Modular IEEE Robot

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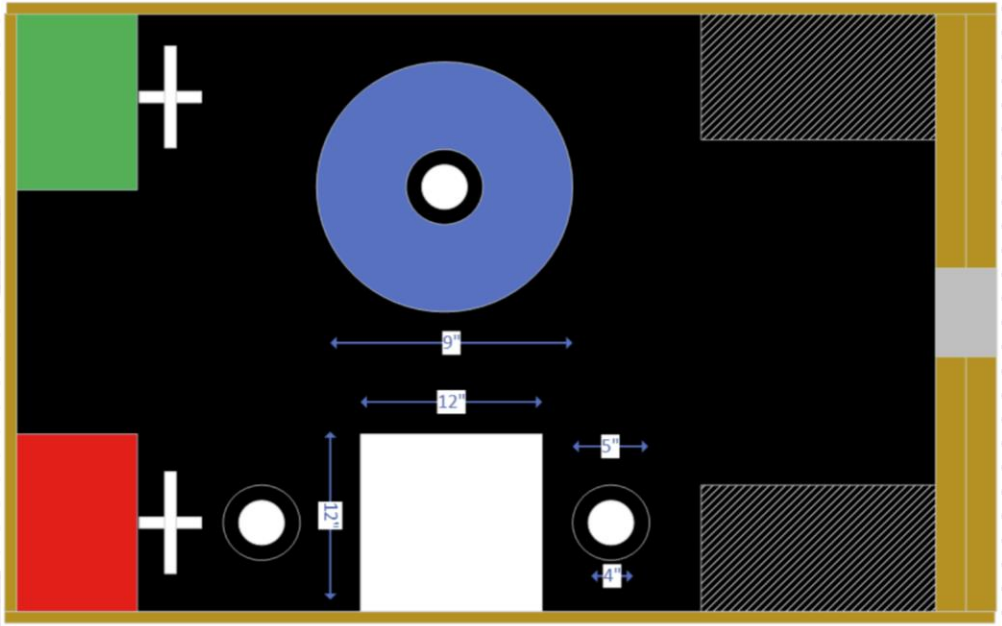
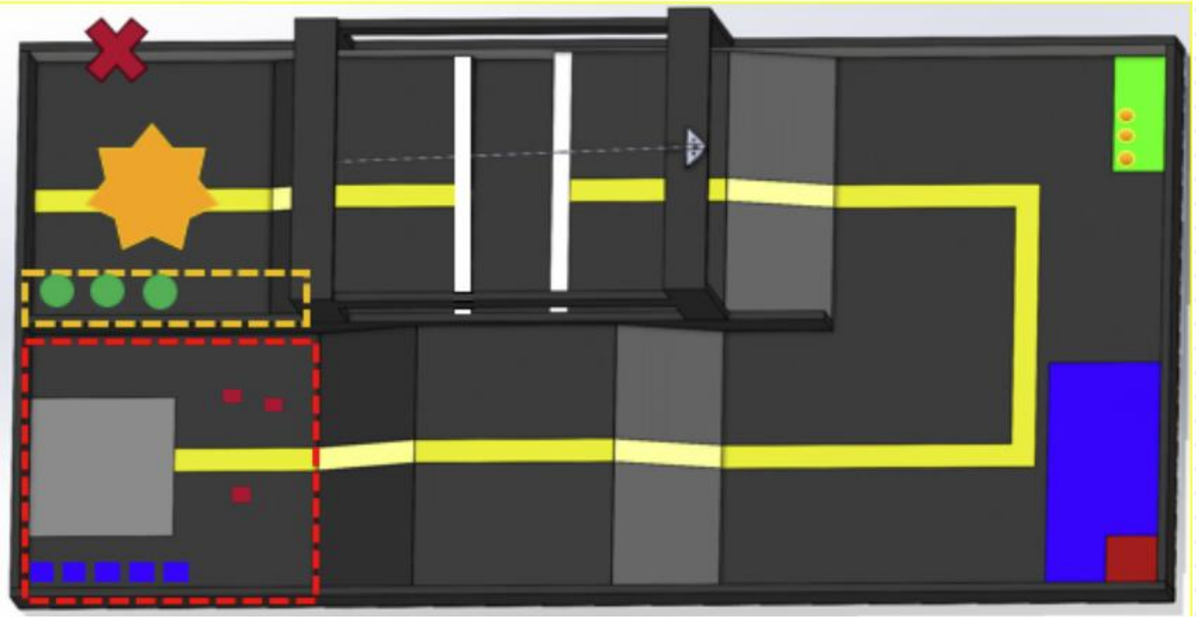
What is the problem?

- **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.



2023



2024

What is the problem?

- **Problem:** Each year, the SECON capstone team faces the same operational problems: motor control, navigation, and wire and battery management.
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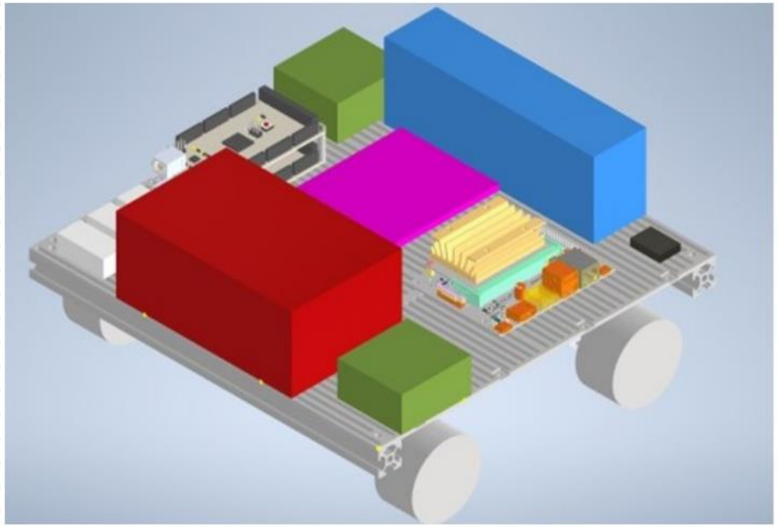
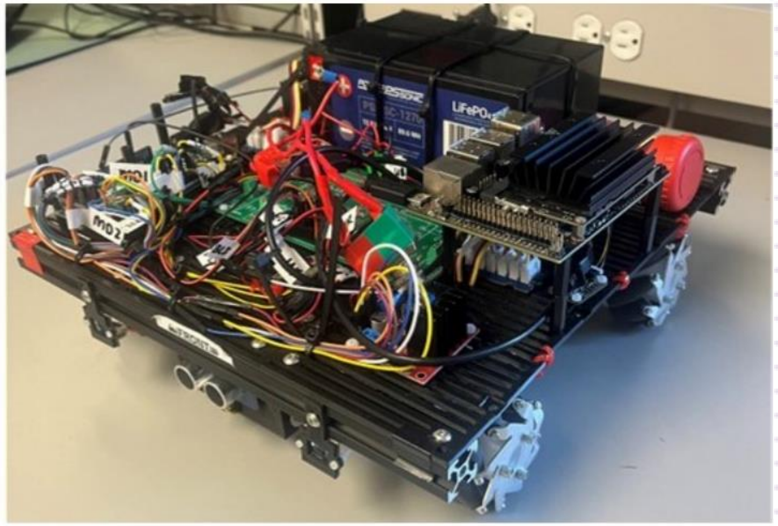
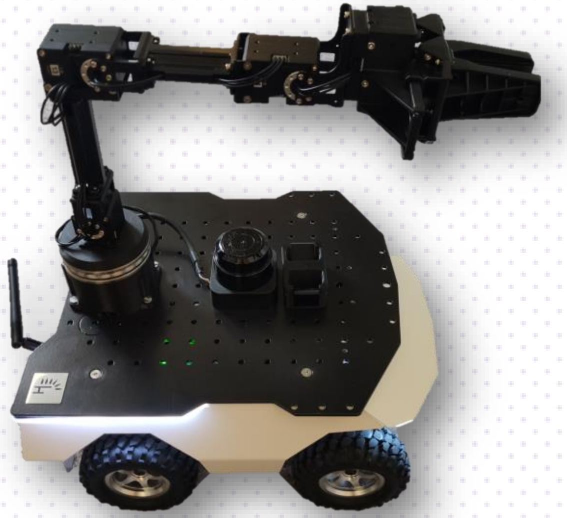




Industry Impact

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

Clearpath Robotics Husky A200



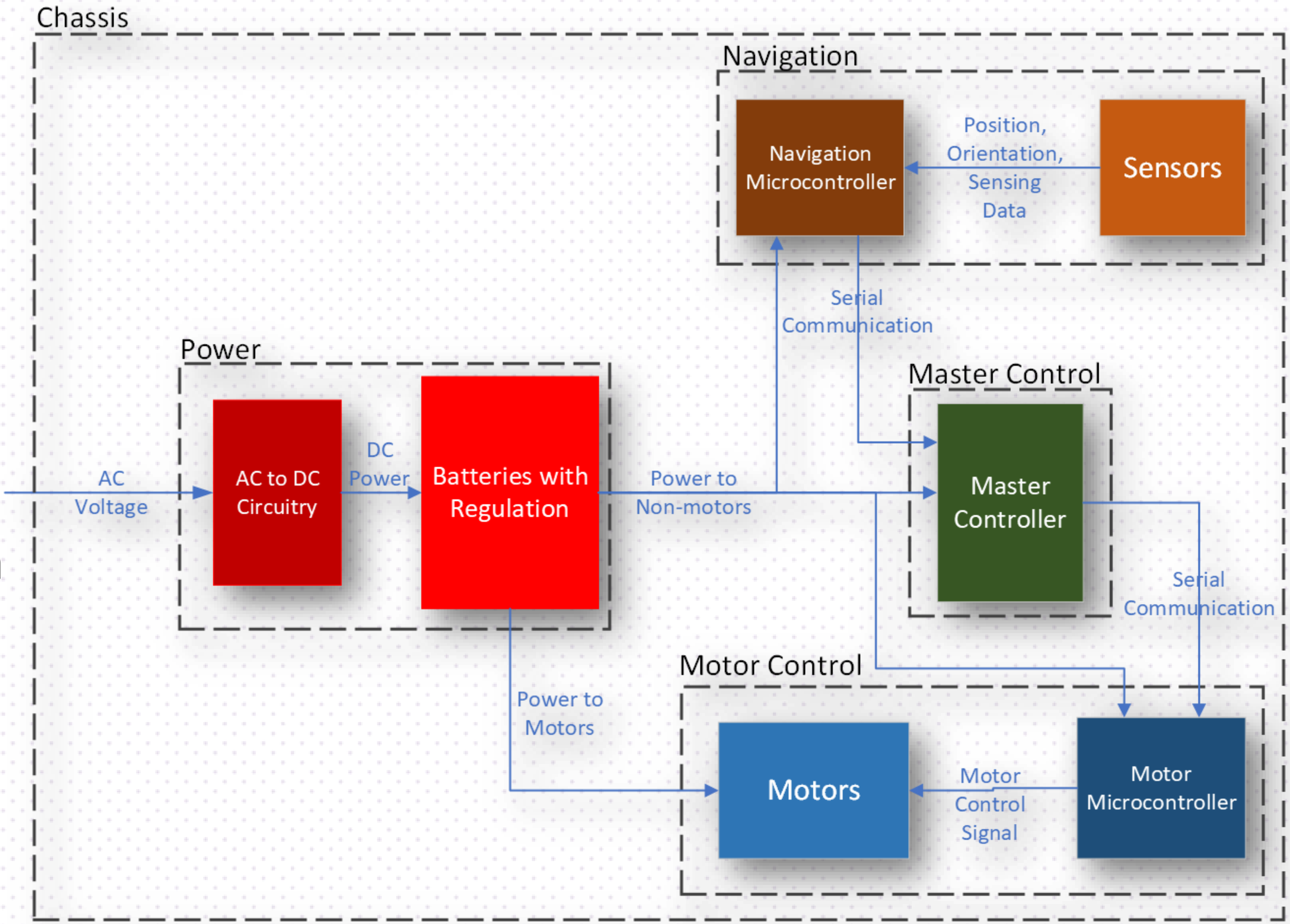
Husarion ROSbot XL

ROS led industry robots

Design

Our priorities:

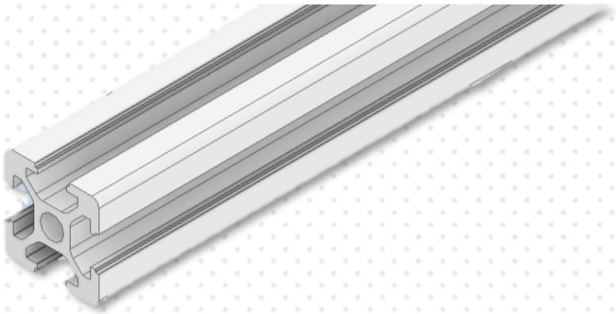
- Modularity
- Autonomous Navigation
- Robust Power System

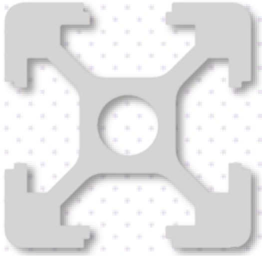


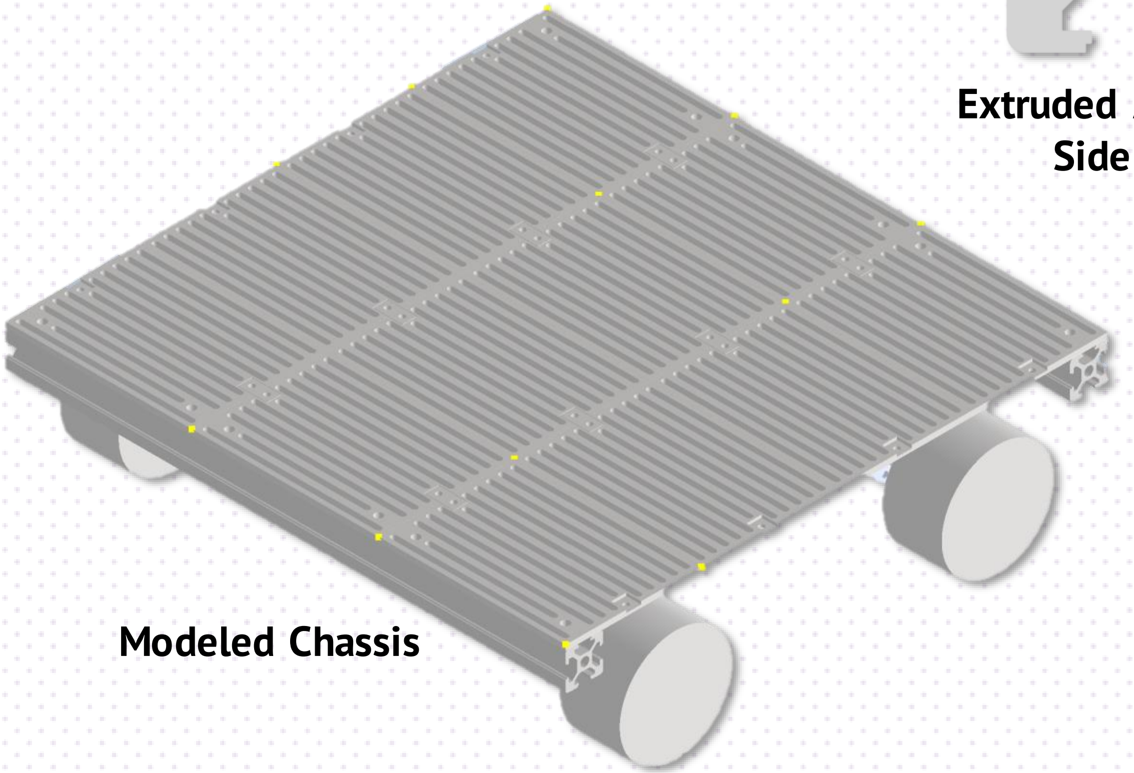
Chassis

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


Drop-in T-nuts

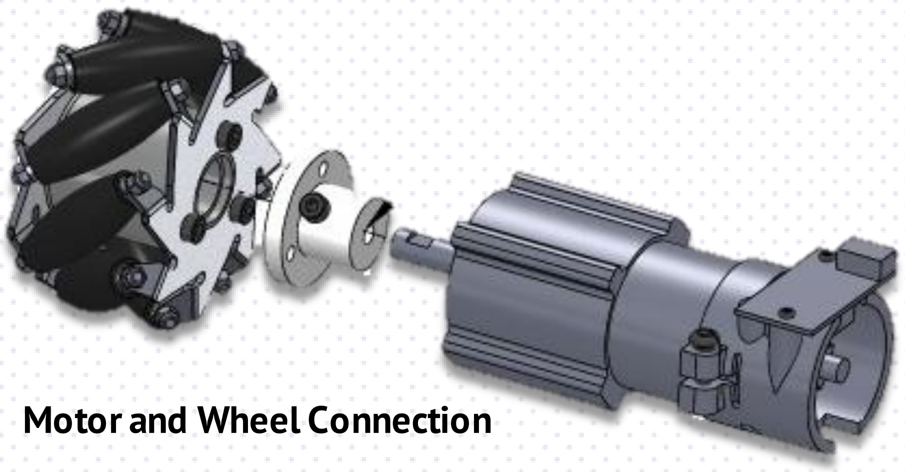

Extruded Aluminum


Extruded Aluminum Side View

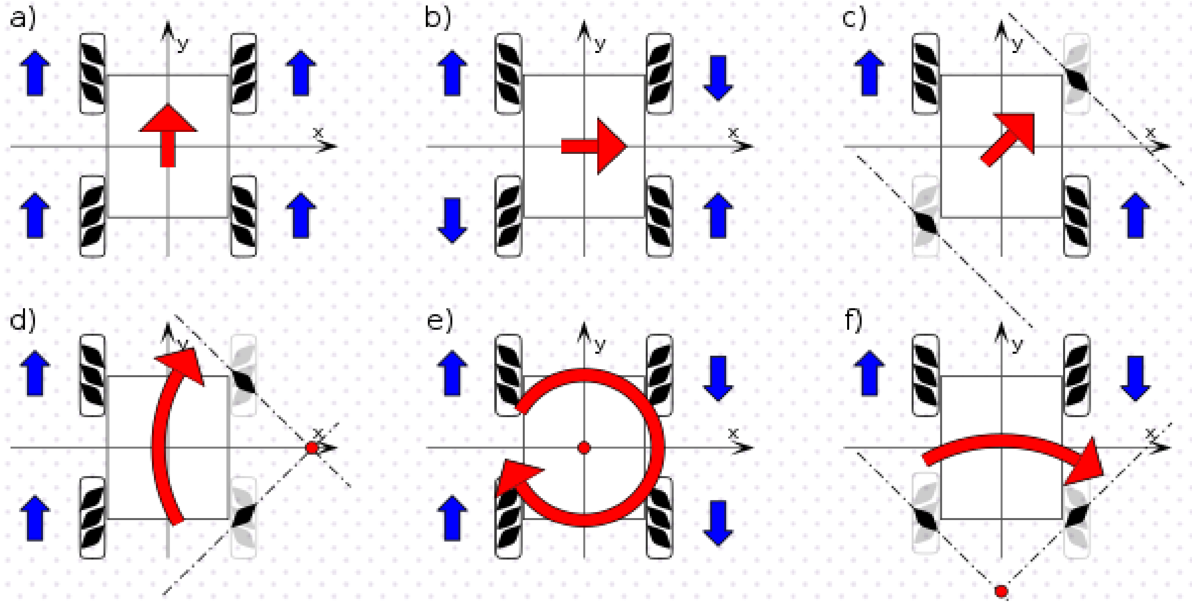

Modeled Chassis

Motor Control

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



Motor and Wheel Connection



Robot Movement from Mecanum Wheels

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.

No Payload		
Trial	Distance (inches)	Speed (ft/s)
1	45.5	0.758
2	47	0.783
3	46	0.767
4	45.5	0.758
5	45.5	0.758

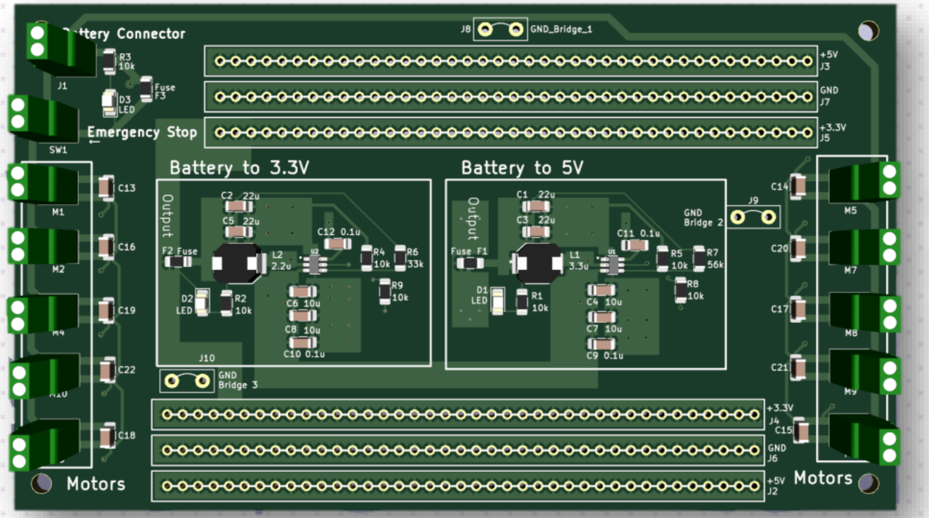
Tile - Capstone Lab		
Trial	Distance (inches)	Speed (ft/s)
1	88	0.733
2	87	0.725
3	87.5	0.729
4	87.5	0.729
5	88	0.733

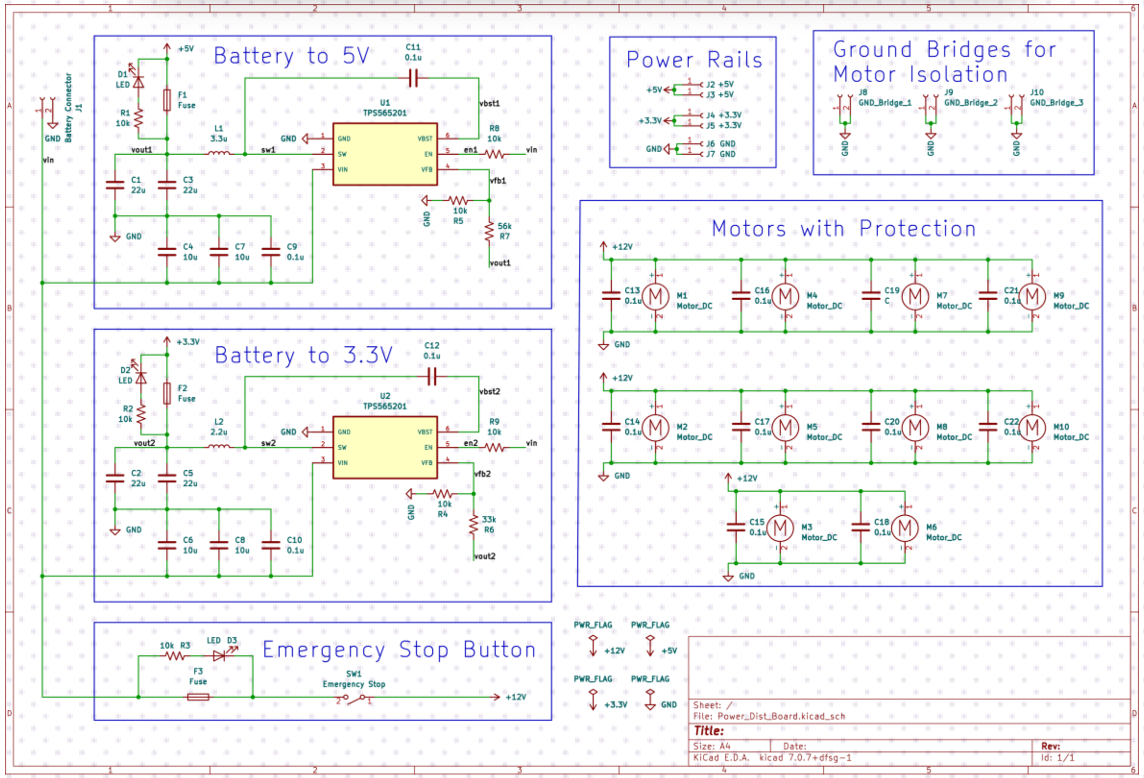
25 Pound Payload		
Trial	Distance (inches)	Speed (ft/s)
1	45	0.750
2	46	0.767
3	45	0.750
4	45.5	0.758
5	45.5	0.758

2023 Arena		
Trial	Distance (inches)	Speed (ft/s)
1	87	0.725
2	87	0.725
3	86	0.717
4	86	0.717
5	87	0.725

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

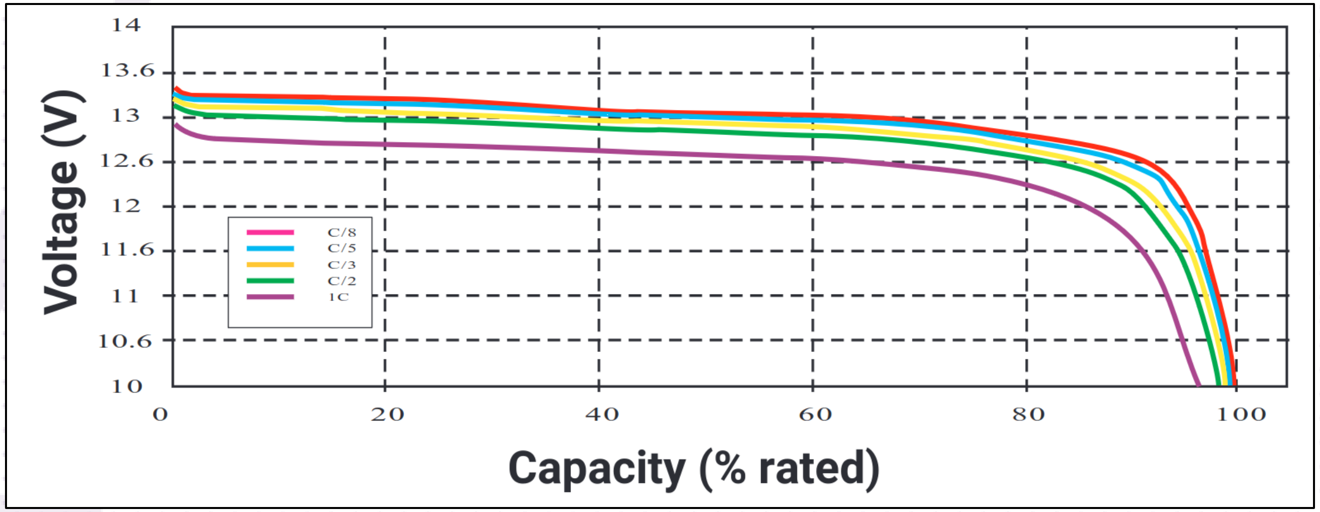


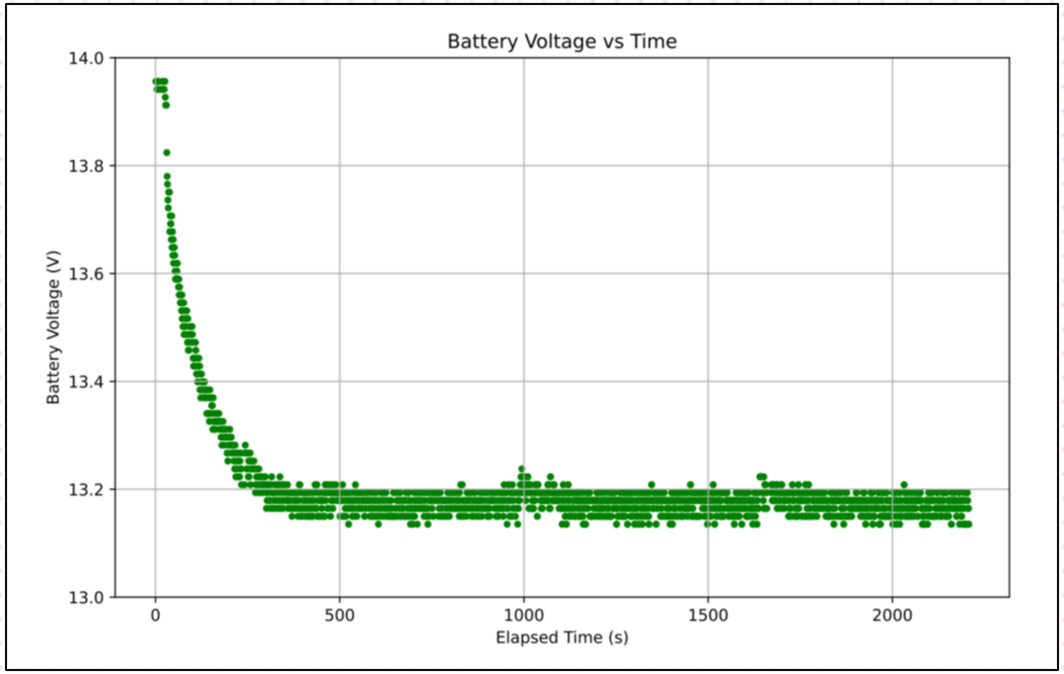


Experiments and Results – Battery Life

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

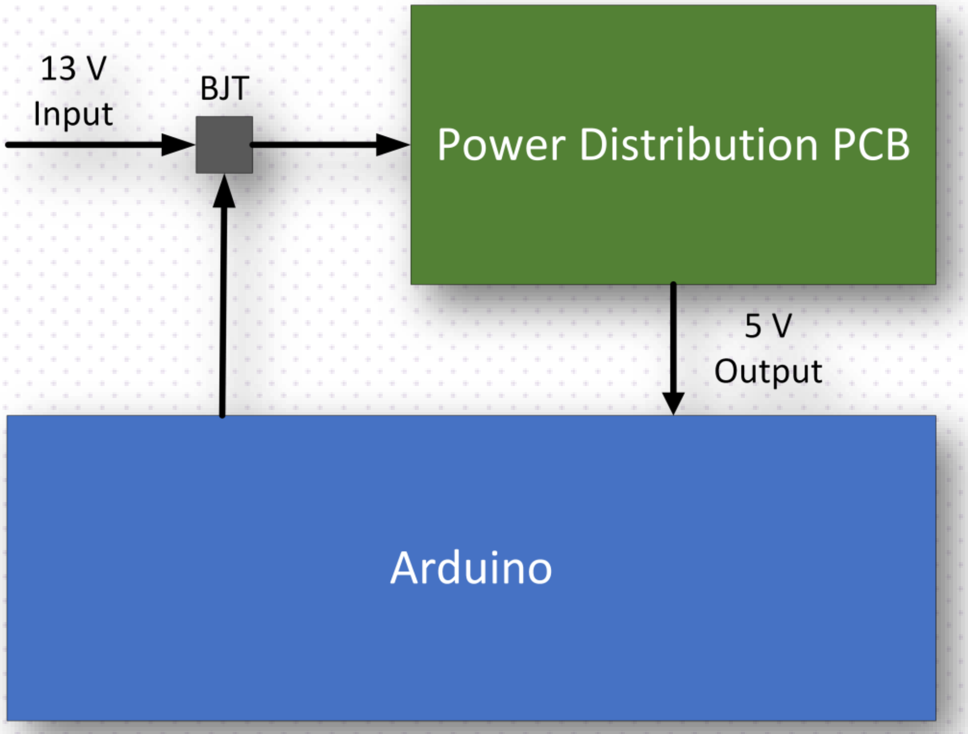
- Battery discharge curve compared to datasheet
  - Estimated battery life to be 4-5 hrs





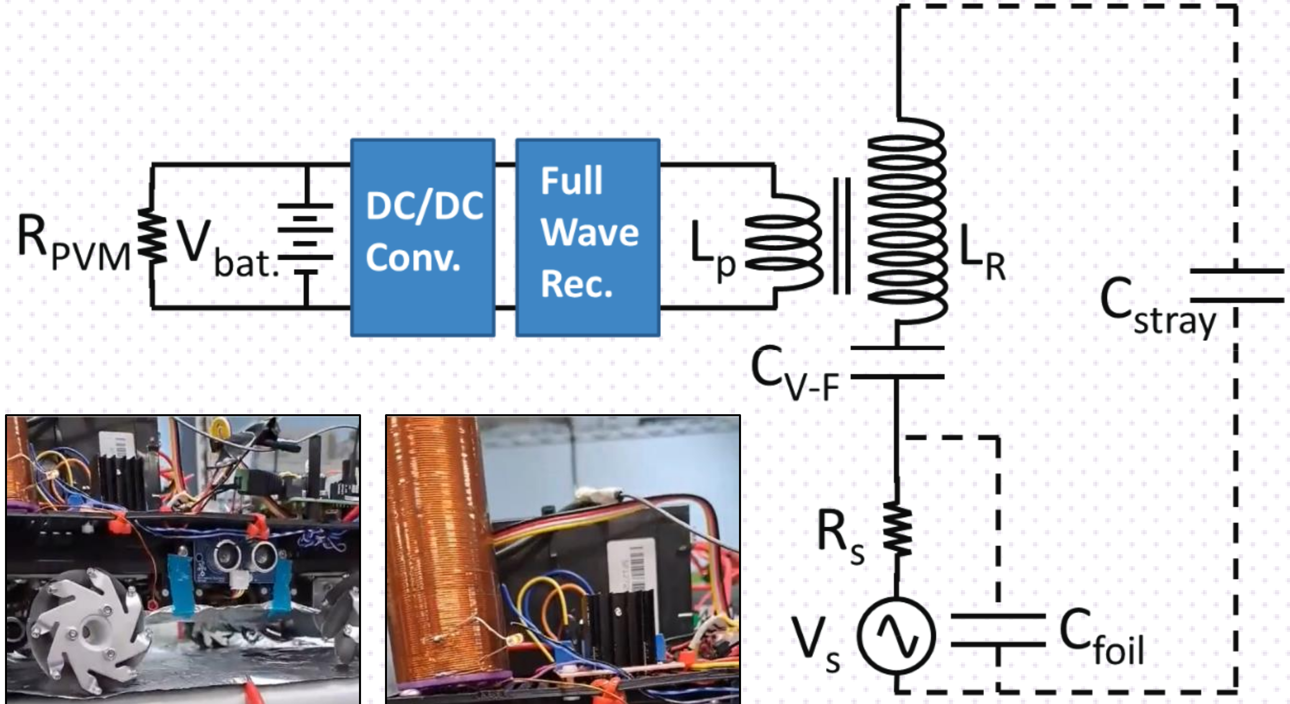
Experiments and Results - Power Board

- 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 4,000,000+ times



Experiments and Results – Wireless Power

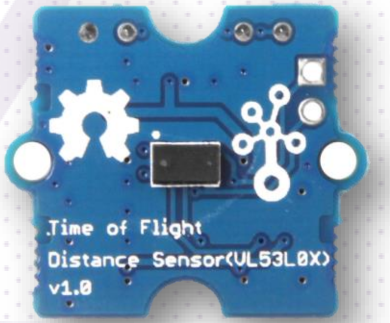
- Capacitive wireless charging was evaluated
- Proof-of-concept demonstrated powering a small load
- Future implementations will require more research and safety precautions



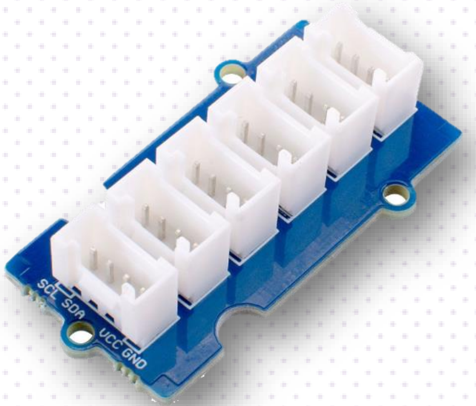
Navigation – Location and Object Detection

- Grove – Ultrasonic Ranger
- Grove – ToF Sensor (VL53L0X)
  - Mini-LIDAR, laser emitter
  - I2C Hub

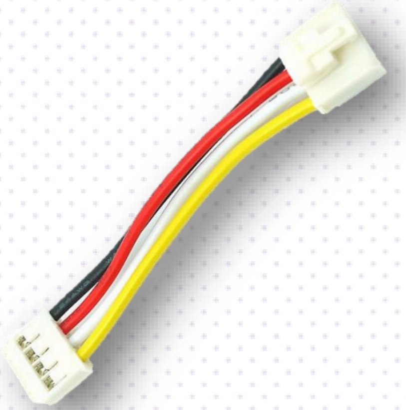
Ultrasonic Ranger



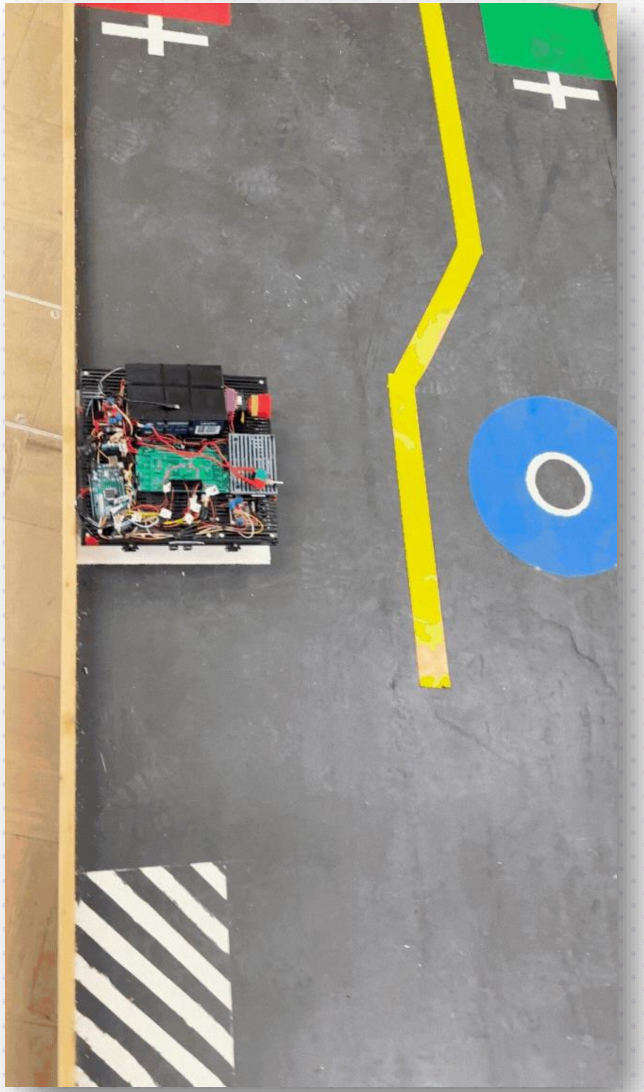
Time of Flight



I2C Hub

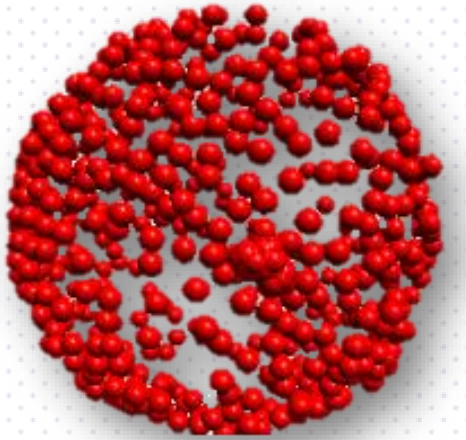


Grove Connectors



Location Demo

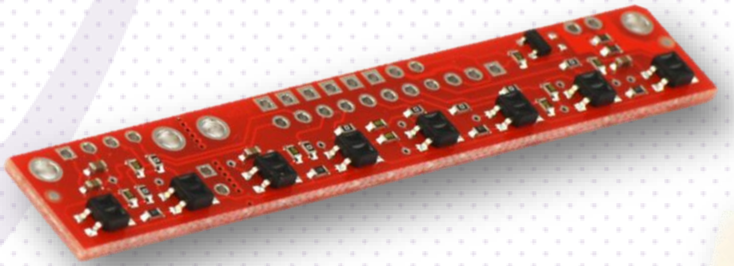
Navigation –
Line Following and Orientation



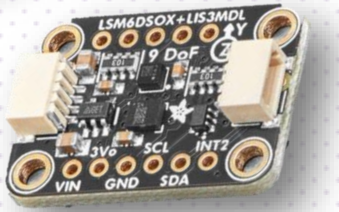
Orientation Calibration Results

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

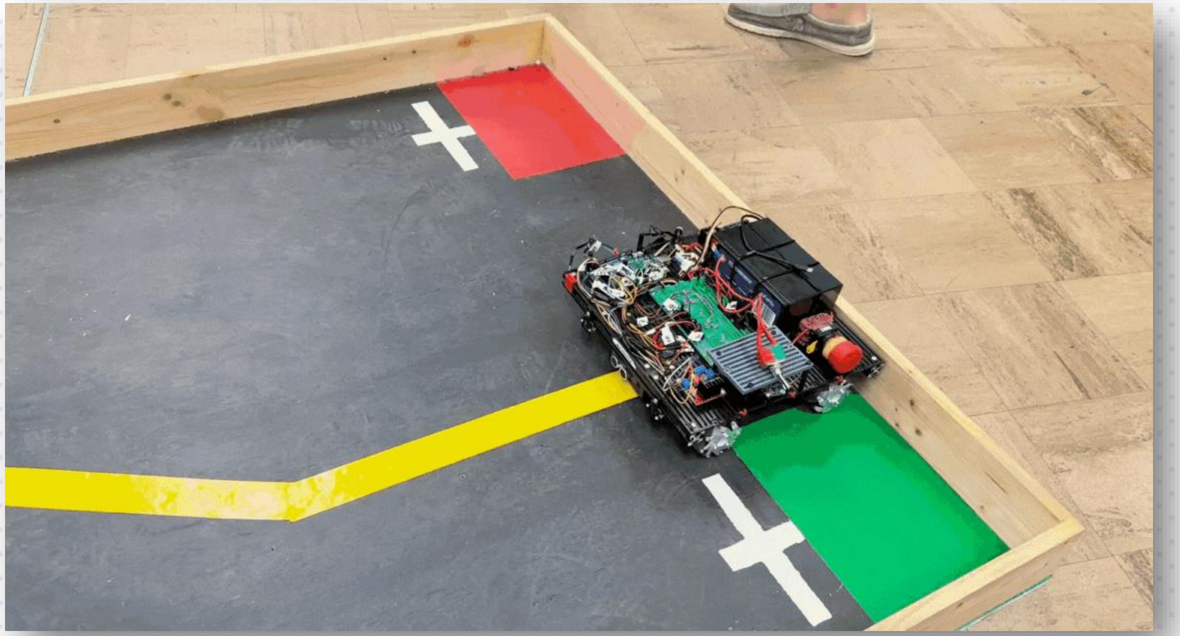
- LSM6DSOX + LIS3MDL 9 DOF
    - Returns roll, pitch, yaw



QTR-8RC



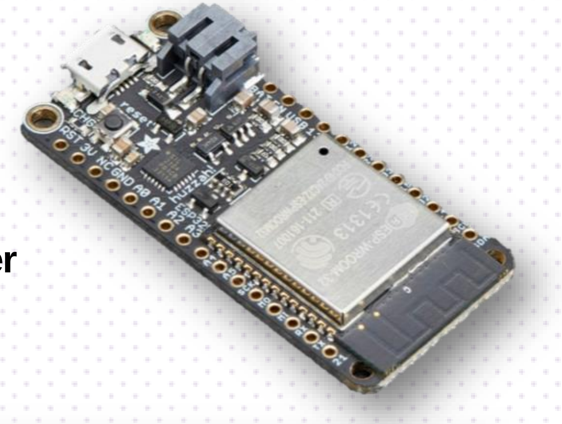
LSM6DSOX + LIS3MDL



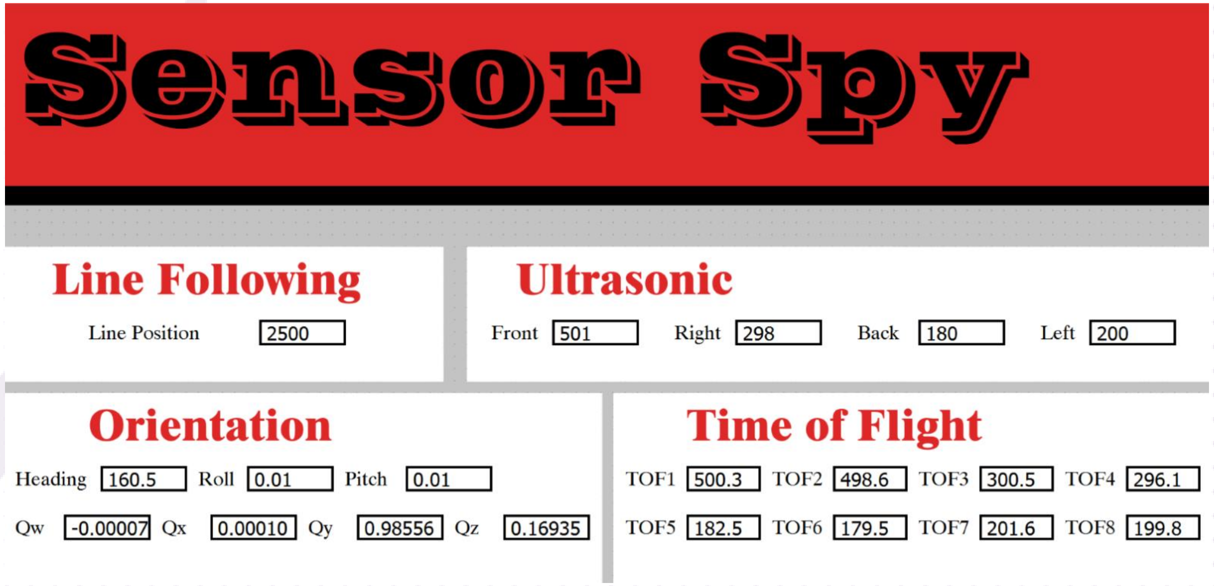
Line Following Demo

Experiments and Results - Sensors

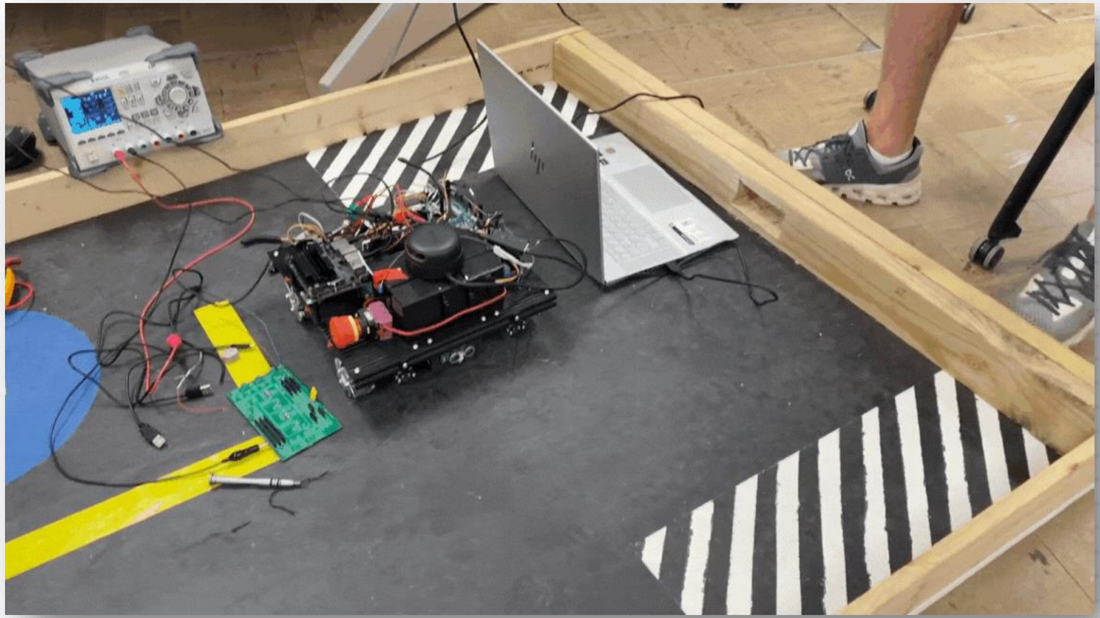
- Two ESP32 microcontrollers were used to transmit data



ESP32 Microcontroller



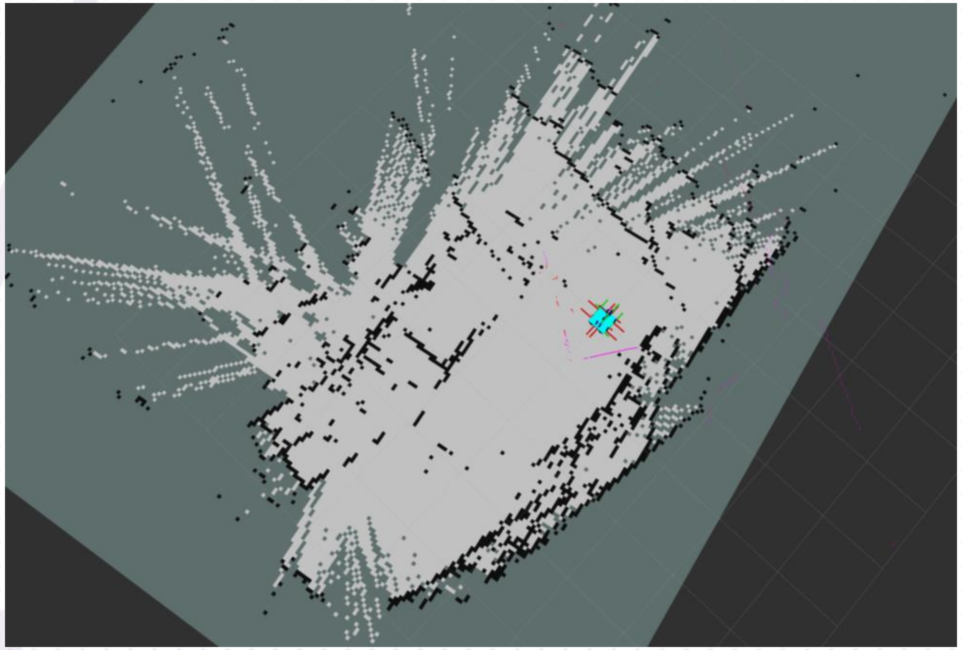
Sensor Spy GUI for real – time sensor data



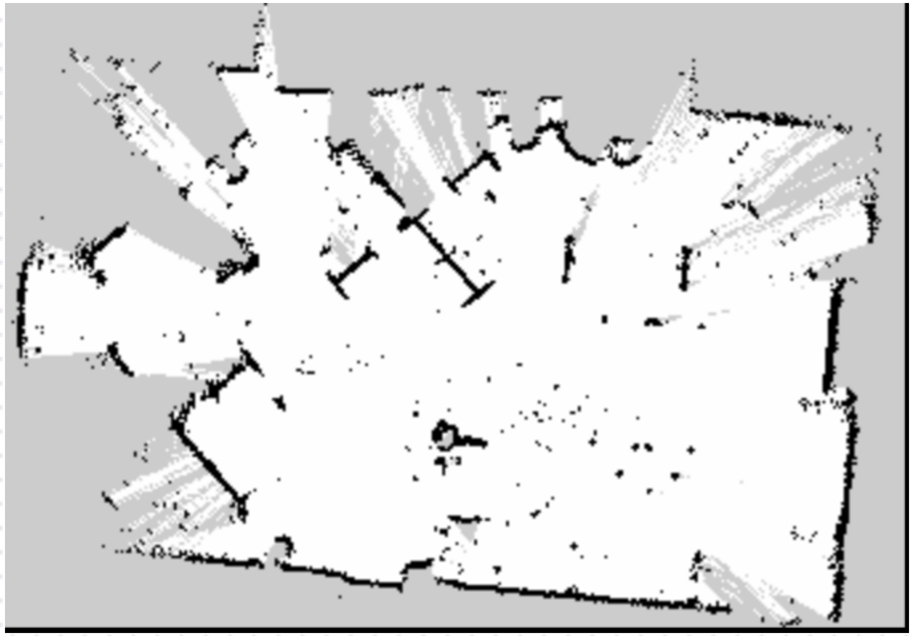
Objection Detection Demo

Nav2 Mapping Issues

- 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



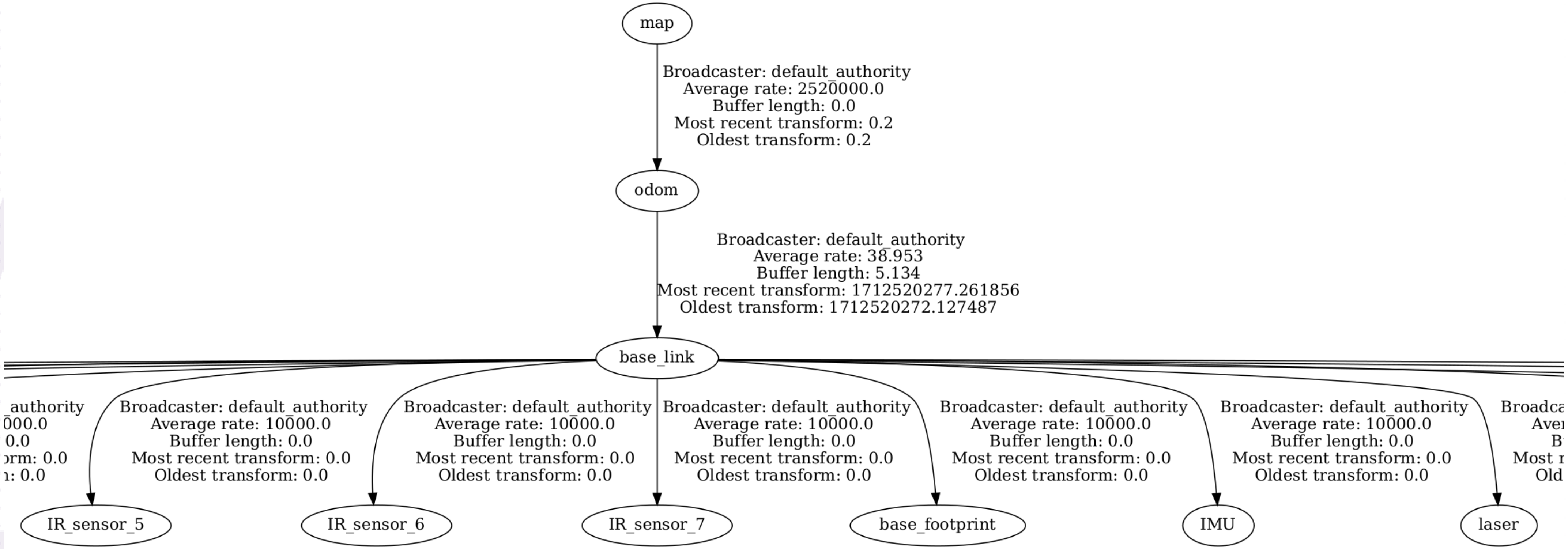
Map of 2024 SECON Board



Map of Capstone Lab

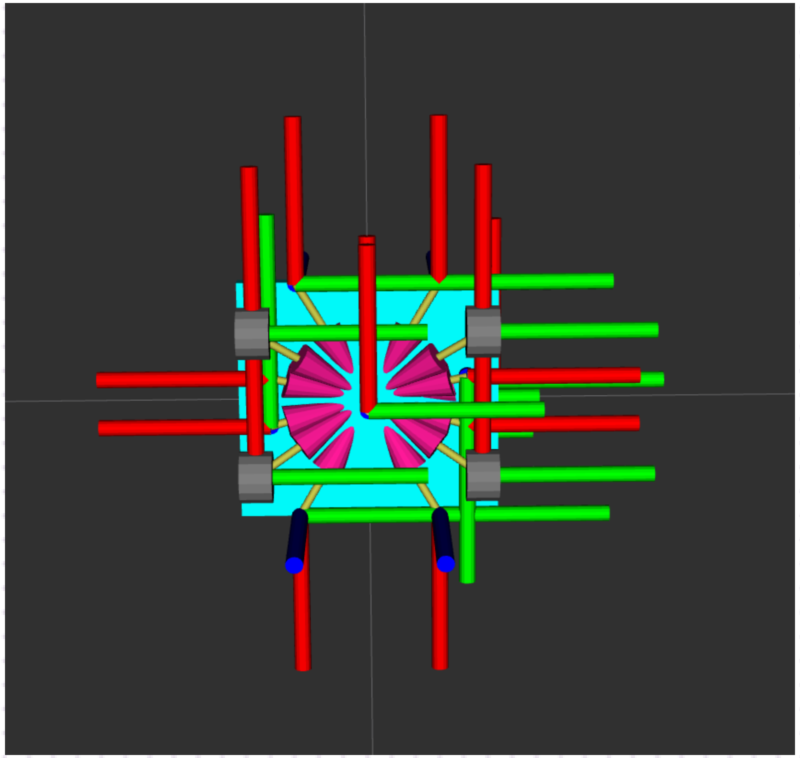
Master Control

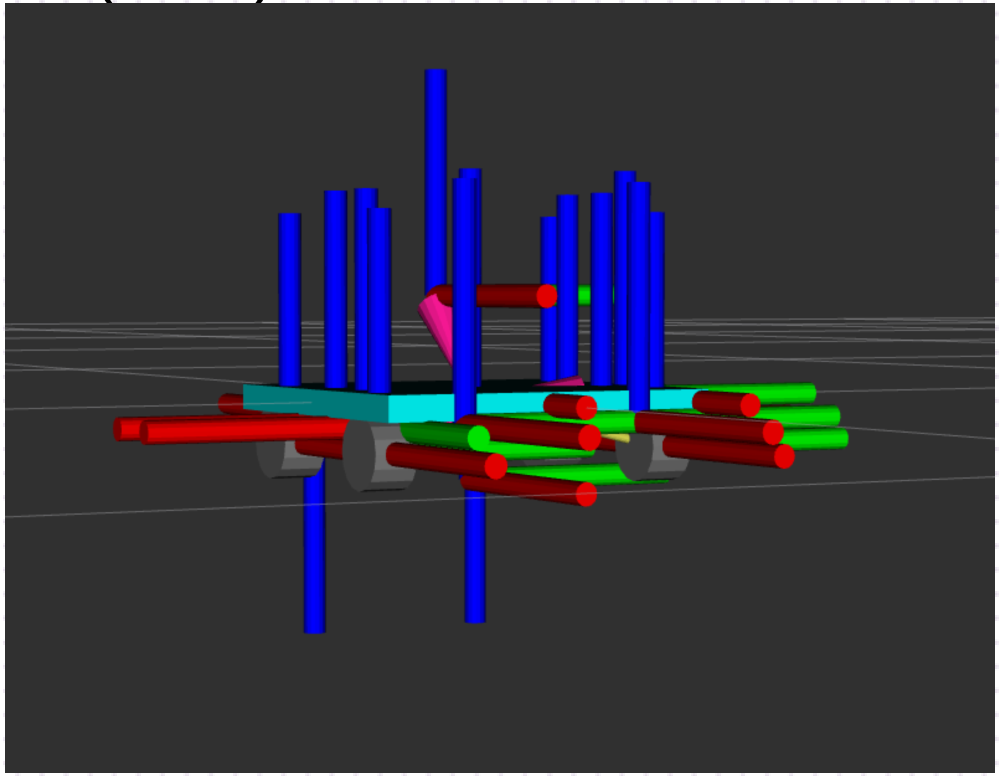
- Utilized ROS2 middleware for SLAM
- Laid foundation for autonomous navigation



Master Control

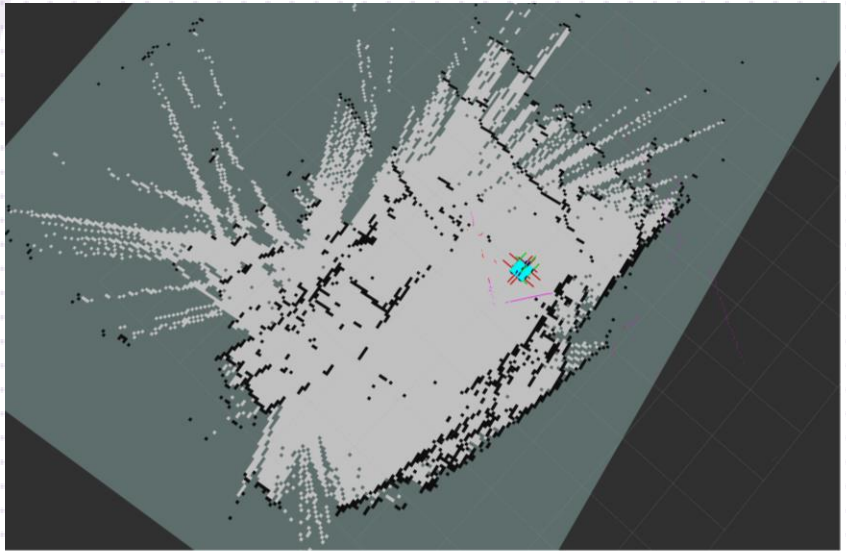
- Rviz2 utilized as the primary GUI
- URDF, robot state publisher, and joint state publisher
  - Established base_link -> base_scan (laser)



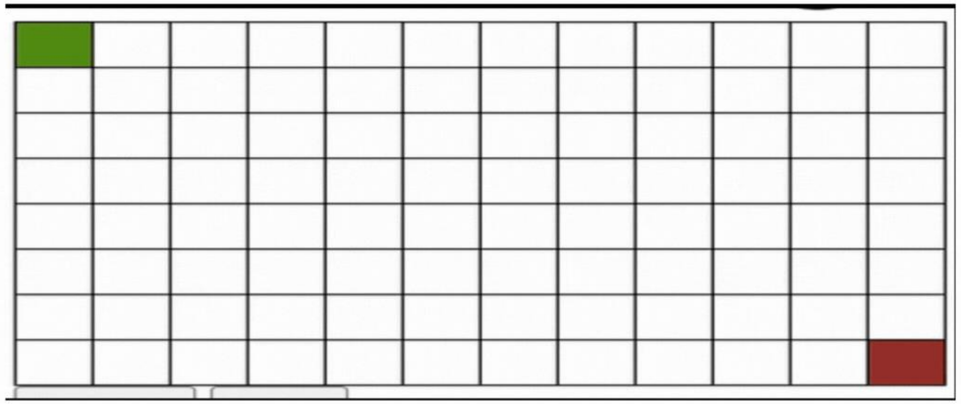


Master Control

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



Map of 2024 SECON Board



A* Search Algorithm Visualization

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

Budget

Proposed Budget	
Subsystem	**Cost**
Chassis	$245.00
Power	$730.00
Master Control	$150.00
Motor Control	$363.00
Navigation	$314.00
Wireless Charging	N/A
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

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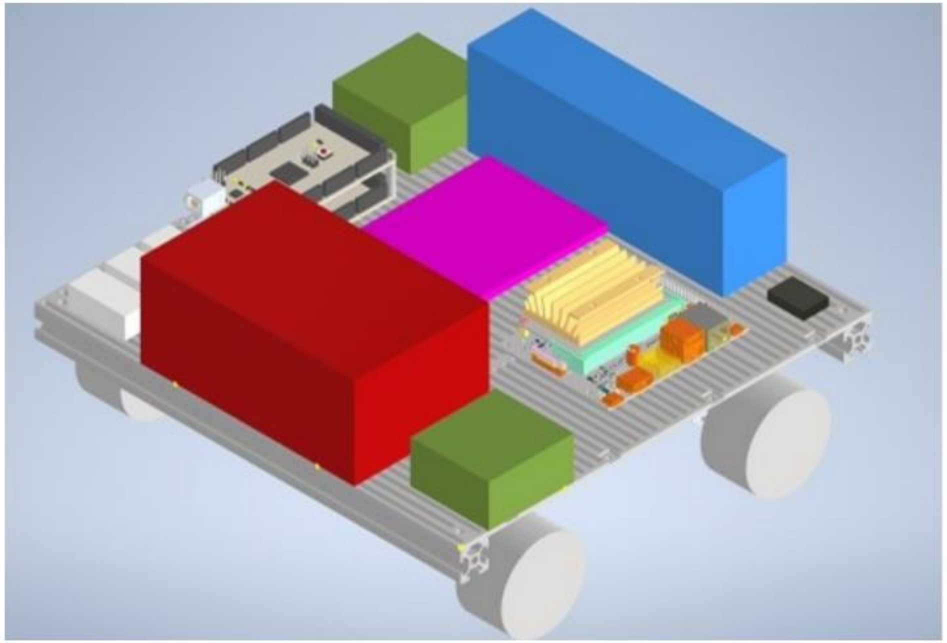
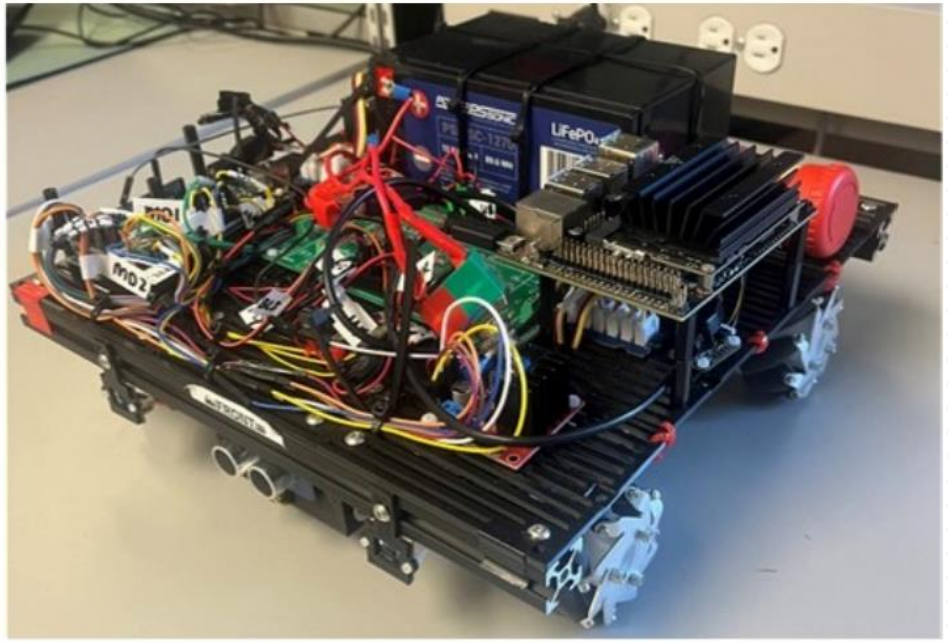
Questions?





Designing Power Board for Current Capabilities

- IPC-2221A PCB Design Standards
- Trace size constrained by physical limitations and required current capacity

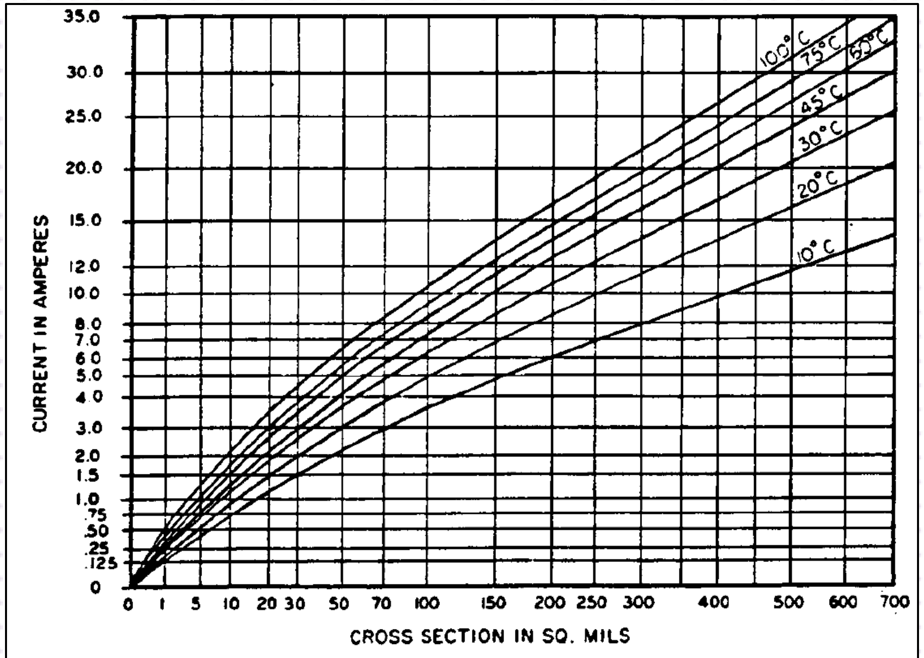


Figure A External Conductors

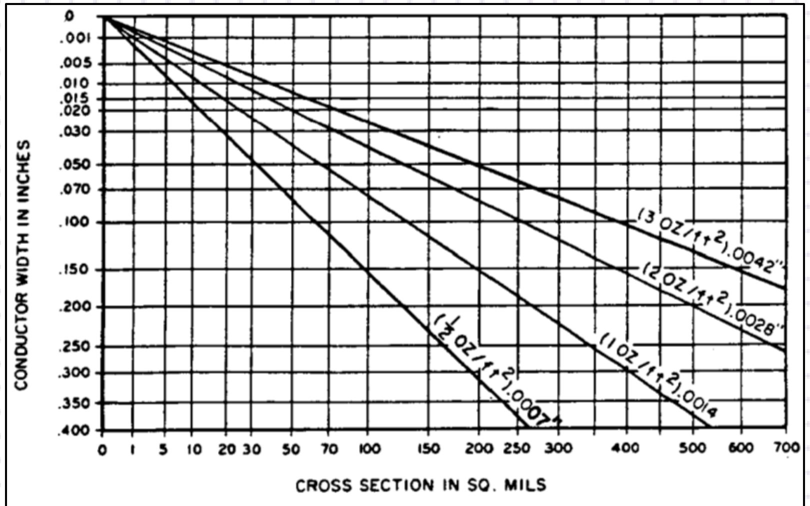


Figure B Conductor width to cross-section relationship