Robotic Automated Platform for Item Delivery - R.A.P.I.D.

Group 23 - Antonio Duchesneau, Alex Green, Arthur Radulescu, & Brandon Holtzman

Meet the Team

Antonio Duchesneau - EE

Alexander Green - CpE

Brandon Holtzman - CpE

Arthur Radulescu - EE

Motivation

- Many trivial deliveries within a workplace take time away from more meaningful work
- We want to reduce the impact of this and increase efficiency in the workplace
- Goal is to assist human labor and enhance it; NOT to replace it.

Overview

- Create an autonomous robot to deliver items securely and efficiently
- Create a driving system that uses both LiDAR and Computer Vision in order to generate paths
- Create a user interface to select a destination for delivery and then verify recipient with RFID

Workload Distribution

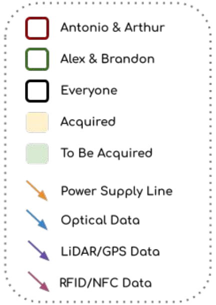
Workload	Primary	Secondary
3D Modeling	Alexander	Brandon
Software Stack Development	Alexander	Brandon
LiDAR Software	Alexander	Brandon
Computer Vision	Brandon	Alexander
Microcontroller PCB Design	Antonio	Arthur
Power PCB Design	Arthur	Antonio
RFID PCB Design	Arthur	Antonio
Driving Subsystem	Antonio	Arthur
Verification (RFID Lock) Subsystem	Arthur	Antonio
Graphic User Interface	Brandon	Alexander

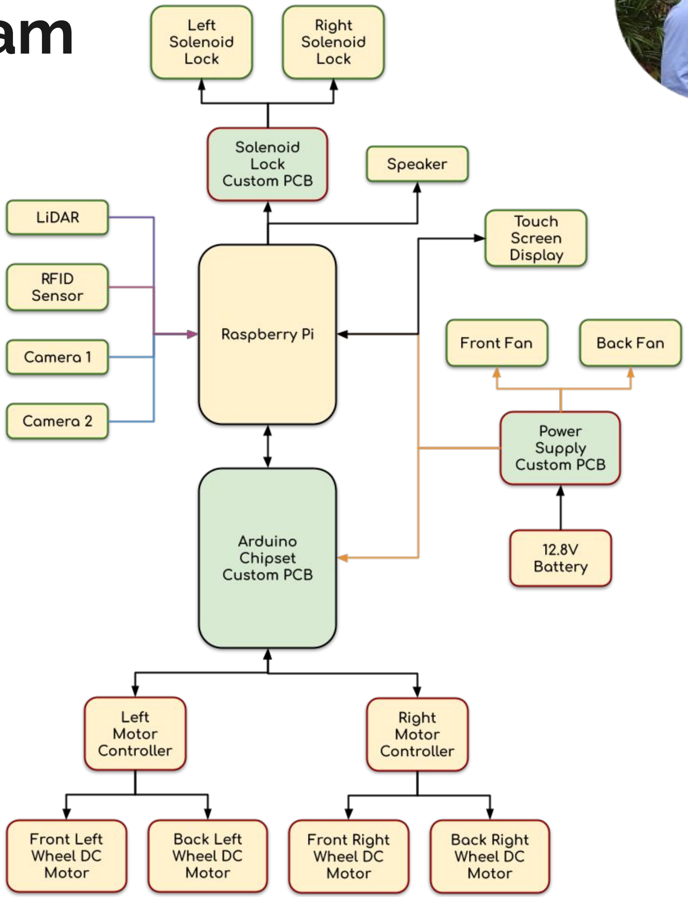
Engineering Specifications

Components	Parameter	Specification
Cameras, LiDAR, MCU	Object Detection and Avoidance	Can identify obstacles 6in^3 or larger and successfully avoid them
GPS/Wifi, Motors	Speed of delivery	Average delivery in the HEC <4 minutes travel time >25 m/min travel speed
Touch Screen Display, RFID, Speaker	User interface and Package Delivery	<45s interaction time when receiving package
PSU	Battery Life	> 30 minutes
Platform body	Weight and Size	< 30 lbs 36” x 24” x 12”
Package Container	Houses package to be delivered	> 6” x 6” x 6”

Overall Hardware Block Diagram

- Raspberry Pi handles computations and processing
- LiDAR and Camera feed provide “vision” to the platform, allows for obstacle detection and avoidance
- Touch screen display acts as user interface, with RFID used for ID verification
    - RFID works with Raspberry Pi to verify ID and open the locks to the package container.
- Raspberry Pi communicates with Arduino Chipset PCB to drive the platform and avoid obstacles.
    - Two motor controllers used to control two motors each
- 12.8V battery connected to Power Distribution PCB, provides 12V and 5V rails.
- Front and Back fans used for active cooling





Component Power Summary

Component	Voltage	Max Sustained Current Draw	Peak Current Draw	Max Wattage	After DC-DC Loss (95% efficiency)
Raspberry Pi Camera Module V3 Wide x2	3.3V	300mA x 2 = 600mA	450mA* x 2 = 900mA*	1.98W	2.08W
Coral TPU USB	3.3V	500-900mA	900mA	2.97W	3.12W
RC522 RFID	3.3V	13-26mA	26mA	0.09W	0.09W
ATmega2560 Motor Controller Board	5V	200-700mA	700mA	3.5W	3.68W
RPLiDAR A1MG-RG	5V	450mA	700mA	2.25W	2.36W
Raspberry Pi 4	5V	800mA	3000mA	4W	4.21W
Aisichen 7in Touch Screen	5V	500mA	750mA*	2.5W	2.63W
Solenoid Lock	12V	430mA x 2 = 860mA	650mA x 2 = 1300mA	10.32W	10.86W
Hardware Ventilation Fans	12V	120mA	120mA	1.44W	1.51W
DFRobot 251 RPM Motors x4	12V	350-2500mA x 4 = 1400-10000mA	7000mA x 4 = 28000mA	120W	126.31W
			Max Continuous Amperage	**Max Peak Amperage**	**Max Wattage**
			15A	**36.5A**	**149.05W**

Battery Technology Comparison

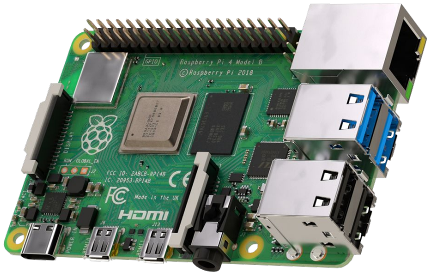
	Lead Acid	Nickel-Cadmium	Nickel-Metal Hydride	Lithium Ion
Energy Density	80-90 Wh/L	50-150 Wh/L	140-300 Wh/L	250-693 Wh/L
Specific Power	180 W/kg	150 W/kg	250-1000 W/kg	250-340 W/kg
Charge/Discharge Efficiency	50-95%	70%-90%	66-92%	80-90%
Energy Price	7-18 Wh/$	23 Wh/$	2-10 Wh/$	7.6 Wh/$
Self-discharge Rate	3% - 20% per month	10% per month	10-15 % per month	0.35-2.5% per month
Cycle Durability	<350 cycles	2000 cycles	700-1000 cycles	400-1200 cycles
Nominal Voltage	2.1V	1.2V	1.2V	3.7V

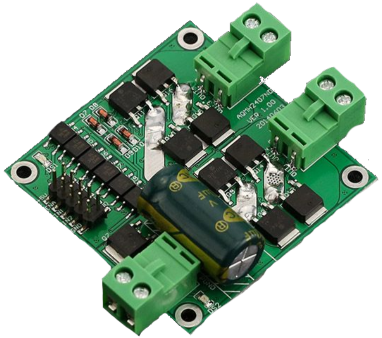
Battery Selection

	NERNAK 12V 12Ah Lithium LiFePO4 Battery	XZNY 12V 18Ah LiFePO4 Battery	BOMUZIK 12V 15ah LiFePO4 Battery
Cost	$46	$65	$59
Nominal Voltage	12.8V	12.8V	12.8V
Amp Hour	12ah	18ah	15ah
Peak Discharge Current	30A (3 seconds)	40A (5 seconds)	45A (3 seconds)
Maximum Continuous Discharge Current	12A	20A	15A
Dimensions	5.94" x 3.81" x 3.71"	5.94" x 3.9" x 3.7"	6.42" x 4.88" x 4.76"
Weight	3.23 lbs	4.3 lbs	3.25 lbs

Driving System

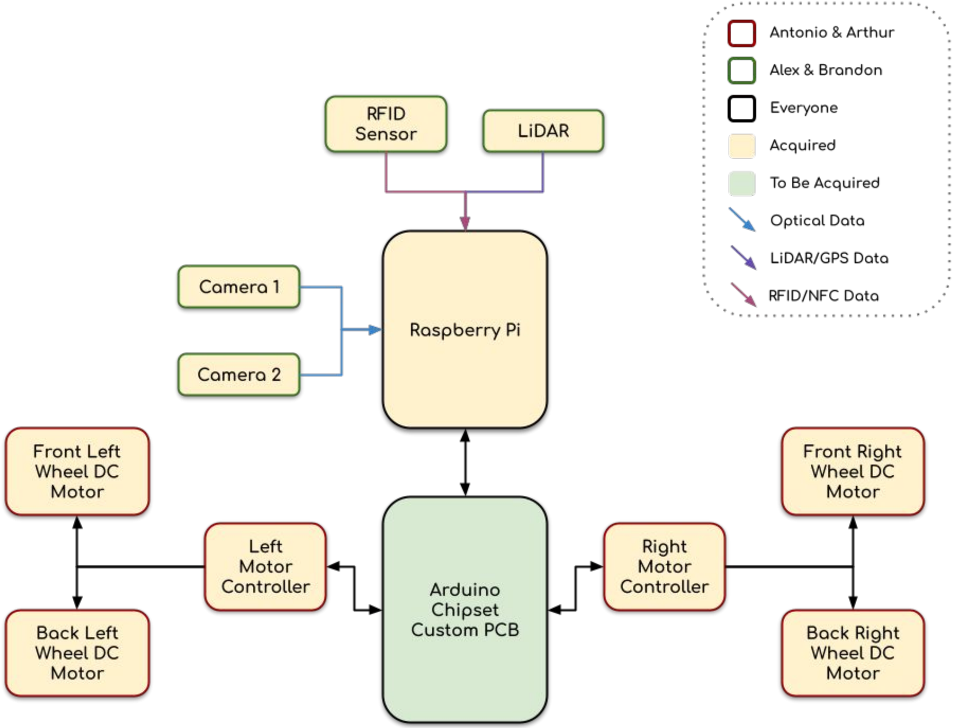
- Consists of four gearmotors that each drive individually
- The two dual channel motor drivers
- Raspberry Pi for generating driving commands (Tx to ATMega)
- ATMega PCB provides logic necessary for motor drivers (Rx from Pi)





Drive System Components & Organization

- Motors: GB37Y3530-12V-251R
- Motor Drivers: DRI0041
- Raspberry Pi 4
- ATMega2560 PCB



Motor Selection

- High torque necessary for load capability of the vehicle
  - DC Gearmotors were considered options
- Include encoders for ease of integration
  - Encoders are easily implemented on Arduino IDE

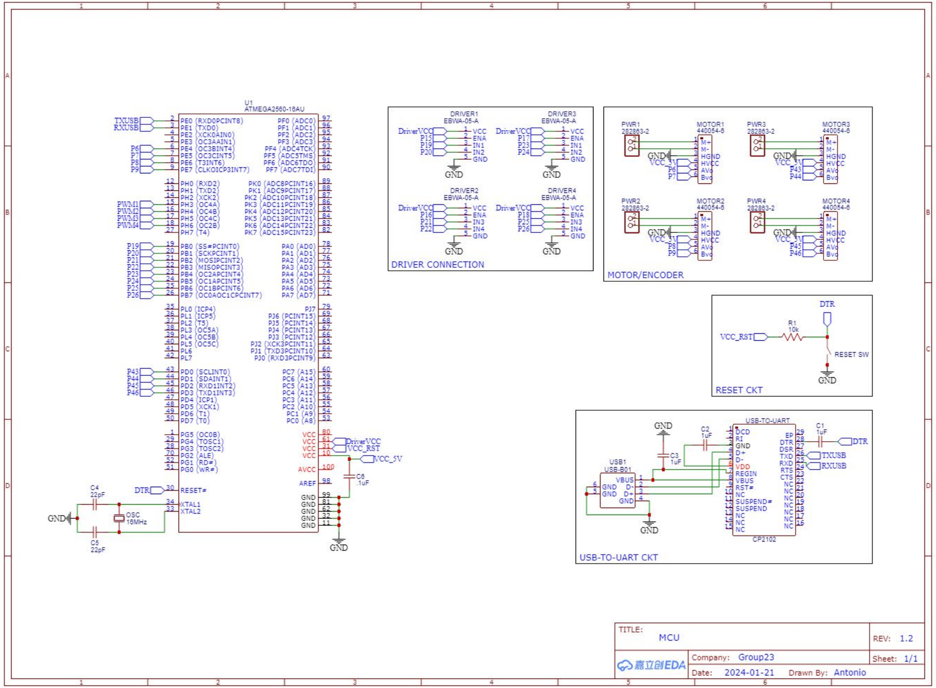
Specification	DFRobot 251 RPM	DFRobot 350 RPM
Operating Voltage	12V DC	12V DC
Speed	251 RPM	350 RPM
Torque	1.75 N-m	1.17 N-m
Encoder Type	Incremental	Incremental
Gearbox Reduction Ratio	43.8:1	34:1
Size / Dimension	Round - 1.457" Dia (37.00mm)	Round - 1.457" Dia (37.00mm)
Length - Shaft and Bearing	0.827" (21.00mm)	0.827" (21.00mm)
Price	$29.99	$29.00

MCU Selection

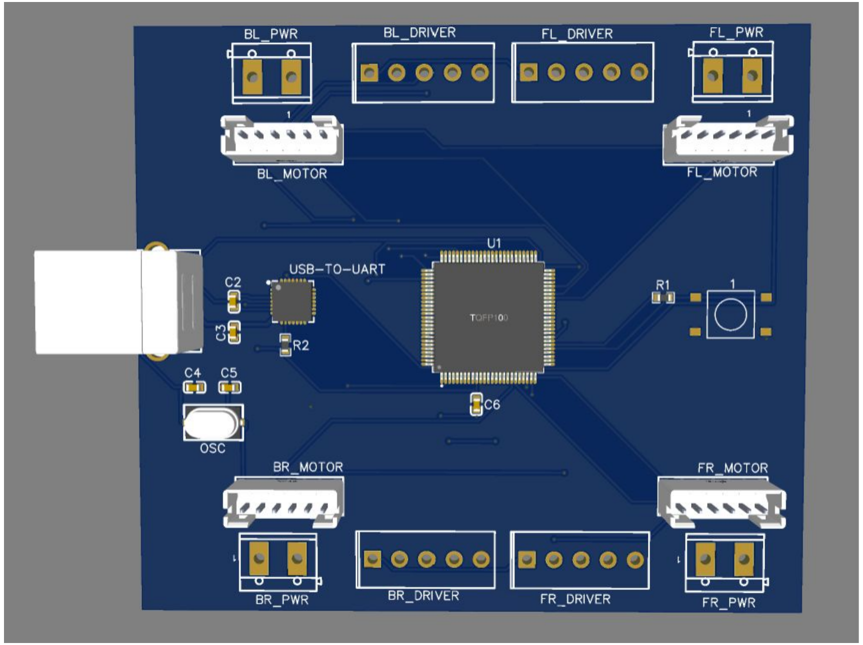
Microcontroller	ATmega2560	ATmega328P
Digital I/O Pins	54	14
Analog Input Pins	16	6
PWM Outputs	15	6
Interrupt Pins	6	2
Flash Memory	256 KB	32 KB
SRAM	8 KB	2 KB
EEPROM	4 KB	1 KB
Clock Speed	16 MHz	16 MHz
Communication	UART, SPI, I2C	UART, SPI, I2C
USB Over Serial	Yes	Yes
Input Voltage	7-12V	7-12V

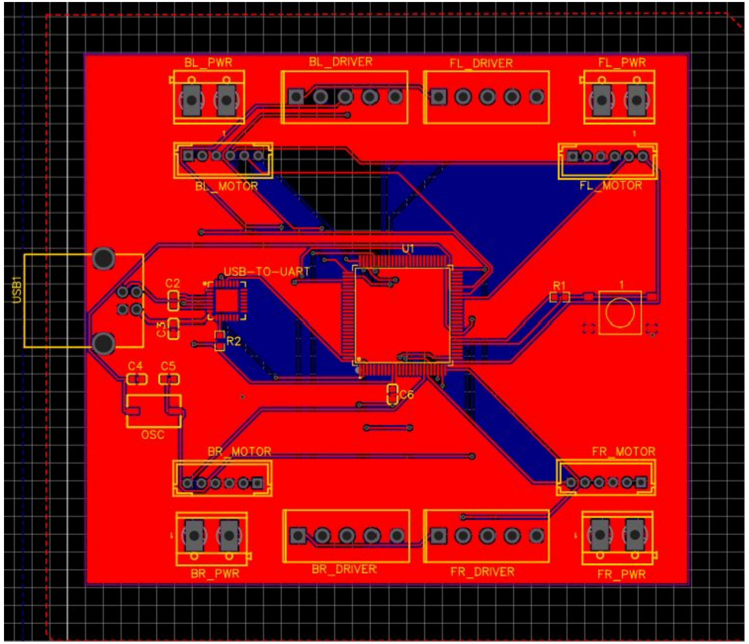
Drive System Schematic

- ATMega2560 is our MCU of choice
  - 20 Digital I/O Pins
    - (4x) PWM capable
    - (6x) Interrupt capable
    - (10x) Regular Digital Pin
- CP2102 is our USB-to-UART bridge
  - On board USB-to-UART function allows for serial communication and power from the Raspberry Pi



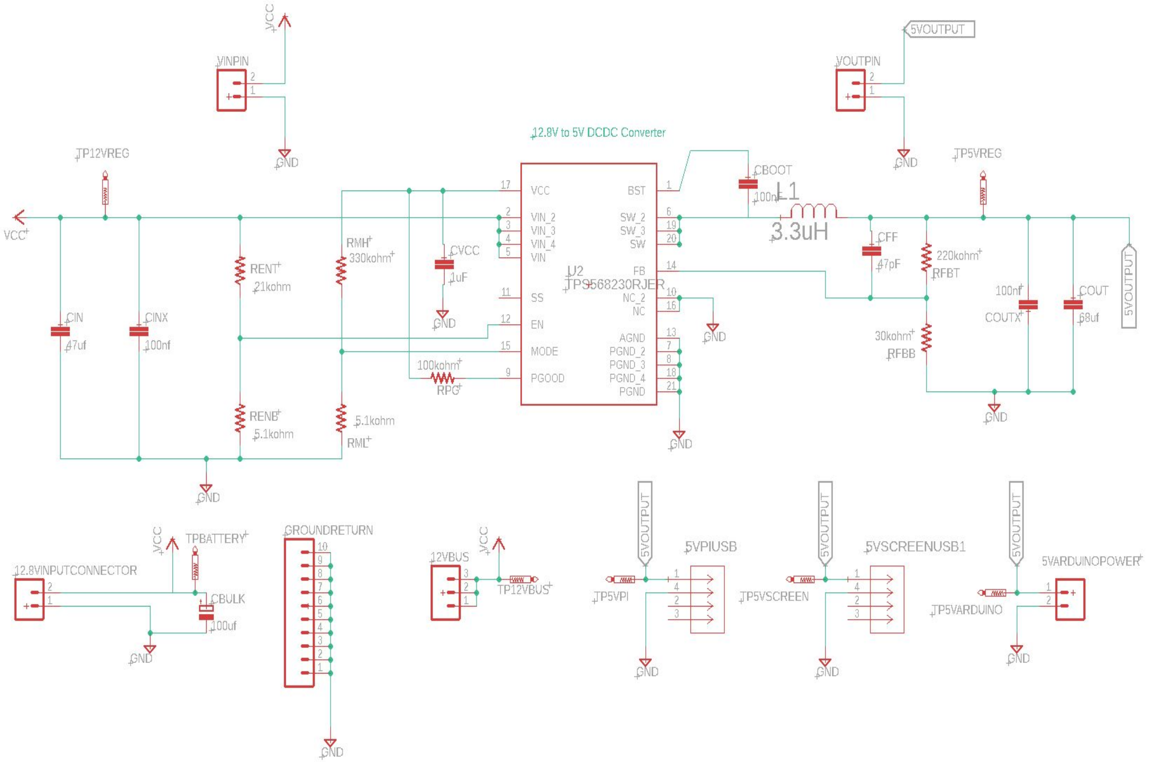
Drive System PCB





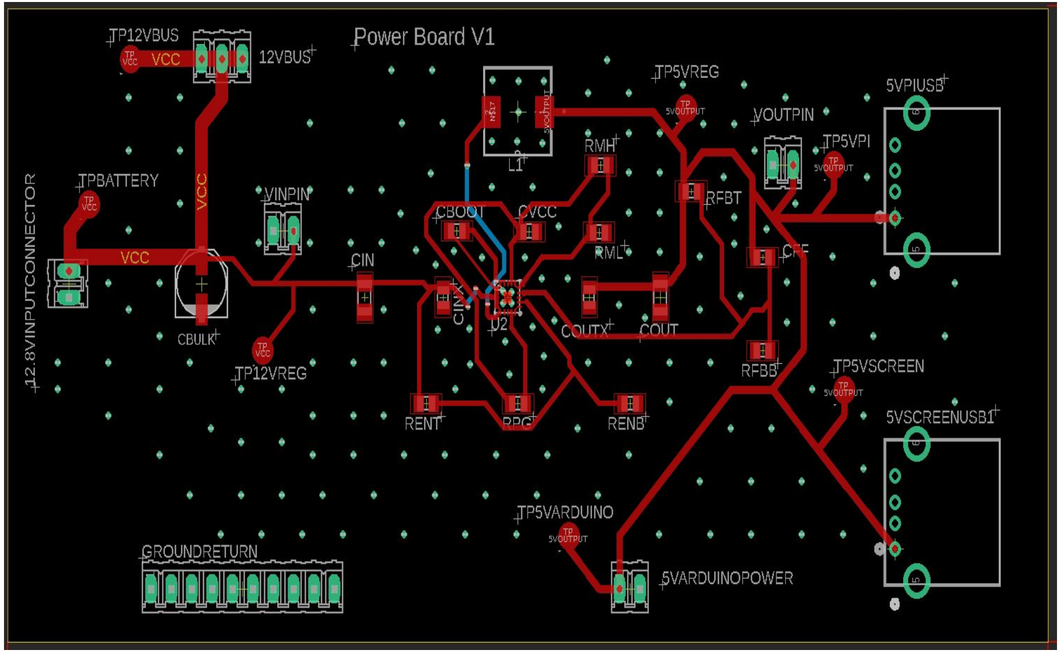
Power Regulation and Distribution Schematic

- Texas Instruments TPS568230RJER buck converter
  - 4.5V-18V Input
  - Up to 8A continuous output current
  - 95%
- 2x USB-A ports
- Amp connectors for 12V and 5V
- Wurth Electronics 7443340330 Power Inductor
  - 8.5A Saturation Current
  - 81 MHz self resonant frequency
  - Shielded Inductor



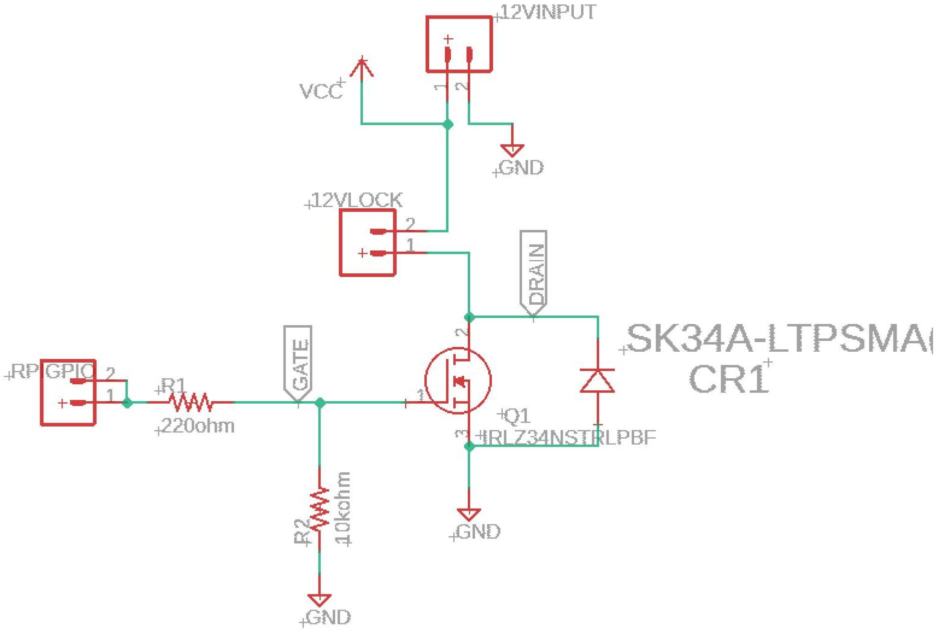
Power Regulation and Distribution PCB

- 2-layer PCB
- Top and bottom layer GND
- Power Distribution Board takes 12V from battery and converts to 5V using TPS568230RJER buck converter IC
- Power is routed to connectors for 12V and 5V (USB and pins)
- Set of connectors dedicated for ground connections for peripherals
- Stitch vias scattered throughout board and thermal vias under IC
- Testpads added to board for signal probing



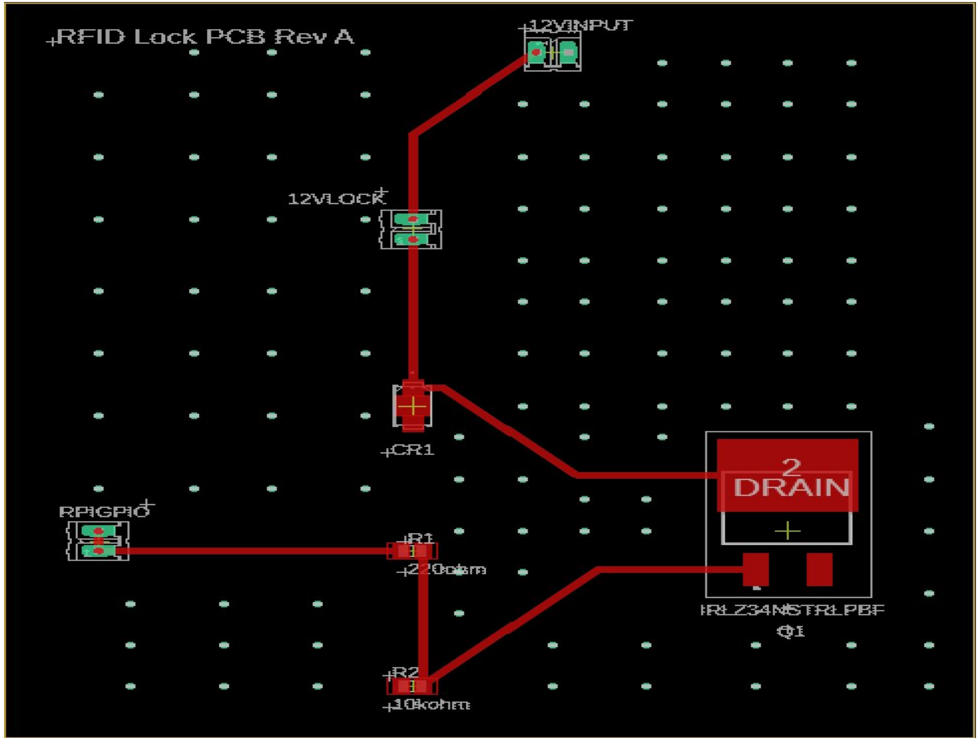
RFID Lock Schematic

- IRLZ34NSTRLPBF N-channel logic level MOSFET used as switch
  - 55V/30A rated
  - 2V Vth
  - 35mohm Rds
- SK34A Schottky Diode
  - Flyback diode
  - 40V reverse voltage max
  - 3A Io average
- Gate and pulldown resistors
- Amp connectors for 12V input and GPIO input from Raspberry Pi



RFID Lock Mechanism PCB

- 2-layer PCB
- Top and bottom layer GND
- 12V powers lock, GPIO pin send signal to MOSFET to turn on or off
- Stitch vias scattered throughout board



Software Summary

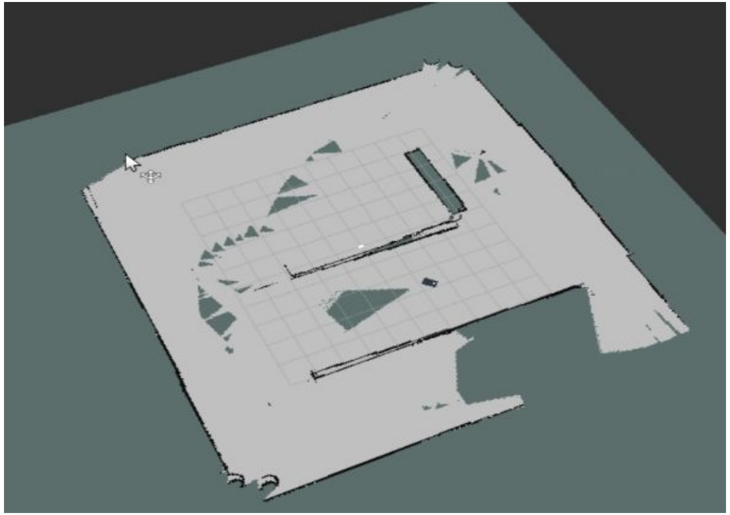
- Linux Operating System
  - Ubuntu 22.04.03 LTS - Jammy Jellyfish
- Robotic Operating System - ROS
- ROS Visualization - RViz
- Gazebo
- OpenCV
- LiDAR Driver Software
- Motor Driver and Encoder Software
- User Verification Software

Robotic Operating Systems - ROS

- Robot Operating System 2
  - Tools
  - Libraries
  - Conventions

ROS

- Navigation Stack



ROS Visualization, GMapping, & Gazebo

ROS Visualization - RViz

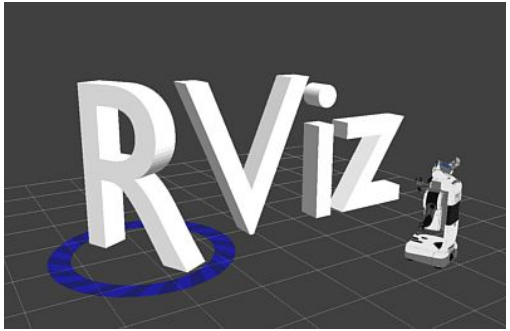
- Live Sensor Data
  - LiDAR
  - Camera

GMapping

- Occupancy grid based map making

Gazebo

- Location Estimation
- Path Generation

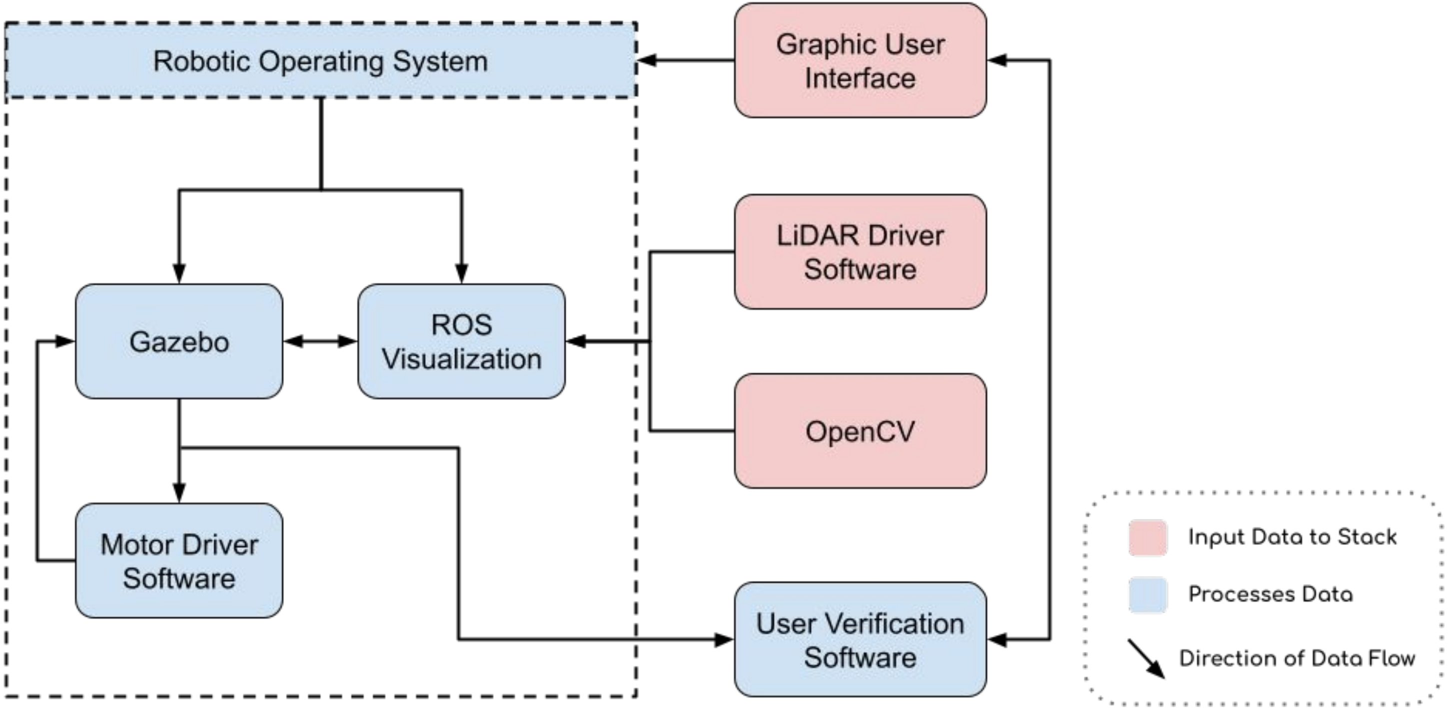


GAZEBO

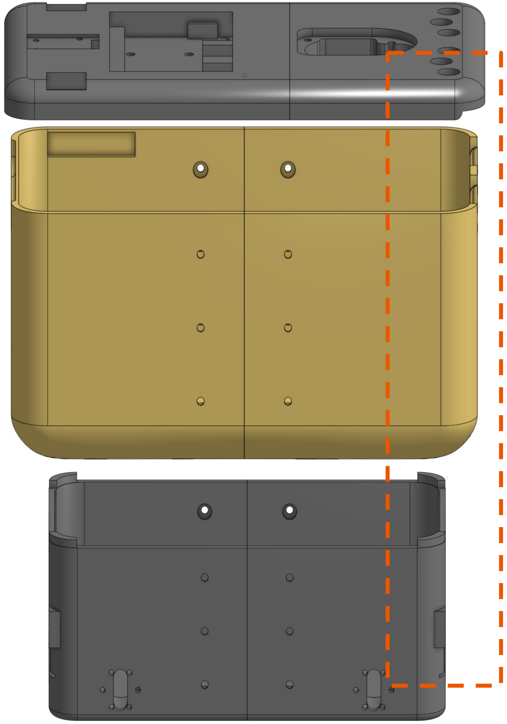
Computer Vision Software

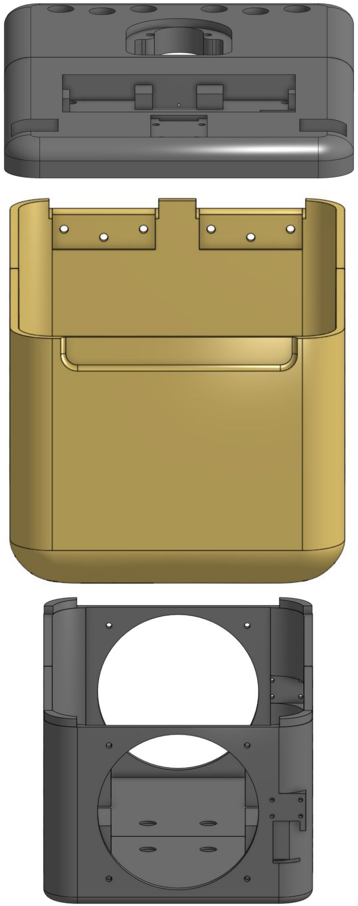
- Using Python with OpenCV for object detection.
- To be used for obstacle detection and navigation.

Software Data Flow Diagram

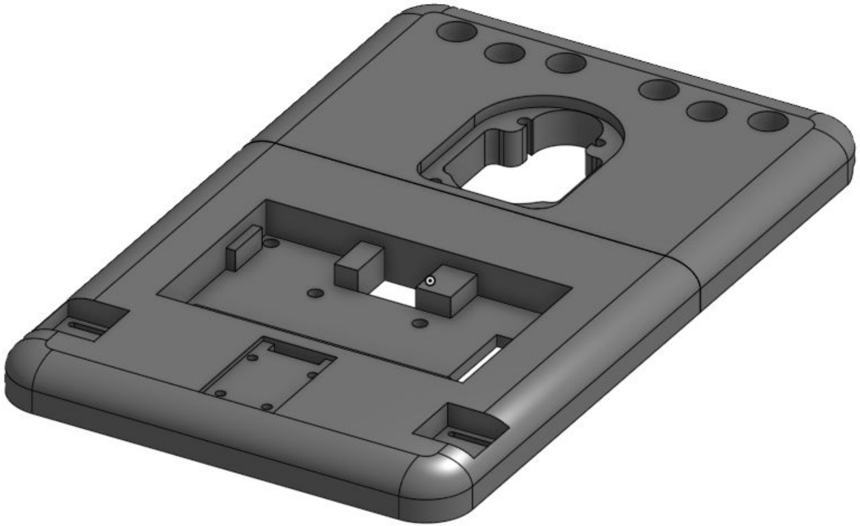


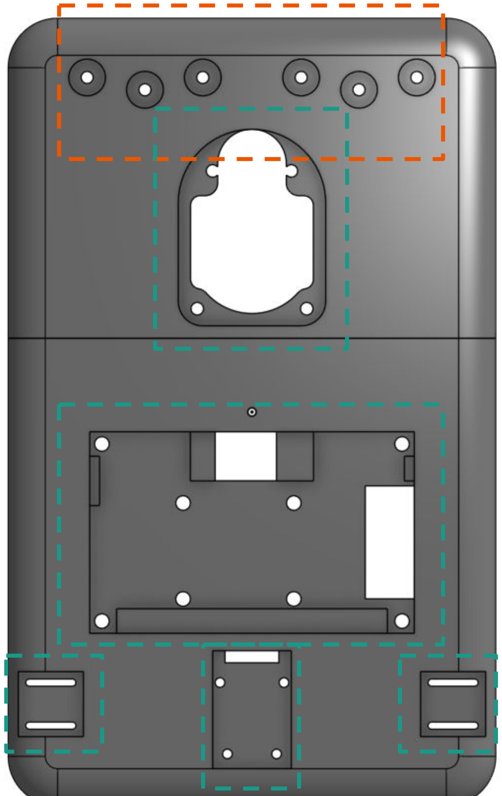
3D Modeling Assembly



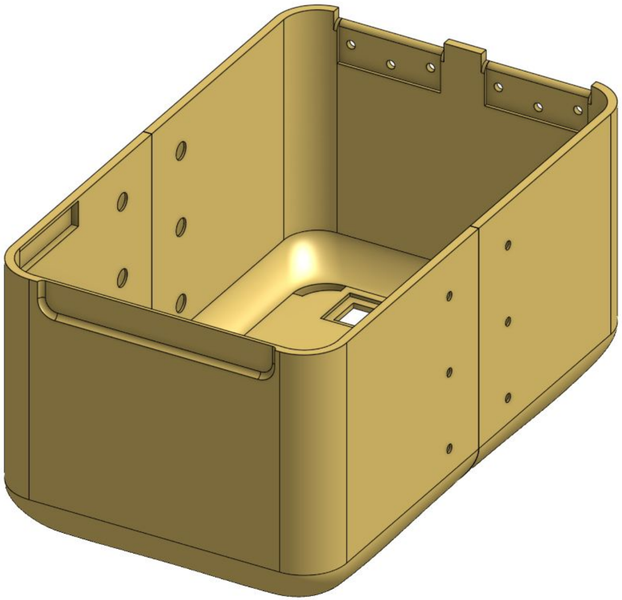


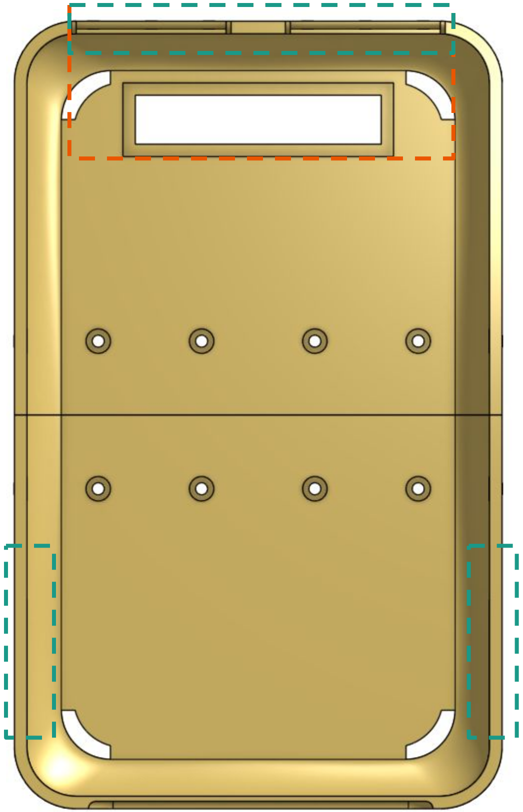
3D Modeling - Lid



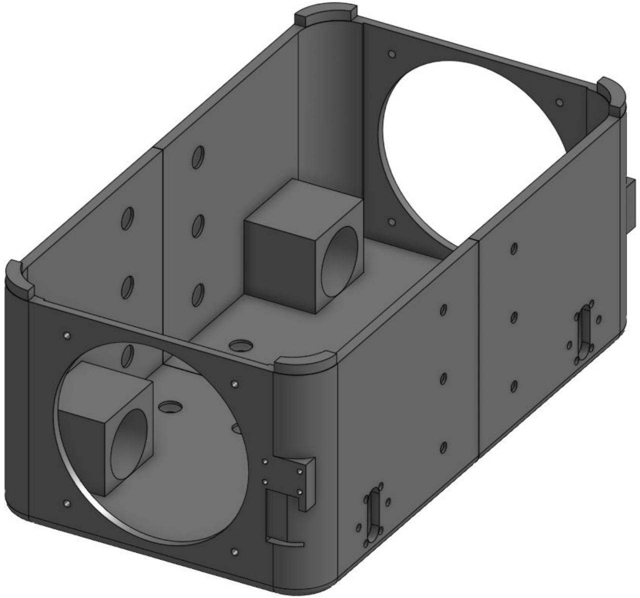


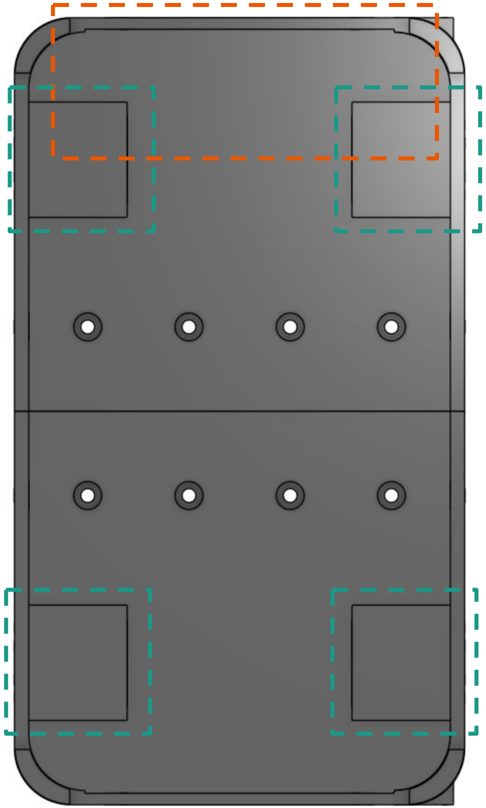
3D Modeling - Cargo Chassis





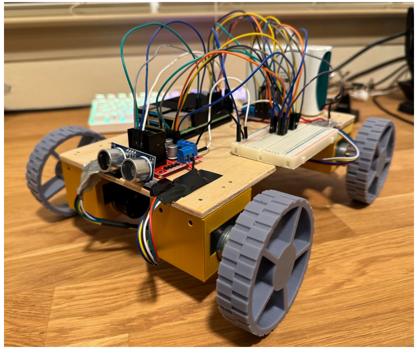
3D Modeling - Electronics Bay



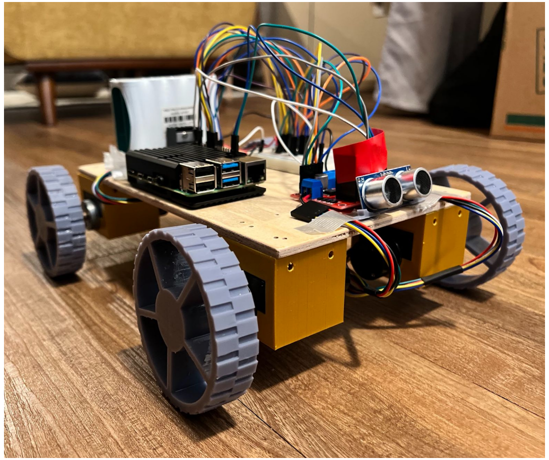


3D Model Prints

Testing - Driving Subsystem

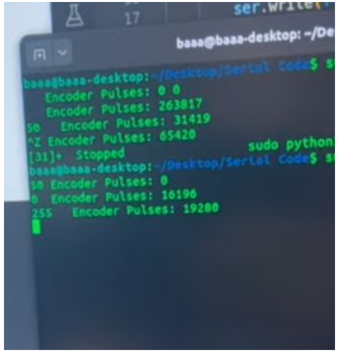


- Our first prototype used direct Raspberry Pi to driver connection.
- Prototype hardware was used to test the base design of our drive system
- Takeaways:
  - An external MCU PCB would control the high population of wires.
  - Difficulties receiving encoder data



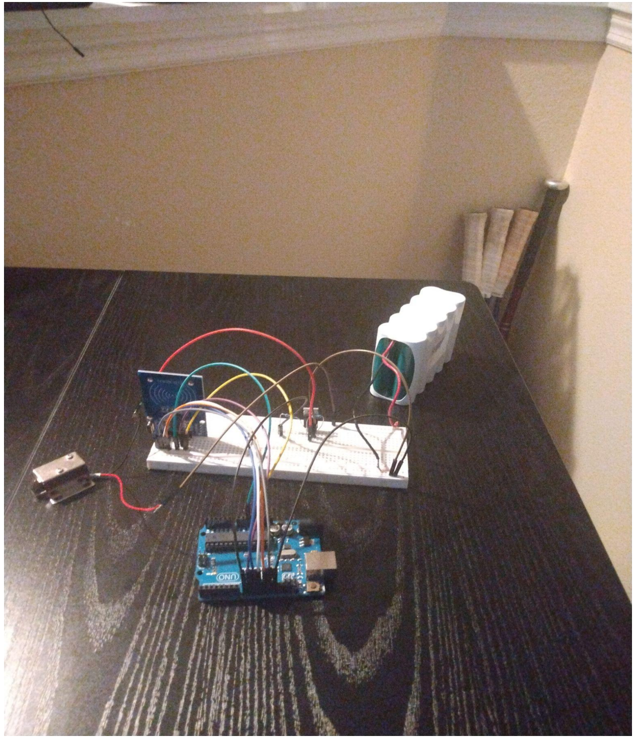
Testing - Serial Connected Driving Subsystem

- Our second test used serial communication from the Pi to an ATMega2560 directly connected to our motor driver
    - Arduino Mega was used in place of our PCB
- PWM data was successfully send via serial communication from the Pi to the Arduino for motor control logic
- Encoder data was successfully received and sent to the Pi



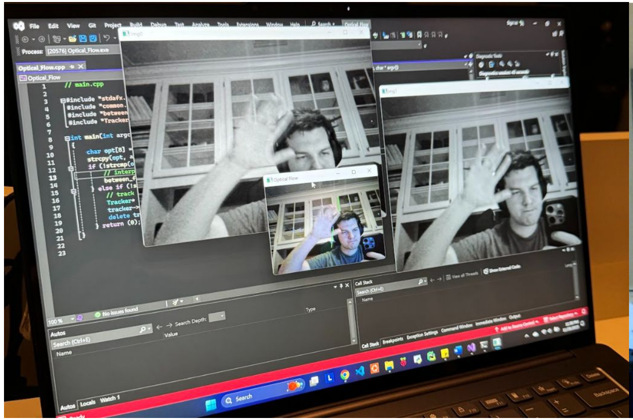
Testing - Recipient Verification Subsystem

- Constructed on breadboard and tested for functionality
- Arduino Uno was used in place of Raspberry Pi for testing
- The lock successfully engaged when the correct RFID tag was read



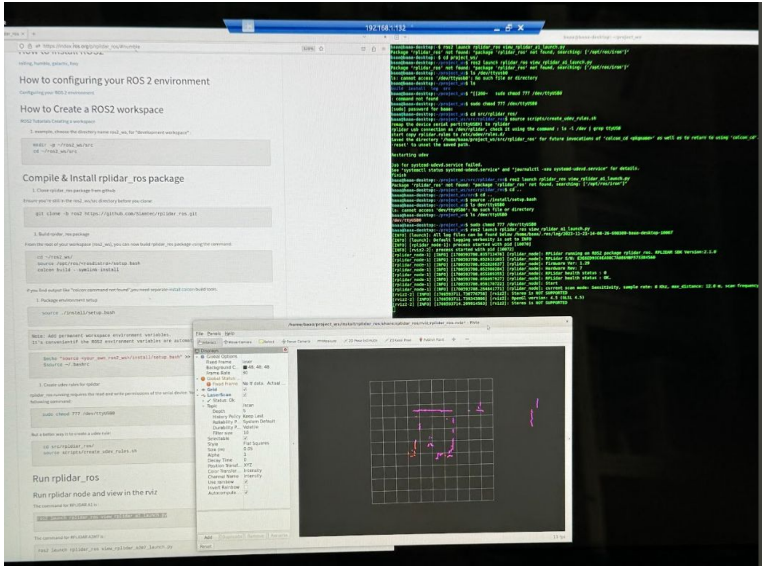
Testing - OpenCV Software

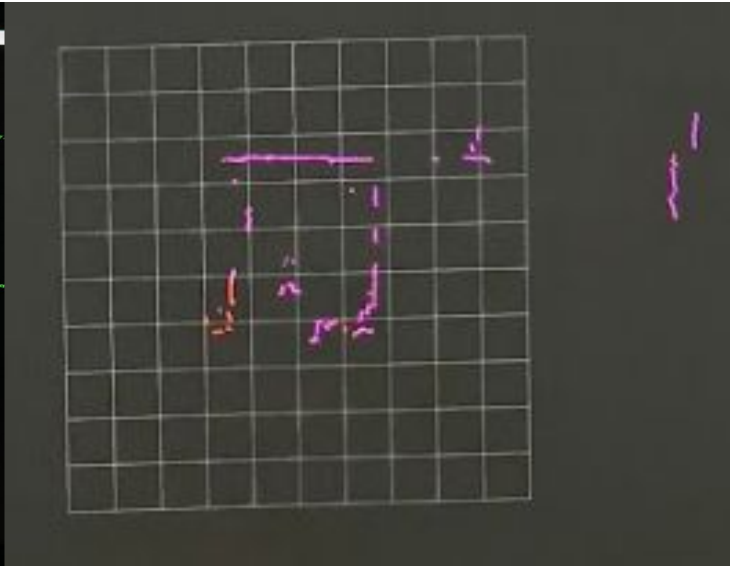
- Testing primarily focused on learning how to use OpenCV to detect objects
- Object recognition was easily implemented on our PCs
- Currently working on implementing with ROS and Gazebo



Testing - LiDAR

- RPLiDAR A1M8-RG
- Sample Frequency of 8KHz
- Range of 0.15 to 12 meters
- 2.50% Accuracy at 12 meters

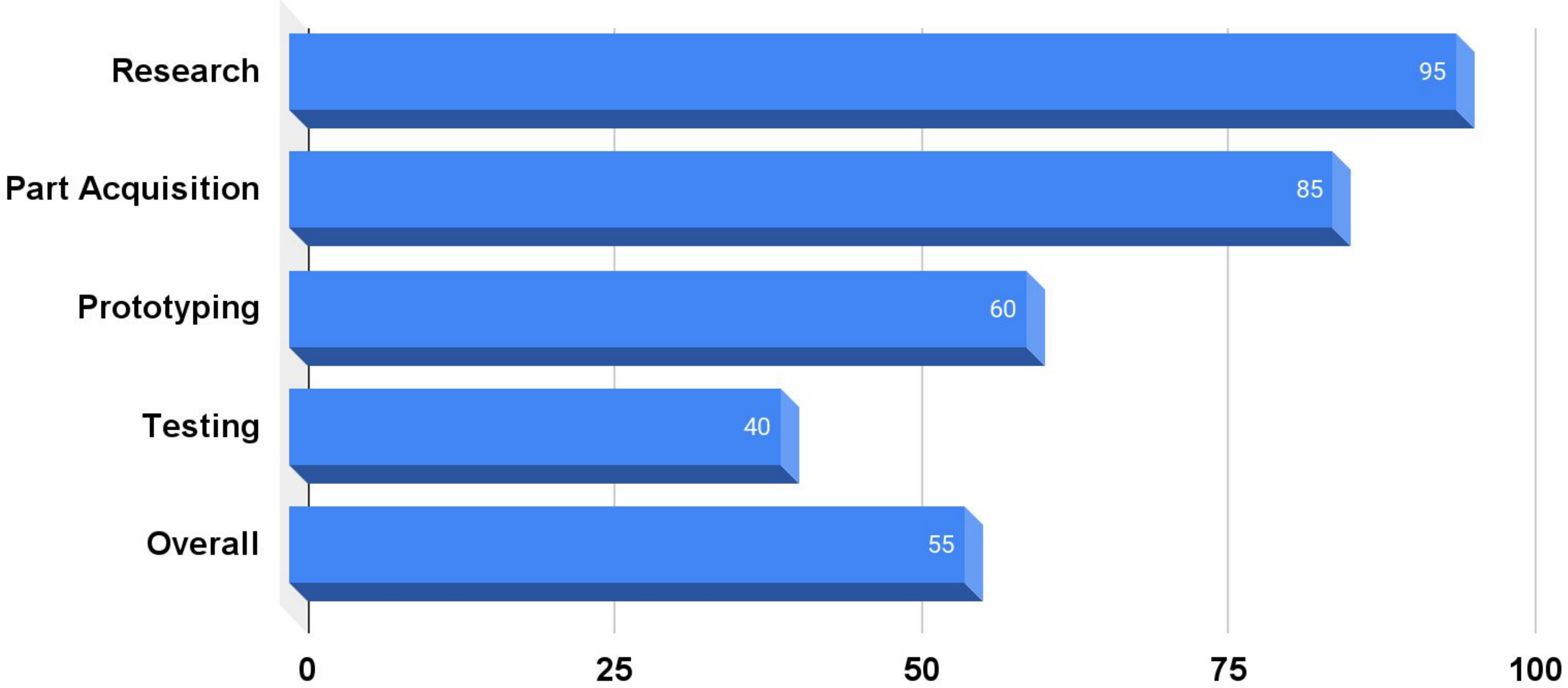




Budget & Financing

Item	Distributor	Quantity Purchased	Cost
Motor Drivers	Amazon	2	$42.00
Screen/speakers	Amazon	1	$51.99
Battery	Amazon	1	$53.99
RFID Module	Amazon	3	$9.99
Solenoid Lock	Amazon	4	$15.99
RFID Cards	Amazon	10	$7.99
32GB Micro SD	Amazon	1	$10.87
ArduCam	Amazon	2	$31.00
Pi Power Supply	Amazon	1	$11.29
Coral TPU	Amazon	1	$82.99
Pi Heat Sink	Amazon	1	$12.59
HDMI to Micro HDMI Cable	Amazon	1	$9.99
Raspberry Pi 4	Amazon	1	$75.99
LiDAR	Amazon	1	$99.99
DC Motors	DigeyKey	4	$109.60
Power Regulation PCBs (Populated)	JLCPCB	5	$49.99
Drive System PCBs (Populated)	JLCPCB	5	$60.00
		Total:	$736.25

Current Progress



Immediate Next Steps

- Reworking software stack on Pi (ROS, Gazebo, OpenCV, etc.)
- Raspberry Pi 5 as possible alternative
- Testing and reordering PCBs
- Refining our OpenCV software with an obstacle library with our 3D software

Questions?