitter	Field of View	30°(V) x 60°(H)
Haptic Motors	Signal Discretion	3+ distinct vibration patterns
Speaker	Output Volume	At least 60dB SPL at 0.5m

Engineering Requirements and Specifications Testing Results

Test Location/ Number	Percentage of requested item announced when cart was within proximity (10 items total).	Was the cart within 0.5m for all announced items? If no, how many items were out of range?	Was the presented obstacle detected at 2m and within 300ms?
Library 1	80%	No - 2	No
Library 2	90%	No - 1	No
Library 3	90%	No - 2	Yes
Library 4	100%	No - 2	Yes
Library 5	100%	Yes	Yes
CREOL 1	90%	No - 1	No
CREOL 2	100%	Yes	Yes
CREOL 3	100%	No - 1	Yes
CREOL 4	100%	Yes	Yes
CREOL 5	100%	Yes	Yes

Optical Design Specifications

Component	Parameter	Target Value	Unit
Pigtailed Laser Diode	Optical Power	50	mW
	Wavelength	650	nm
	Operating Current	130	mA
	Operating Voltage	2.4	V
	Fiber Type	Single Mode	
Fiber Splitter	Splitting Ratio	50:50	
	Port Configuration	1x2 or 2x2	
	Fiber Mode Type	Single Mode	
	Operating Wavelength	650	nm
	Excess Loss	0.3	dB
	Splitting Ratio Accuracy	~±6	%
Collimating Lens	Focal Length	6	mm
	Diameter	6	mm
	Coating	AR	
DOE (Diffractive Optical Element)	FOV (V x H)	>30 x 30	Degrees
	Diffraction Pattern	Grid (60x60)	
Camera Sensor Module	QE (at 650nm)	50	dB
	SNR	20	dB
	Resolution	1920 x 1080	
	Dynamic Range	70	dB
	FOV (V x H)	70 x 50	Degrees

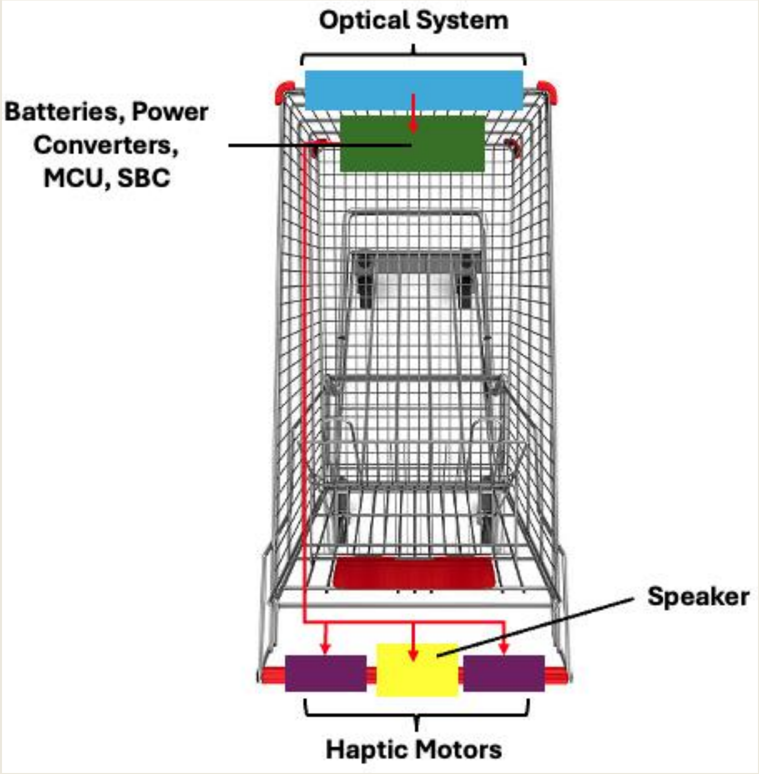
HARDWARE DESIGN

High Level Design Diagram

Optical System at Front of Cart for Larger Distance Range

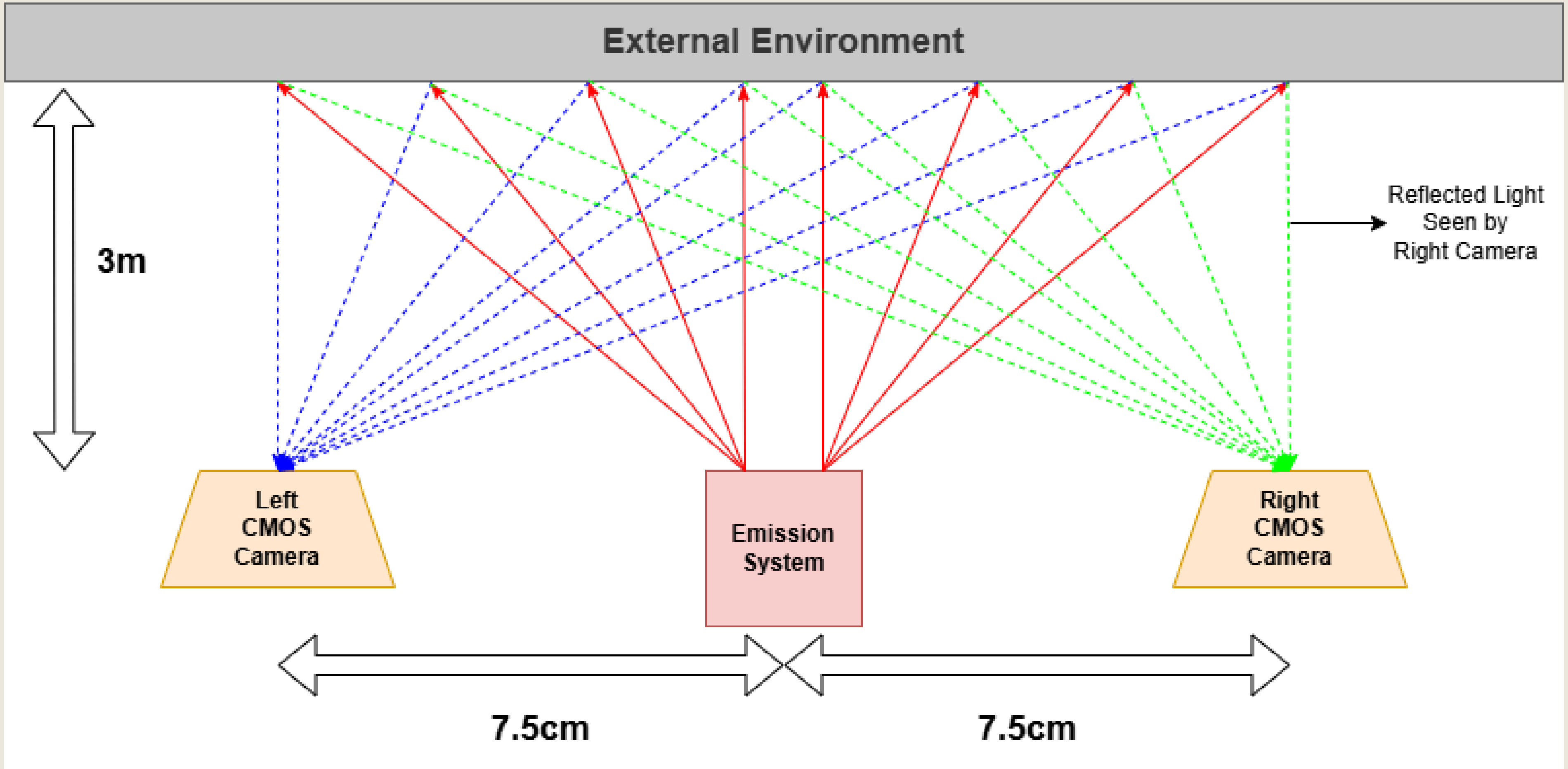
User Output Peripherals on Handlebars

In our prototype, these are closer together than they would be in a full-sized shopping cart, but the idea remains the same.

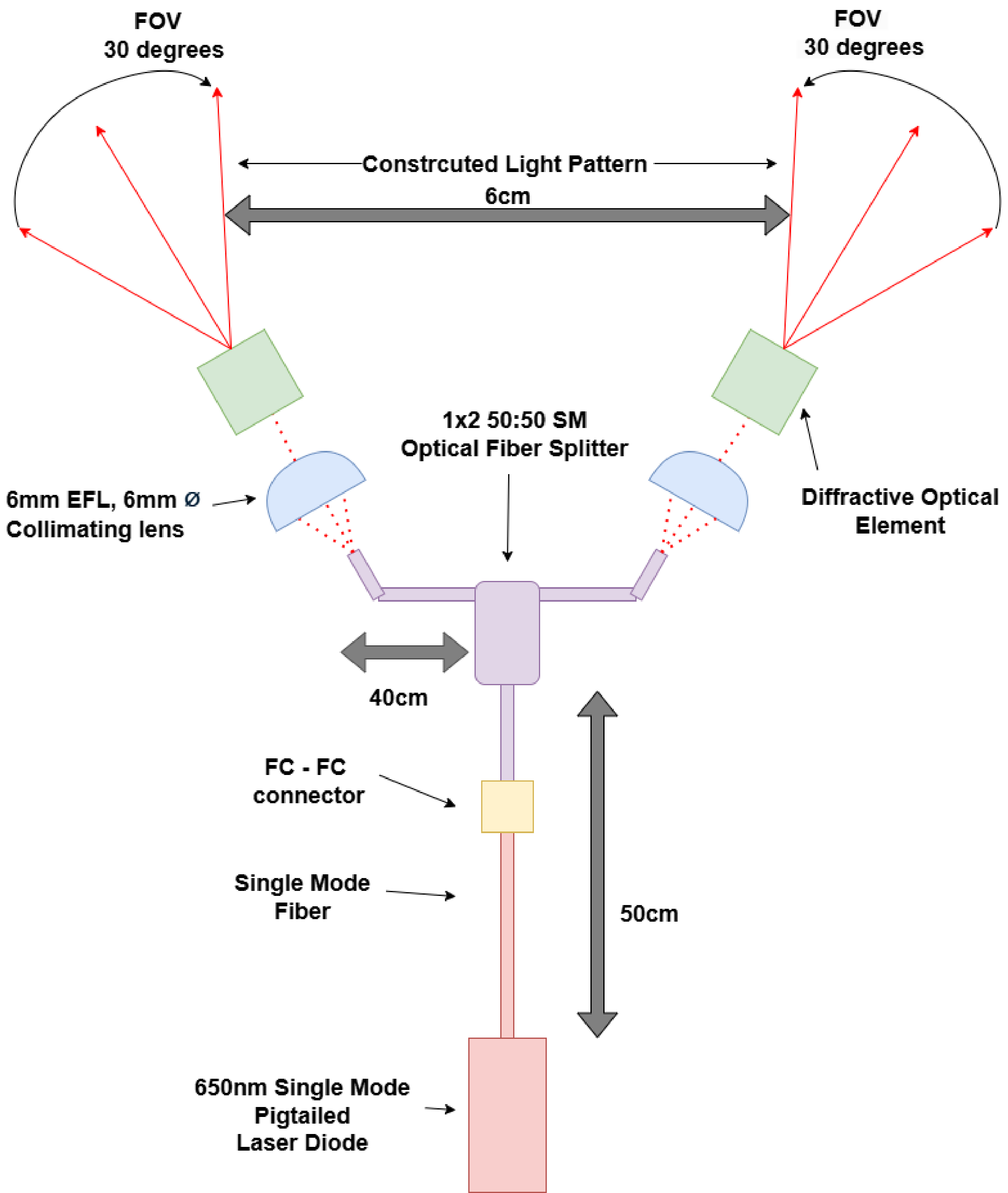


Pictured: Original block diagram, actual implementation

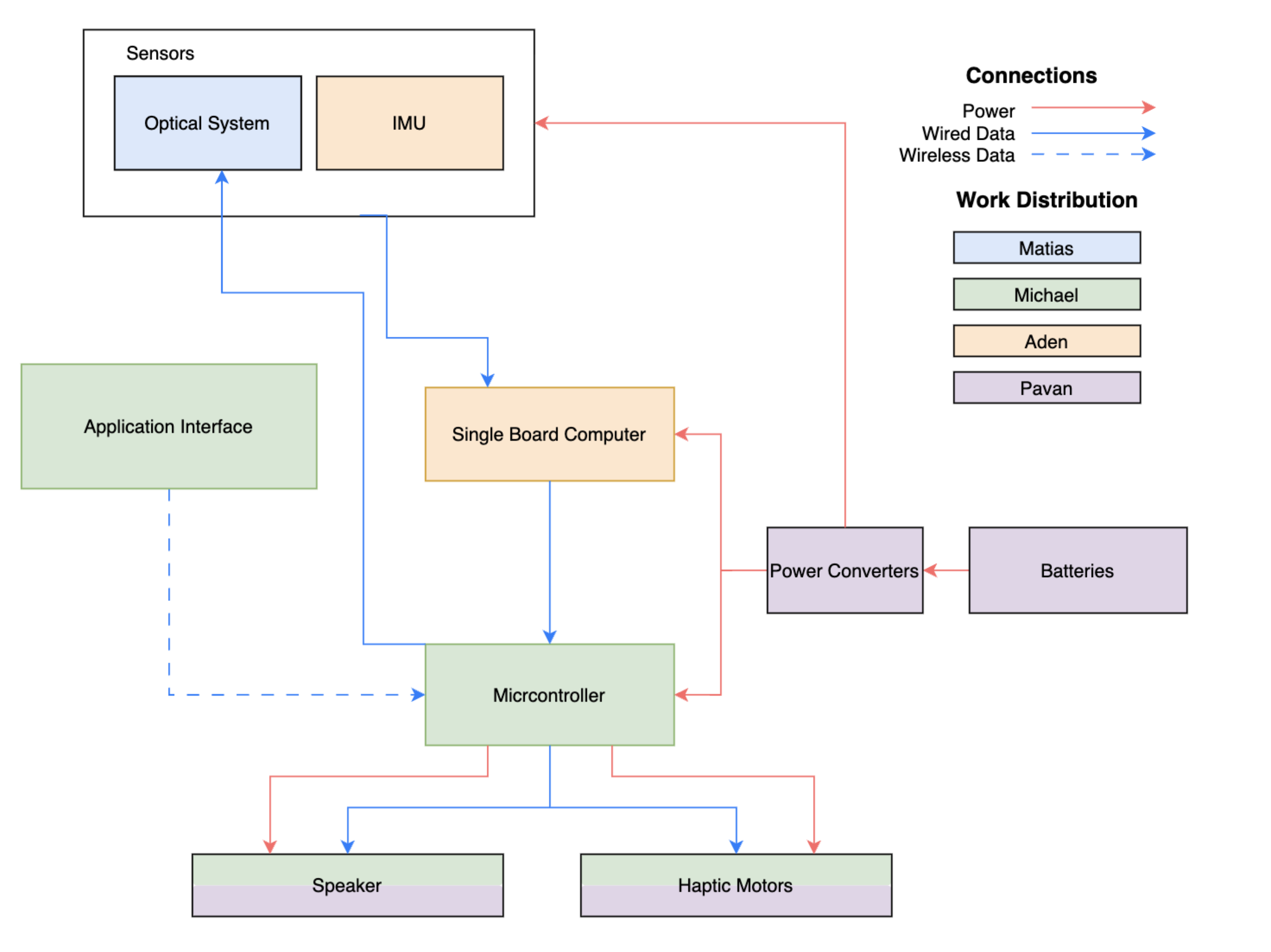
Optical Detection Hardware Block Diagram



Optical Emission Hardware Block Diagram



Electrical Hardware Block Diagram



ELECTRICAL HARDWARE AND COMPONENT SELECTION

Microcontroller Part

Selection: ESP32-WROOM-32E (16MB FLASH)

- Have used prior in Real Time Systems (familiarity)
- Widely used for many examples and support
- PlatformIO C/C++ or Arduino libraries available – both with FreeRTOS for task scheduling

Family Name	Benefits	Drawbacks
STM-32	Wide use in industry	Harder to source development boards with fast turnaround
ESP-32	Familiarity with Use Easy C Libraries Wide use in industry Easy to source development boards for testing	Can be slightly more expensive than competing solutions.
MSP430	Tends to be a cheaper solution Easy to source development boards for testing	Lesser Capabilities, Simple Nature.

SBC

Selection: Raspberry Pi 5 (16GB RAM)

- Low power
- Easy to use I/O
- Familiarity from prior projects

Product	Advantages	Disadvantages
Raspberry Pi 5	Dual core ARM processor, enough for our uses Several SKUs for different amounts of RAM Official support for ROS2	Modern, less backtested support.
NVidia Jetson Nano	Standard and known formats	Relatively old Not used by many products.
Latte Panda	High compute power, more than enough for our uses.	High power requirements High heat generation High cost

IMU Part

Selection: CEVA BNO085

- More robust noise filtering leads to better signal for the applications
- 9-DoF
- Robust built-in firmware and drivers for Linux and ROS2

IMU Name	Advantages	Disadvantages
Bosch BMI270	Robust on-chip noise filtering Contains Titan Core for on-chip configuration	More complex, needs software loading on startup More development time due to complexity No ROS2 driver
CEVA BNO085	Has ROS2 drivers Robust on-chip noise filtering Newest solution, best community and manufacturer support 9 DoF (includes magnetometer)	Does not allow on-chip configuration – not needed for our purposes (good stock settings better) Most expensive.
TDK MPU6000	Has ROS2 drivers Large back catalog of prior support Lower default frame times, easier to filter in post-processing	Older, falling out of favor (some drivers must be backported) Little to no on-chip noise filtering

Audio - Speaker

Selection: 8 Ohm 1W Voice Range Speaker

- Range suited for speech cues
- Higher impedance at sufficient volume within a grocery store environment
- Low power consumption

Product	Nominal Impedance (Ohms)	Rated Power (W)	Sensitivity (dB SPL)	Frequency Range (Hz)
2.5 Inch Full Range Speaker	4	3	88.5	200-20000
1.1 Inch (28 mm) 8 Ohm Voice Range Speaker	8	8	86	650-6000
1.5 Inch (40 mm), 8 Ohm Voice Range Speaker	8	1	81	350-6000

Audio - Driver

Selection: Class D (PAM8302AASCR)

- Greatest efficiency
- Lightest weight
- Capable of supporting the 8 Ohm 1 W speaker (rated for 2.5 W and at least 4 Ohm)

Amplifier Class	Typical Efficiency	Pros	Cons
A	~15-35%	No possibility of crossover distortion.	Inefficiency = heat Single ended designs prone to hum and higher levels of distortion.
B	~70%	Relatively high efficiency.	Potential for significant amounts of crossover distortion and compromised fidelity
A/B	~50-70%	More efficient than Class A. Relatively Inexpensive. Crossover distortion can be rendered moot.	Efficiency is good, but not great.
G & H	~50-70%	Improved efficiency over Class A/B.	Costlier than Class A/B but higher power levels are achievable in a smaller form factor.
D	>90%	Best possible efficiency Light weight.	Pulse width modulators operating at relatively low frequencies can compromise high frequency audio reproduction. Some designs produce varying sound quality depending on speaker load.

Haptic - Motor and Driver

Selection: Coin ERM

- Very cheap, including common DC drivers (DRV2605L)
- Supports libraries for multiple modes
- Strong haptic feedback
- Precision doesn't matter much
- Easy to integrate with the shopping cart handlebar

Motor Type	Mechanism	Drive Signal	Power Consumption	Haptic Feedback	Size	Cost
ERM	Rotation of an unbalanced mass	DC Voltage	Moderate	Strong but imprecise	Larger than LRA and Piezo	Low
LRA	Linear oscillation of a mass on a spring	AC Voltage at resonant frequency	Low	Moderately strong, more precise than ERM	Compact	Moderate
Piezo	Deformation of piezoelectric material	AC Voltage at highfrequencies	Low to moderate	Very high precision	Ultra-compact	High

Power Distribution Table

Component	Supply Voltage	Maximum Current Draw	Maximum Power Consumption	Average Power Consumption (90% Efficiency)
ATLS104D Laser Driver	3-5V (3.3V)	200 mA	0.66W	0.73W
CEVA BNO085 IMU	1.71-3.63V (3.3V)	790 uA	0.0026W	0.003W
PAM8303AASCR Class D Amplifier	2-5.5V (3.3V)	450 mA	1.485W	1.65W
DRV2605L Haptic Motor Driver (One-Hot)	2-5.2V (3.3V)	80 mA	0.264W	0.293W
ESP-32 Microcontroller	3.0-3.6 V (3.3V)	200 mA	0.66W	0.73W
Raspberry Pi 5	5V	5A	25W	27.78W
Total	**-**	**6A**	**28.07W**	**32.2W**

Power Source Technology

Selection: LiFePO4 (Li-ion) Battery

- Portable, reliable power
- Increased weight manageable due to cart chassis
- System requirements: **Maximum 35W, 6A peak current draw**
- Products have additional capacity with included over-current, over-discharge, and overcharge cases

Battery Technology	Energy Density	Output Capacity	Cost	Rechargeable Cycle Life	Safety	Potential Risks
LiFePO4	High	Moderate	Moderate	500-5000 cycles	Moderately safe with protection circuits	Overheating, thermal runaway without protection
LiPo	Very high	High	Moderate	300-500 cycles	Less safe, prone to swelling and puncture	Thermal runaway, risk of swelling without protection circuitry
NiMH	Moderate to low	Low	Low	Up to 1000 cycles	Very safe	Bulky and heavy

Product	Voltage (V)	Capacity (Ah)	Cost	Safety
XZNY LiFePO4	12.8	8	$24.99	Built-in BMS
NERMAK LiFePO4	12.8	10	$33.99	Built-in BMS
BtrPower LiFePO4	12.8	8	$29.99	Built-In BMS

Voltage Regulators

Selection: LM2679SX-ADJ Switching Regulators

- High efficiency, low heat robust regulators
- Supports maximum current draw (5A) and battery input voltage (12.8V)
- Multiple regulators used for various component demands (adjustable output voltage model)

Regulator Type	Efficiency	Heat Dissipation	Noise	Cost	Applications
Switching	High (~90%)	Low	Higher	Higher	High-power, high-efficiency
Linear	Low (~30-50%)	High (excess power dissipated as heat)	Very low (ideal for sensitive circuits)	Lower	Low-power, low-noise

Product	Input Voltage Range (V)	Output Current (A)	Output Voltage Range (V)
LM2679SX-ADJ	8-40	5	1.21-37
LM2576S-ADJ	4-40	3	3.3-37
TPS543521	3.8-18	5	0.6-17.[illegible]

OPTICAL HARDWARE AND COMPONENT SELECTION

Depth Measuring System Technology

Technology	Depth Accuracy / resolution	Environmental constraints	Reliability	Feasibility	Cost
Active Stereo Vision	Medium-High	Low-Medium	High	Medium	Medium-High
Passive Stereo Vision	Medium	Medium	Medium	Medium	Low
Structured light depth sensing	Medium-High	Medium	Medium	Medium	Medium
Sonar	Low-Medium	High	Low	High	Low
Lidar	Very High	Low	High	Low	Very High

Selection: Active Stereovision

- Robust and Reliable
- Somewhat commonly used (Xbox Kinect)
- Cheaper than LiDAR

Pigtailed Laser Diode Product

Product Manufacturer and Number	Optical Power	Fiber type	Operating Voltage (V)	Operating Current (mA)	Threshold Current (mA)	Price (USD)
Xinland Group 650nm 50mW	50mW	SM	2.4	130	50	110
Civilasers 650nm Pigtailed Laser(SM)	80mW	SM	2.4	180	55	211
Laser Tree LT-660030-SM-FC	30mW	SM	2.5	135	55	155
Shengshi PLD-F85	120mW	SM	2.4	300	18	78.66

Selection: Xinland Group 650nm 50mW

- Reliable Manufacturer
- Cheaper than most products

Laser Diode Driver Product

Product	Mode	Input Supply (V)	Max Output Current (mA)	Price (USD)
LDD200P Series 200mA	Constant current	5 - 12	200	$105.00
Thorlabs LDC205C Benchtop LD Current Controller	Constant current, constant Power	120 (AC)	500	$1210.31
ATLS1A104D	Constant Current	3.3 - 5	1000	$69.00

Selection: ATLS1A104D

- Cheap
- Easy to use – DAC current set

DOE Light Pattern

Pattern type	Depth Information Quality	Environmental Robustness	Processing Complexity
Random Dots	High; Unique local features, low ambiguity	Moderate; Innefective with non-solid objects, resilient against occlusion	High; Exhaustive feature matching required
Dot Array	Moderate-high; Suffers from pattern ambiguity, dependent on number of dots	Low-Moderate; Innefectiove with non-solid objects	Moderate; Geometric asumptions would help,
Horizontal and Vertical Lines	Moderate; Suffers from ambiguity, Dependent on number of lines	Moderate-High; Effective with non-solid objects	Low; edge detection is computationally efficient

Selection: Horizontal and Vertical Lines

- Low processing complexity
- Most amount of features

DOE Product

Product Manufacturer and Part Number	Grid Size (V x H)	Field of View (V x H)	Material	Line Density in a 100cm^2 area 3m away Possible features	Cost
DigigramDTC-25	60 x 60	40 x 40	PET or PMMA	5.4 16.47	$80
Laserland QYG-004	51 x 51	30 x 30	PMMA	6.2 22.63	$1.5
HOLOEYE DE-R256	51 x 51	30 x 30	Polycarbonate (PC)	6.2 22.63	$72
Lasermate DOE-SG60	60 x 60	30 x 30	PET	6.7 27.36	$23

Selection: Lasermate DOE-SG60

- Reliable Manufacturer
- High amount of possible features
- Cheaper than other available products
- Designed for 650nm which caused problems with 850nm laser

Camera Sensor Technology

Sensor Technology	Spectral Compatibility and Sensitivity	Image Quality	System Integration	Cost and Availability
CMOS	Moderate; QE of 50% at 650nm, higher in back-side illumination sensors	Good resolution; moderate noise; decent dynamic range	High; Low power and easy integration	Low cost High availability
sCMOS	High; QE of >70% at 650nm; good for low light	Exceptional resolution; Low noise; Wide dynamic range	Moderate; Higher power consumption, higher computational power	Moderate-High cost Moderate-High availability
CCD	Moderate; QE of 65% with back-side illumination	Low noise; Excellent uniformity; Slower readout	Moderate; Higher power consumtion, larger size, outdated	Moderate cost Moderate availability
EMCCD	Very High; QE of >90% at 650; good for low light	Ultra low noise; High uniformity; few photon detection	Very low; Complex electronics, cooling requirements	High cost Low-Moderate availability

Selection: CMOS

- Reliable and very commonly used
- High QE at VIS wavelength
- Plug and Play USB

Camera Sensor Product

Camera name (Sensor name)	QE at 650nm (%)	SNR (dB)	Resolution	Dynamic Range (dB)	Price (USD)
Arducam Pivariety 2.2MP Mira220	54	40	1600 x 1400 (2.2 MP)	62dB	110
Arducam 1MP OV9281	~30	38	1280 x 800 (1MP)	68	25
Thorlabs CS165MU	20	69	1440 x 1080 (1.6MP)	66.4	850
Arducam 2MP IMX323	90	42	1920 x 1080 (2MP)	72	49

Selection: Active Stereovision

- Cheap option
- Good for lowlight environments
- UVC compliant, no extra drivers needed

Fiber Optic Splitter Technology

Splitter technology	Insertion and Excess Loss (dB)	Wavelength Uniformity	Availability and Cost
FBT	Moderate; Insertion loss: 3.2-3.5 Excess loss: 0.19-0.99	Moderate; Sensitive to wavelength changes of more than 100nm	High availability Low cost
PLC	Low; Insertion loss: 3.11-3.21 Excess loss: 0.1-0.2	High; Sensitive to wavelength changes of more than 200nm	High availability Moderate cost

Selection: Active Stereovision

- High available in market
- Cheap options
- Most comonly used for 1x2 connectors

Fiber Optic Splitter Product

Product Distributor and Number	Insertion and Excess Loss (dB)	Splitting Ratio Accuracy	Operating Wavelength Range	Cost
Thorlabs #TW670R5F1	Insertion: ≤4.2 dB, Excess: ≤0.3 dB	50:50 ±6%	650nm ±75nm, With the posibility of handling other wavelengths at higher attenuation	$415
Anhui Wanchuang Communication Technology SM 650nm 1x2	Insertion: ≤3.8 dB, Excess: ≤0.5 dB	50:50 ±6.5%	650nm ±20nm, With the posibility of handling other wavelengths at higher attenuation	$230
Qingdao Applied Photonic Technologies 650nm SM 1x2 50:50	Insertion: ≤3.9 dB, Excess: ≤0.8 dB	50:50 ±6.5%	650nm ±60nm, With the posibility of handling other wavelengths at higher attenuation	$180

Selection: Active Stereovision

- Reliable Manufacturer
- Low Excess loss
- Big range of operating wavelength

SCHEMATICS & PCB DESIGN

PCB Design Choices

Main Board:

- ESP32, UART-to-USB module (CP2102), IMU, speaker amplifier, haptic motor drivers.
- Contains input/outputs to the SBC, output connectors to the peripherals devices (speaker/haptics), input power and programming connections.
- Separation of analog components and lines (DAC, ADC, speaker amplifier) from digital components and lines.

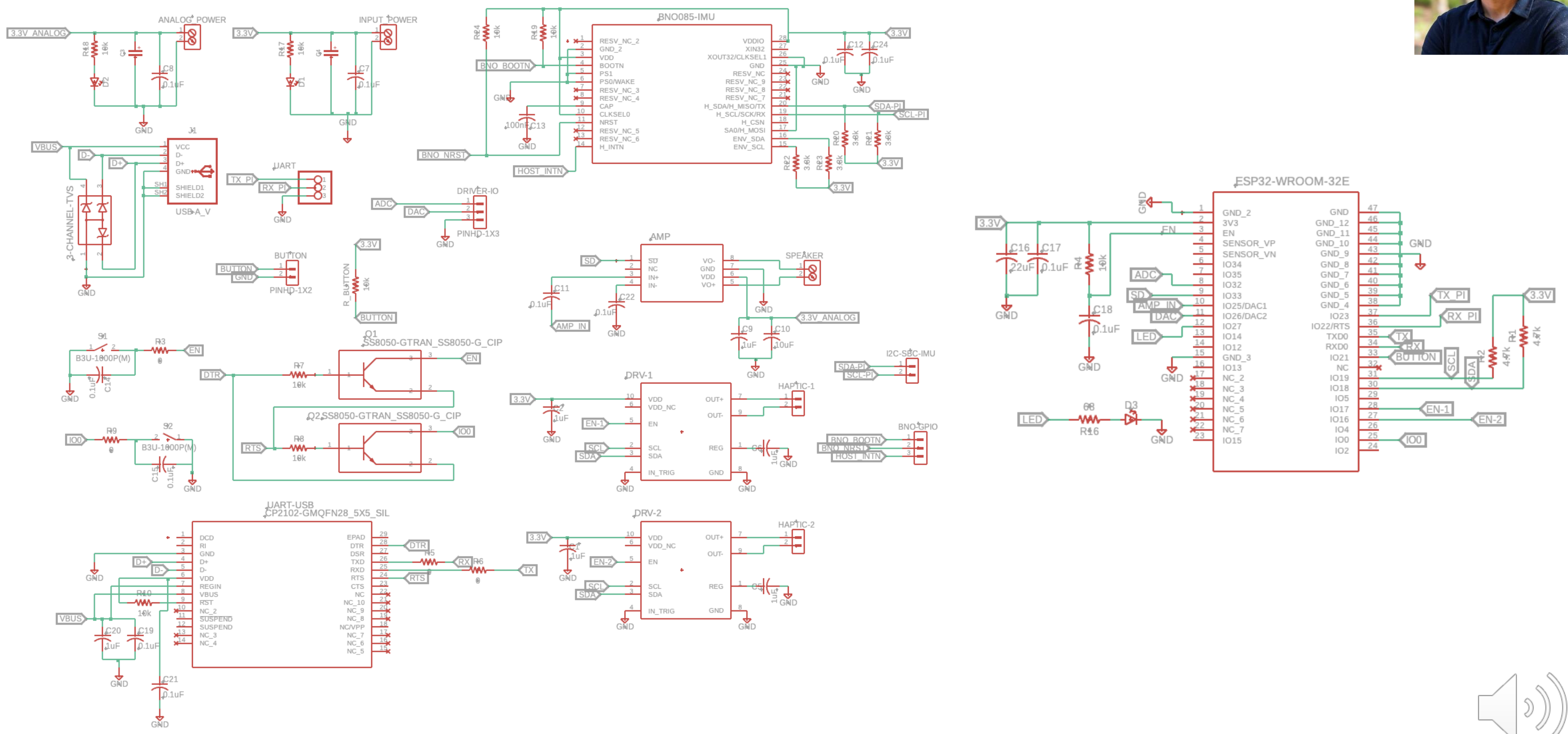
Power Daughterboards:

- Adjustable switching regulator for both 5V and 3.3V output for various components and separation of digital and analog supplies.
- Input from battery, output to boards.
- Easy to replace in the event of failure or burnt-out boards. On-board status LEDs.

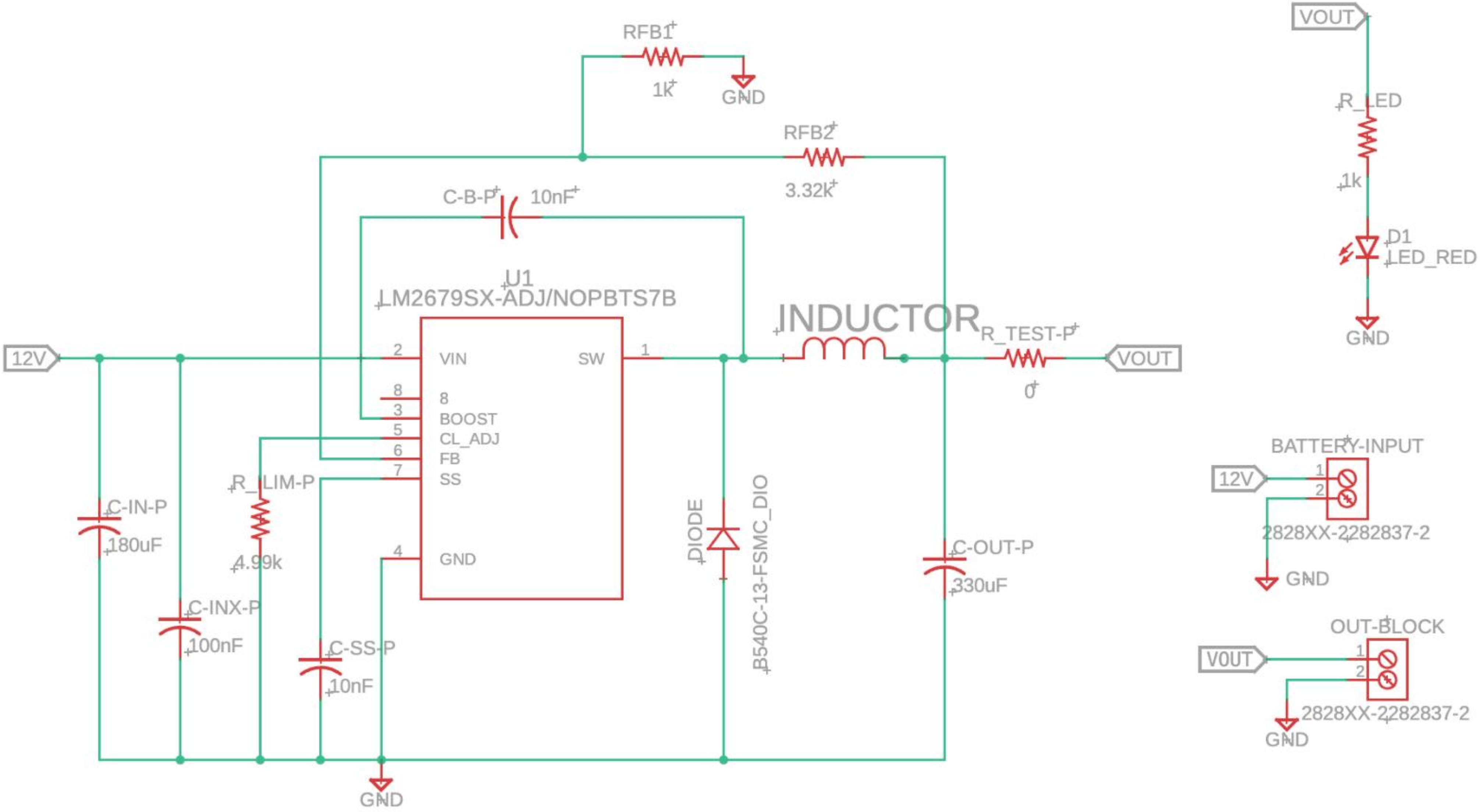
Laser Diode Driver Daughterboard:

- Laser diode driver, input/output to MCU for laser modulation and current diagnostics, separate input power supply and output to laser diode terminals.
- Dedicated board for analog and thermal management. Closer positioning to the laser diode mount.

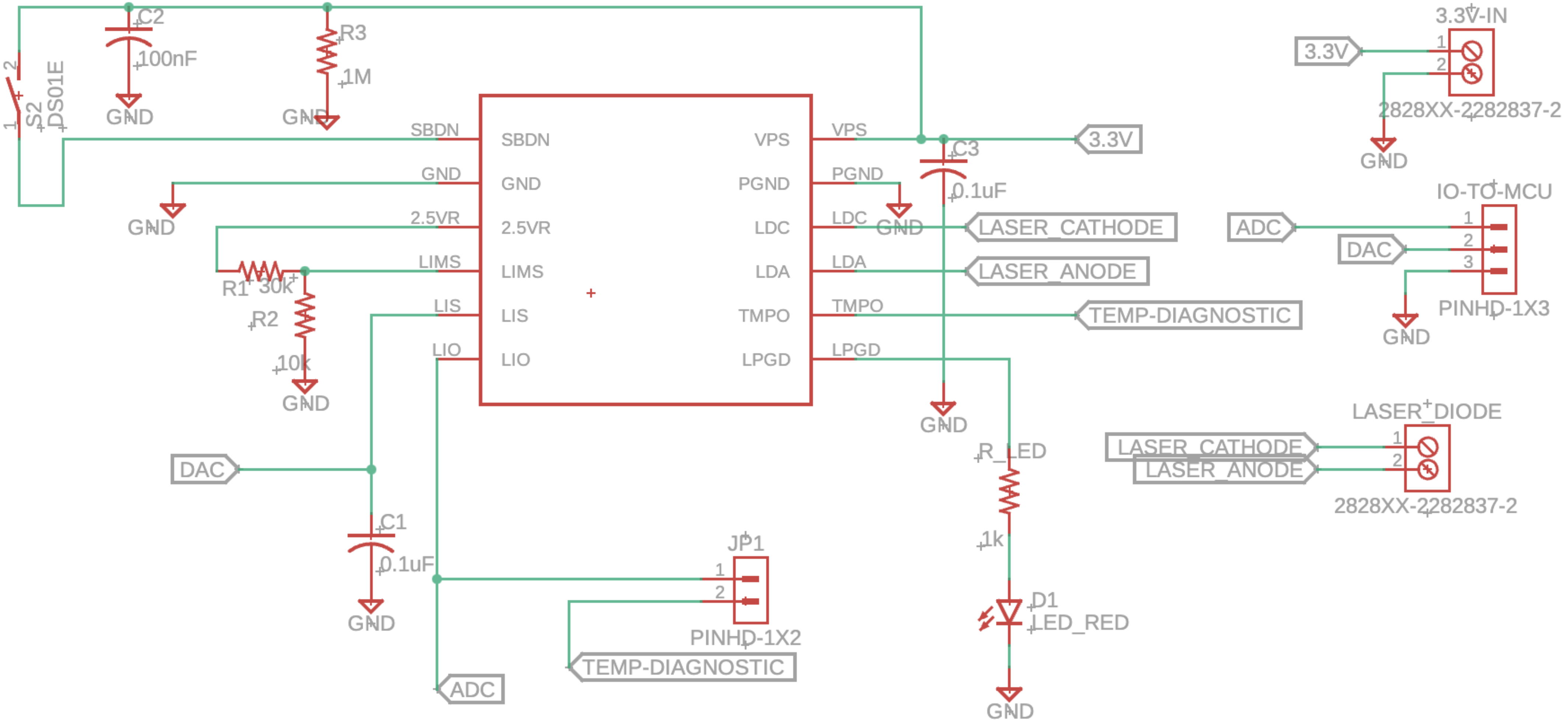
Main Board Schematic



Switching Regulator Schematic

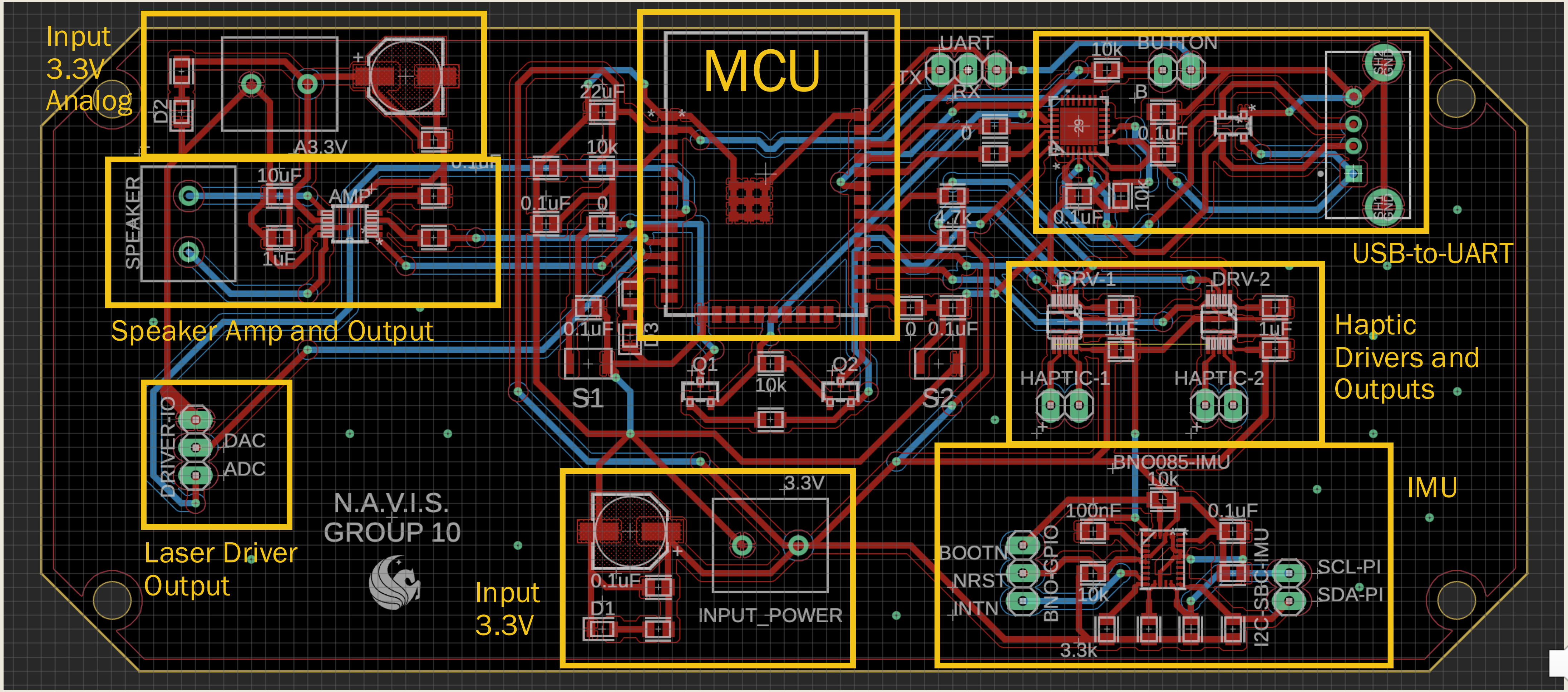


Optical Driver Board Schematic



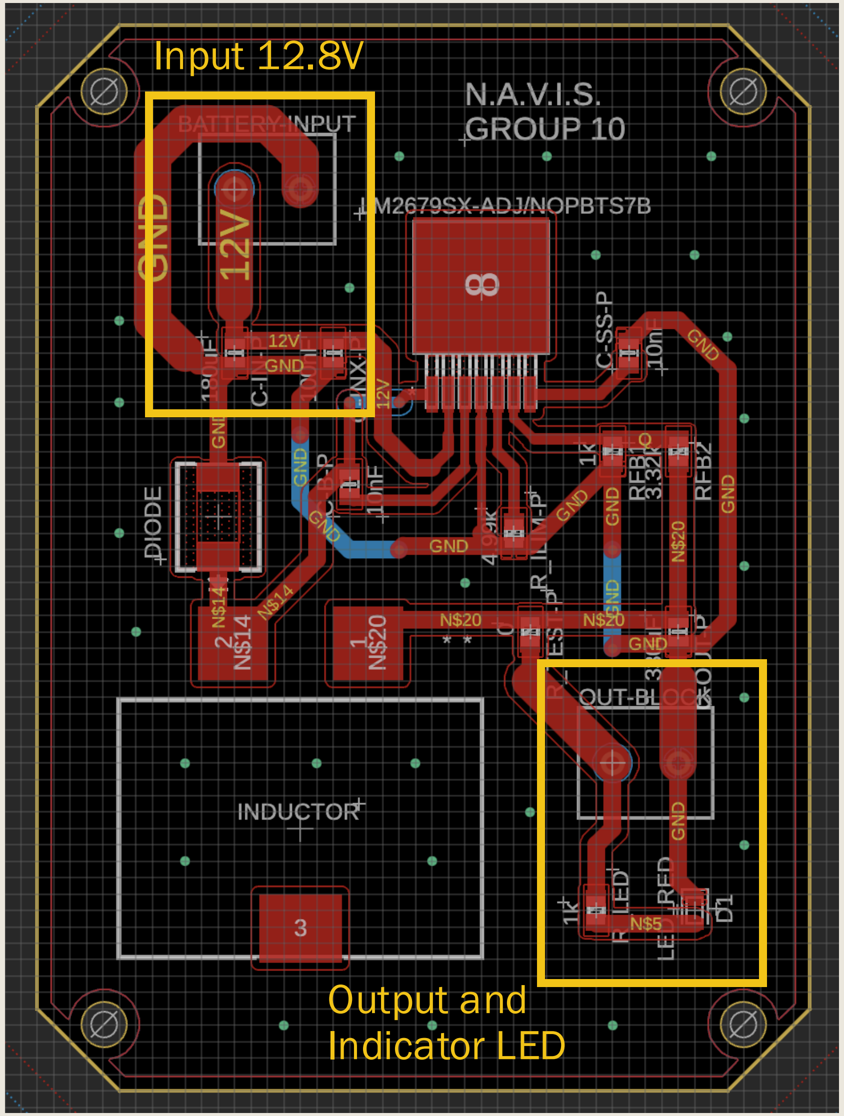
PCB Layouts

Main Board

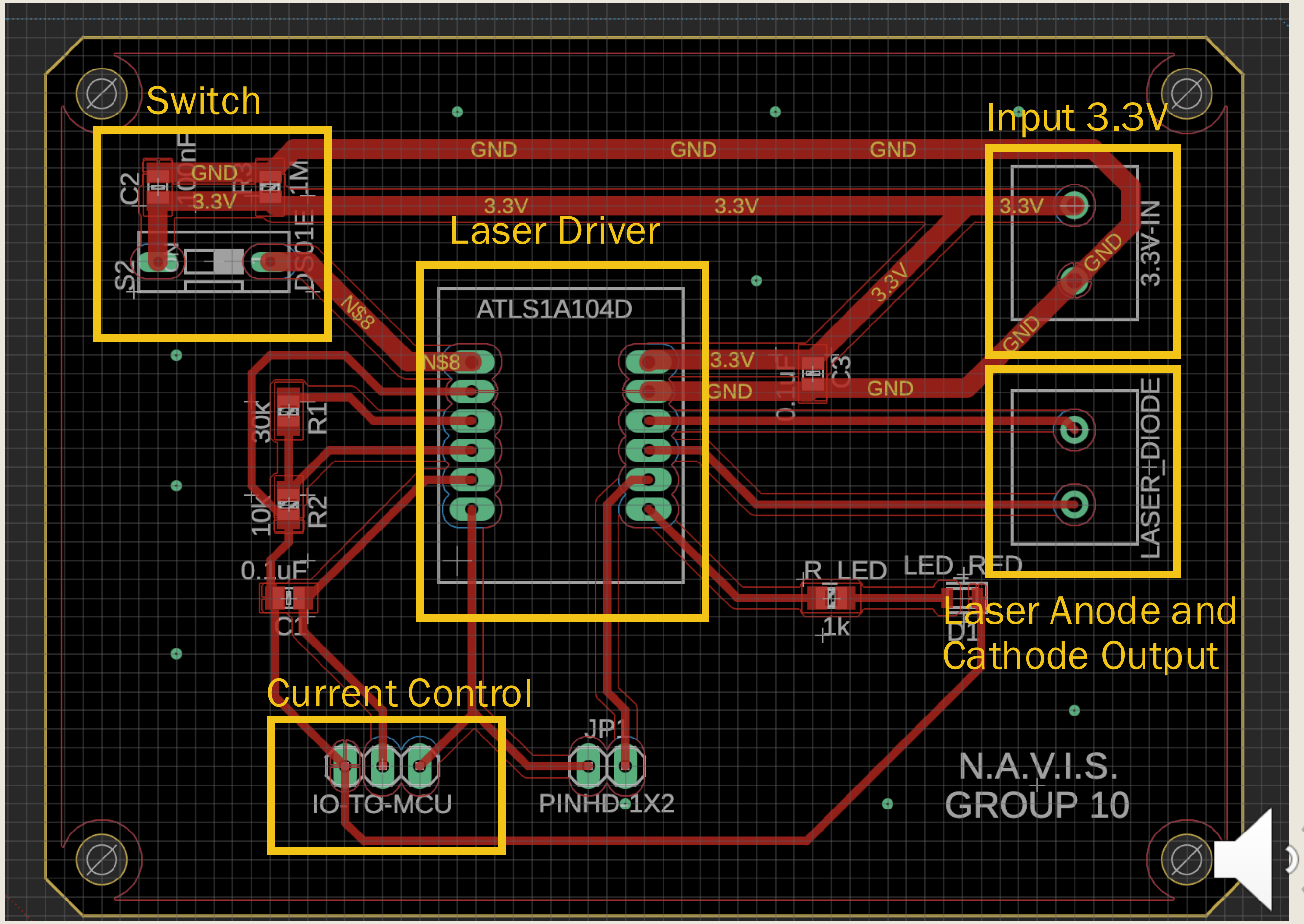


PCB Layouts

Switching Regulator

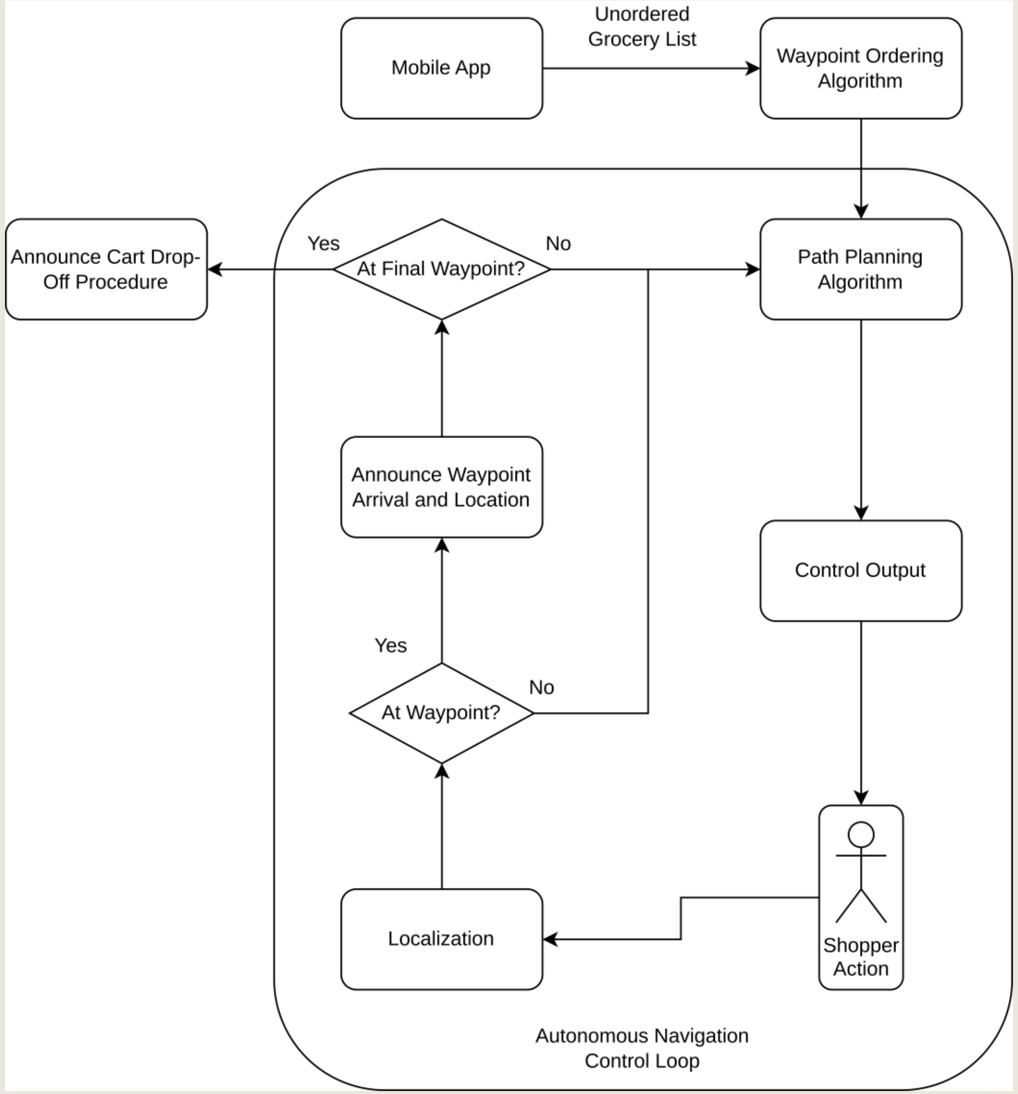


Laser Diode Driver

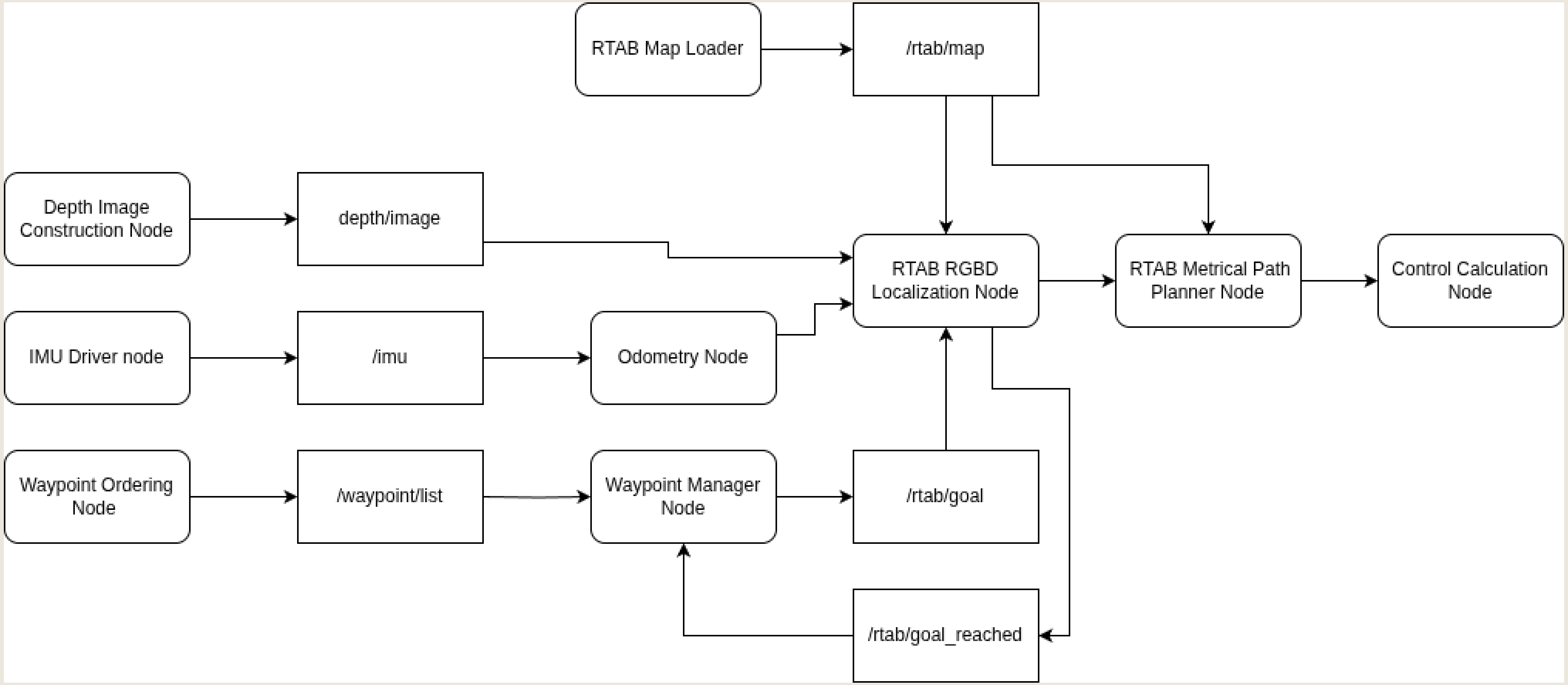


SOFTWARE DESIGN

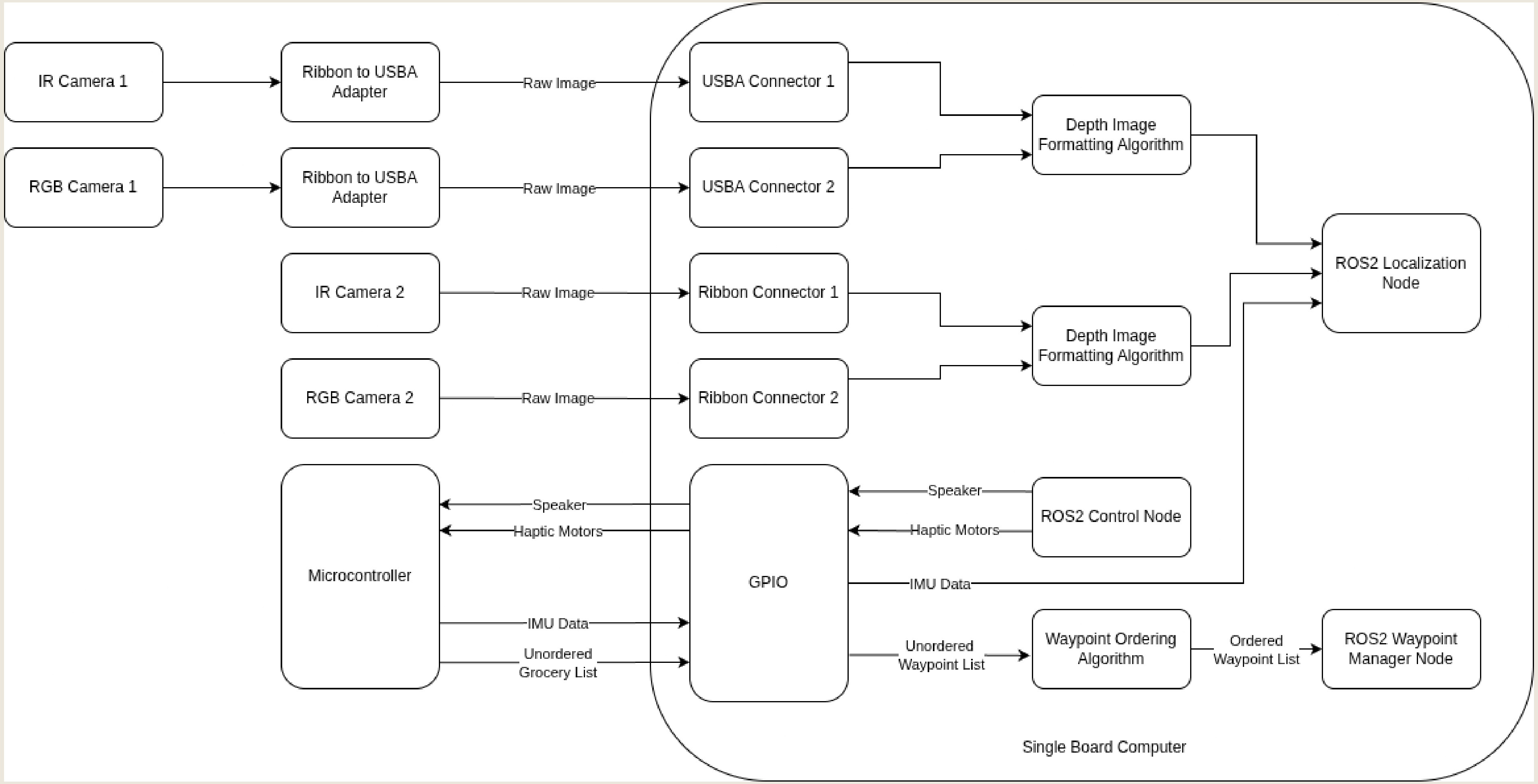
Autonomous Navigation Flowchart



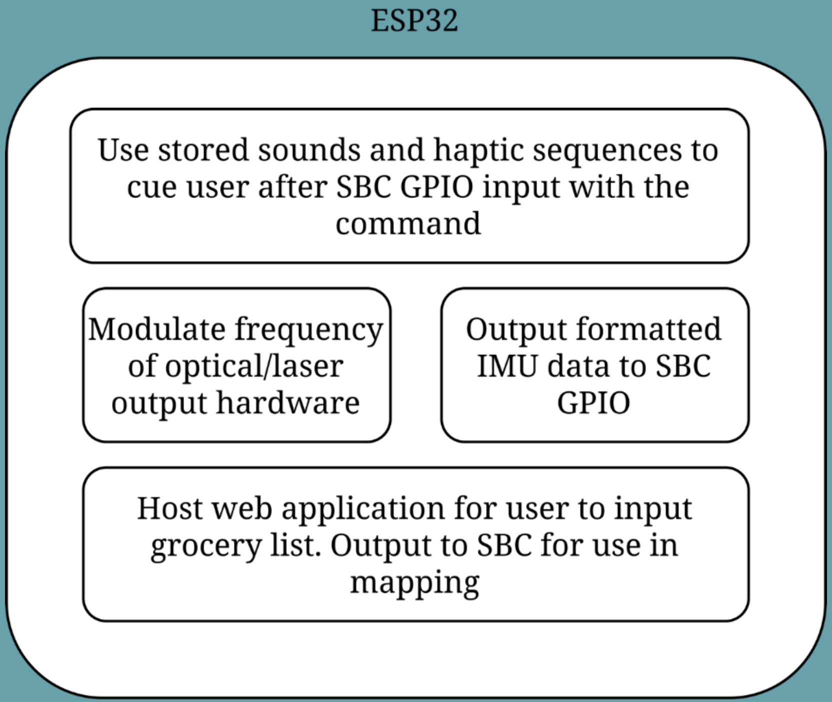
ROS2 System Architecture

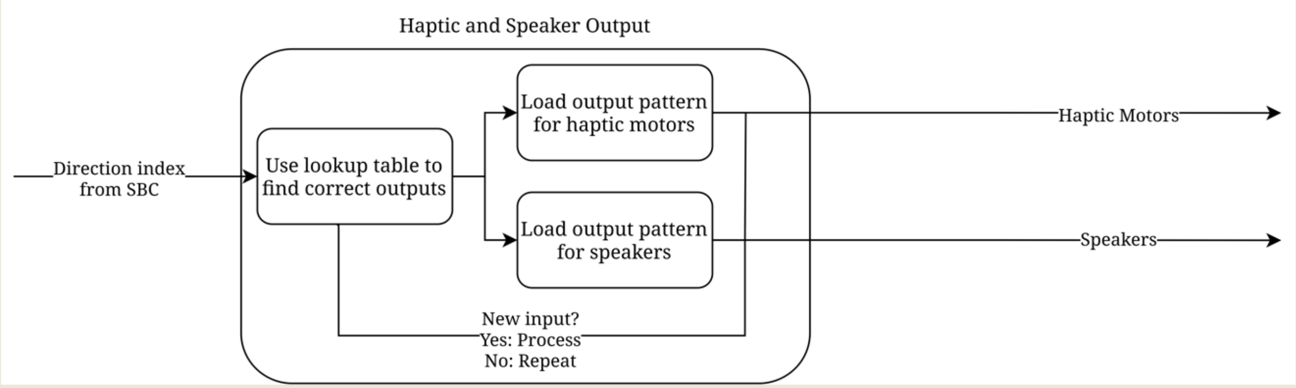


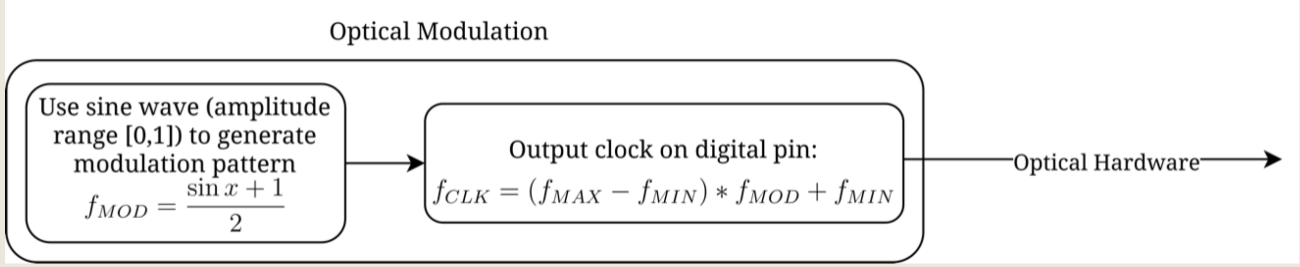
SBC IO Block Diagram



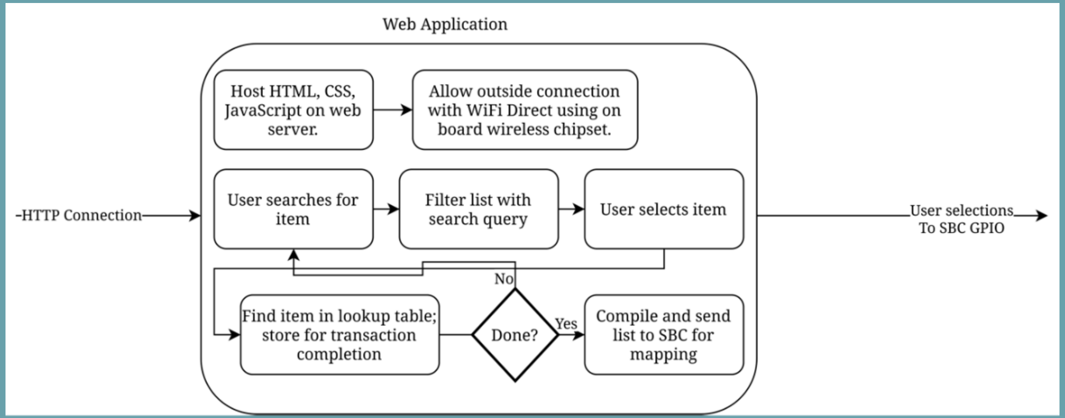
Microcontroller Programs

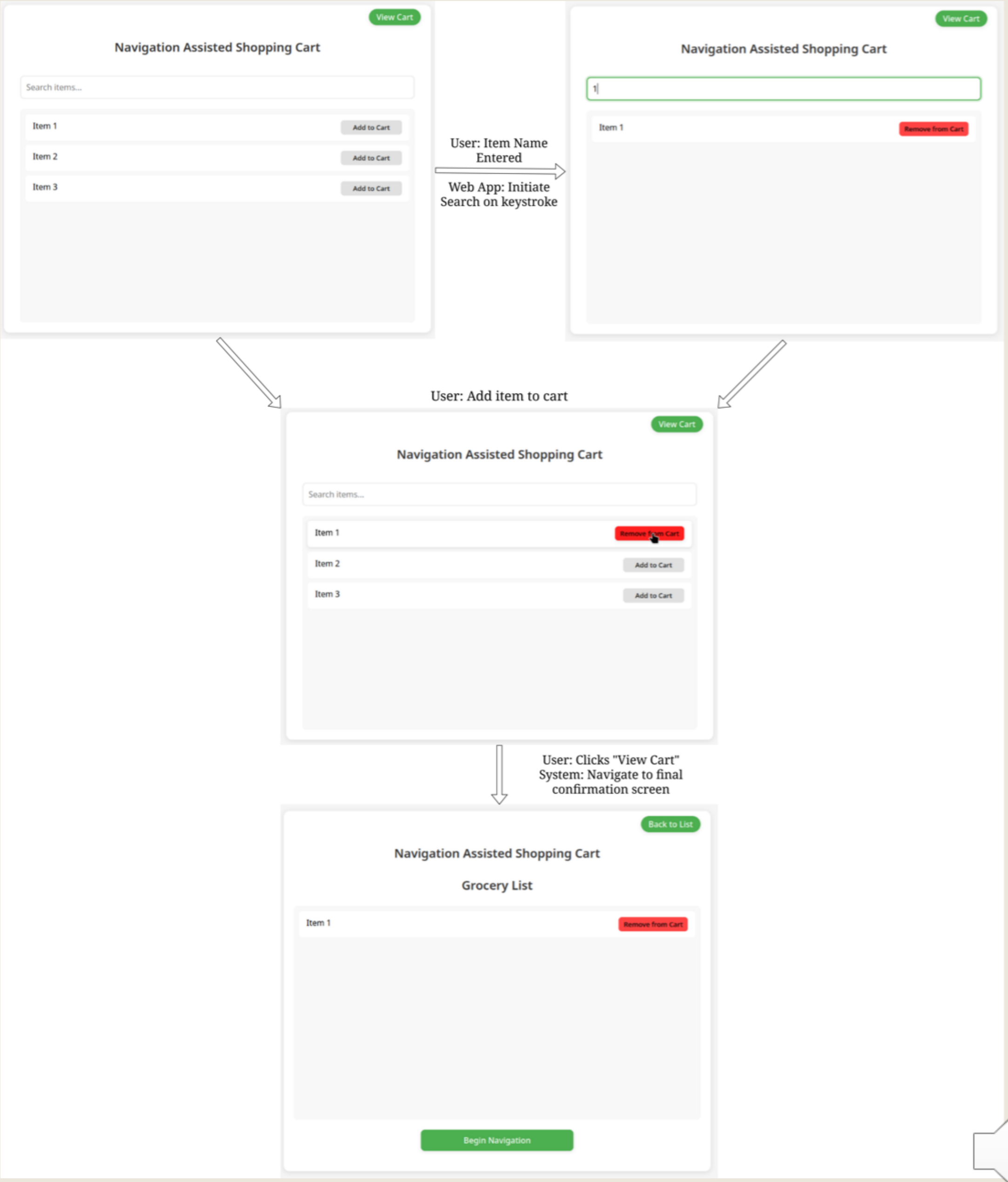






Microcontroller Programs – Web App Overview & UI





SOFTWARE COMPARISON AND SELECTION

Wireless Communication

Wireless communications leveraged between the **user's device and the system** as an **input peripheral**

WiFi should have **high availability** in stores and other locations where the product will be used.

- **WiFi** (IEEE 802.11)
  - Grocery List Input
  - Web app <-> Pi & MCU

- **Bluetooth** NOT USED
  - Lower bandwidth
  - Slower
  - Advantage: Point-to-Point Connections
    - WiFi has WiFi Direct for this problem

Wired Communication

Relying on Wired protocols for communication between components – **higher reliability**

Popular and standardized communications protocols are used instead of novel implementations because of **support and ease of use.**

- USB
    - Cameras -> Raspberry Pi
- I2C
    - IMU <-> Raspberry Pi
    - Haptics & Audio <-> MCU
- UART
    - Raspberry Pi <-> MCU

Control Outputs

Selection: Haptic + Speaker

- Gives user the most agency
- Extremely easy to implement as opposed to autonomous motor control or full visualization

Name	Ease of Integration	Advantages	Disadvantages
Haptic	Easy	Can be tuned to be extremely intuitive Very easy to implement Gives user agency	Not extremely robust, allows for collision risks
Speaker	Medium	Easy to give detailed instructions without having to visualize or make motor control scheme	A bit harder to implement than the buzzer
Video Indication	Very Hard	Can be extremely intuitive Gives user agency Customizable	Extremely difficult to design UI and implement software Non-welcoming of completely blind people
Autonomous Control	Very Hard	Extremely robust	Extremely hard to develop

Inter-Process Communication

Selection: DDS

- ROS2 runs DDS under the hood
- Provides a lot of needed infrastructure

DDS Implementation	Latency	Scalability	Ease of Implementation
DDS	Moderate	High	Moderate
MQTT	High	Moderate	Moderate
Custom Rust/C++	Low	Low	Difficult

SLAM Implementation Comparison

Selection: RTAB-Map

- High amount of infrastructure for stereo-vision-based SLAM
- Holds its own planner, so no need for Nav2 interfacing

SLAM Implementation	Available Infrastructure	ASV Interface Quality	NAV2 Interface Quality	Available Documentation
RTAB-Map	High	High	Moderate	High
Slam-toolbox	High	Low	High	High
ORB3_SLAM	Moderate	High	Low	Low

TESTING AND INTEGRATION

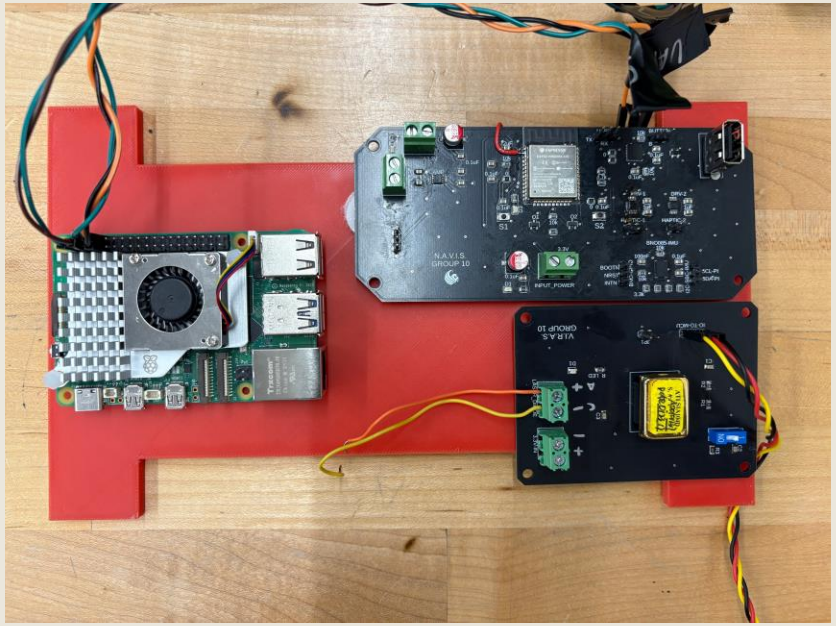
PCB Testing

Successes:

- Switching regulators successfully power all components – load tested.
- Proper booting and peripheral control on main board
- Laser driver drives various diode parts

Challenges:

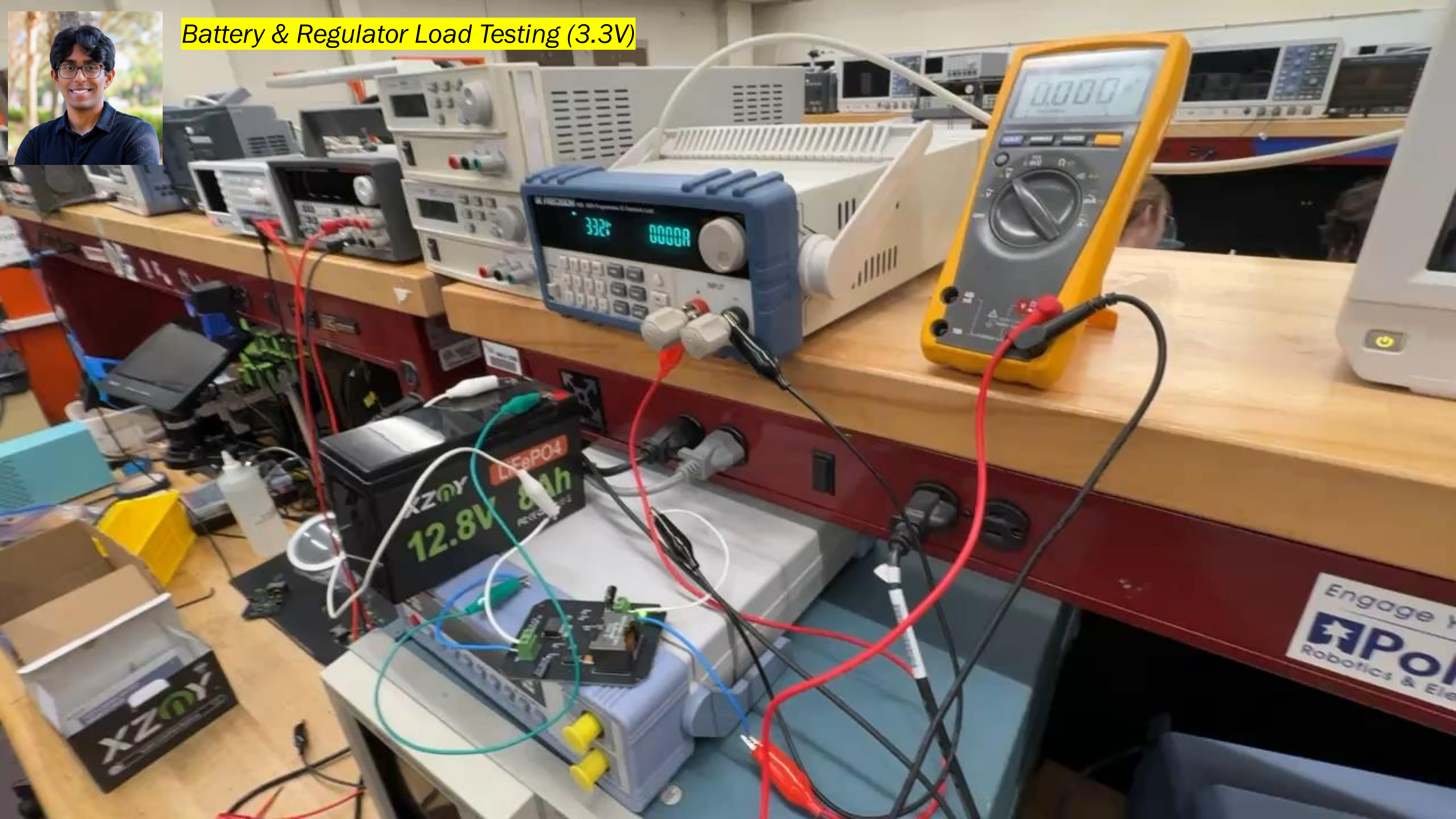
- Incorrect footprint for electrolytic capacitor - Soldered matching electrolytic capacitor on pads – results in a successful output.
- Incorrect filtering capacitor orientation on speaker – Ordered v2 with correct orientation and additional buffer capacitors
- Haptic motors reduced from 4 to 2



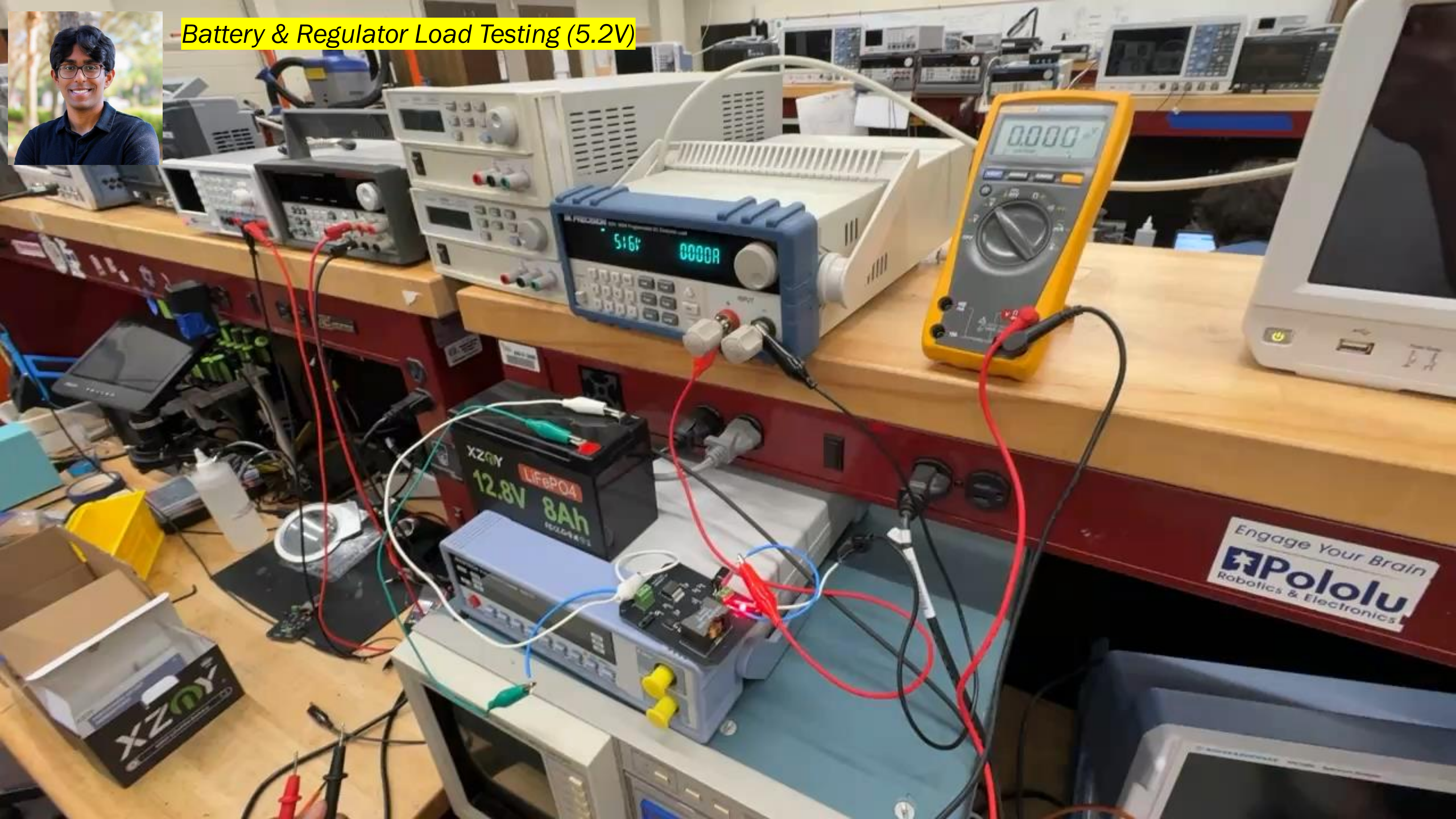
Logic boards assembly

Power boards assembly

Battery & Regulator Load Testing (3.3V)

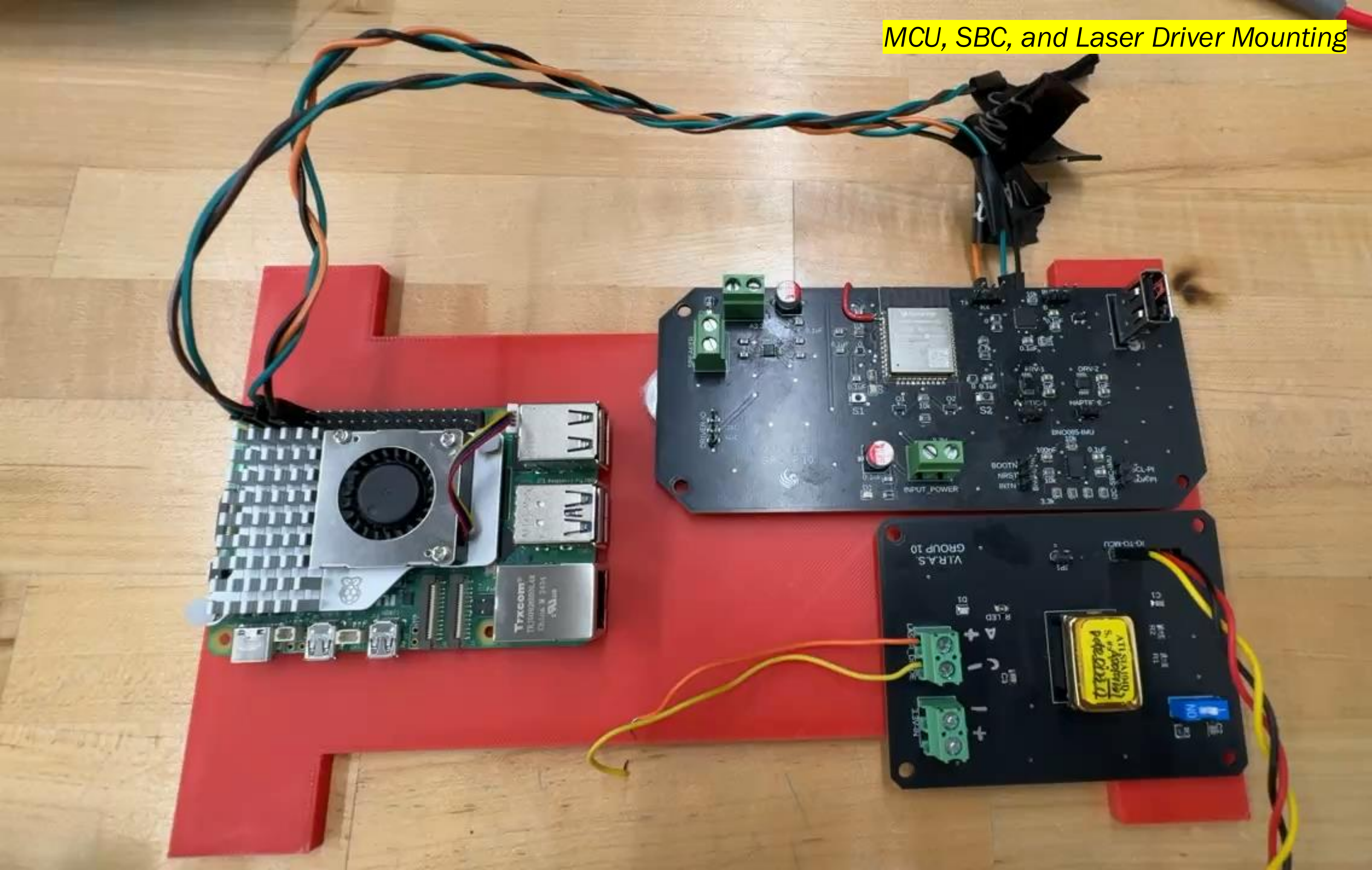


Battery & Regulator Load Testing (5.2V)

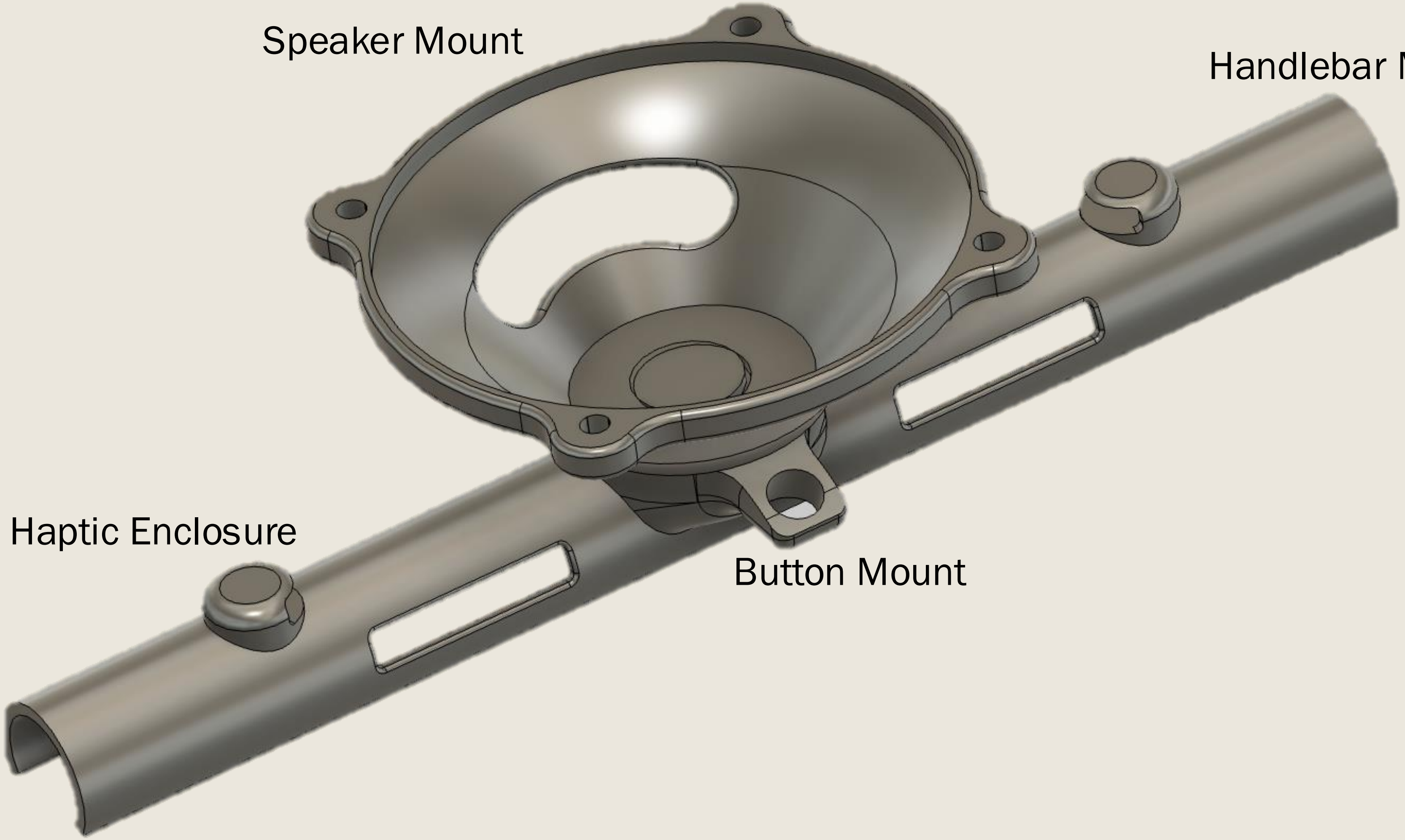


Pictured: Regulator Mounting

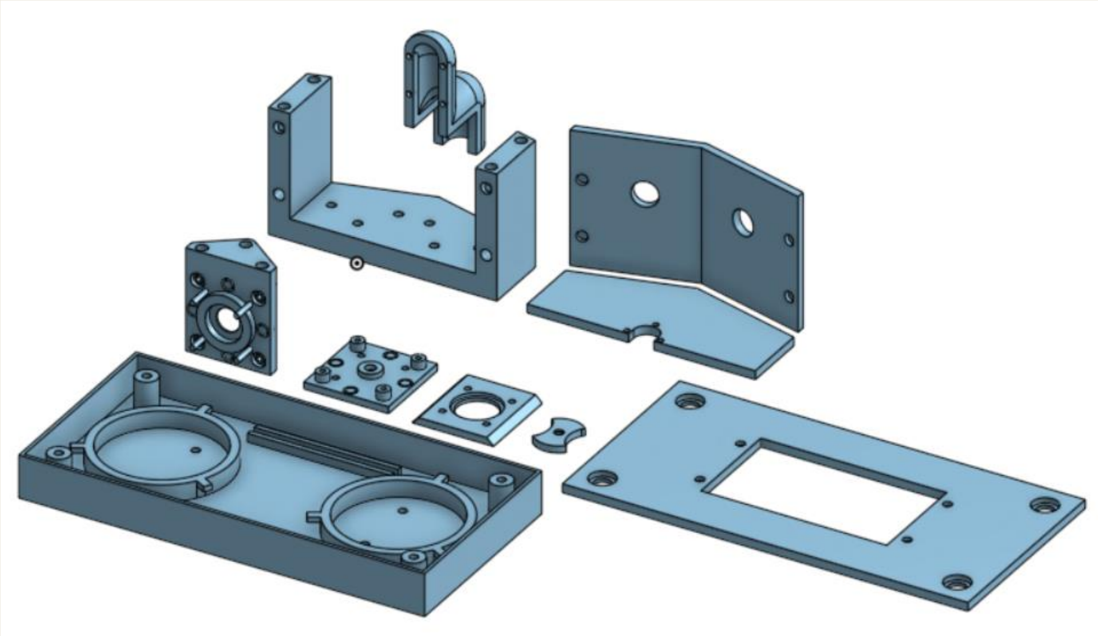
MCU, SBC, and Laser Driver Mounting

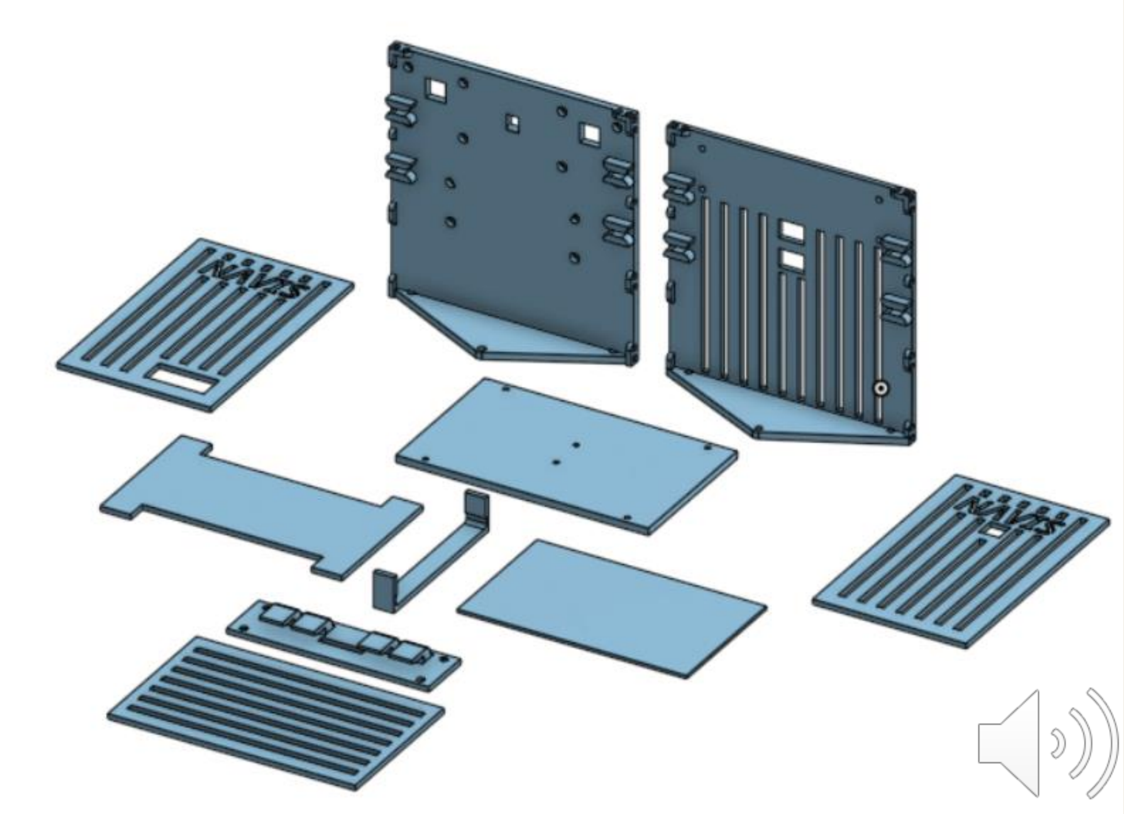


Peripherals Housing

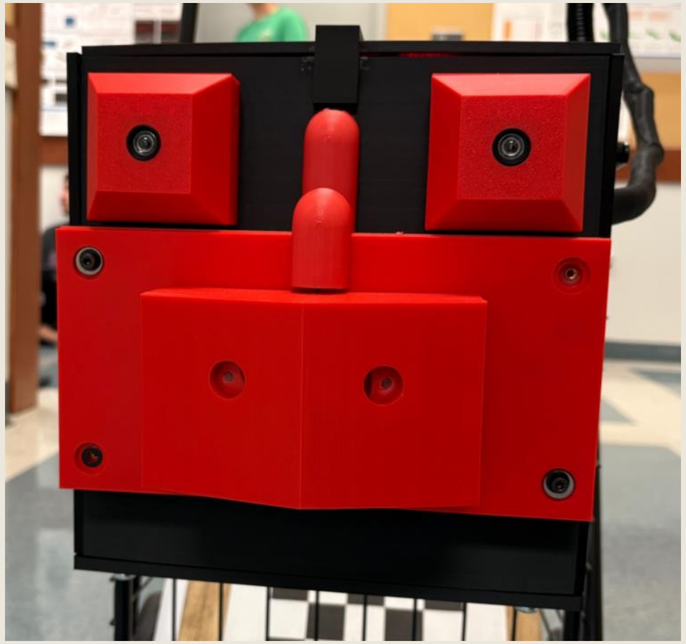


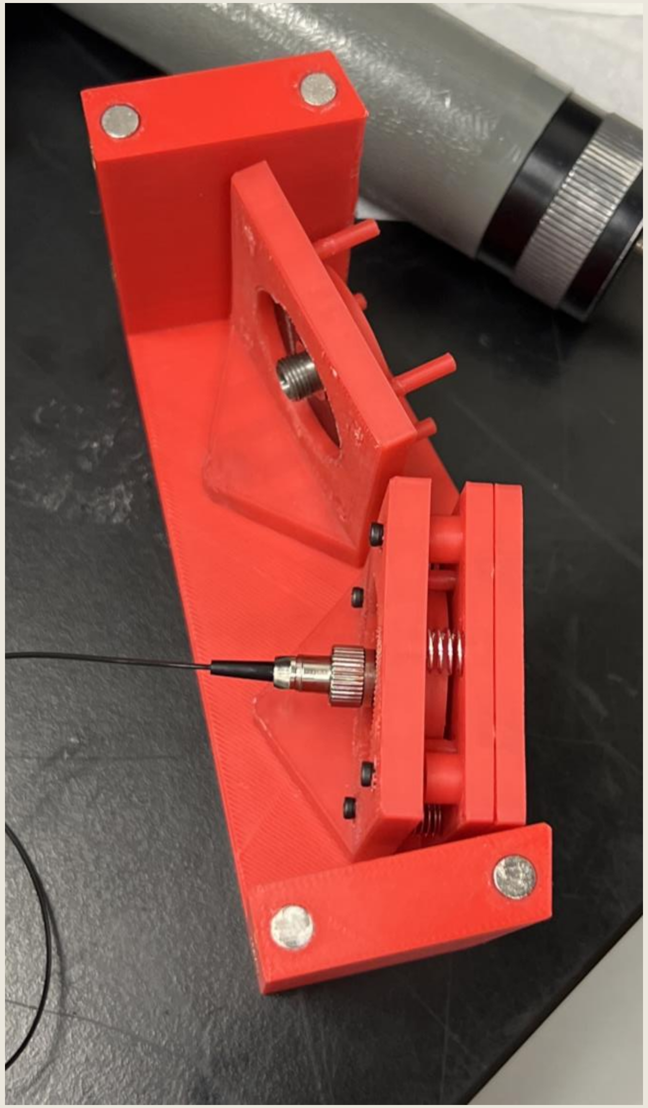
Electronics and Laser Housing

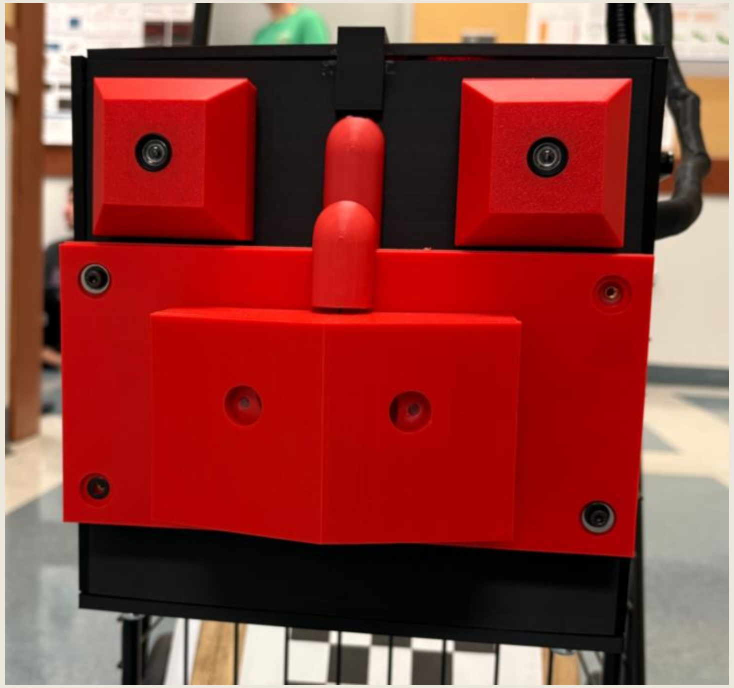




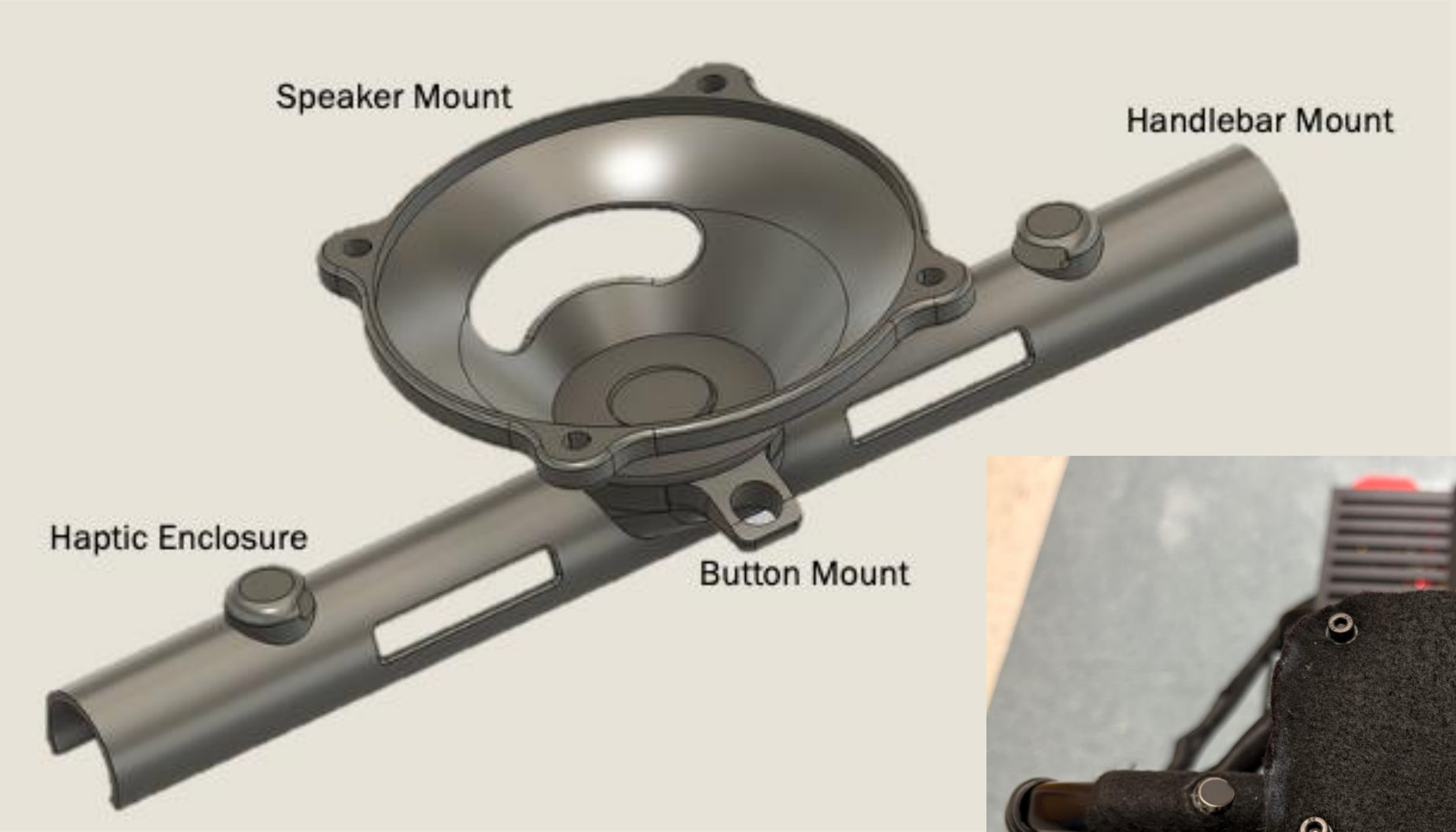
Final Enclosure

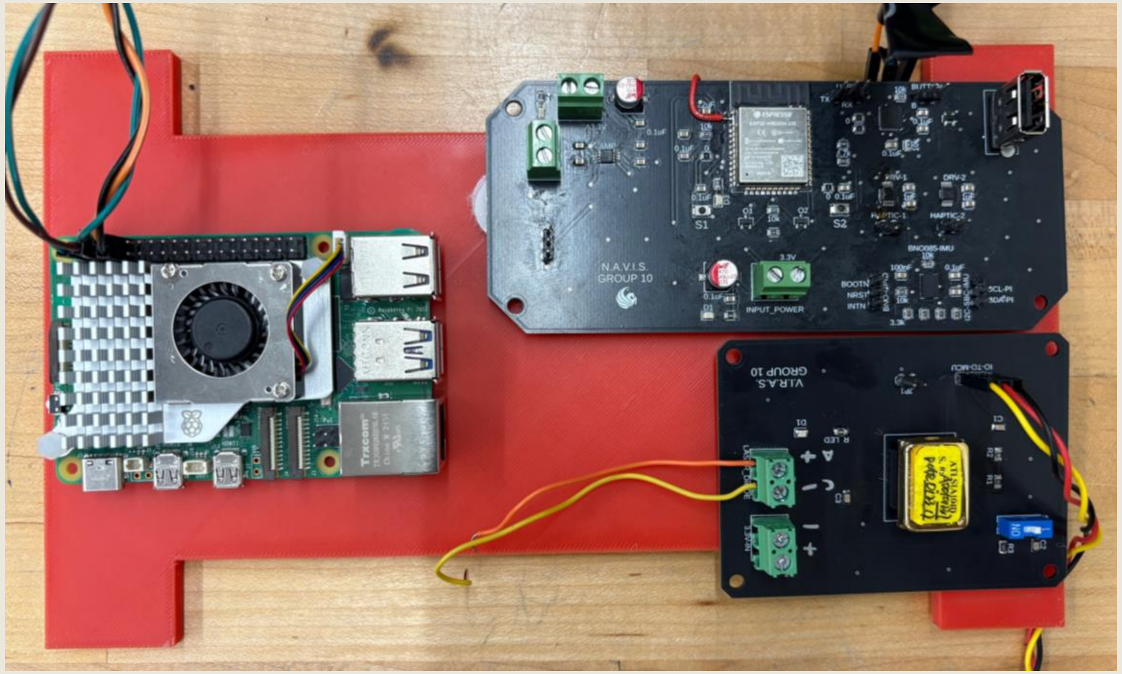


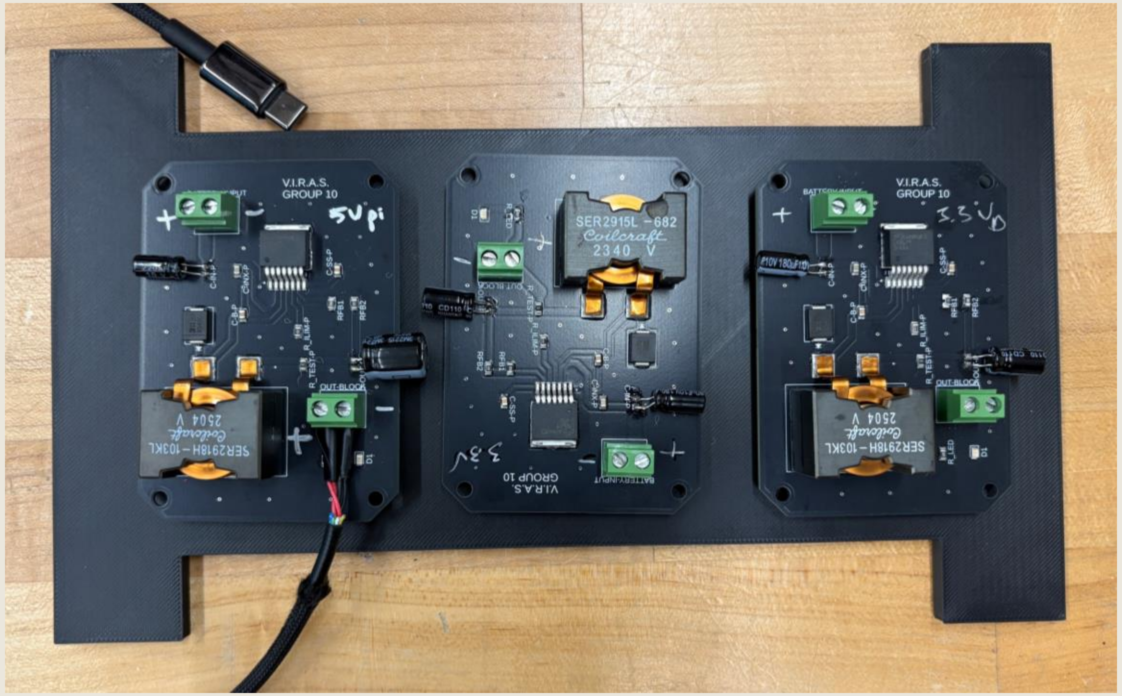





NAVIS
OFF
ON

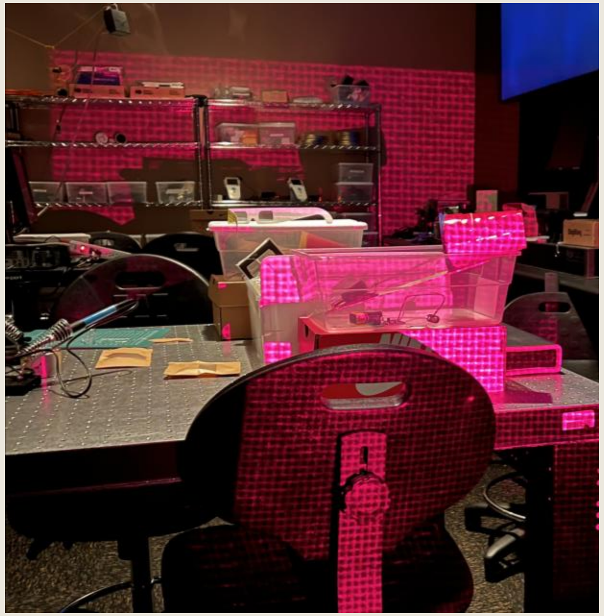

Speaker Mount
Handlebar Mount
Haptic Enclosure
Button Mount

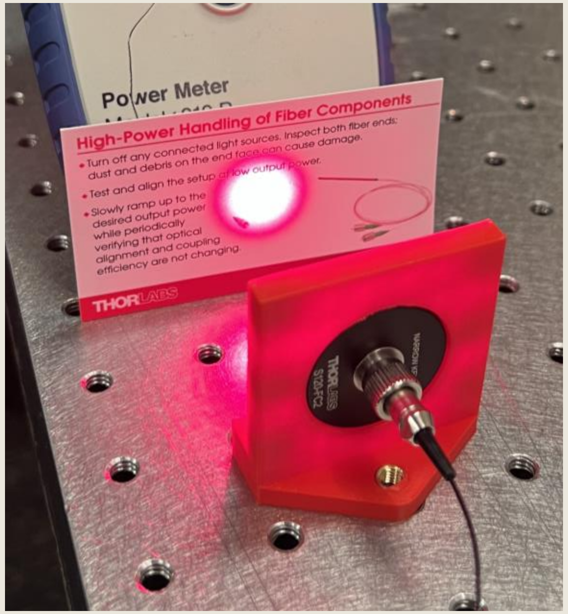

N.A.V.I.S.
GROUP 10
INPUT_POWER
V.I.R.A.S.
GROUP 10

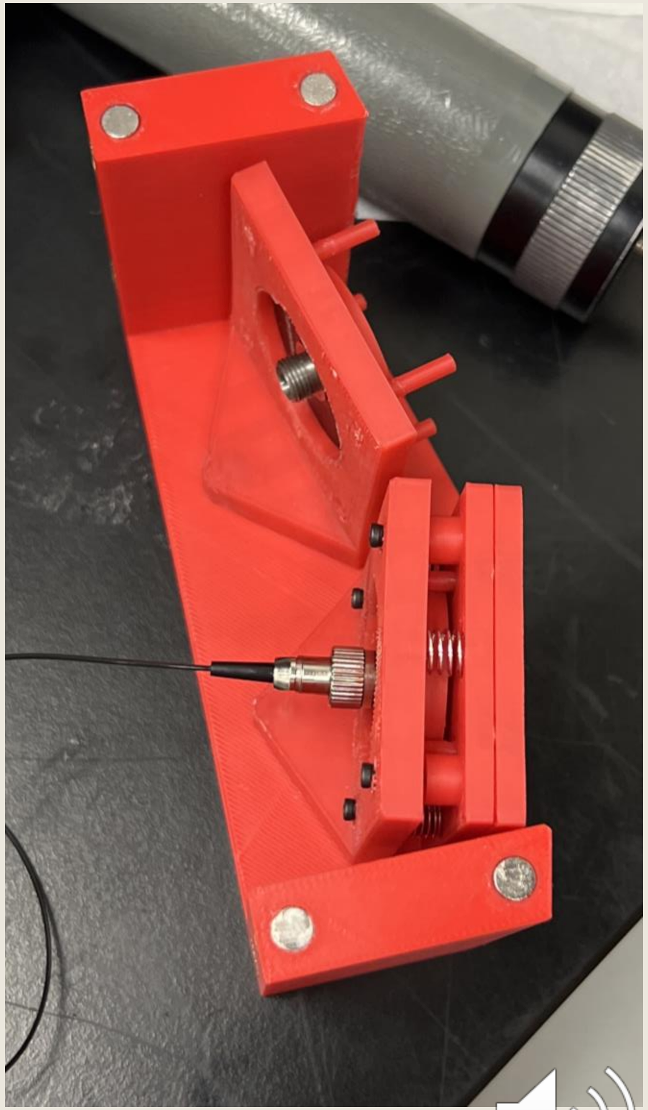

V.I.R.A.S.
GROUP 10
5V pi
SER2915L-682
Coilcraft
2340 V
V.I.R.A.S.
GROUP 10
3.3V
SER2918H-103KL
Coilcraft
2504 V

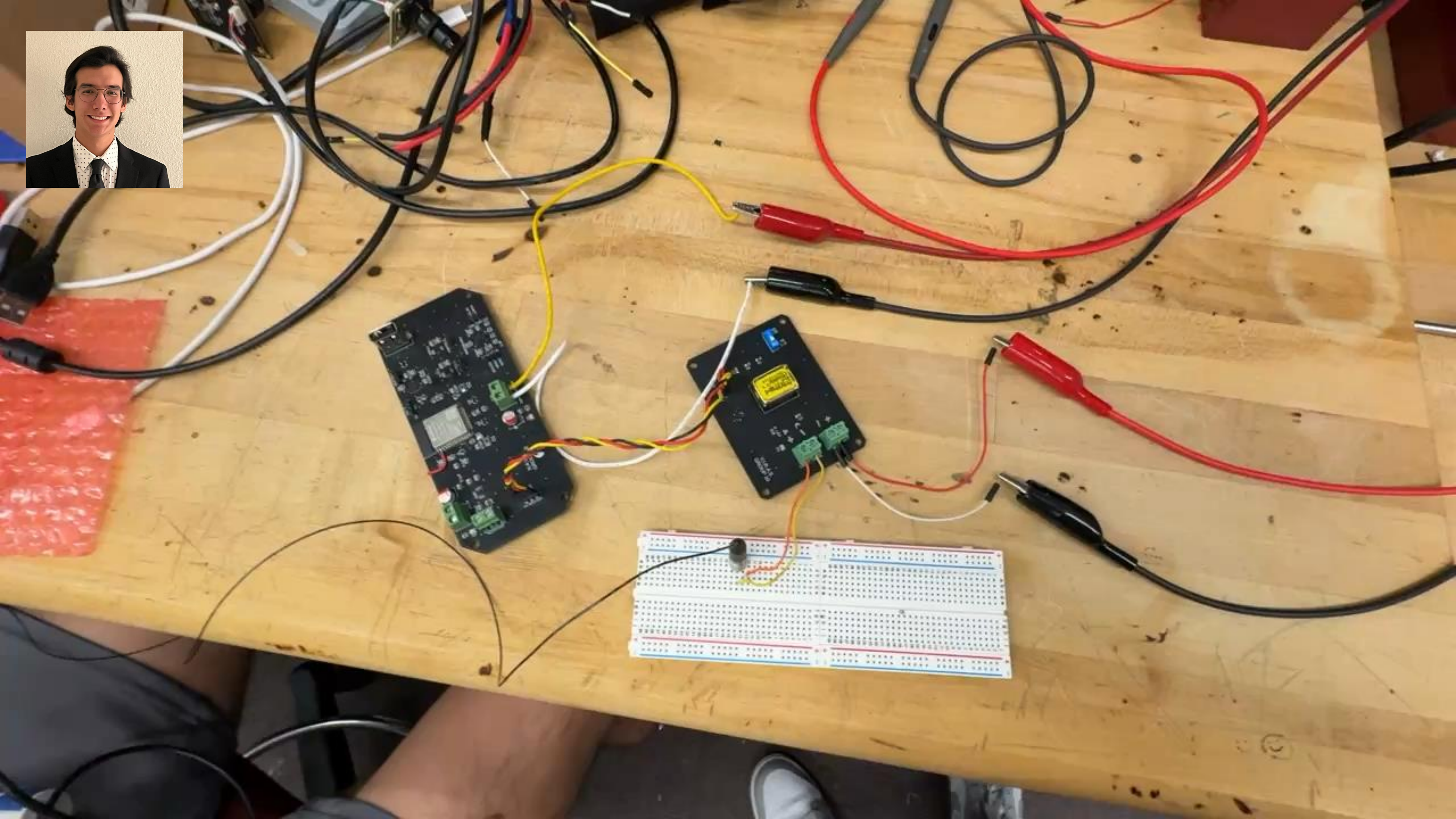
Optical Testing

- Tested different methods for lens and fiber alignment, where a spring-loaded contraption to adjust lens distance to fiber was 3D printed.
- Coupling loss calculations were made to determine if the use of connectors between fibers is enough instead of splicing fibers.
- Wavelength drift based on temperature changes on the diode was made to determine splitter and bandpass filter bandwidth
- Although focal lens to back surface of lens was found in the Zemax simulation of the lens, a movable mount with a sCMOS camera was still made to visualize diameter of beam when different focal distances where used.





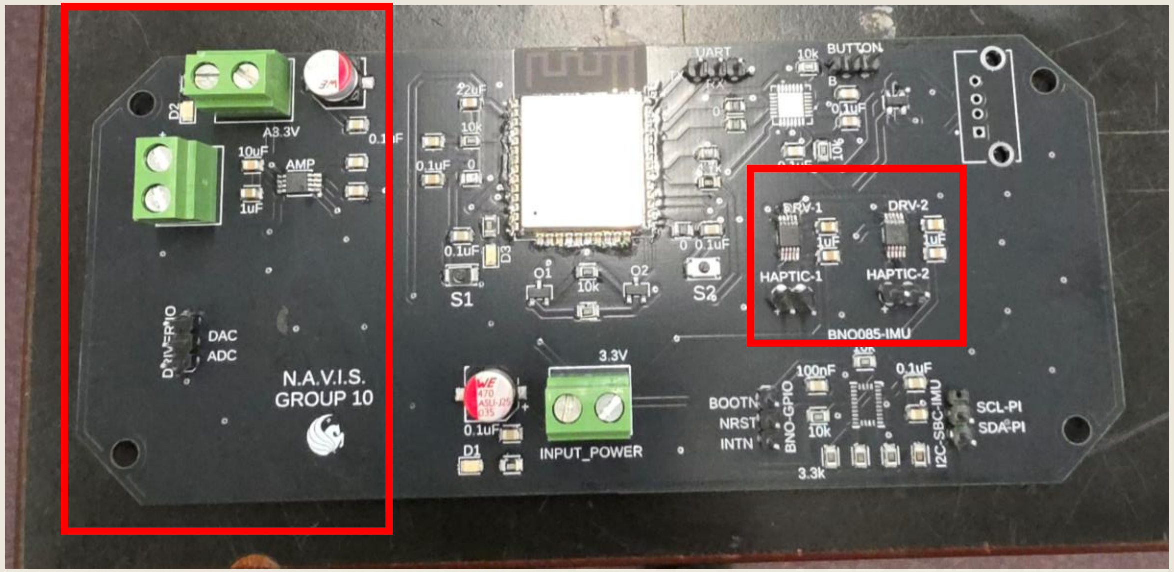




Electrical Component Testing – Pre-Integration

- Assembled main board with MCU and peripherals.
- Tested all programs at once with ifdef debug flags inside code.
- Removed 2 haptic motor drivers, leaving two as one-hot on the I2C bus.
- Challenges:
  - *A few DOA components and noisy outputs – solved with replacements and capacitor power filtering*
  - *DMA DAC output interfering with laser driver current set DAC – solved with separate stereo channel for laser current set.*

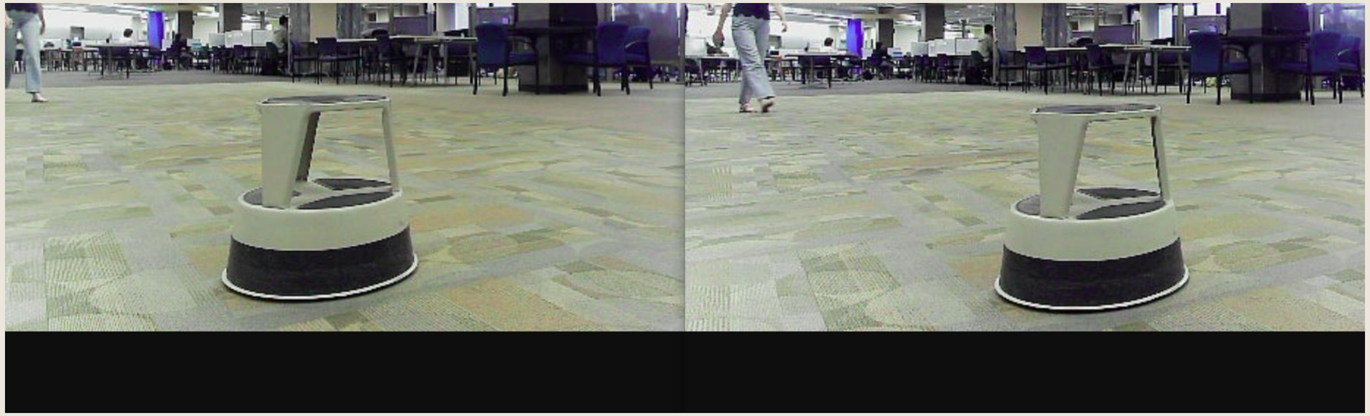
DACs

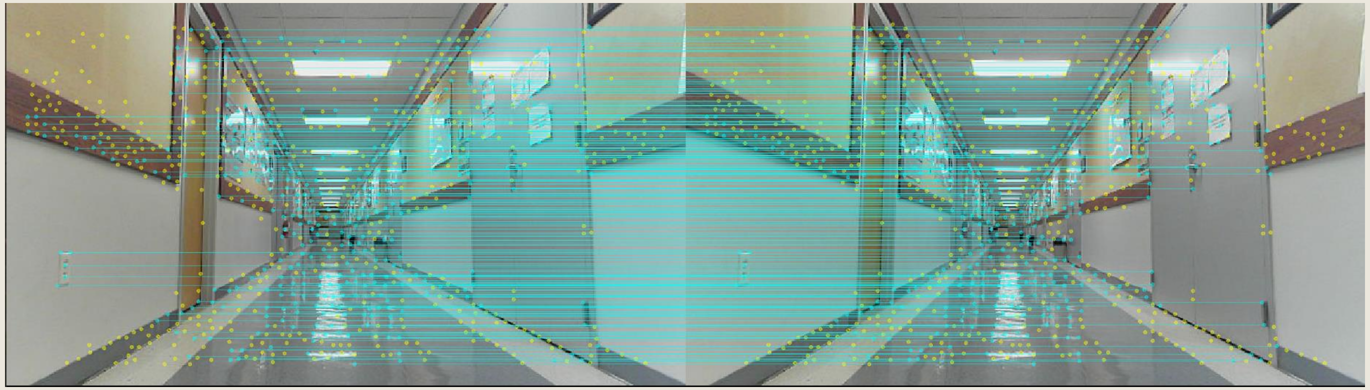


Pictured: Main board v2

Software Testing - SBC (Active Stereo-vision & Localization)

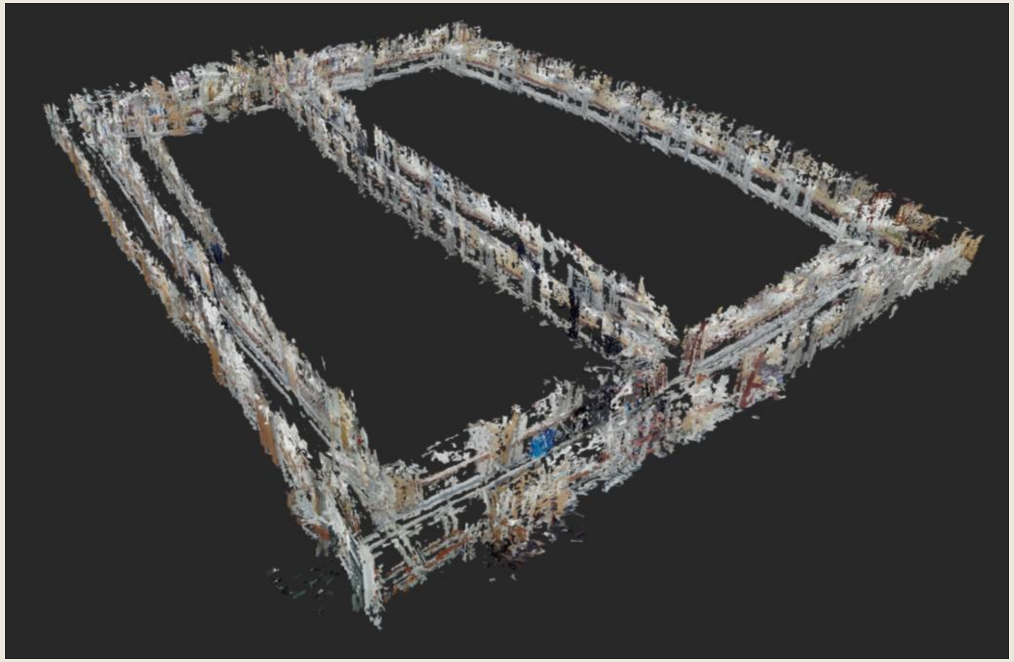
- Designed custom synchronized OpenCV Gstreamer Driver
- *640x360p, 30fps, <5ms sync*
- Fed synchronized images into RTAB-Map Stereo-Odometry algorithm
- Fused IMU and Stereo-Odometry sources using custom-tuned Kalman Filter
- Challenge
  - Standard coordinate systems for camera outputs and ROS2 are different
  - Manually parsed and tuned 70+ feature identification and odometry parameters

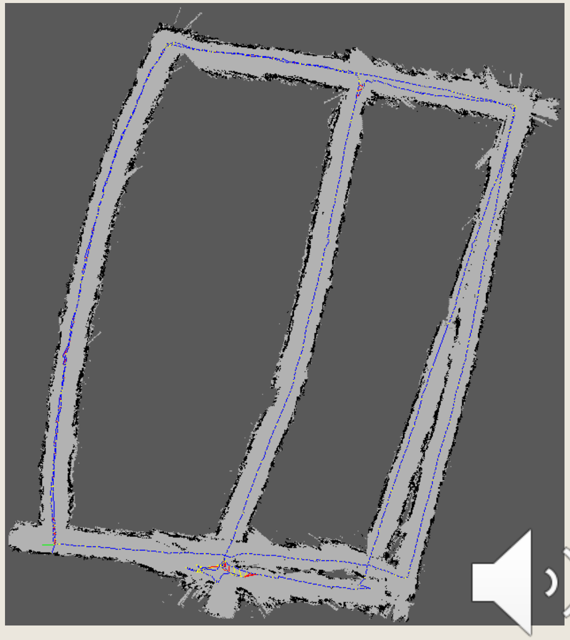




Software Testing - SBC (SLAM)

- RTAB-Map Stereo-SLAM was utilized to develop the necessary 2D Occupancy Grid
- Challenges included:
    - SLAM parameter tuning
    - Overheating of Raspberry Pi – Solved with heatsink, fan, and more airflow.
- Pictured: Point cloud map, Occupancy Grid Map, CREOL 2nd floor

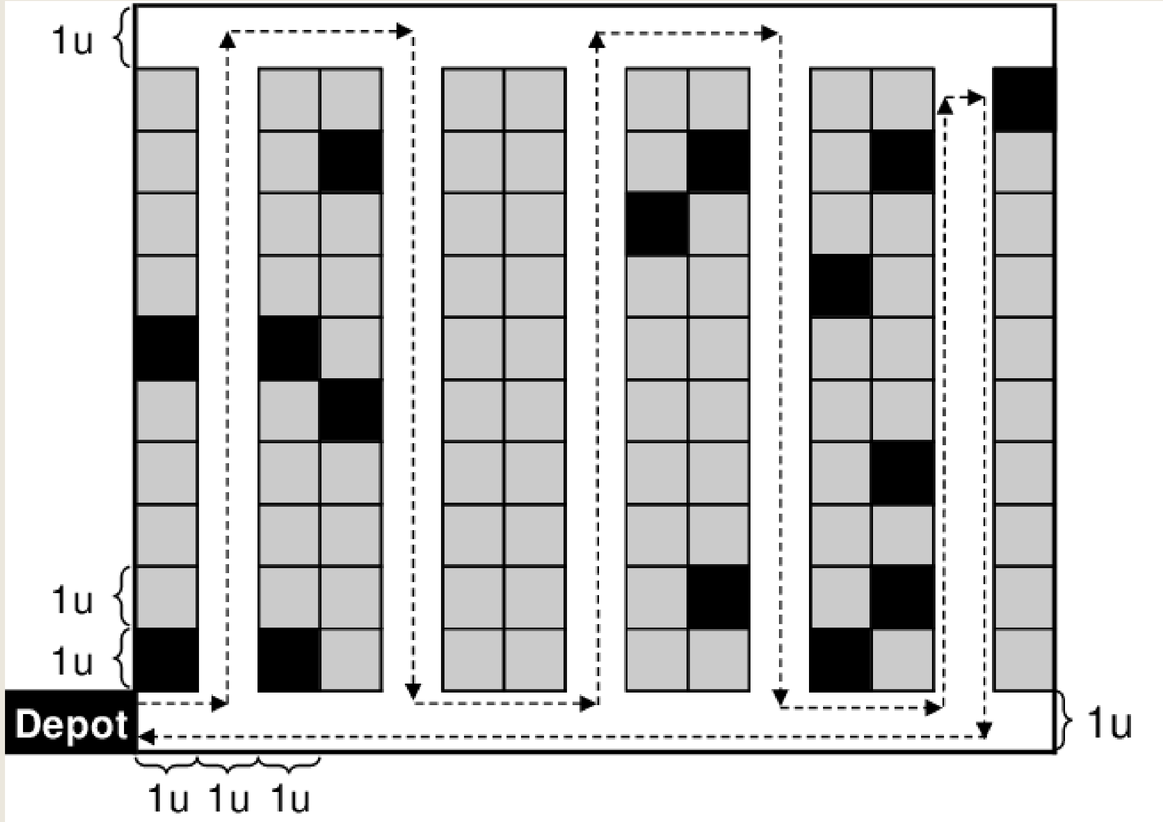




Software Testing - SBC (Navigation)

- Custom S-Shape Routing Algorithm Implemented (1)
  - Dynamic Planning was implemented, but was found to be to computationally expensive
- Control Action Calculations
  - 4 logic branches based off waypoint type to for speaker output
  - Custom buzzer intensity calculation (2)
- Challenges:
  - After finding out dynamic planning was too expensive, custom routing, control, and obstacle detection algorithms had to be developed

1.

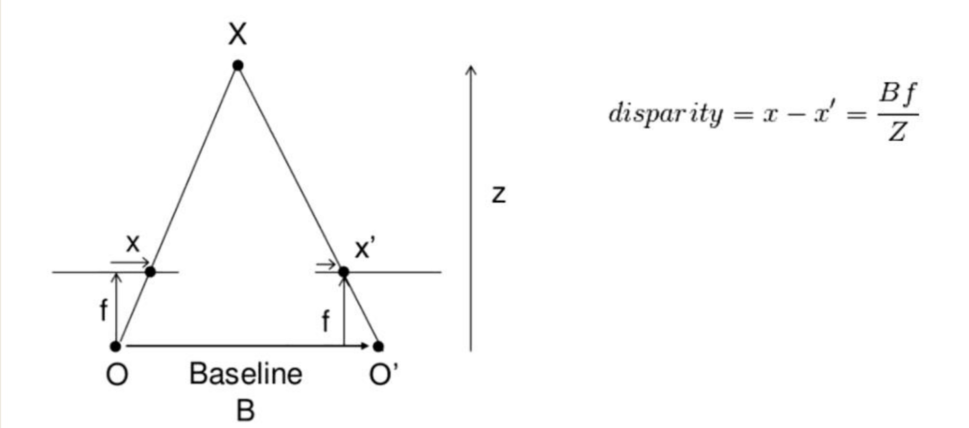


2.

$$X = e^{\frac{255}{\pi}(\text{cur\_yaw} - \text{desired\_yaw})}$$

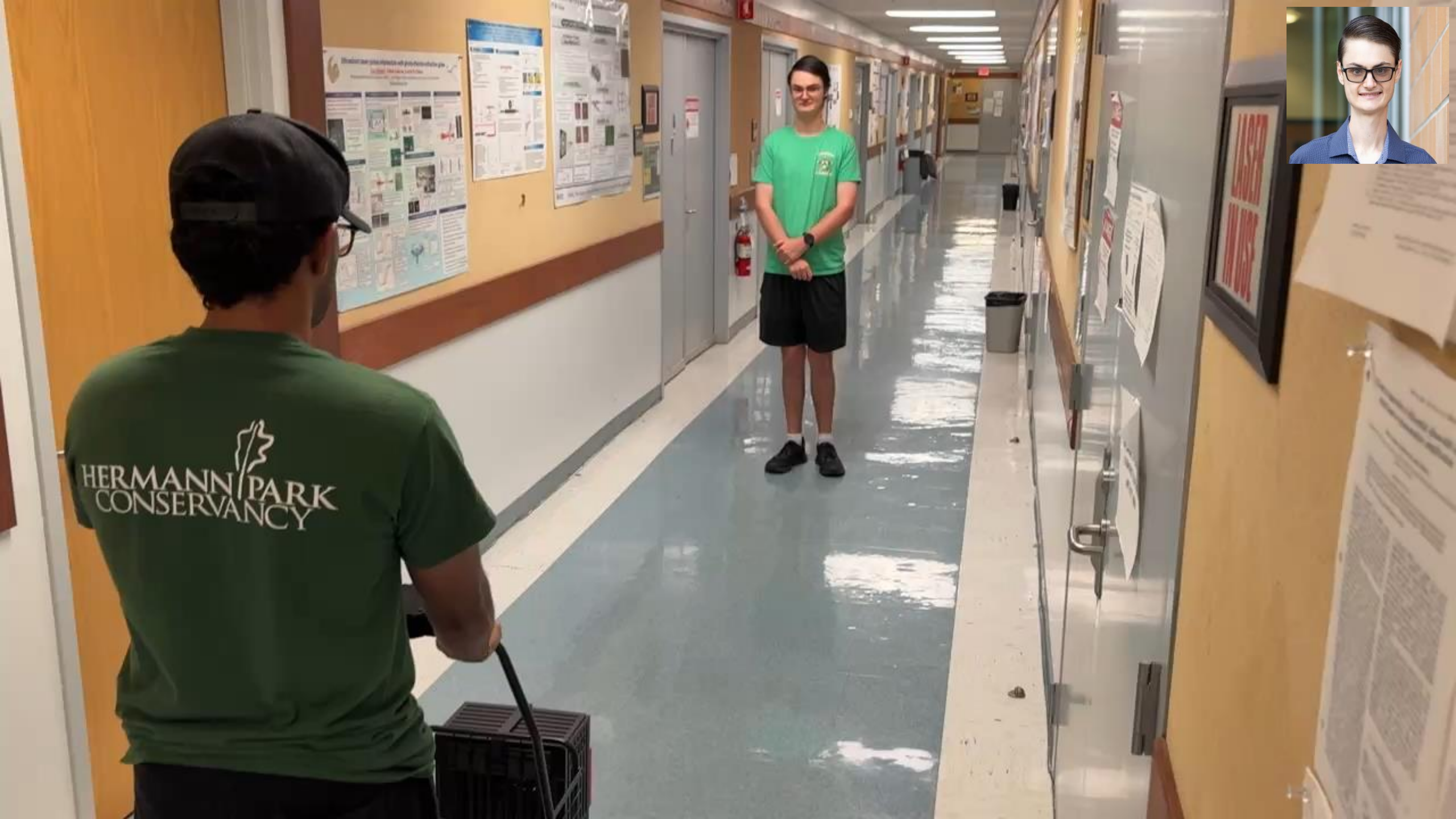
Software Testing - SBC (Obstacle Detection)

- Depth Calculations from a Disparity Map
- Challenges:
  - Noise – *5x5 Nearest Neighbor Blur*
  - Interference from Ground and Walls – *Implemented Region of Interest (RoI)*
  - Calculations Heavy – *Used a Lighter Approximation*



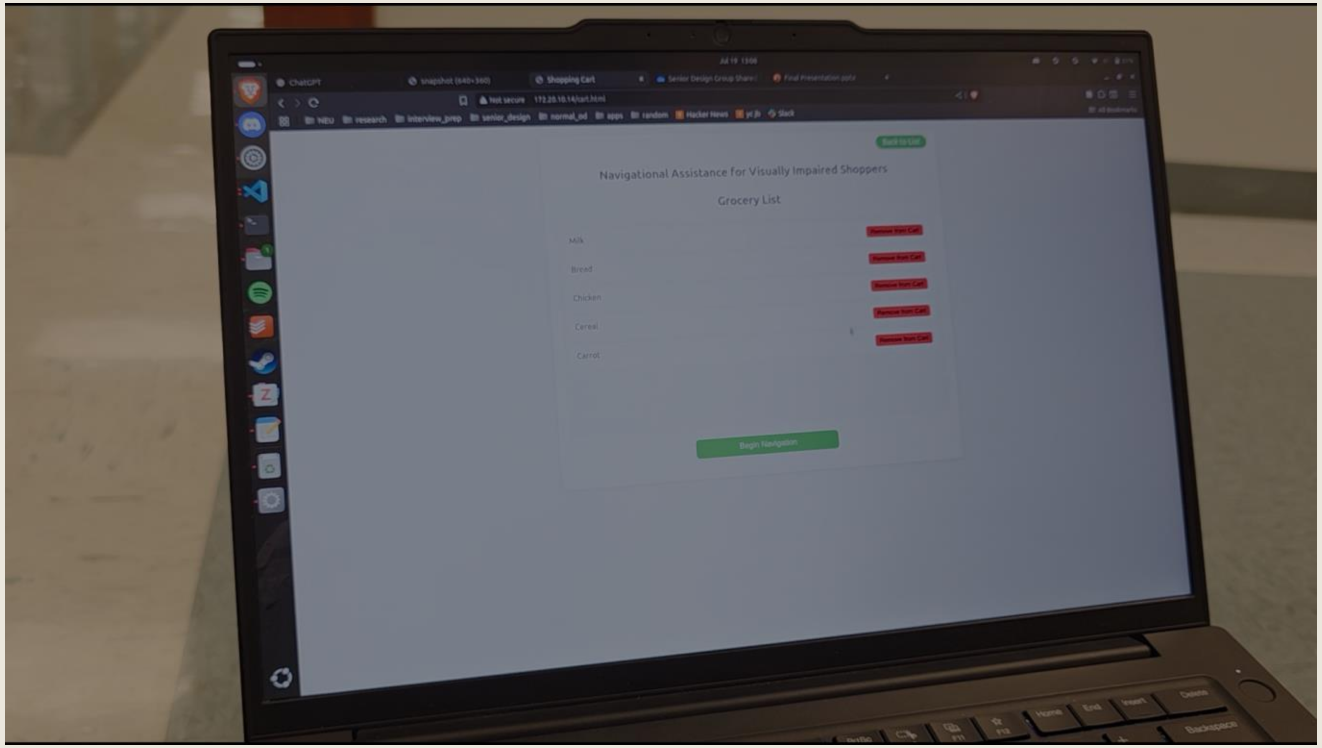
Src: The OpenCV Project, Used Under License

```
[1752943502.995696885] [obstacle_detector]: No significant obstacle found.
[1752943503.142419114] [obstacle_detector]: No significant obstacle found.
[1752943503.302908448] [obstacle_detector]: No significant obstacle found.
[1752943503.367269084] [obstacle_detector]: No significant obstacle found.
[1752943503.459926496] [obstacle_detector]: No significant obstacle found.
[1752943503.704977897] [obstacle_detector]: No significant obstacle found.
[1752943503.856920027] [obstacle_detector]: No significant obstacle found.
[1752943503.928772964] [obstacle_detector]: No significant obstacle found.
[1752943521.876300500] [obstacle_detector]: Obstacle detected at 1.67 m, setting flag and publishing.
[1752943527.955906629] [obstacle_detector]: No significant obstacle found.
[1752943527.956892345] [obstacle_detector]: Obstacle flag reset.
```


HERMANN PARK
CONSERVANCY
LASER IN USE

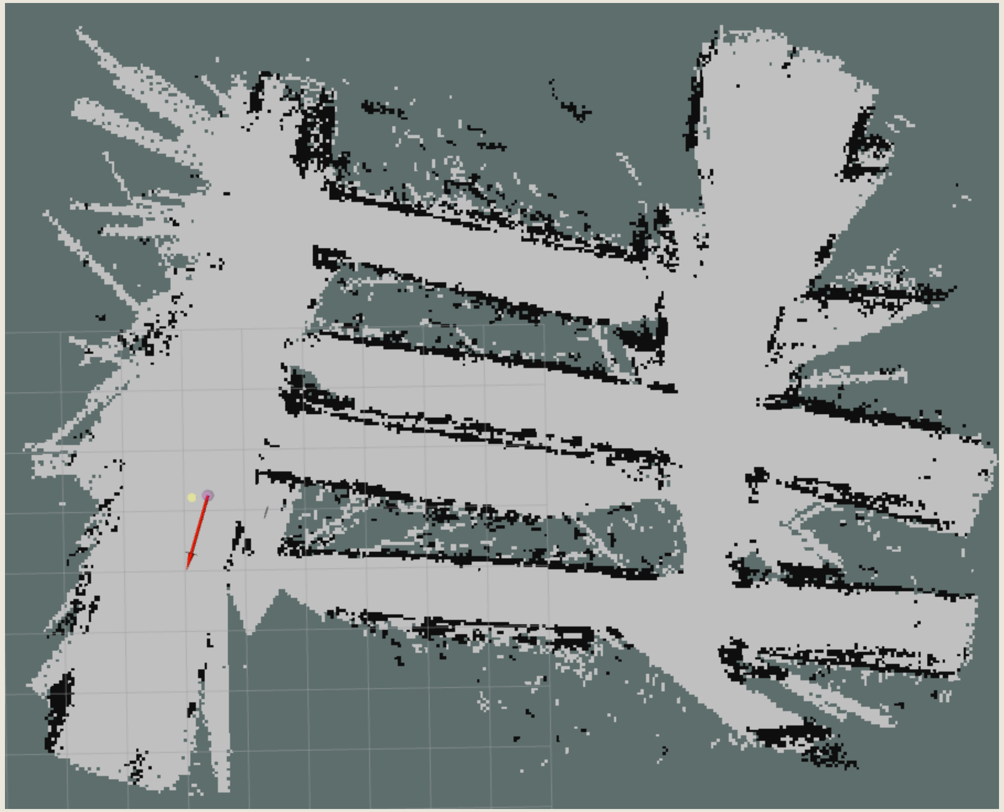
MCU <-> SBC Integration

- Tested UART between MCU-SBC for grocery item selection and peripheral outputs
  - *UART was default routed to Bluetooth*
  - *Certain commands not received correctly.*
- Tested web app with full system
  - *WiFi Hotspot not allowing local device access – Fixed with WAP on SBC*



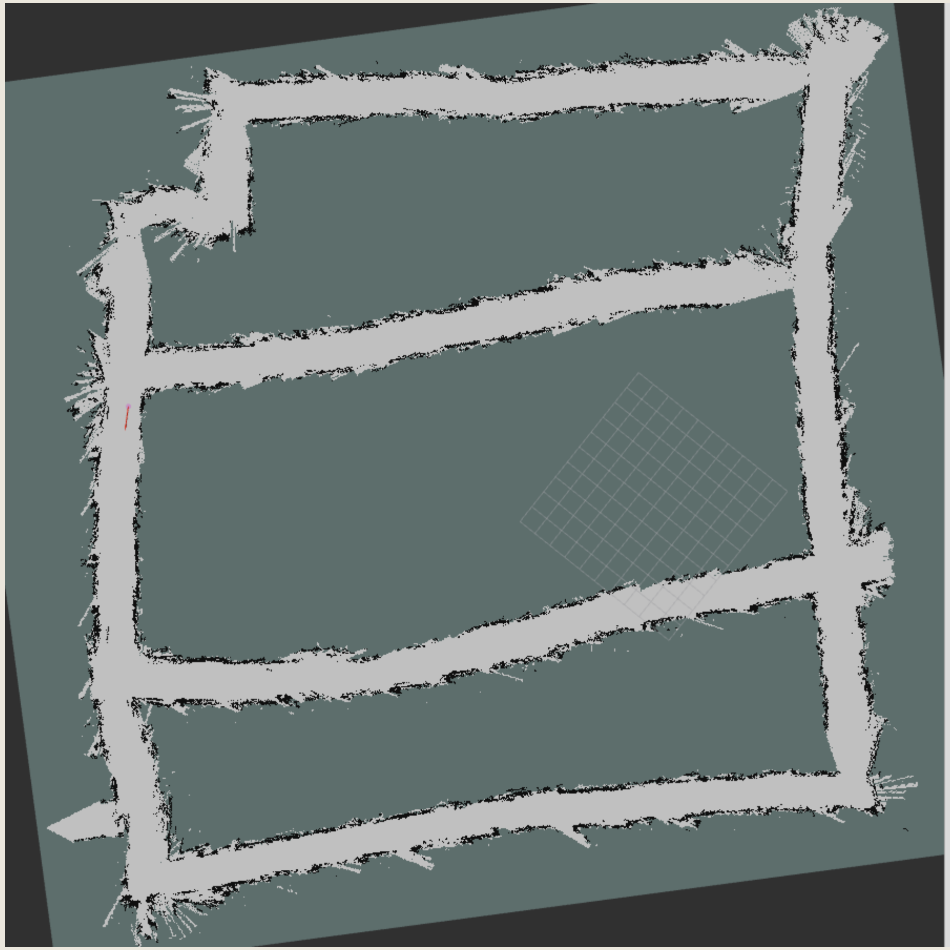
Complete System Testing - Library

- Original plan was to map at library due to:
  - Accessible aisles
  - Originally believed larger maps would cause irredeemable odometry drift
- Challenges experienced:
  - A lot of foot traffic
  - Inconsistent lighting
  - Narrow and long aisles -> aisles merging during mapping even with very slight odometry drift



Complete System Testing - CREOL

- After realizing the second floor of CREOL was organized in consistent –length aisles, we tested and got better results
- Benefits:
  - Sparser and wider aisles allow for more consistent SLAM loop closures
  - Less foot traffic
  - Controllable lighting conditions



Administrative Content - Budget

Components / Subsystem	Target Price
System Enclosure	$50
Optics (Laser, Driver, Fiber, and Cameras)	$750
Electrical (excluding PCBs and SBC)	$300
PCBs	$175
Single Board Computer	$125
Total	**$1400**

Administrative Content – Work Distribution

Team Member	Responsibilities
Matias Barzallo	Active Stereo Vision Optical Design and Development
	Laser Diode Electrical Integration
	CMOS Camera Electrical Integration
Michael Castiglia	Project Manager and Administrative Content
	Microcontroller Software and Integration
	Sensor Driver and Integration
	Web App Design and Development
	High Brain - Low Brain Board Communications
Aden McKinney	Autonomous Navigation Stack Design and Development
	Control Output Software Development
Pavan Senthil	Power System Design and Implementation
	PCB Design
	Peripheral Hardware Integration
	CAD and Housing Development

THANK YOU!