Modular IEEE Robot

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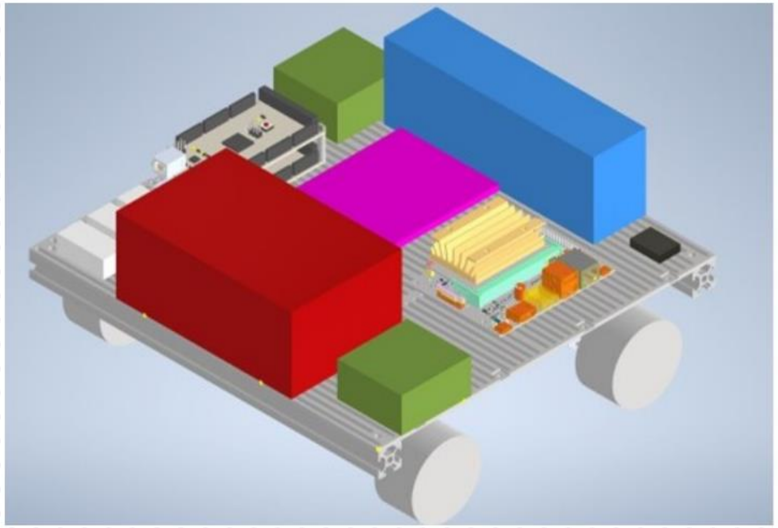
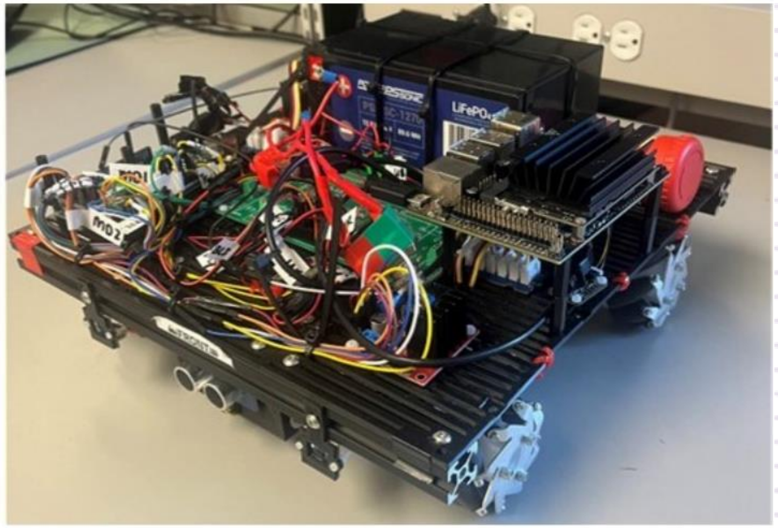
IEEE

What is the problem?

- **Problem:** Each year, the SECON capstone team faces the same operational problems: motor control, navigation, and wire and battery management.
- **Solution:** Create a sound robot platform with navigation control, precise motor control, integrated battery charging, and adaptable modules.





Industry Impact

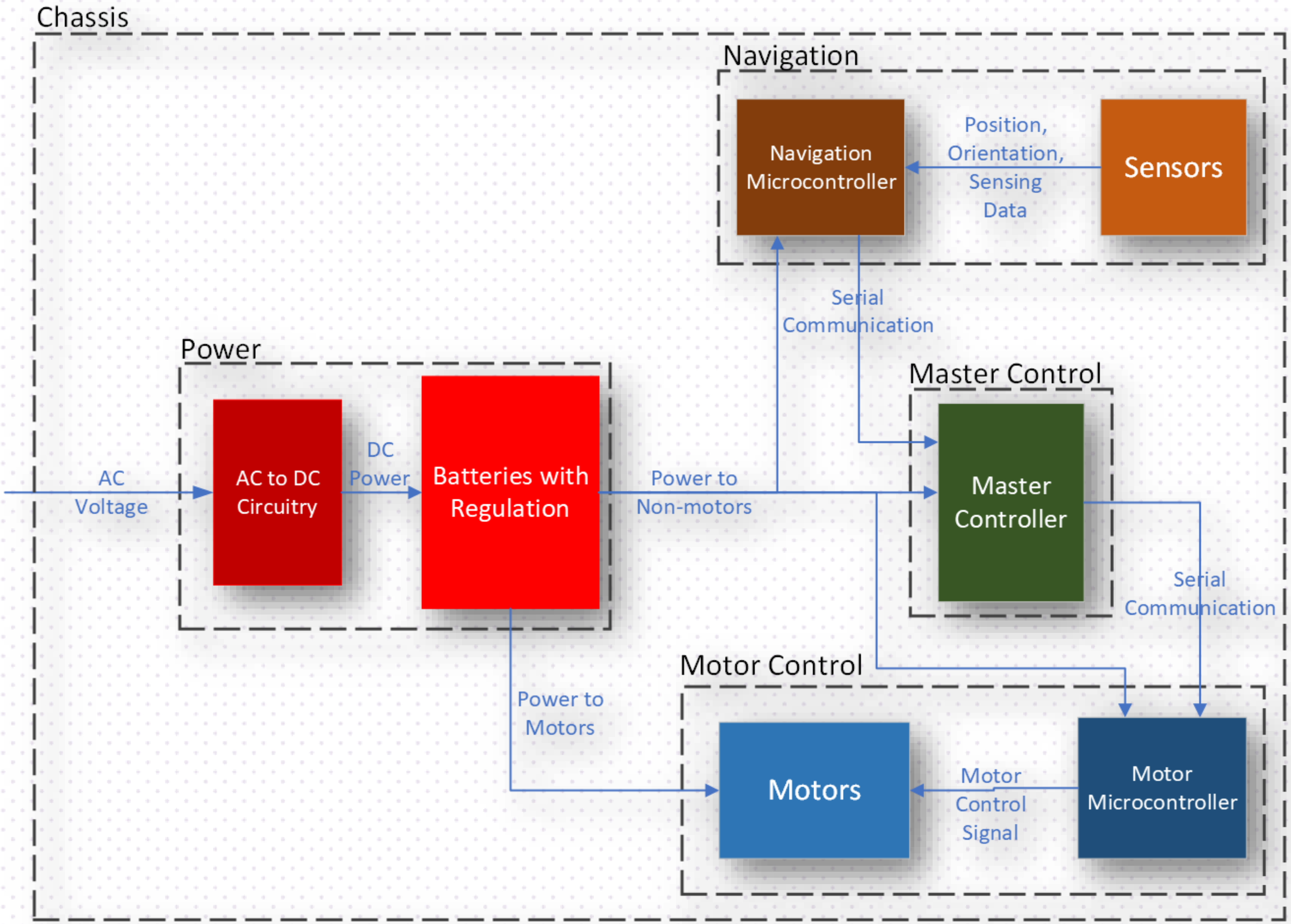
- ROS led navigation allows for diverse applications
- Universal coding convention
- Small size and adaptability for multi-purpose use

Clearpath Robotics Husky A200

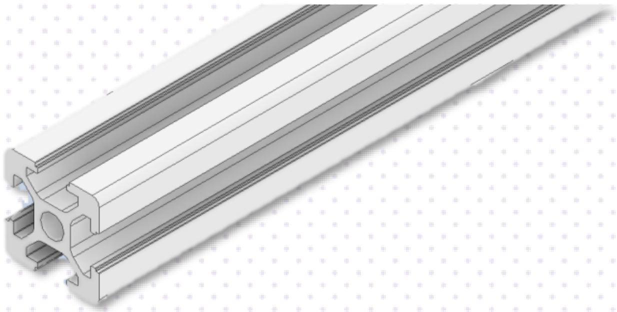
Design

Our priorities:

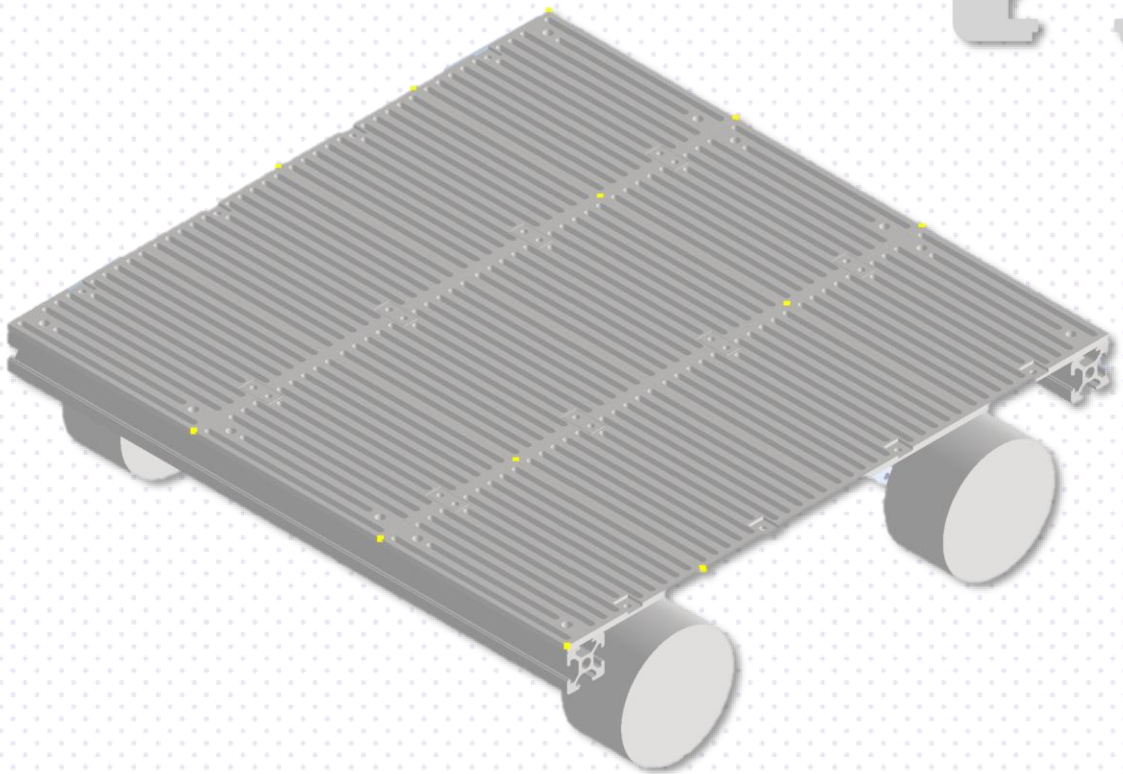
- Modularity
- Autonomous Navigation
- Robust Power System



Chassis



- Modularity and Organization
  - Extruded Aluminum
  - Drop-in T-nuts
  - Slotted Sheets
- Iteration process with 3D components
- Motor attachment



Motor Control

- Navigation
  - Full range of movement
  - Reliable and consistent motor response
- Mecanum wheels
- DC motors

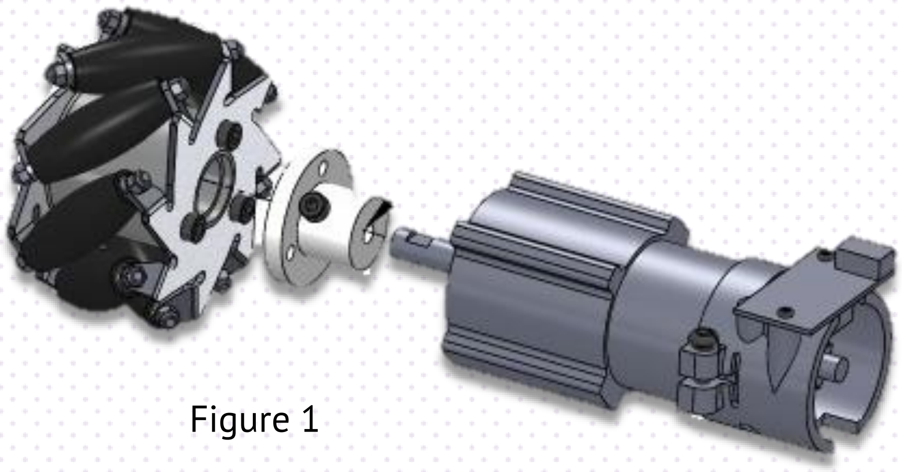


Figure 1

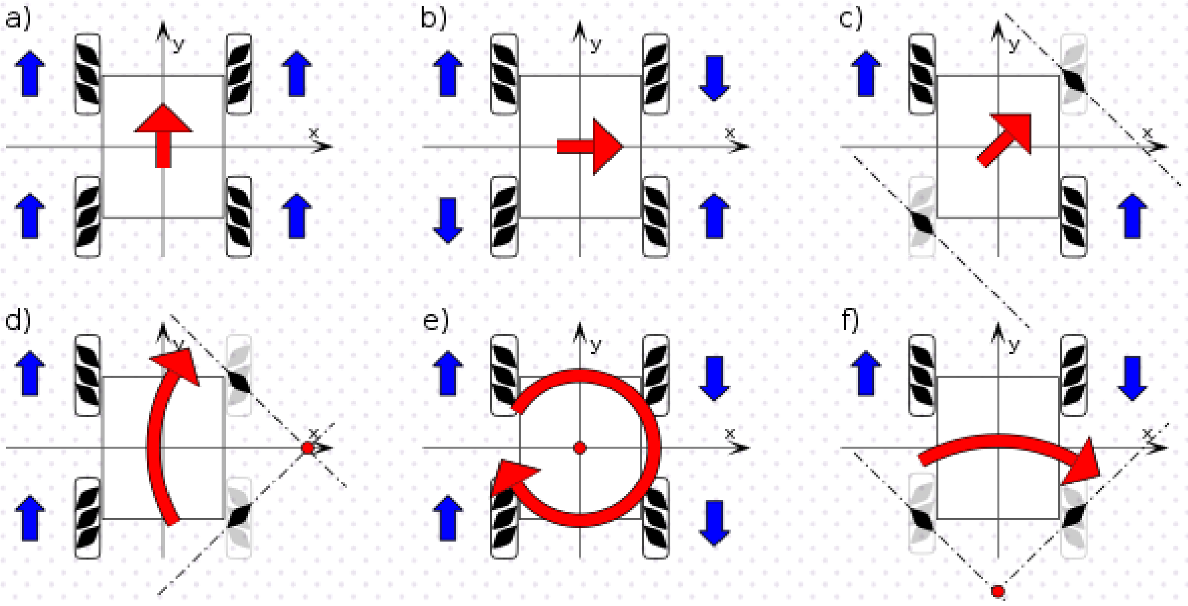
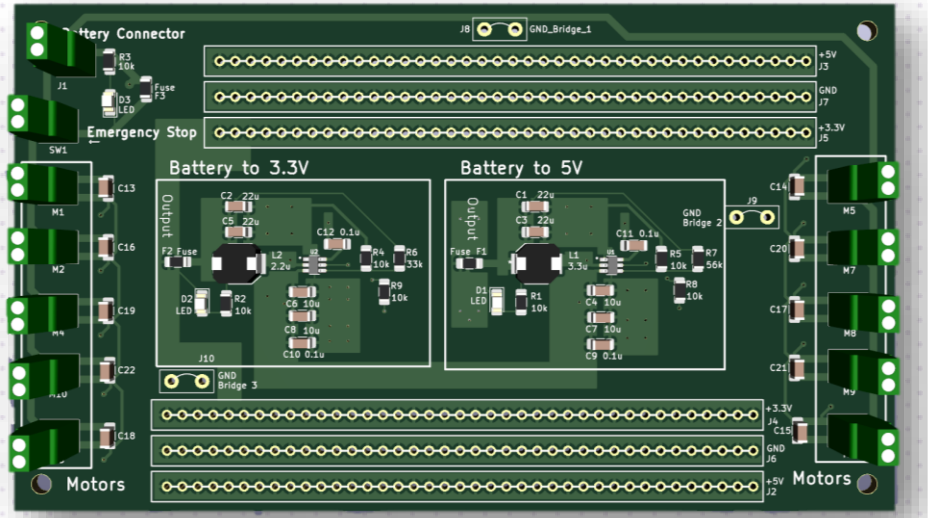
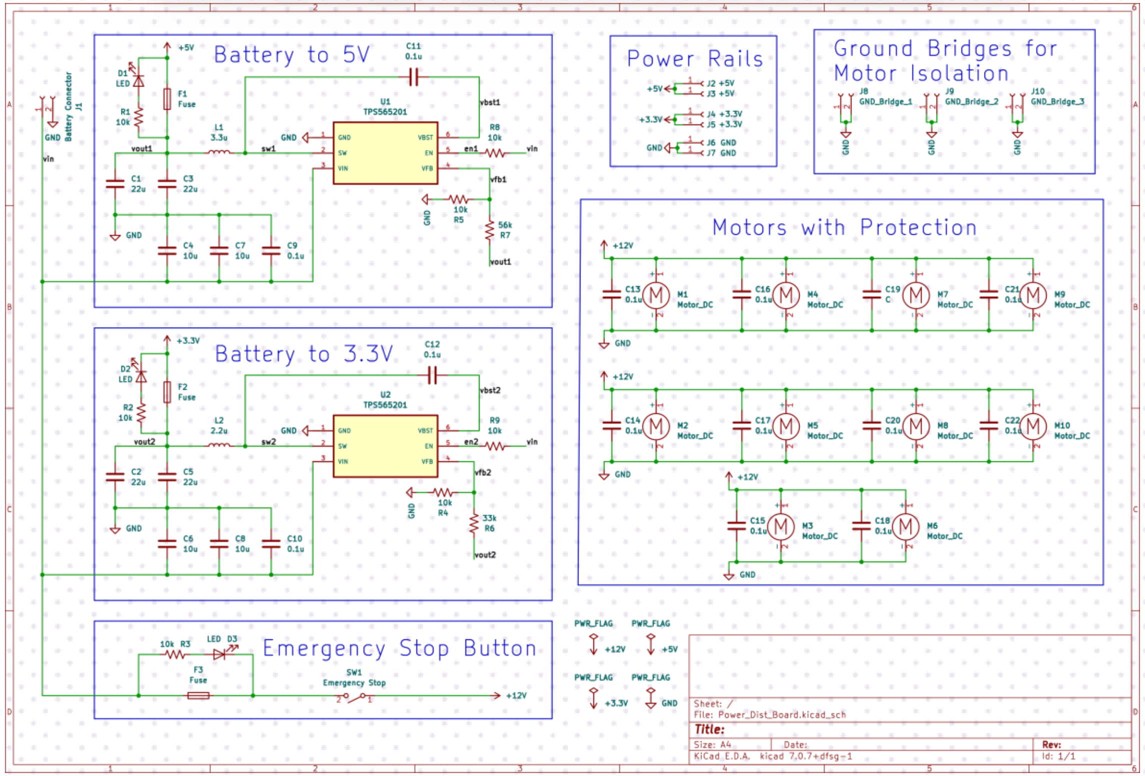


Figure 2

Power

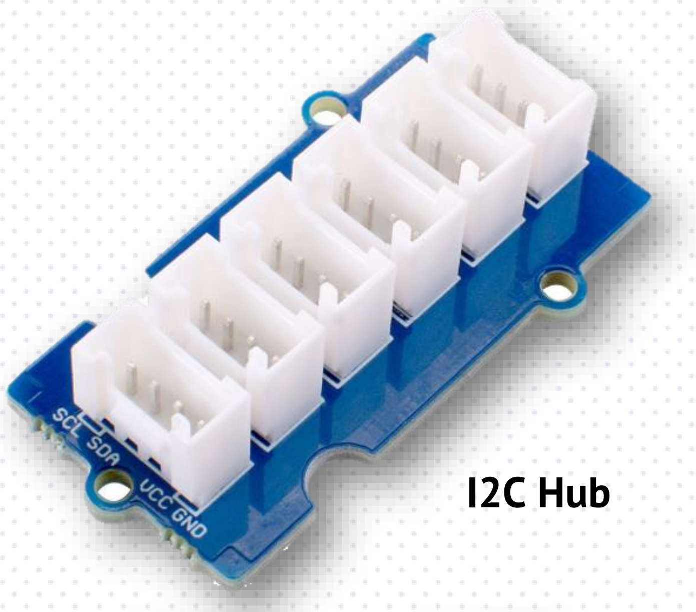
- Battery
  - Motor runtime of 30 minutes
- Power Distribution
  - Battery power to 3.3 V and 5 V rails
  - Design based around TI buck converters
- Wireless Charging
  - Experimental system to charge robot while in arena





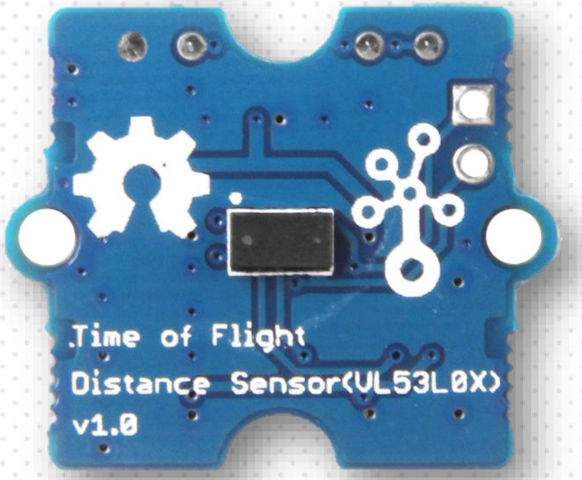
Navigation – Location and Object Detection

- Grove – Ultrasonic Ranger
- Grove – ToF Sensor (VL53L0X)
    - I2C Hub



I2C Hub

Ultrasonic Ranger

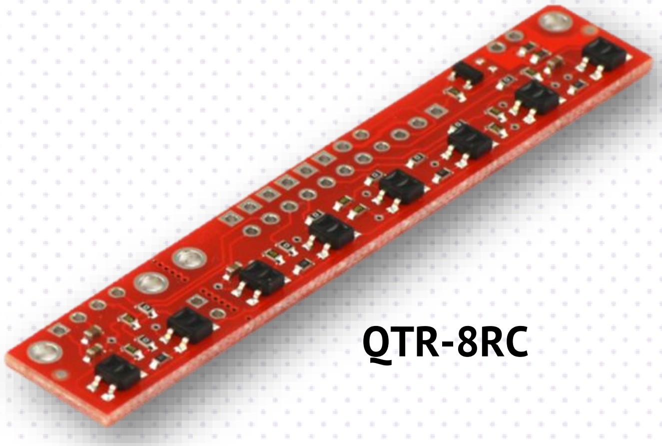


Time of Flight

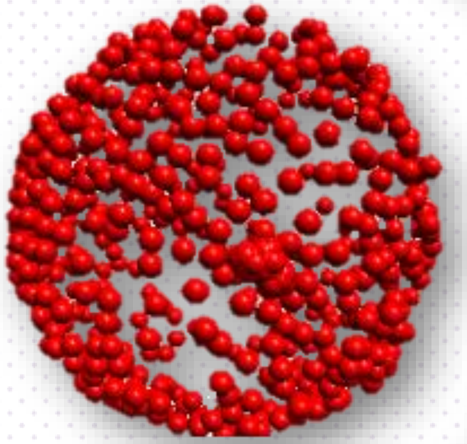
Navigation –
Line Following and Orientation

- Pololu QTR-8RC reflectance array
  - Returns values from 0-1000

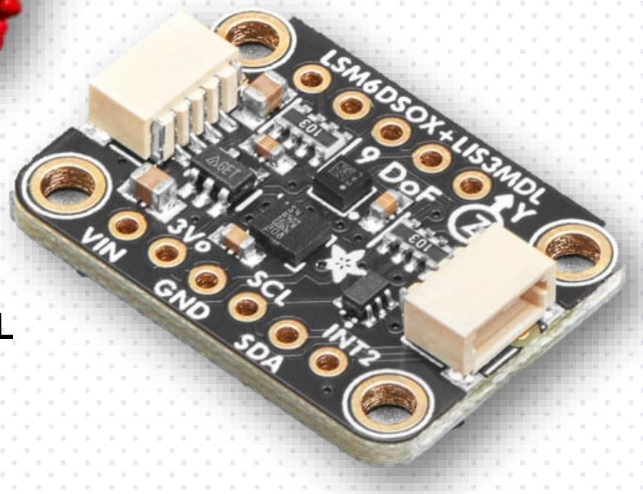
- LSM6DSOX + LIS3MDL 9 DOF
  - Returns roll, pitch, yaw



QTR-8RC



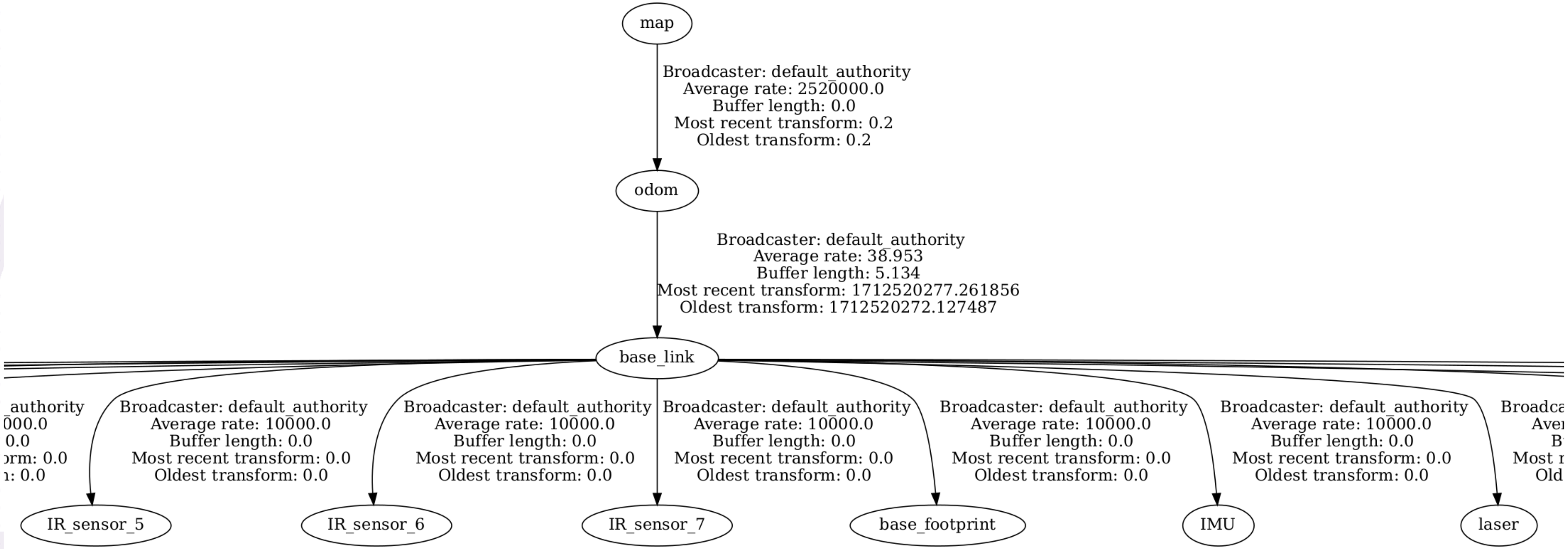
Orientation Calibration Results



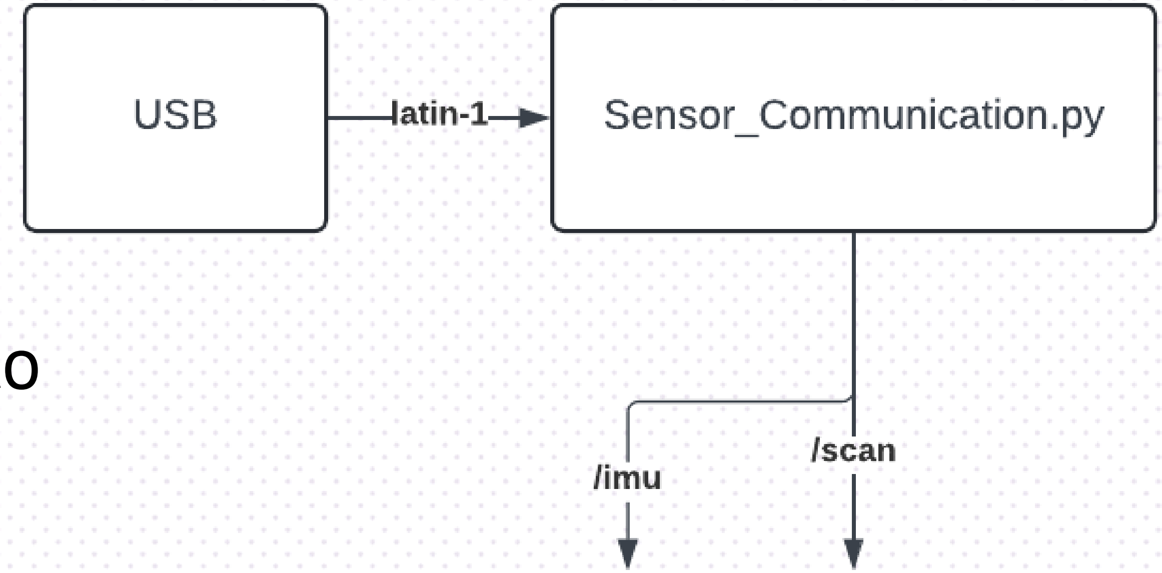
LSM6DSOX + LIS3MDL

Master Control

- Utilized ROS2 middleware for SLAM
- Laid foundation for autonomous navigation



Master Control



- Sensor intake: used pyserial to read, parse and publish data onto ROS2 topics

Data Parsing from Serial Port

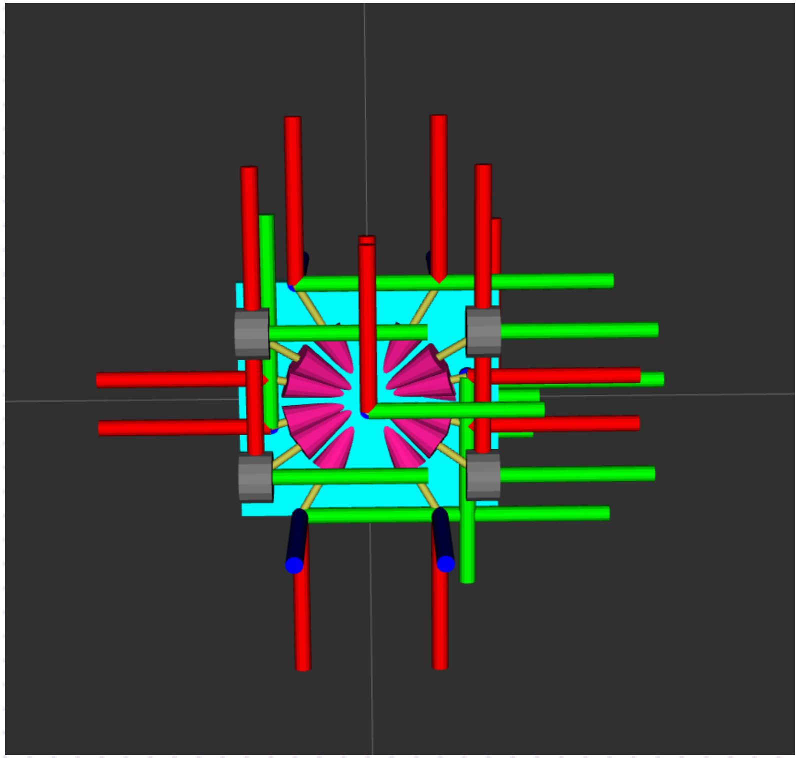
```
def data_read_callback(self):

    if self.serialInst.in_waiting:
        self.data.clear()
        packet = self.serialInst.readline()
        rec = packet.decode('latin-1').rstrip('\n')
        rec = rec.replace('<', '')
        rec = rec.replace('>', '')
```

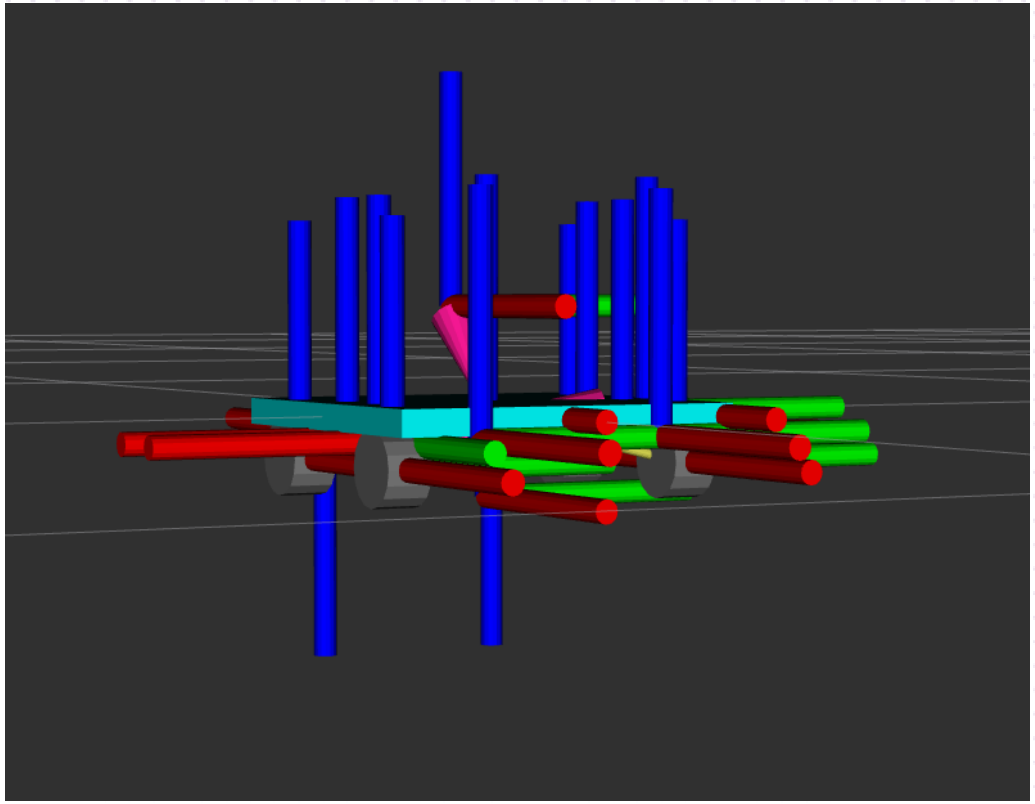
ROS2 Publisher

```
def publish_IMU(self):
    imu = Imu()
    imu.header.frame_id = "IMU"
    imu.header.stamp = self.get_clock().now().to_msg()
    imu.orientation.w = float(self.data[4])
    imu.orientation.x = float(self.data[5])
    imu.orientation.y = float(self.data[6])
    imu.orientation.z = float(self.data[7])
    self.IMU.publish(imu)
```

Master Control

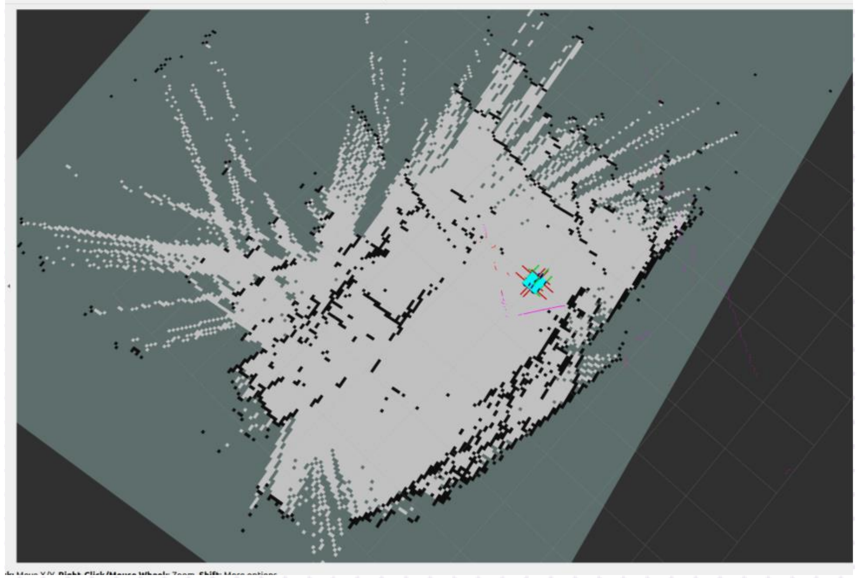
- Rviz2 utilized as the primary GUI
- URDF, robot state publisher, and joint state publisher
  - Established base_link -> base_scan (laser)

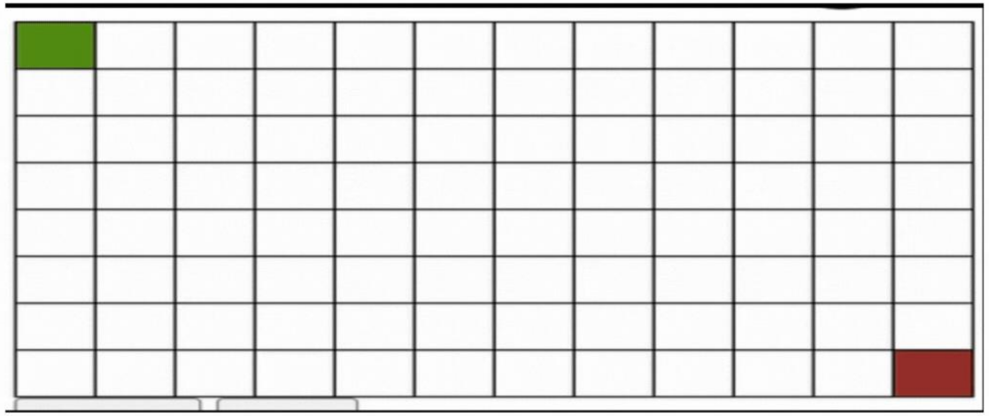




Master Control

- Robot_localization used for localization and mapping
  - Ekf filter
  - Published odom -> base_link
- SLAM toolbox used for mapping
  - A* search algorithm configured for navigation

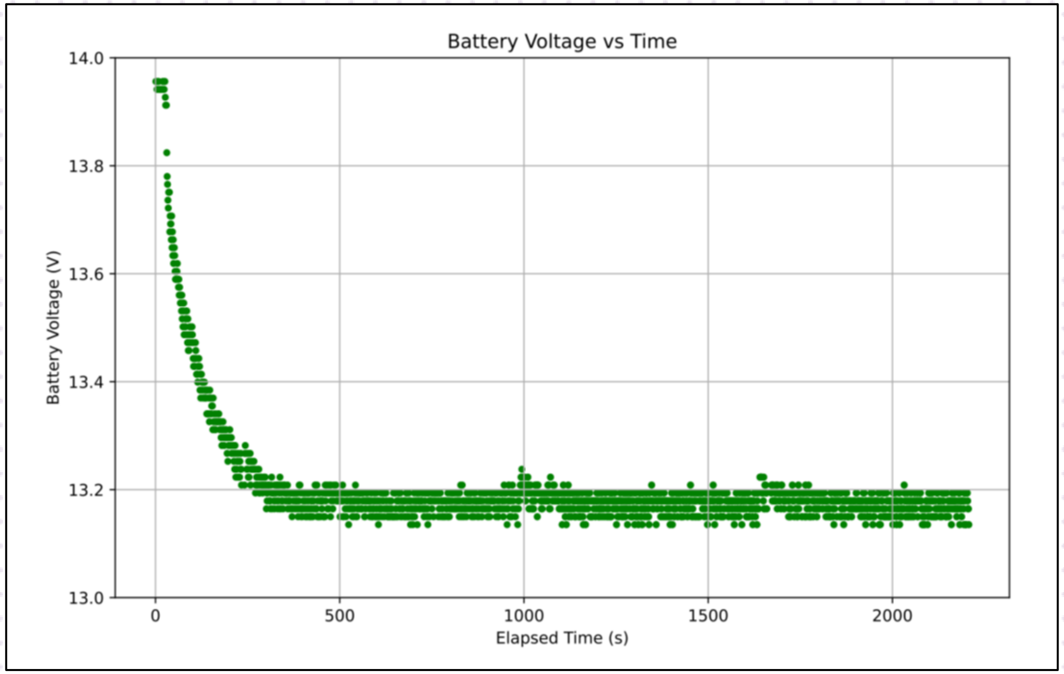


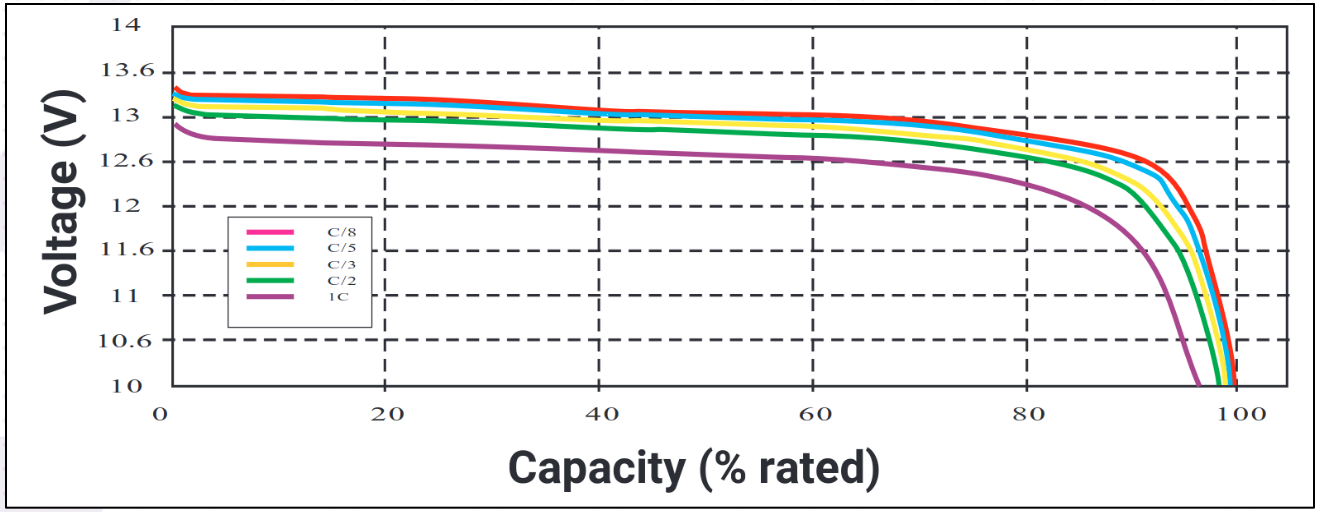


Experiments and Results – Battery Life

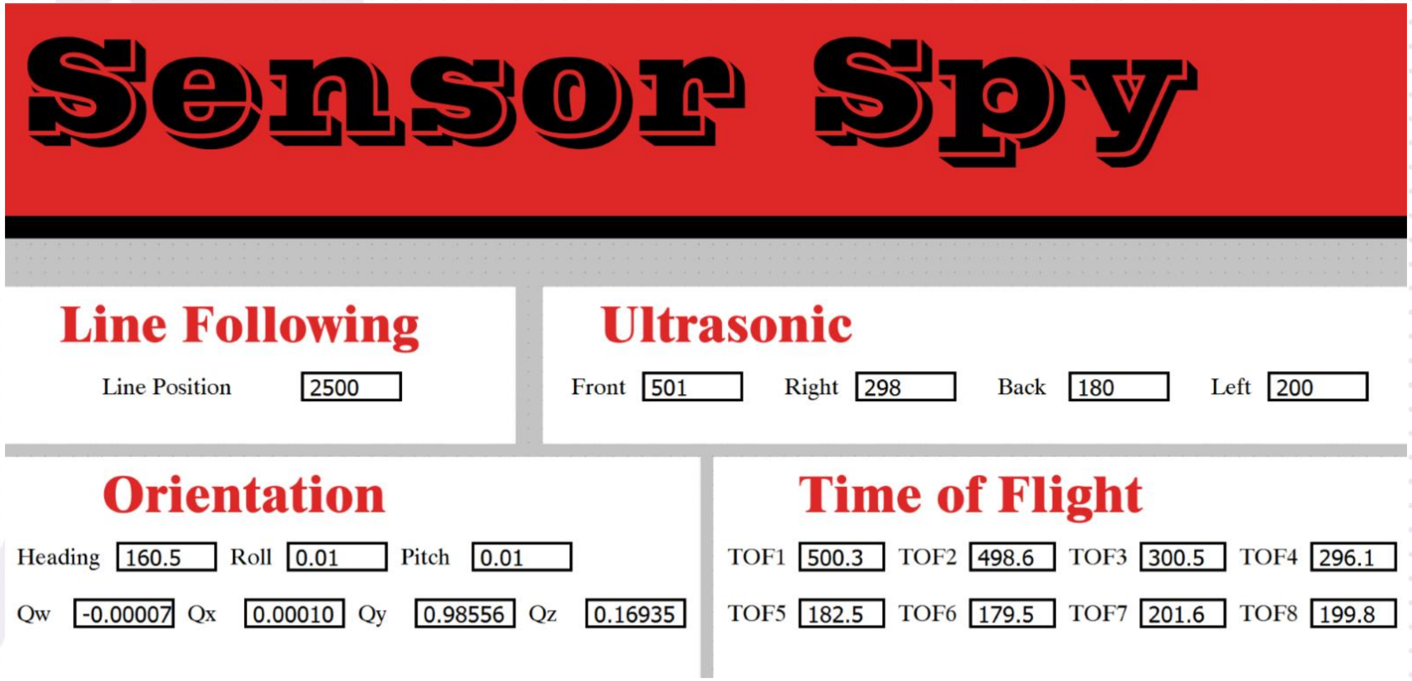
- Robot run in circles in place in 10-minute increments

- Battery discharge curve compared to datasheet
  - Estimated battery life to be 4-5 hrs

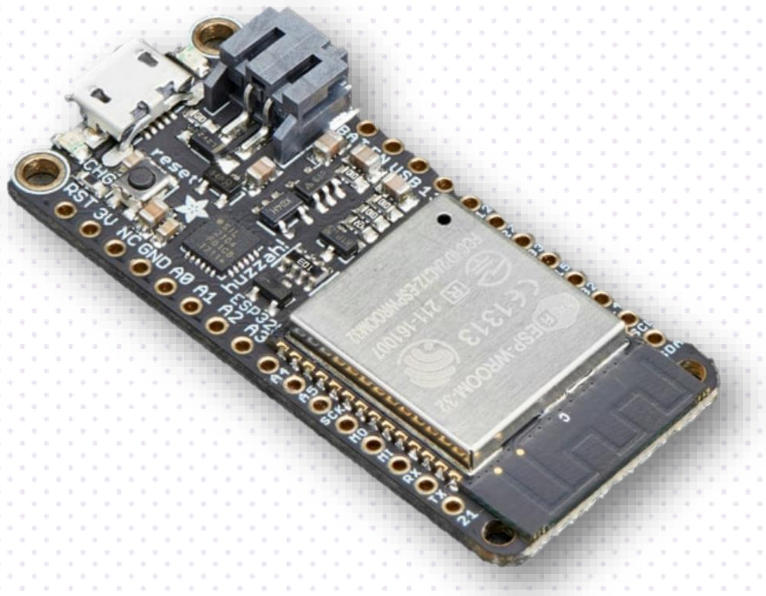




Experiments and Results - Sensors



Sensor Spy GUI for real – time sensor data

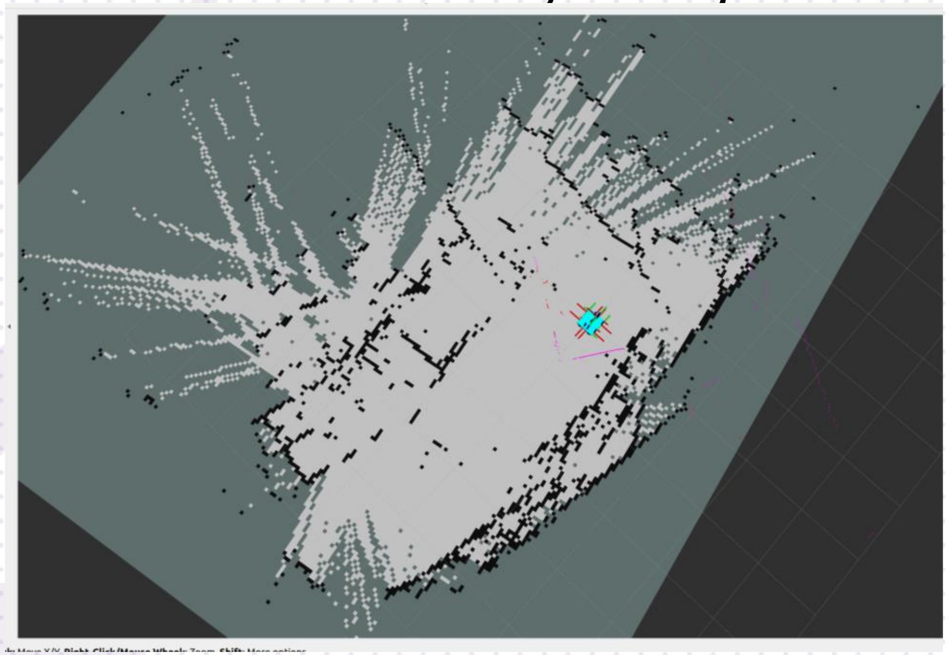


ESP32 Microcontroller

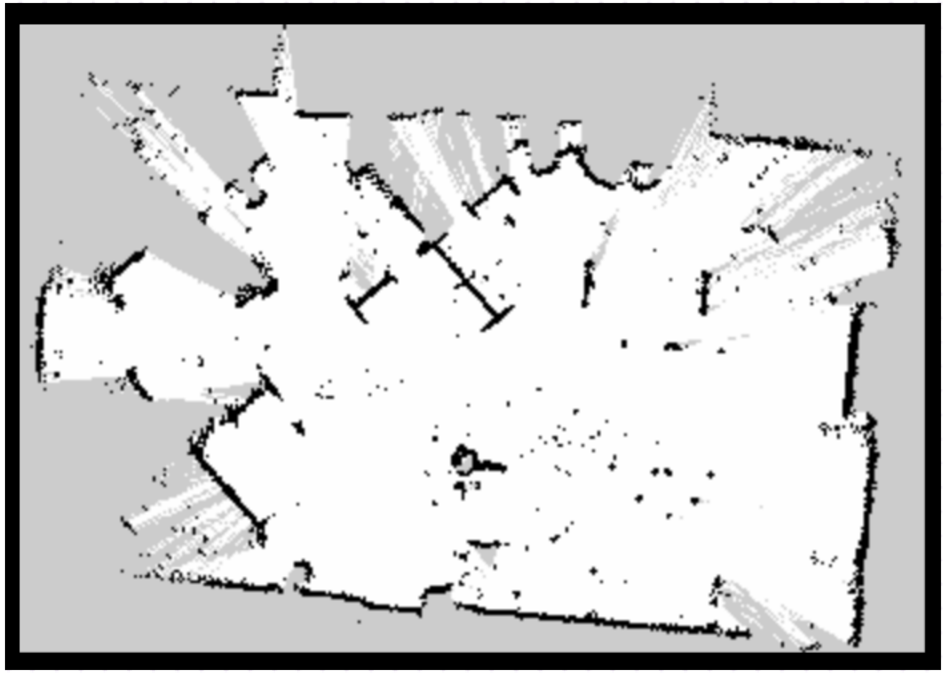
- Two ESP32 microcontrollers were used to transmit data

Experiments and Results - Nav2 Mapping

- No working odometry: issues with the accuracy of our IMU
- No base scan for mapping
  - Initial solution: use other scanners to make a mock lidar
  - Solved by using Slamtec's Rplidar a2m8



Mapping Trial 1



Mapping Trial 3

Experiments and Results – Speed

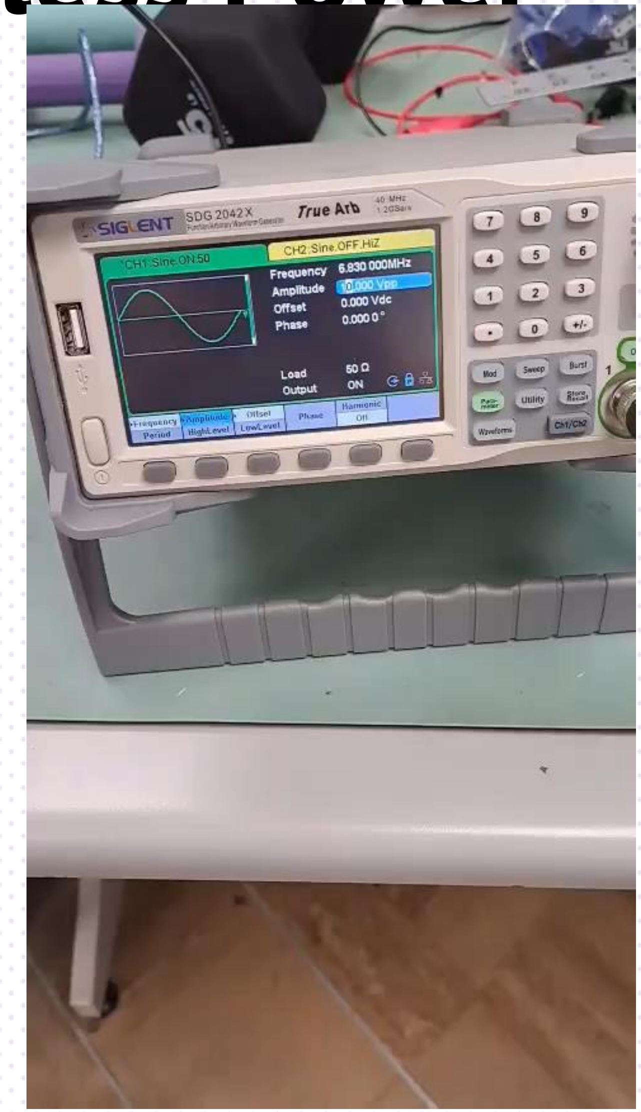
- Target: 2 ft/s (1.36 mph)
- Actual: 0.731 ft/s

Ran the robot in a straight line for a preset number of seconds and measured the distance.

Tile - No Payload / Capstone Lab		
Trial	Distance (inches)	Speed (ft/s)
1	45 / 88	0.75 / 0.733
2	47 / 87	0.783 / 0.725
3	46 / 87.5	0.767 / 0.729
4	45.5 / 87.5	0.758 / 0.729
5	45 / 88	0.75 / 0.733

25 Pound Payload / 2023 Arena		
Trial	Distance (inches)	Speed (ft/s)
1	87 / 45	0.725 / 0.750
2	87 / 46	0.725 / 0.767
3	86 / 45	0.717 / 0.750
4	86 / 45.5	0.717 / 0.758
5	87 / 45.5	0.725 / 0.758

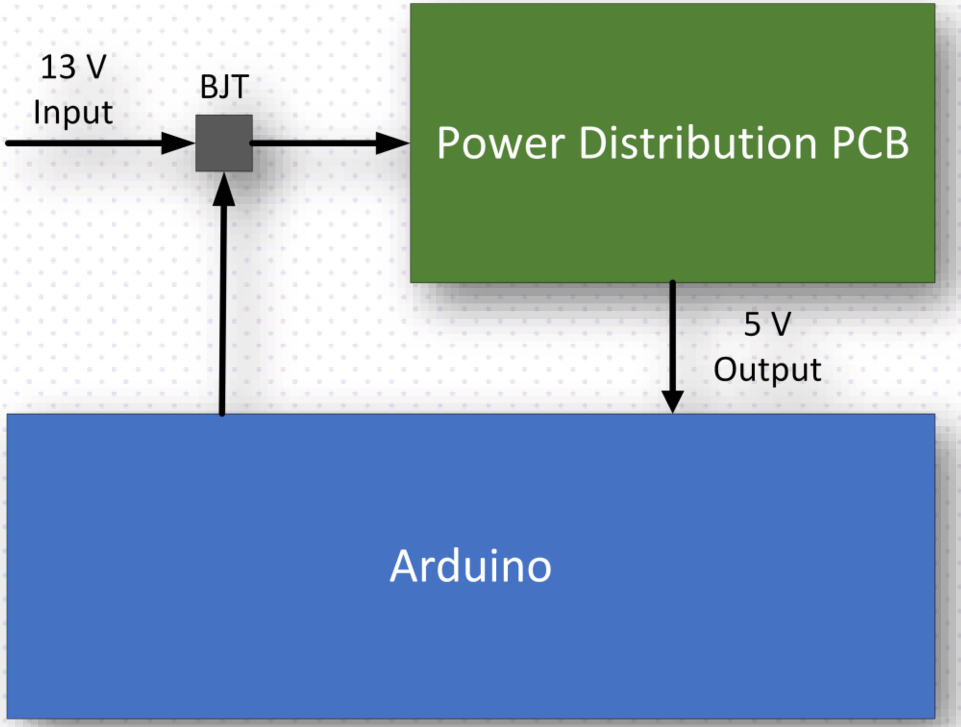
Experiments and Results – Wireless Power



- Capacitive wireless charging was evaluated as a method of providing power to the robot while testing
- Proof-of-concept demonstrated powering a small load
- Future implementations will require more research and safety precautions

Experiments and Results - Power Board

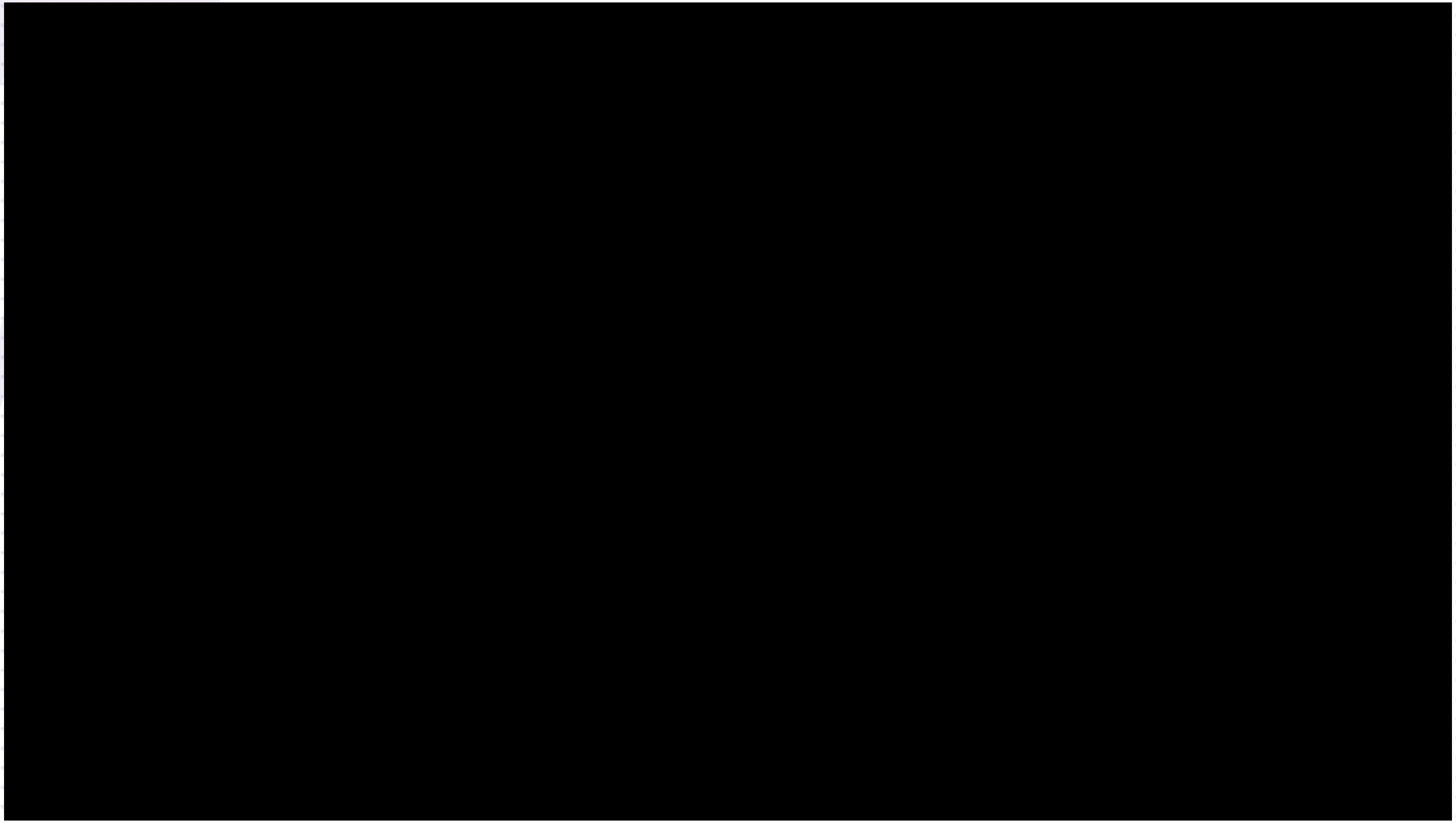
- Can source up to 5 A from each voltage rail
- Microcontroller used to emulate turning the power board on and off
  - Tested number of power cycles the power board can survive
  - Board has currently been power cycled around 660,000 times



Summary Results

	Constraint	Was it met?
1	Single start button	Yes
2	Allocated spot for alternate start method	Yes
3	Customizable dimensions (only take up half cubic foot)	Yes
4	Plug and play adaptable	Yes
5	Robust centralized charging system	Yes
6	Evaluate wireless charging	Yes
7	Single emergency stop for motors	Yes
8	Design power bus so motors don't inhibit operation	Yes
9	Travel inclines and declines up to 25 degrees	Yes
10	Turn 360 degrees and move forward and backward based on sensors	Yes
11	Navigation system controls movement, knows location within 2 inches, maximum speed of 2 ft/s	No
12	All components will be 3D printed	Yes
13	Line sensor attachment will be between 0.125 and 0.375 inches off the ground	No
14	Frame can withstand 20 pounds	Yes

Line Following Demo



Budget

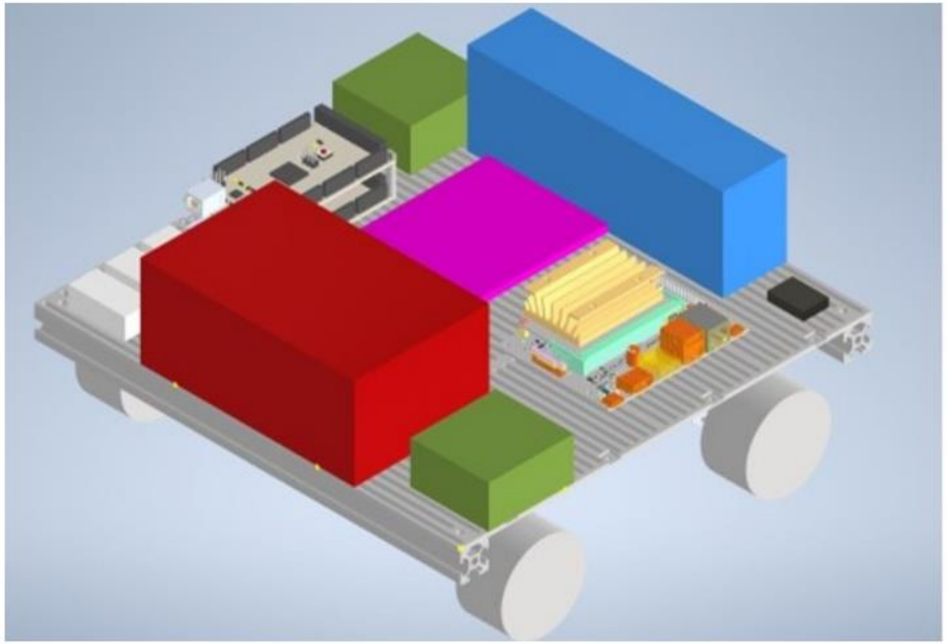
Proposed Budget	
Subsystem	**Cost**
Chassis	$245.00
Power	$730.00
Master Control	$150.00
Motor Control	$363.00
Navigation	$314.00
Wireless Charging	$0.00
Miscellaneous	$200.00
Total Cost	$2,002.00

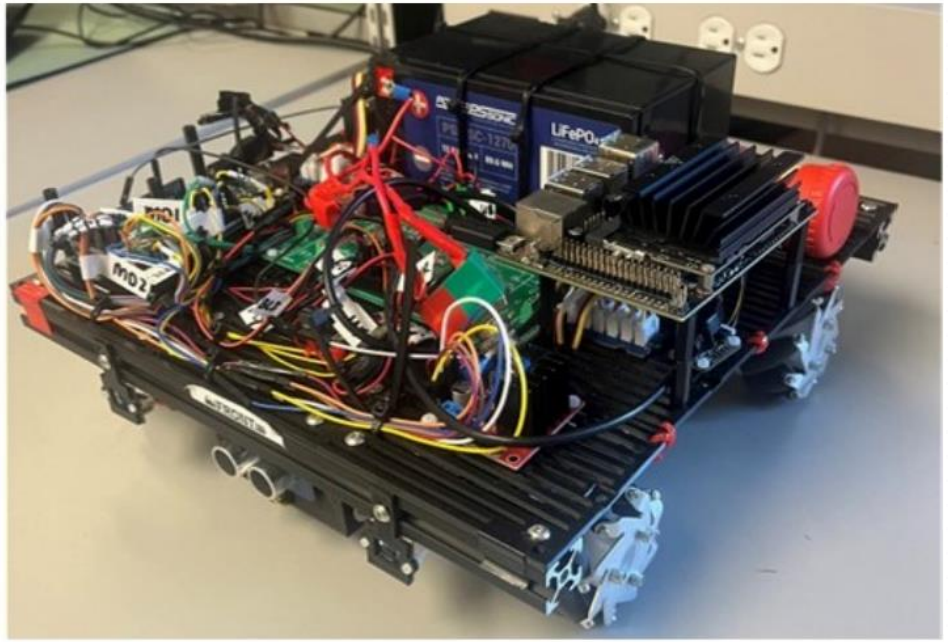
Final Budget	
Subsystem	**Cost**
Chassis	$145.01
Power	$428.80
Master Control	$196.44
Motor Control	$318.73
Navigation	$424.23
Wireless Charging	$134.06
Miscellaneous	$0.00
Total Cost	$1,647.27

References

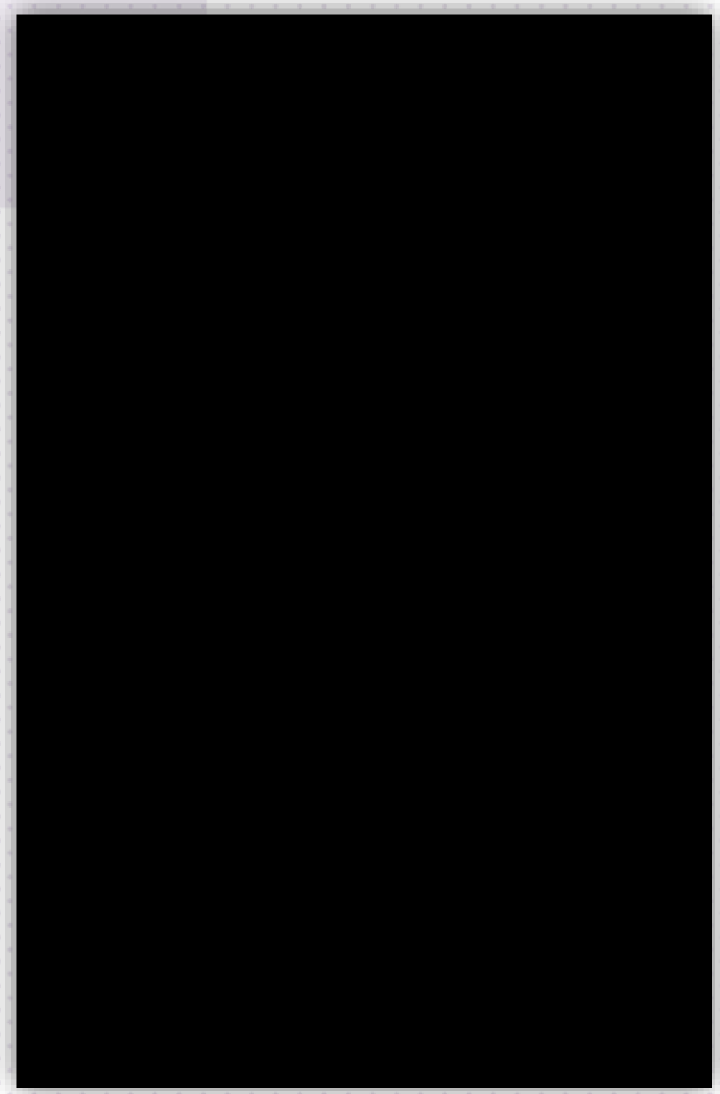
[1] "NFPA 79: Electrical Standard for Industrial Machinery". [Online]. Available: https://link.nfpa.org/free-access/publications/79/2121
[2] "Using the National Electrical Code (NEC) Ampacity Charts," May 2021. [Online]. Available: https://www.nfpa.org/~/media/Files/Code%20or%20topic%20fact%20sheets/NECAmpacityWorkflow.pdf
[3] "IEEE Code of Ethics," Jun. 2020. [Online]. Available: https://www.ieee.org/about/coporate/governance/p7-8.html
[4] "RF Exposure Considerations for Low Power Consumer Wireless Power Transfer Applications," Jan. 2021. [Online]. Available: https://apps.fcc.gov/kdb/GetAttachment.html?id=g5f2nQFxHnlMbja%2FFzq1QQ%3D%3D&desc=680106%20D01%20RF%20Exposure%20Wireless%20Charging%Apps%20v03r01&tracking_number=41701

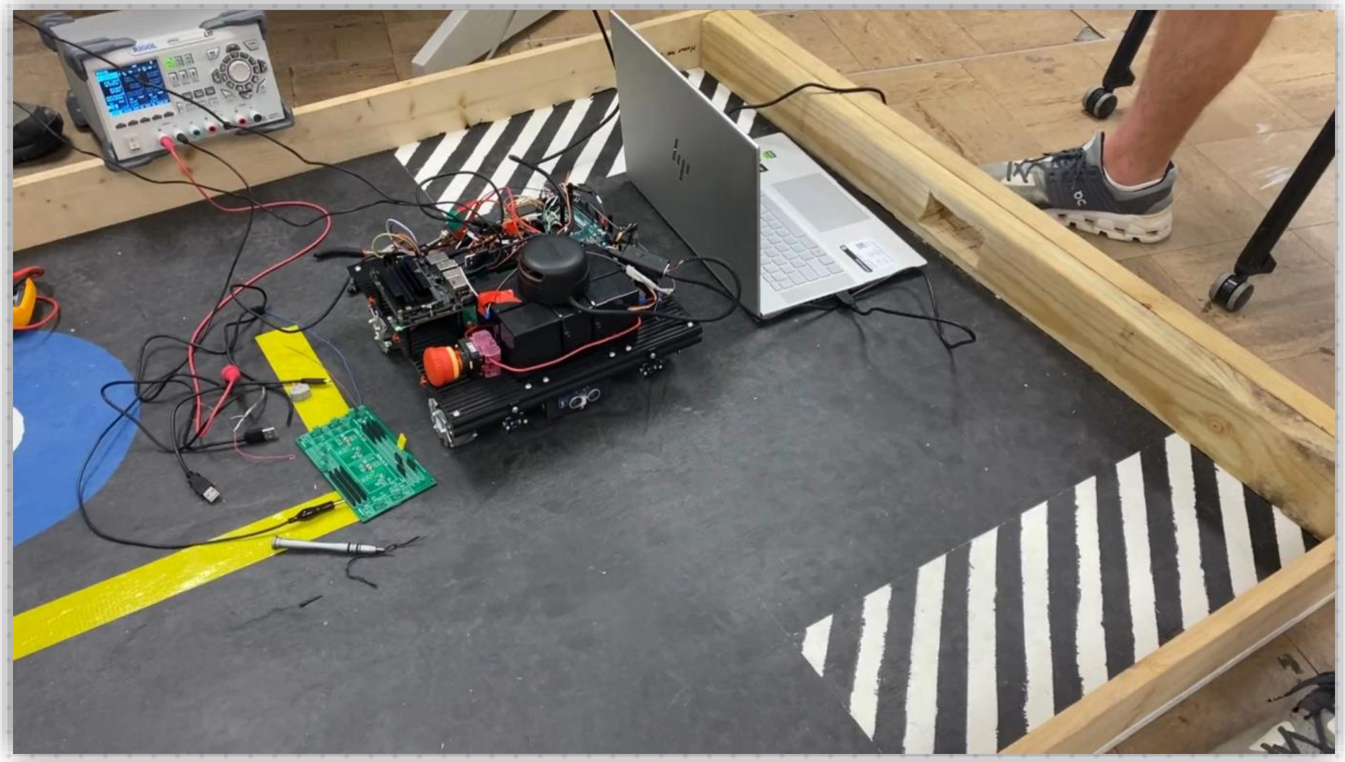
Questions?





Position Sensing and Object Detection Video





Designing Power Board for Current Capabilities

- Temperature of PCB substrate
- copper traces are narrowest right at the buck converter pins – point of failure
- Had to find copper weight that could support current at 0.5 mm width (min width of 3.3v/5v output trace) - which yielded 2 oz
- Source: IPC-2221A(L): Generic Standard on Printed Board Design Section 6 Figures 6-4A and B

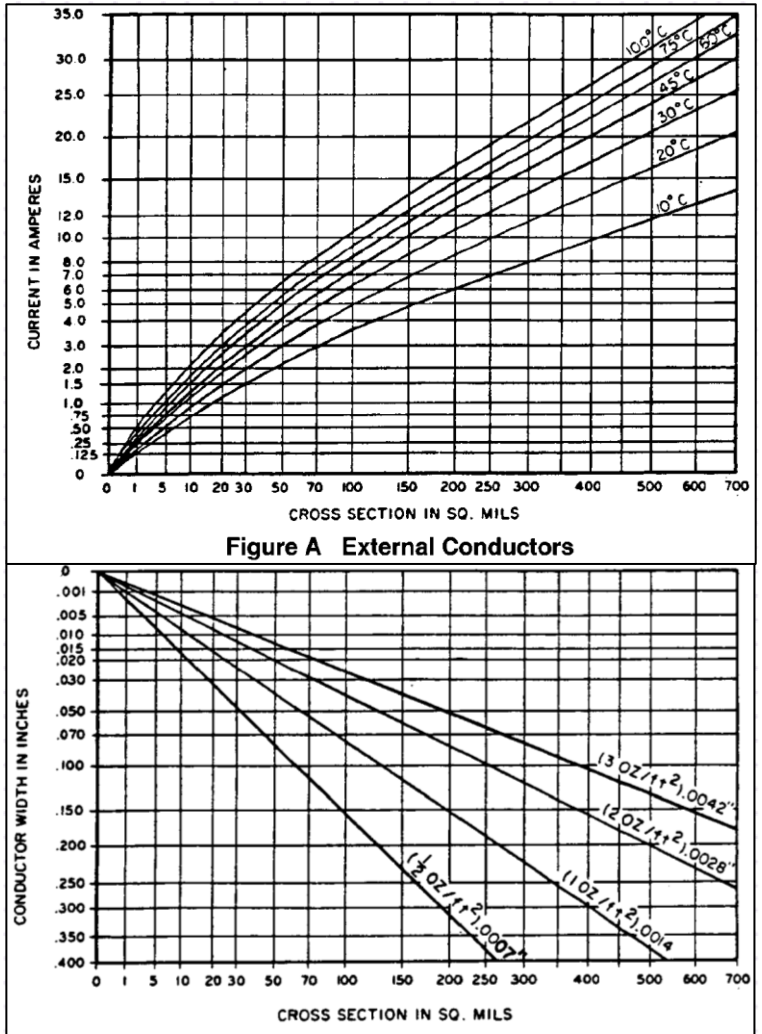


Figure A External Conductors

Figure B Conductor width to cross-section relationship