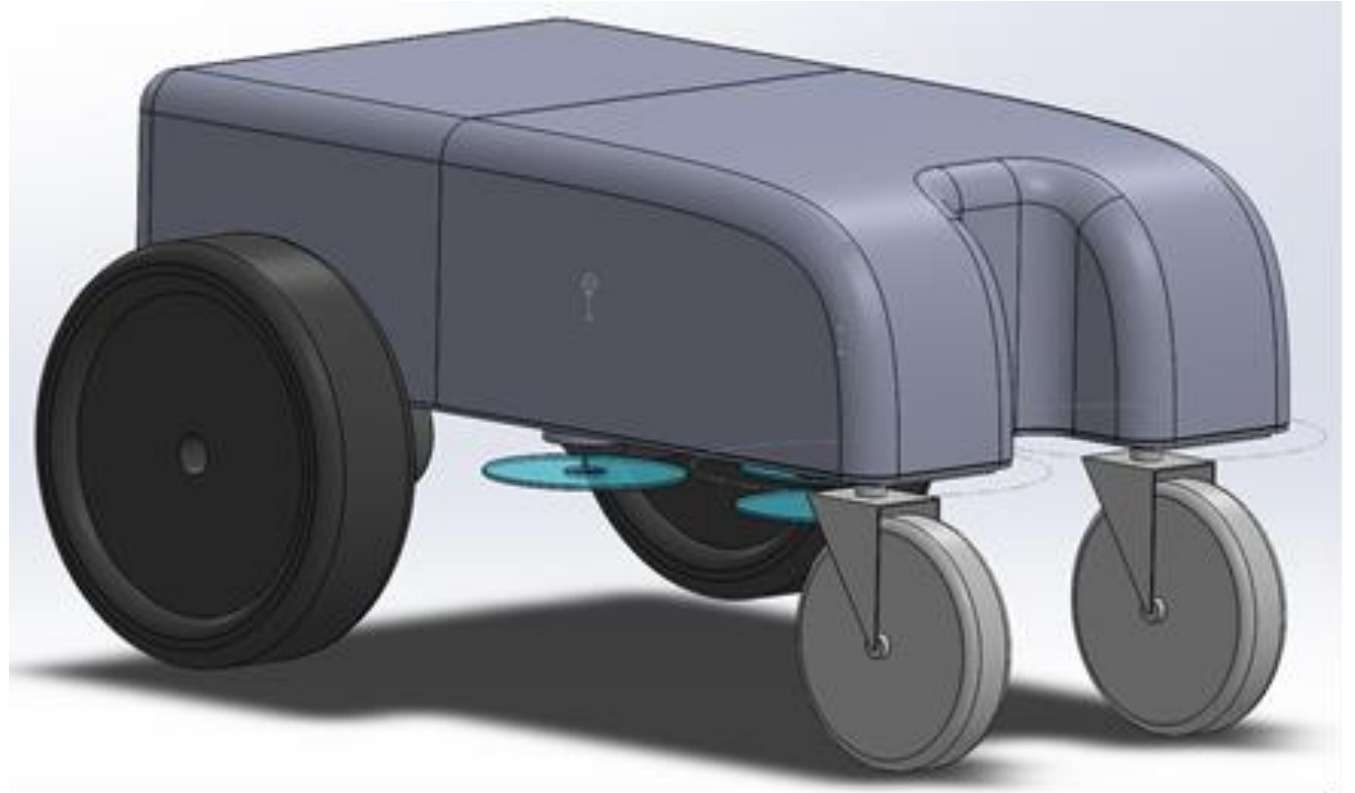# E-Goat Robotic Solar Farm Mower

Group 26:

- Steven Cheney - CpE

- Jordan Germinal - CpE

- Eduardo Guevara - CpE

- Davis Rollman - CS

- Jonathan Smith - EE

# Project Description

- Device will be an autonomous vehicle designed to navigate obstacles

- A portable device that is highly durable to the elements of the environment

- Using a proximity wire, vehicle will be able to maneuver and maintain a specific area to navigate

- Mower will utilize sensors to detect objects (beams or people) and stop based on proximity

# Motivation

- Solar energy provides very cheap power, after the initial large investment

- However, there are a few large upkeep costs, one of which is the upkeep of the grass in the field, which was $200,000 last year at Duke Energy's site

- Most of the cost is human labor

- One potential solution is an autonomous electric rover, which not only save human labor time, but also more environmentally friendly, as it is powered by electric rather than gas

# Goals and Objectives

- To produces a rover-based robot and provide the articulated motion needed to move the weed whacker across the terrain and cut grass.

- To produce a Navigation and Control solution to identify grass areas that need attention (i.e., cutting), avoid any obstacles such as solar panel structures, and provide overall motion control of the rover-based robot.

- To produce a power supply unit for the rover. Grass cutting may take place at night and charge during the day. To accommodate such a scenario the system must use a defined battery storage technology with charging capability.

- To complete the challenge competition at during the month of April in 2020. The main objective is to complete the 10-foot-wide, by 50-foot-long course working around obstacles within a 15-minute time constraint.

| Designation | Description |
| --- | --- |
| CSC-01 | Robotic rovers must use an off-the-shelf battery powered trimmer (no metal blade must be string-based) to cut grass. |
| CSC-02 | The rover may consist of an off-the-shelf remote-controlled system that is modified for the application but should still have an autonomous mode or capability. |
| CSC-03 | The robotic grass cutting rovers must be equipped with a remote kill switch that can turn off the cutting system and locomotion at a distance of approximately 50 feet. |
| CSC-04 | An off-the-shelf battery and charger must be utilized. |
| CSC-05 | The rover must be capable of safely navigating in uneven terrain (~ 3-inch terrain differential over ~ 2-foot span in any direction) without capsizing while avoiding a series of obstacles. |
| CSC-06 | No part of the system must be of a height no taller than 20 inches from the ground |
| CSC-07 | The system must operate independently and have no attachments to existing solar farm array structures. |

| Designation | Description |
| --- | --- |
| CSC-08 | Total systems materials and assembly cost target: $1500 |
| CSC-09 | The ability to cut grass at an acceptable height (3 to 6 inches) is considered a plus. |
| CSC-10 | The system must traverse the large areas and maneuver around PV support structures. |
| CSC-11 | Avoid any damage to surrounding infrastructure, the environment and humans |
| CSC-12 | Provide a math model to estimate how much grass area the robot can cut per hour. |
| CSC-13 | System to provide a secondary safety protocol to deal with rogue objects, in addition to the remote kill switch. |
| CSC-14 | The System also to include location beacon with independent power supply for a defined period of time. |

# Customer Specifications and Constraints

# Hardware Block Diagram
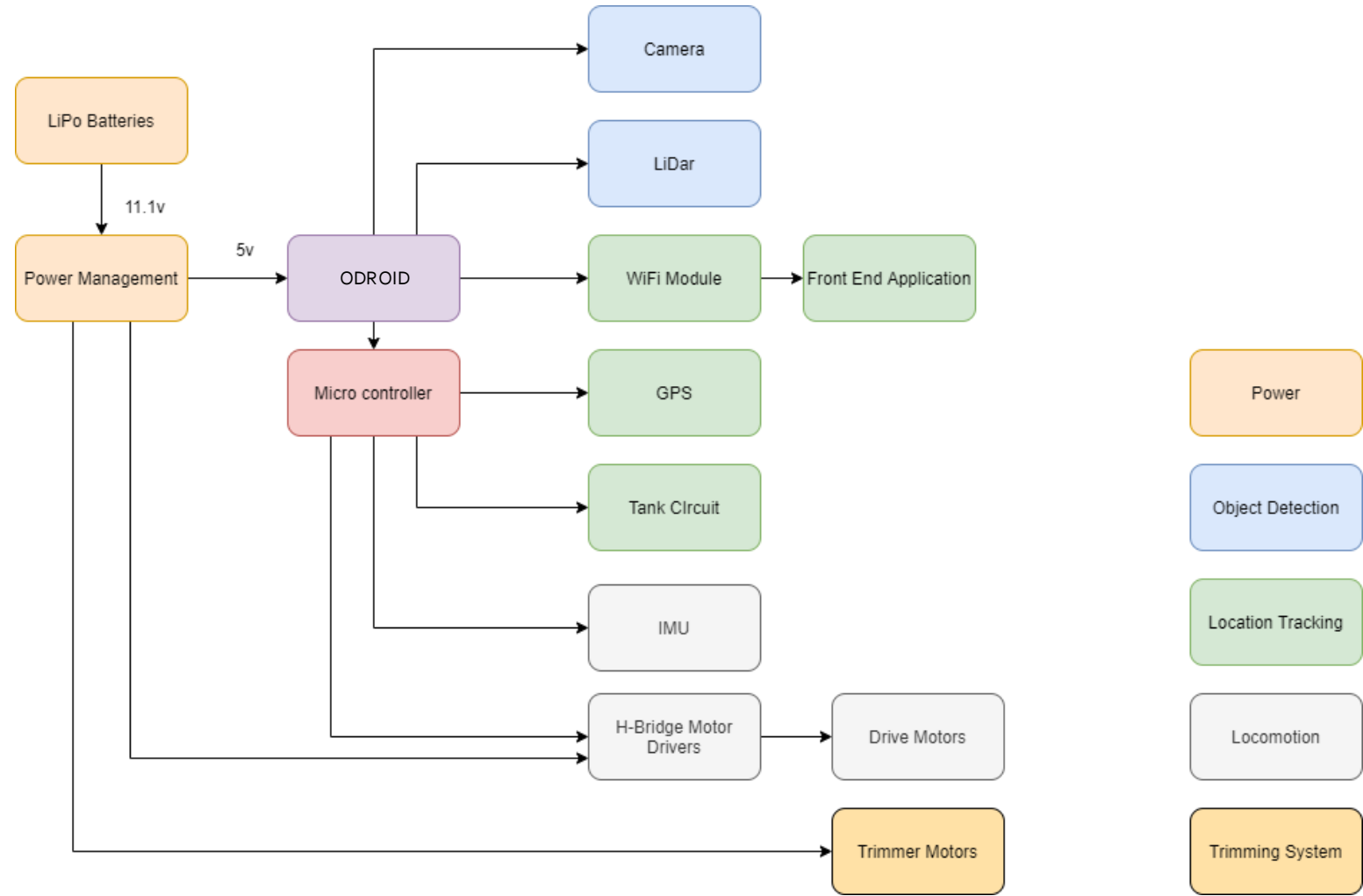
# Communication Block Diagram
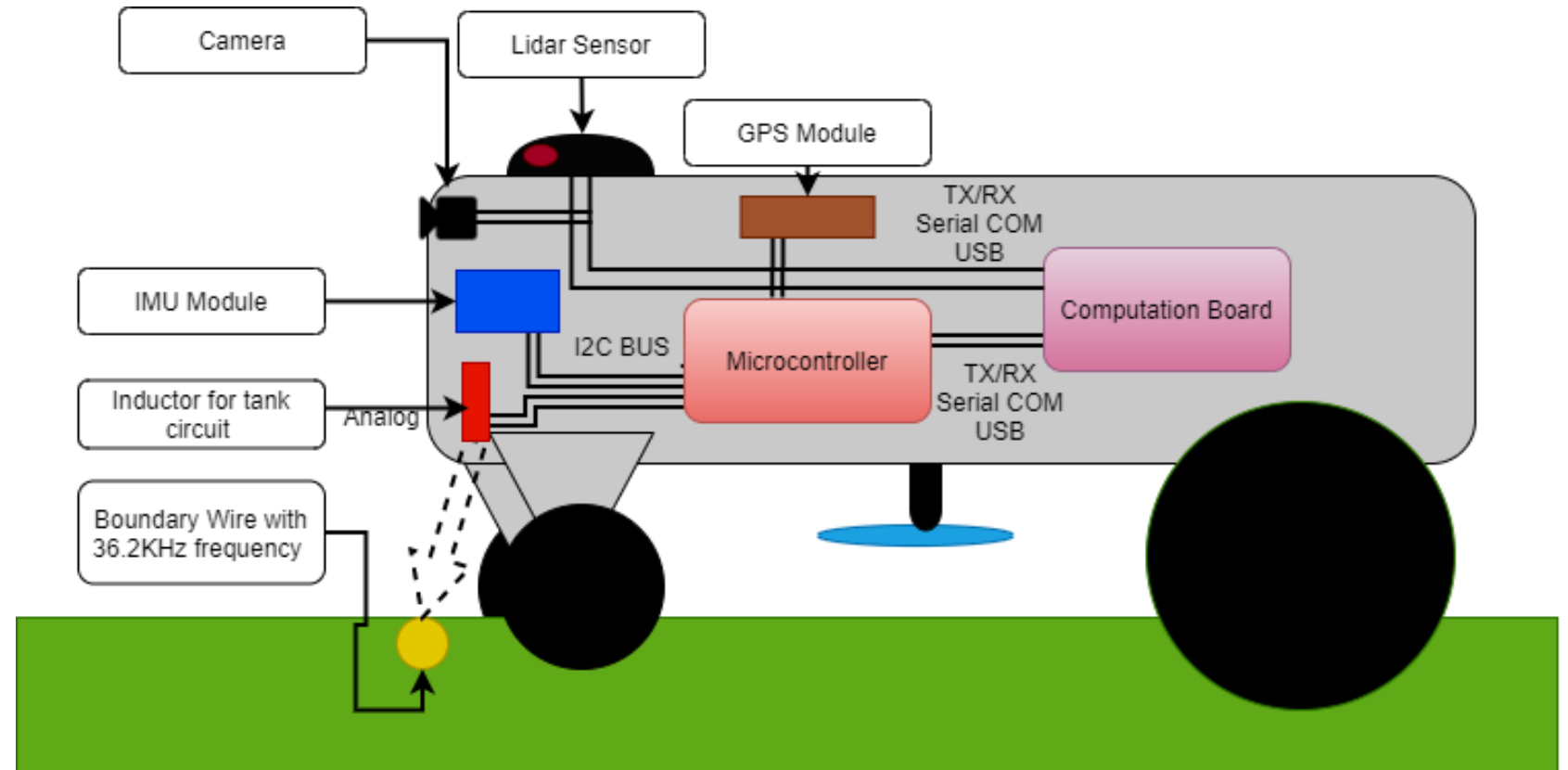
# Division of work

| | Steven | Jordan | Eduardo | Davis | Jonathan |
|---|---|---|---|---|---|
| **ROS** | | Primary | Primary | Secondary | |
| **Human and obstacle Detection** | | Secondary | | Primary | |
| **Power systems** | Secondary | | | | Primary |
| **Locomotion** | Primary | | Secondary | | Secondary |
| **PCB Design** | Secondary | | Secondary | | Primary |
| **Wireless communication / control app** | | Secondary | | Primary | |
| **Navigation sensors** | | Secondary | Primary | Secondary | Secondary |

# Driver/Motor

- H bridge design to control motor movement
- Series of On-Off pulses (PWM)
  - Controls the amount of power delivered without wasting power
- Pulse bit to control the direction of the wheels
  - Clockwise vs anti-clockwise
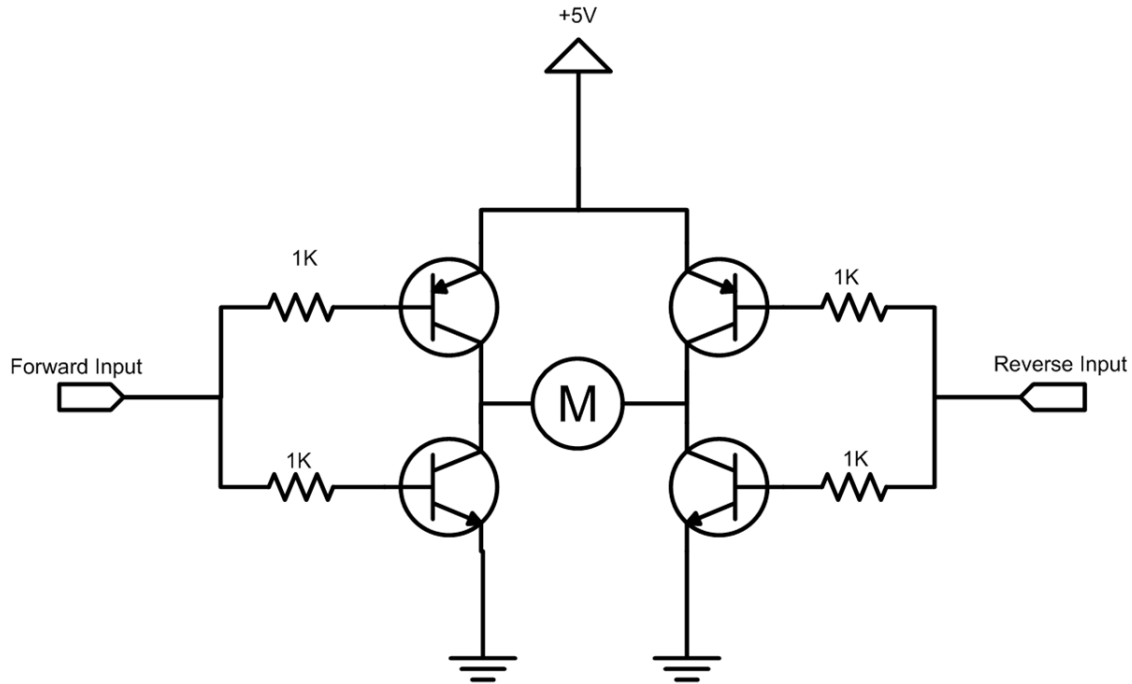
# Trimmer Head

- Fast but efficient
- Pre-purchased motor
- RPM Requirement: 6,000

## Commercial vs Custom Mower Head

Ryobi one+: 9300 rpm, $69, largest    Jiaruixin RS550: 30000 rpm, $15, smallest    MD5-2450: 50000 rom, $85, medium size

| Criteria | Weight | Evaluation | | | Score | | |
|---|---|---|---|---|---|---|---|
| | | Ryobi one+ 18v | Jiaruixin RS550 | MD5-2450 | Ryobi one+ 18v | Jiaruixin RS550 | MD5-2450 |
| Speed | (5) | 1 | 2 | 3 | 5 | 10 | 15 |
| Cost | (3) | 2 | 3 | 1 | 6 | 9 | 3 |
| Size | (2) | 1 | 3 | 2 | 2 | 6 | 4 |
| Total score | | | | | 13 | 27 | 22 |

# Trimmer Motor

## Comparing Custom Trimmer Motors

| Criteria | Weight | Evaluation | | | Score | | |
|---|---|---|---|---|---|---|---|
| | | RS550 | JD3-24135-CVC | MD5-2450AS-AA-C | RS550 | JD3-24135-CVC | MD5-2450AS-AA-C |
| Speed | 5 | 2 | 1 | 3 | 10 | 5 | 15 |
| Size | 3 | 3 | 1 | 2 | 9 | 3 | 6 |
| Cost | 2 | 3 | 1 | 2 | 6 | 2 | 4 |
| Total Scores | | | | | 25 | 10 | 25 |

# Wheel Motor

- Torque > Speed
- Weight requirement
- Accuracy in navigation

Driving Motors (Amp Flow)

A28-150: 2237.1 Watts (3hp), $344    E30-150: 745.7 Watts (1hp), $79    F30-150: 1715.11 Watts (2.3hp), $239

| Criteria | Weight | Evaluation | | | Score | | |
|---|---|---|---|---|---|---|---|
| | | A28-150 | E30-150 | F30-150 | A28-150 | E30-150 | F30-150 |
| Power | 3 | 3 | 1 | 2 | 9 | 3 | 6 |
| Cost | 5 | 1 | 3 | 2 | 5 | 15 | 10 |
| Size | 2 | 1 | 3 | 2 | 2 | 6 | 4 |
| Total Scores | | | | | 16 | 24 | 20 |

# MCU

- Provide Low side computation for IMU, GPS, Perimeter Wire, and PWM Motors

- Publish and subscribe to ROS topics connected Odroid

- Support multiple forms of communication and signal I/O such as I2C, Serial, and Analog input.

| | ATmega2560 | ATmega328P | MSP432P401RIPZ | MSP4305529 |
|---|---|---|---|---|
| Development Board | Arduino Mega2560 | Arduino Uno | MSP432P401R SimpleLink | MSP-EXP4305529LP |
| Cost | ~$12.00 | ~$2.00 | ~$8.00 | ~$7.00 |
| Digital I/O | 86 | 14 | 40 | 40 |
| Analog input pins | 16 | 6 | 8 | 8 |
| Input Voltage | 1.8 to 5.5 | 1.8 to 5.5 | 1.6 - 3.7 | 1.6 - 3.7 |
| Clock Speed | 16MHz | 8MHz | 48MHz | 25MHz |
| Program Memory | 256Kb | 32Kb | 96Kb | 128Kb |
| I2C Support | YES | YES | YES | YES |
| Analog Input Support | YES | YES | YES | YES |

# Boundary Wire Subsystem

- Keep autonomous mower rover is operating with the specified 50x10 foot

- Ensure the safety of people and equipment.

- Composed of two pieces of equipment
  - Function Generator
  - Tank Circuit (EMF sensor)
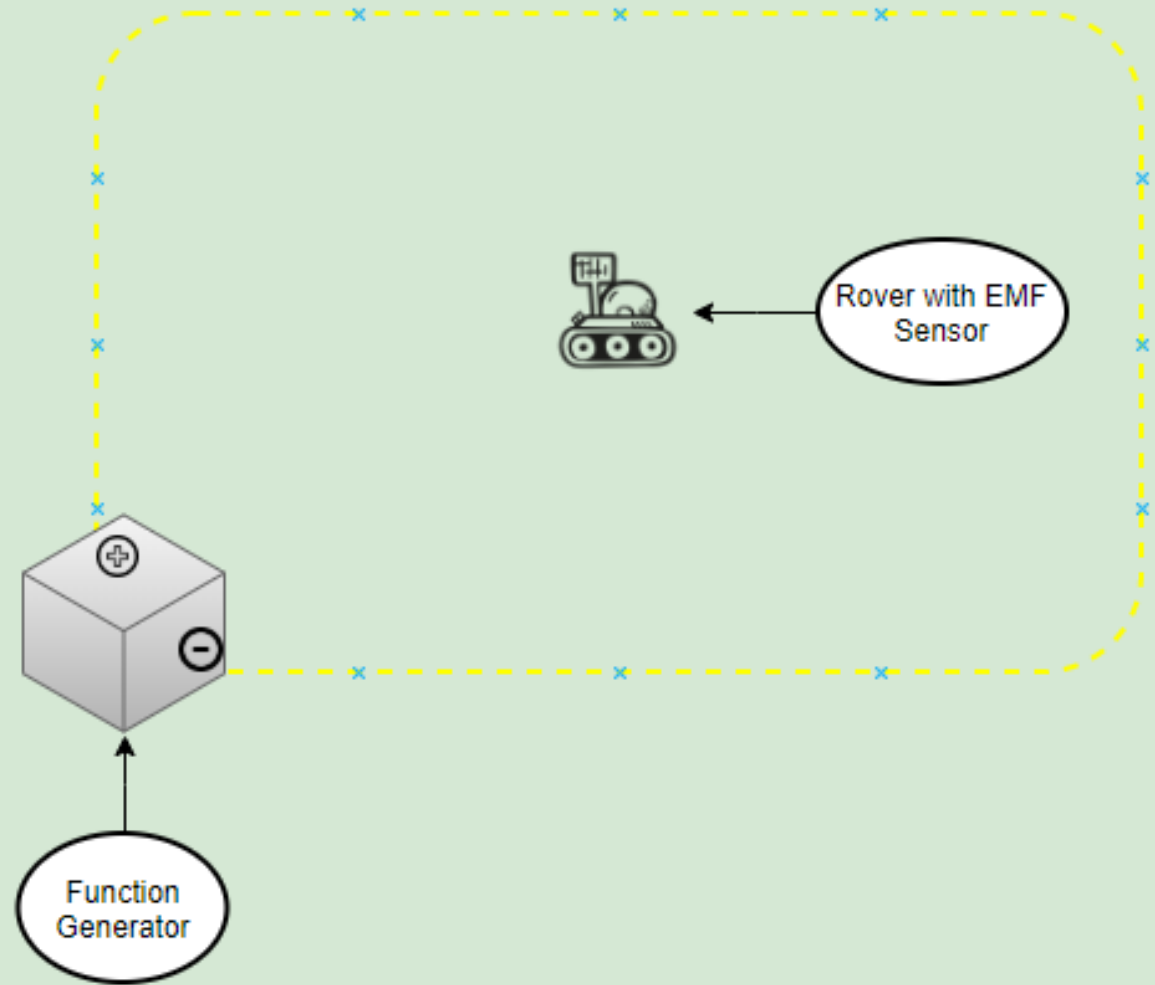
# Boundary Wire Subsystem

- Function Generator:
  - Driven by an NE555 timer integrated circuit
  - Create a functional square wave and output over 150ft
  - Output frequency target:
    - L = 30Khz
    - H = 43Khz

- Tank Circuit:
  - LC Circuit to for reading the frequency of the function generator
  - Calculated Resonance frequency:
    - ~34Khz
  - An Op-Amp LM324 will be used to amplify the signal gained from our circuit.

# Perimeter Wire Part Selection

| Item | Description |
|---|---|
| Perimeter Wire | 100m Automower Boundary Wire 20AWG |
| Screw Terminals | 3xED10561-ND, 125V, 6A, 1x02 2.54mm Screw Terminals |
| Timer | TI NE555P Timer |
| Op-Amps | TI LM324N |
| Resistors | 4x1MΩ(1206), 4x10kΩ(1206), 1x3.3kΩ(1206), 1x12kΩ(1206), 1x47Ω(2W Axial-0.6) |
| Capacitors | 2x22nF(1206), 1x100nF(50V 1206), 1x100nF(1206), 1x1μF(1206), 1x1.2nF(1206) |
| Inductors | 2xRLB0914 Inductors 1mH |
| Housing | 10x5cm Plastic Container |

# Testing and Implementation

1. Measurement of 150ft of Perimeter Wire.

2. Measurement of inductor to Perimeter wire to sense EMF field.

   Tank Circuit
   can approximately sense up to 8 inches from perimeter wire with correct isolation from subsystem

# IMU -

## FXAS21002C  &  FXOS8700

- Keep orientation  and direction  for rover

- Provide control  for new heading position and directions  for rover

- I2C communication  with the microcontroller

- Powered  using a 3.3v

| Module Package | Sensors | Degrees of Freedom | ADC Resolution | Output Data Rate |
|---|---|---|---|---|
| FXOS8700 | Accelerometer | 3-Axis DOF | 14-bit | 1.563 to 800 Hz |
| | Magnetometer | 3-Axis DOF | 16-bit | 1.563 to 800 Hz |
| FXAS21002C | Gyroscope | 3-Axis DOF | 16-bit | 12.5 to 800 Hz |

| Features | FXAS21002C | FXOS8700 |
|---|---|---|
| Supply DC Voltage | 1.95 -3.6v | 1.95 -3.6v |
| Scale Ranges | ±2g /±4g /±8g | ±250 /500 /1000/2000$^\circ$/s |
| Current Draw | 240μA- 80μA | 2.7mA |
| Temperature Range | -40$^\circ$ to +85$^\circ$C | -40$^\circ$ to +85$^\circ$C |

# IMU Testing and Integration

1. Arduino Mega2560 connected via I2C bus connection

2. Linux Terminal echoing ROS topic that is publishing Pitch, Yaw, and Heading.

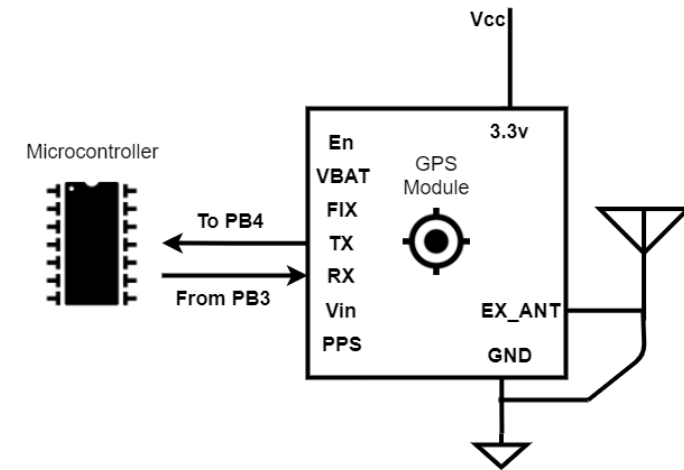3. Software tool used to calibrate IMU for sensor fusion
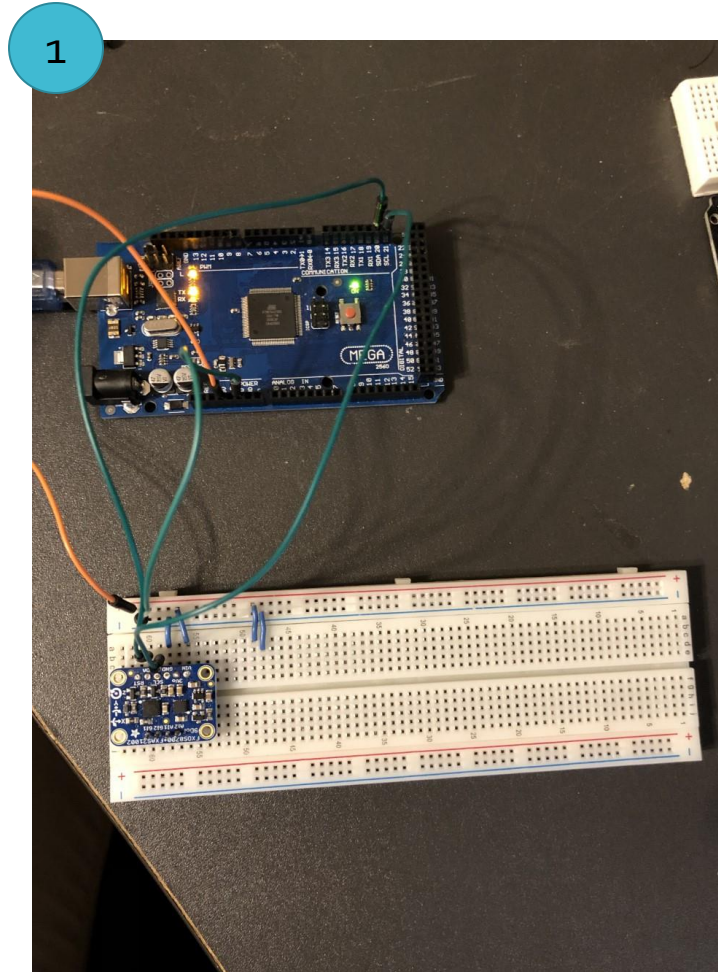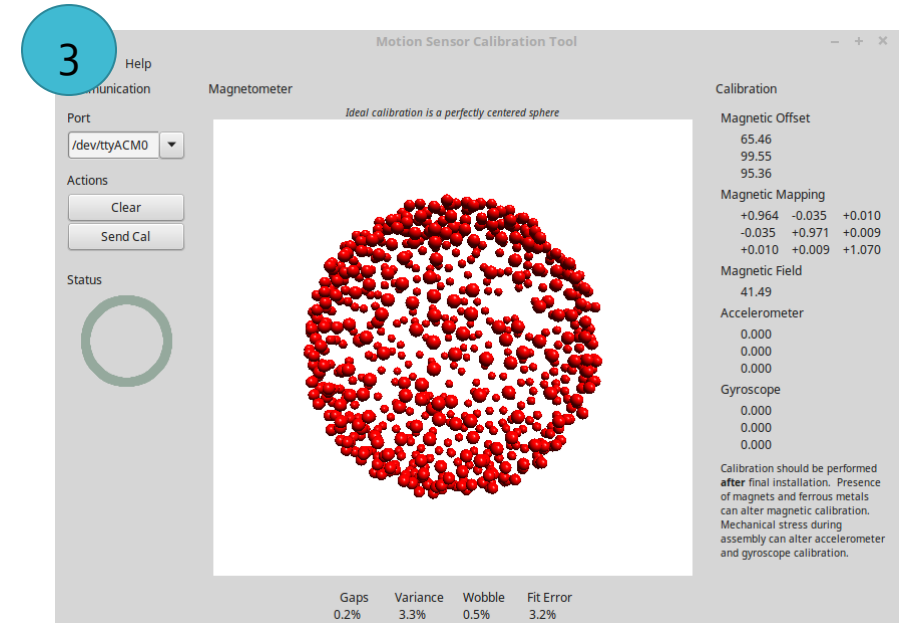
# GPS -MTK3339

- Provide Users approximation status on the field

- Low powered to be operable after main batteries are depleted

| Features | MTK339 |
| --- | --- |
| Cold Start | 34 sec |
| Vcc | 3.3v |
| Satellites | 22 |
| Dimensions | 16x16x5mm |
| Velocity Accuracy | ±0.1m/s |
| Update Rate | 1 to 10Hz |
| Acquisition Sensitivity | -145dBm |
| Operating Current | 20-25mA |
| Tracking sensitivity | -165dBm |

# GPS Testing and Integration



1. Connection of GPS to Arduino Mega2560 through a hardware Serial connection

2. Linux Terminal echoing ROS topic that is publishing GPS coordinates and fix status.

3. GPS Antenna

# Software Block Diagram



**Arduino**
- H Bridge
- ROS Serial
- GPS
- Boundary Wire Sensors
- IMU Sensor

**SBC**
- Lidar
- Camera
- ROS
- TensorFlow
- Communication Web Server
- Wifi Access Point

**Control App**
- React Native
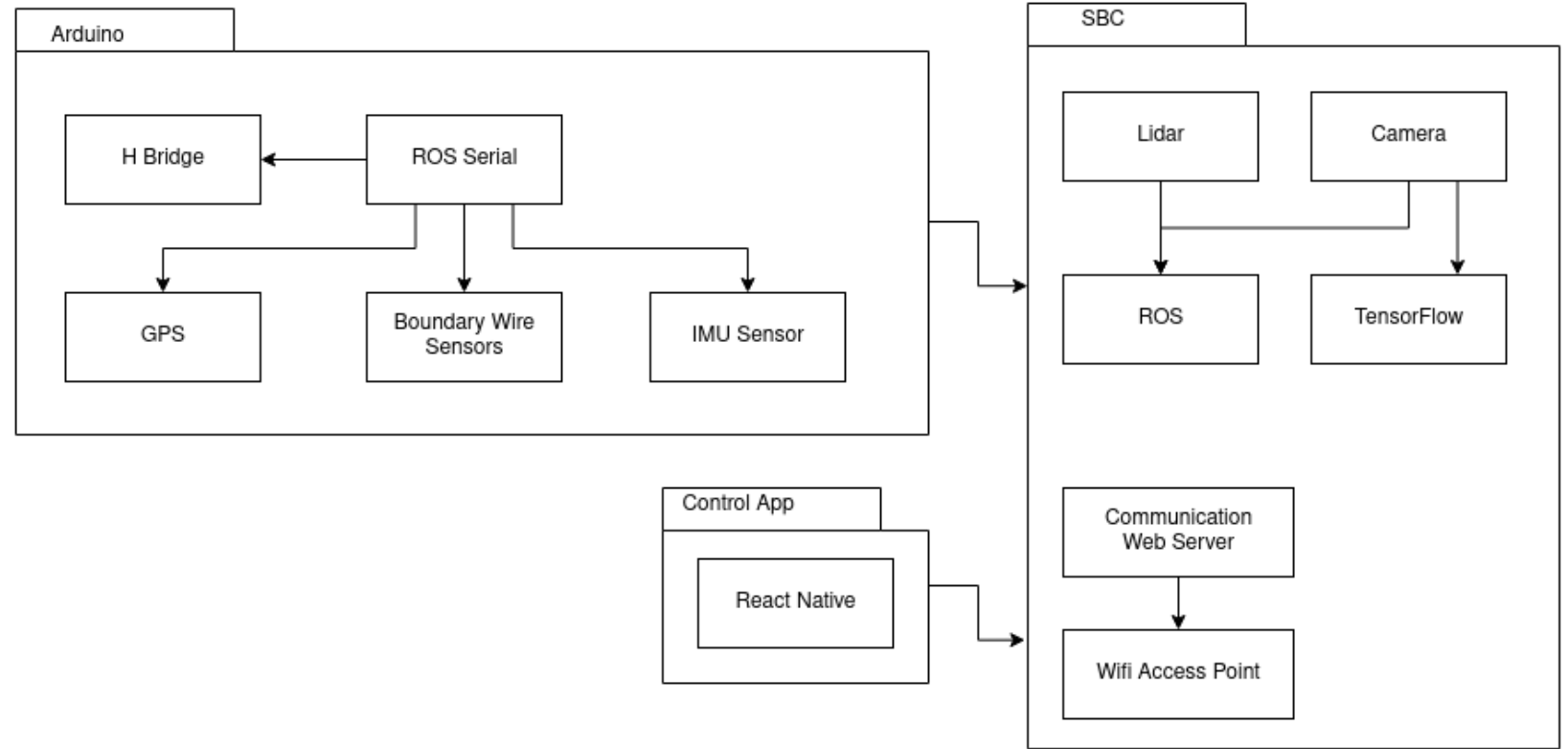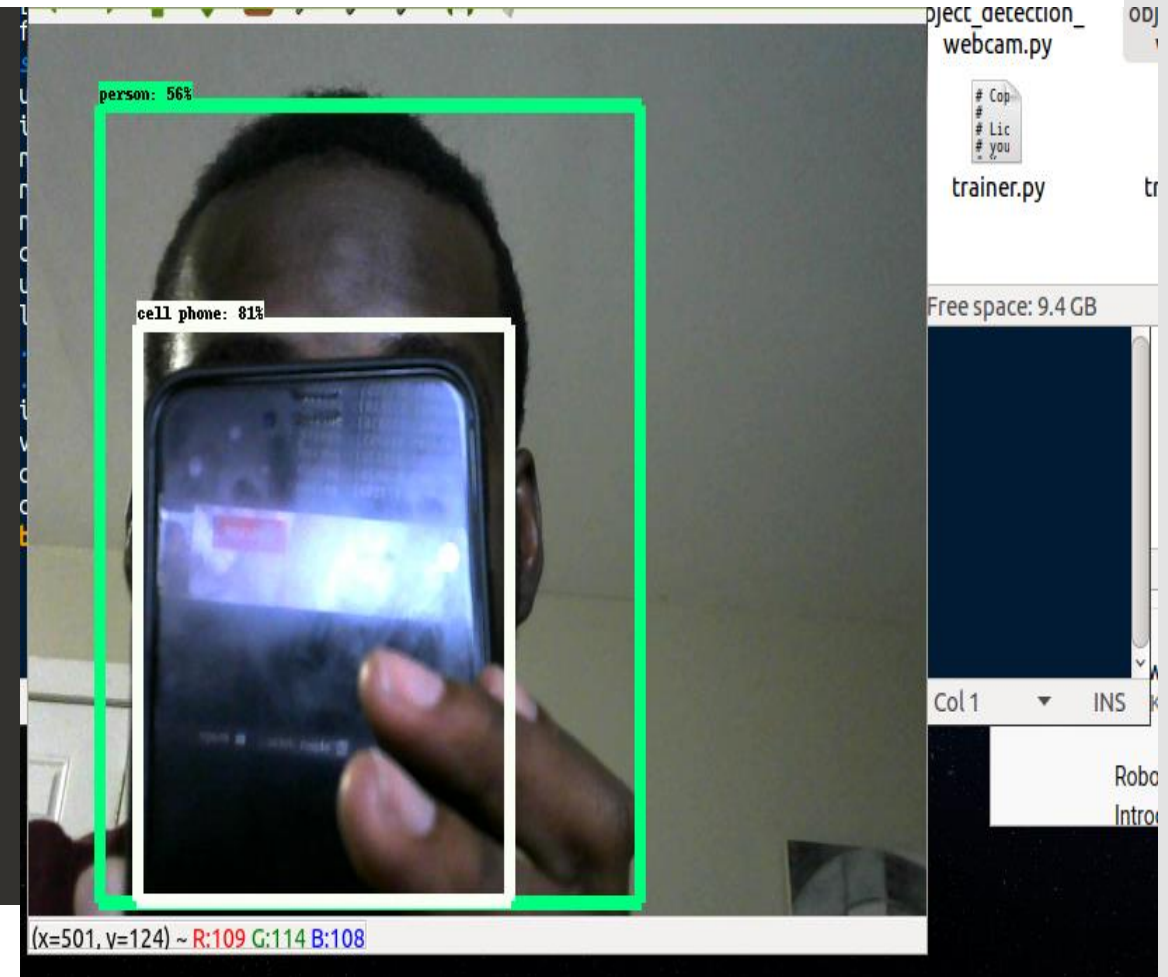
# Object Detection (Cam)

- Camera used for Computer Vision

- Python running on the Odroid SBC

- Single Shot Multibox Detector (SSD) with MobileNet

- COCO Dataset

- Using Tensor flow API and OpenCV

- Fast and reliable

# Tensor Flow API

- The model has been trained on the MS COCO dataset (Common Objects in Context).

- A dataset of 300k images of 90 most found commonly objects:
    1. Dogs
    2. Cats
    3. Laptops
    4. Teddy bear
    5. Chair
    6. Phones
    7. And others

# Mobile App and Connection

- In lieu of a wireless data internet connection such as LTE, the rover will have a wifi access point built in, and all outside connection will go through that.

- This limits us in range, but it will still be useable for our requirements

- The mobile app (written in React Native) will communicate over a simple REST api to the main ROS node, and allow a user to perform basic functions such as starting and stopping the rover

# ROS / Software

- ROS stands for Robot Operating System

- ROS is a set of software libraries and tools that help you build robot applications
- ROS is open-source and can be installed in many operating systems, but it has fast performance in Linux which makes the best OS for ROS.
- Main programming language used are C++ and Python

ROS Publisher/ Subscriber nodes

Microcontroller

Publisher | Subscriber

Publisher/Subscriber Channels

Computation Board

Publisher | Subscriber

Publisher → IMU

Publisher → GPS

Publisher → EMF

Publisher / Subscrieber → PWM

Publisher / Subscrieber → Lidar
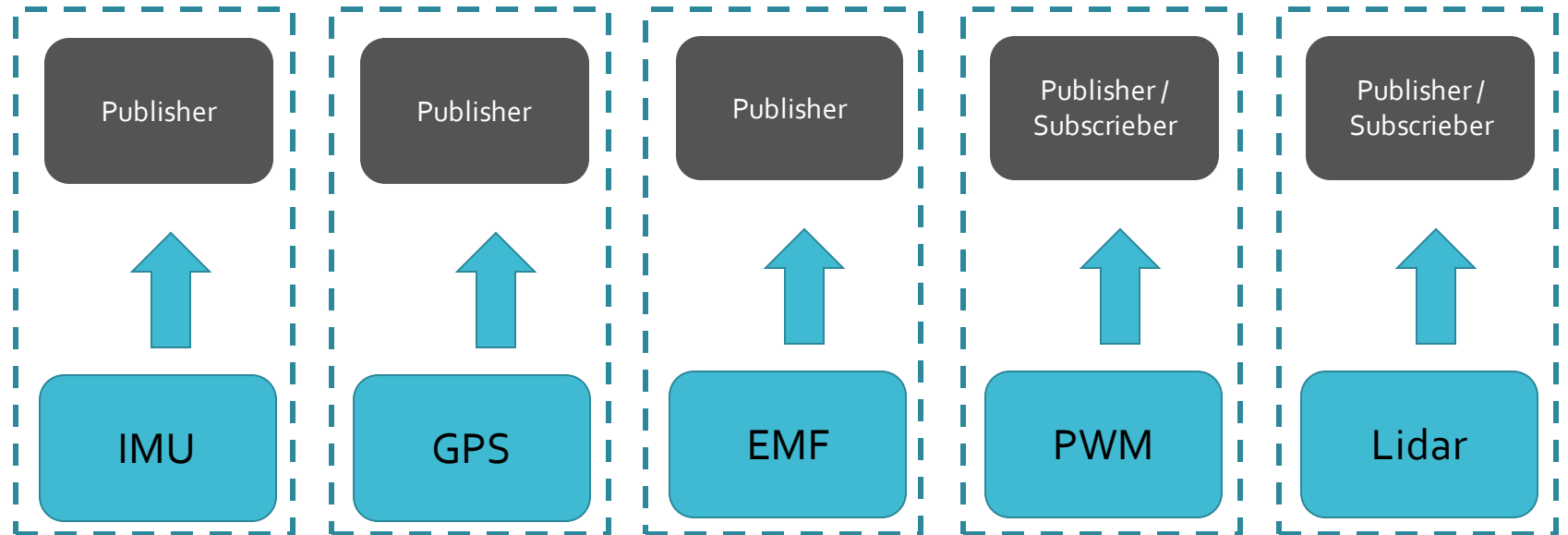
# ODROID-XU4

- A powerful Single Board Computer and energy efficient hardware.

- The ODROID-XU4 supports running various versions of Linux including:
    1. Ubuntu 16.4 and
    2. Android 4.4 KitKat and 5.0 Lollipop.



| | |
|---|---|
| Size | 83 x 58 x 22 mm approx.(including cooling fan) |
| RAM | 2Gbyte LPDDR3 RAM PoP stacked |
| CPU | Samsung Exynos 5 Octa 5422 (4x up to 2.1 GHz + 4x up to 1.4 GHz) |
| Storage | Supports eMMC5.0 HS400 and/orMicro SD |
| GPU | Mali-T628 MP6 |
| Video | Full HD |
| USB | 2xUSB3 1xUSB2 |
| Power source | 5V/4A |
| Storage types | Micro SD EMMc Sata(optional) |
| Network Connectivity | Gigabit Ethernet |
| CPU Instruction set | ARMv7-A |
| GPIO | 24 Pins |
| Display Port | HDMI 1.4a |

# Object Detection(Lidar)

- Lidar scans its environment and collect data

- The data collected is broadcasted on /scan topic

- Lidar can be used to detect object which is why we used as part of our object detection components

- Very accurate and fast

```
odroid@odroid:~$ rostopic type /scan
sensor_msgs/LaserScan
odroid@odroid:~$ rosmsg show sensor_msgs/LaserScan
std_msgs/Header header
  uint32 seq
  time stamp
  string frame_id
float32 angle_min
float32 angle_max
float32 angle_increment
float32 time_increment
float32 scan_time
float32 range_min
float32 range_max
float32[] ranges
float32[] intensities
```
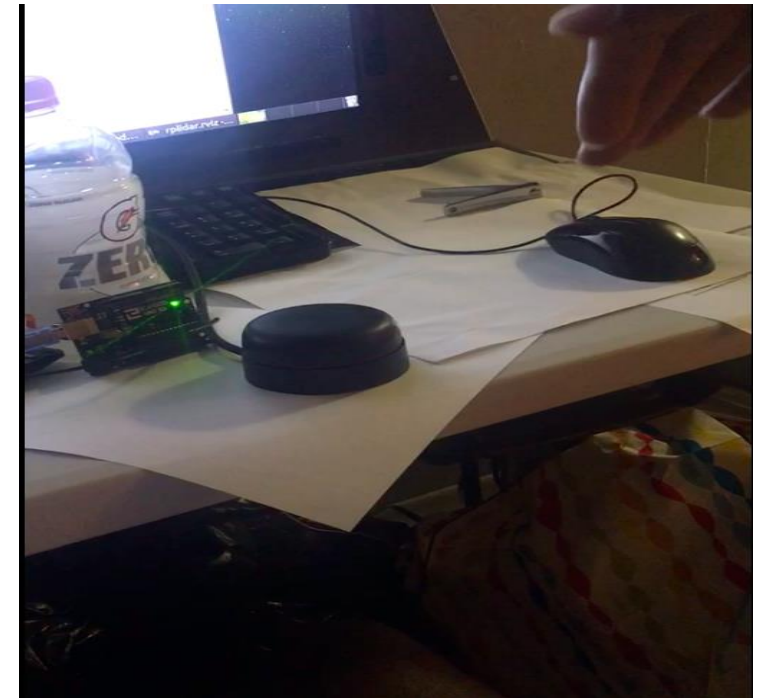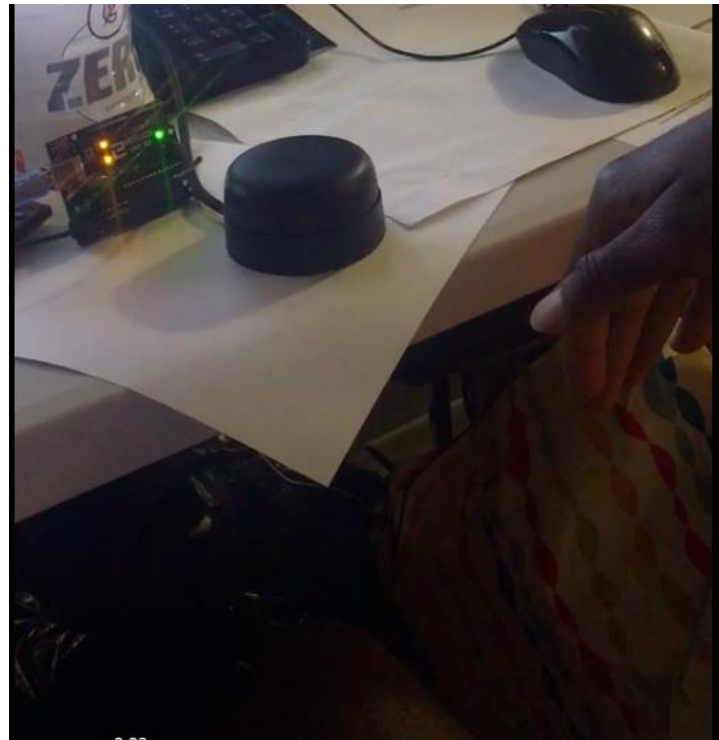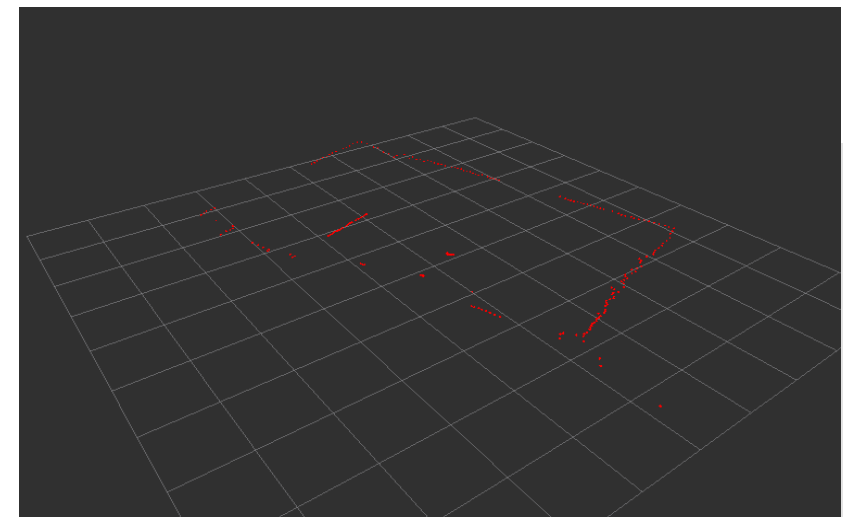
# ROS/Code

```python
def talker(hello_str):
    global x
    #Name of Node we want to Publish to
    pub = rospy.Publisher('chatter', String, queue_size=10)

    rate = rospy.Rate(10) # 10hz
    if x:
        rospy.loginfo(hello_str)
        pub.publish(hello_str)
        rate.sleep()

    else:
        pub.publish("No")
        rospy.loginfo("No")
```

```python
def listener():
    #Name of Node
    rospy.init_node('scan_node')
    #setting the name of the topic we want to subscribe to
    sub=rospy.Subscriber("/scan", LaserScan, callback)
    # spin() simply keeps python from exiting until this node is    stopp
        rospy.spin()
```

```python
def callback(data):
    global x
    #print len(data.ranges)
    #print data.ranges[0]
    #print data.ranges[180]
    if data.ranges[359]<1:
        x = True
    else:
        x = False
    talker("Yes")
    print data.ranges[359]

    #print  "looo"
    #return x
```

# PCB Schematic

- Bare bones because most of the components and sensors are separate discrete parts

- made in Eagle
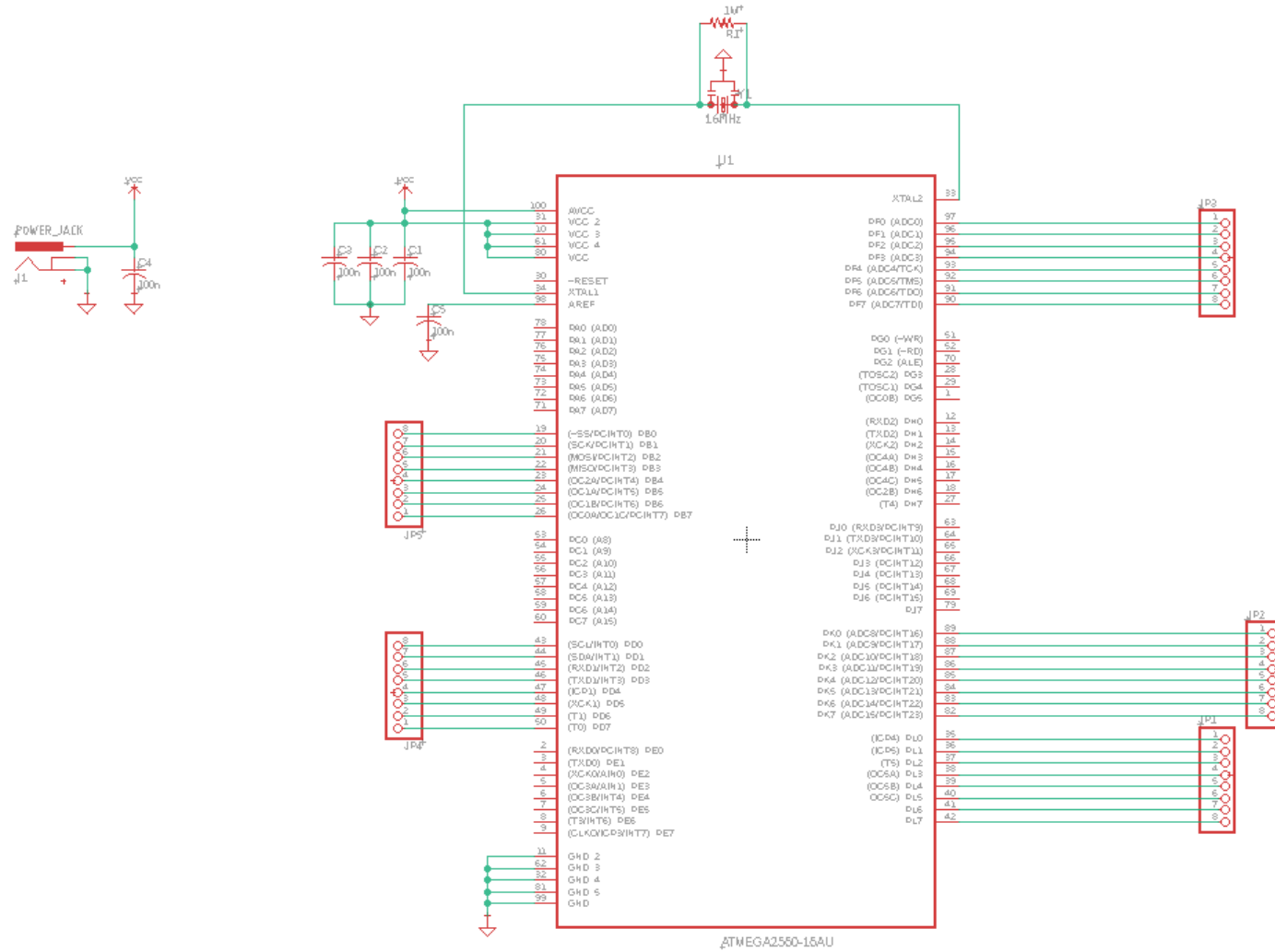
# Printed Circuit Board v1.0

- Dimensions: 2.5"x2"

- Layers: 2

- Vias used to connect top and bottom layers as well as GND

- Pin headers for easy testing, experimenting, and debugging
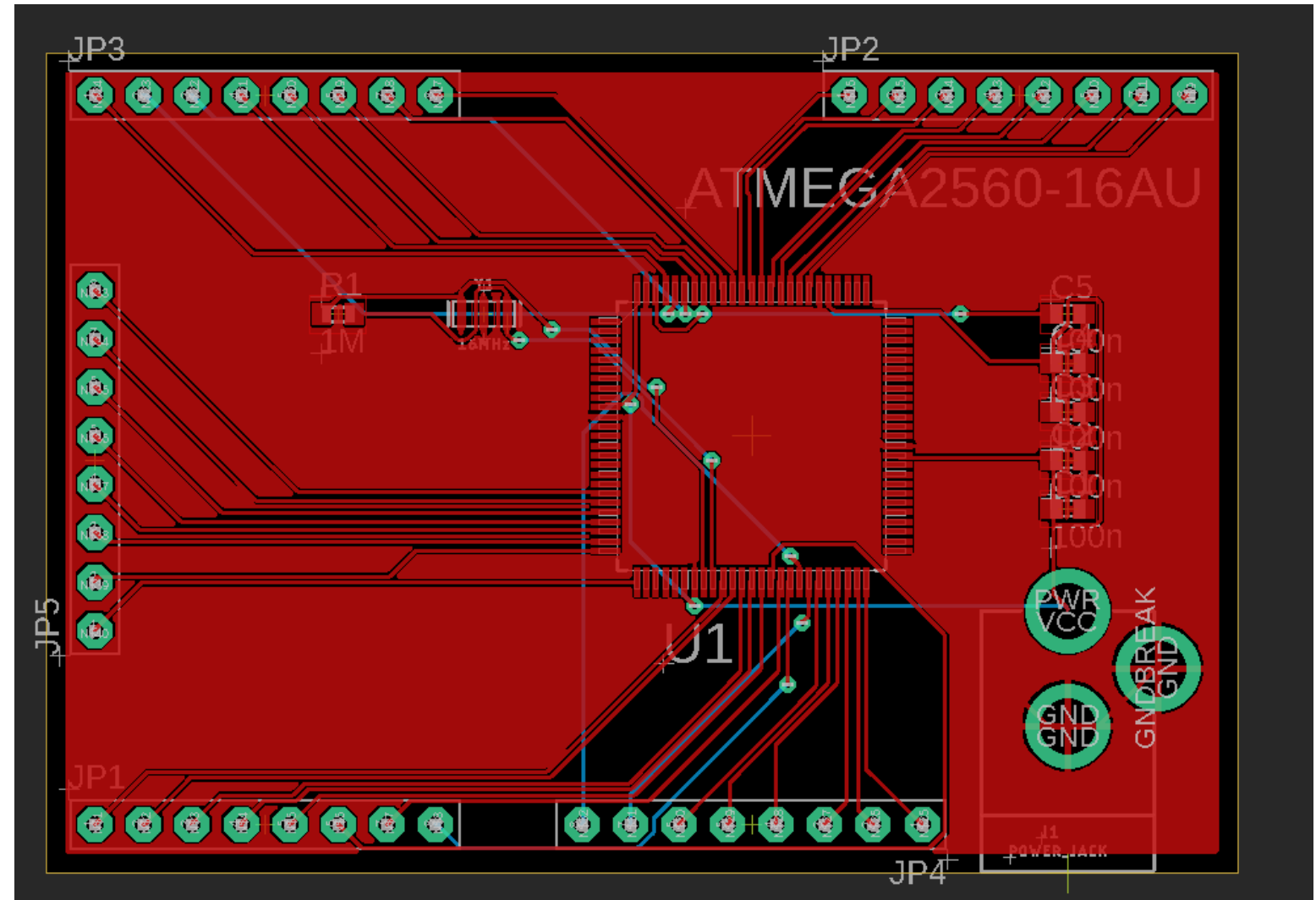
# Wheel Motor Power System

- 12V 15000mAh battery powering both wheel motors

- Remote relay to turn on and off wheel motors(kill switch)

- 3V coin cell battery to go into relay remote control
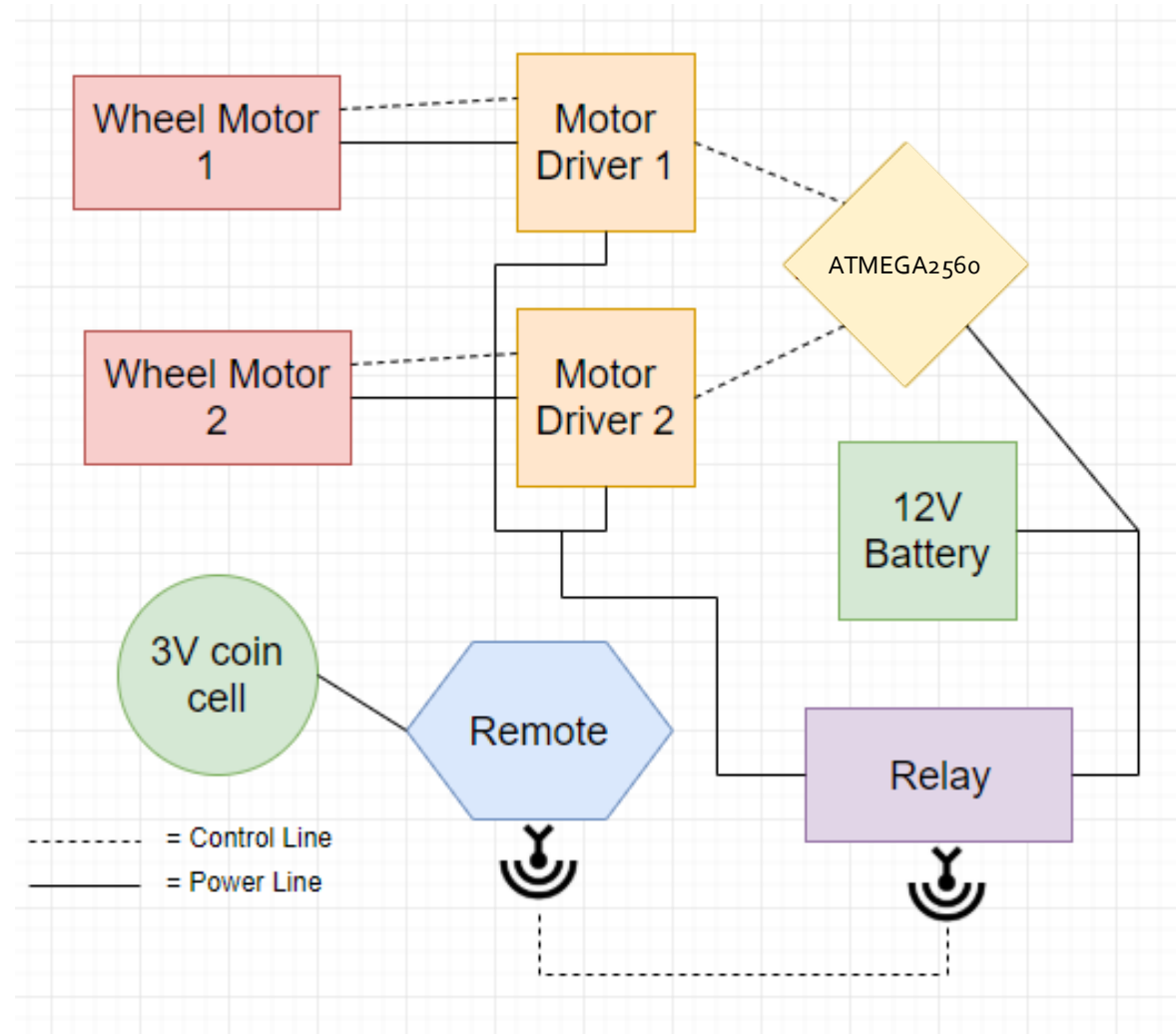
# Trimmer Motor Power System

- 3 12V Lipo batteries rated for 8000mAh

- Remote relay to turn on and off trimmers (kill switch – on a different channel)
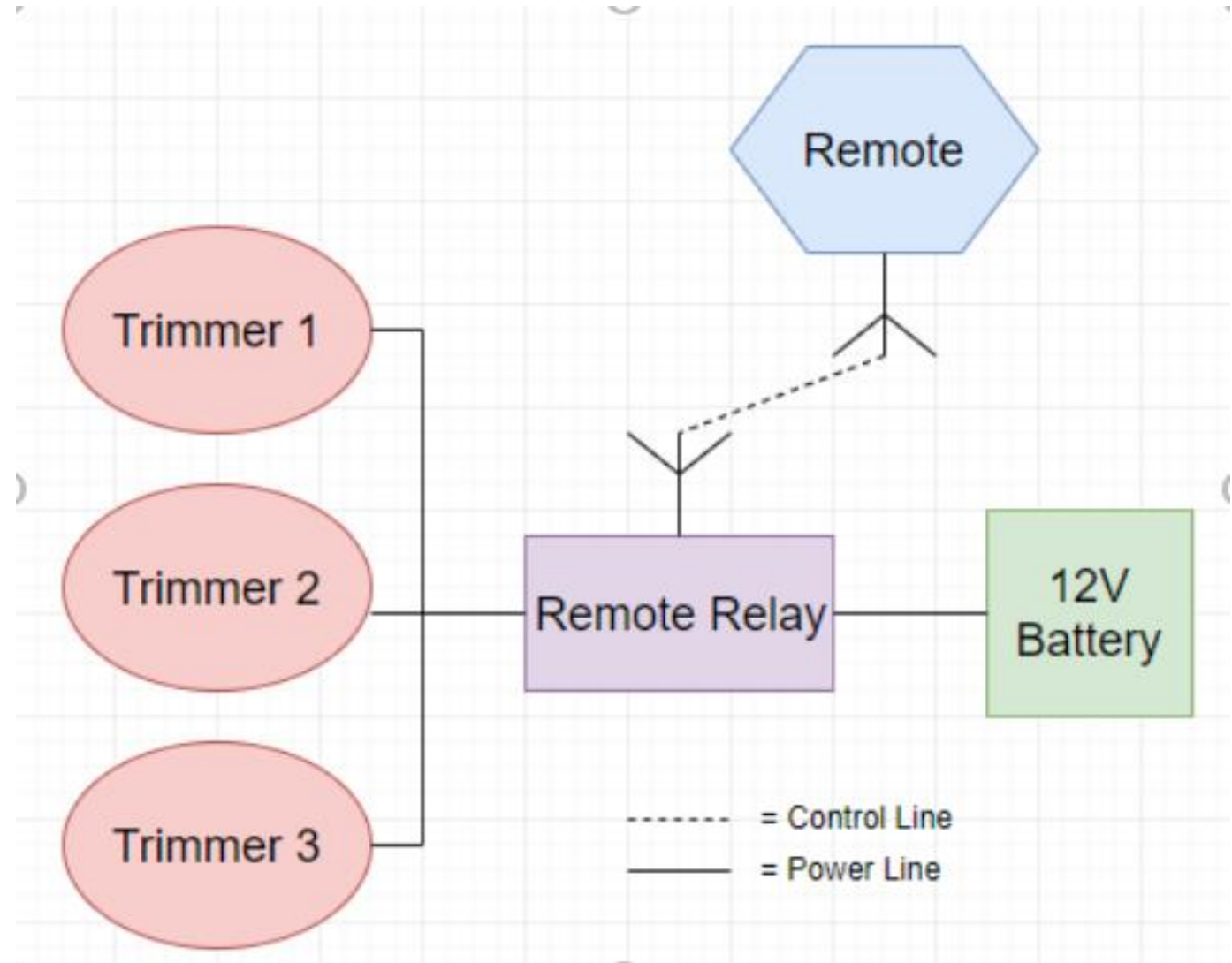
# Financing

- Option to be personally financed

- Primarily financed by Duke Energy and Orange County Utility

- Total Budget provided by Duke Energy and OUC: $1500

- Total Budget currently used: approximately $1040/1500

# Budget

| Part | Description | Price | Quantity | Total | Link | Ordered | Picked Up | Must Be Returned | | Budget | Total Spent | Remaining Budget |
|------|-------------|-------|----------|-------|------|---------|-----------|------------------|---|--------|-------------|------------------|
| Caster Wheel | Steelex D2580 6-1/4" inch swivel heavy duty industrial wheel. 440 pounds weight capacity. Mounting plate measures 4-1/2 by 4 inches. Distance between holes: 3.46" x 2.95". Height to Mounting Plate: 7.48" | $15.86 | 1 | $15.86 | https://www.amazon.com/Steelex-D2581-Swivel-Industrial-8-Inch/dp/B0000DD1D1/ref=sr_1_9?keywords=rubber%2Bcaster%2Bwheels&qid=1572975881&s=industrial&sr=1-9&th=1 | YES | YES | NO | | $1,500.00 | 1040.11 | $459.89 |
| Drive Wheels | ATR Wheel and Shaft Set Pair 8mm bore - 10 inch Traction Lug Item #: TD-163-008 | $107.52 | 1 | $107.52 | https://www.superdroidrobots.com/shop/item.aspx/atr-wheel-and-shaft-set-pair-8mm-bore-10-inch-traction-lug/1995/ | YES | YES | YES | | | | |
| Driving Motors | Lynxmotion 12V 90-rpm 99.11 oz-in 1:26.9 Brushed DC Gear Motor w/ Encoder | $84.33 | 2 | $168.65 | https://www.robotshop.com/en/lynxmotion-12v-90-rpm-9911oz-in-1269-brushed-dc-gear-motor-w--encoder.html | YES | YES | N/A | | | | |
| Trimming Motors | weelye Universal 550 15000RPM Electric Motor RS550 12V Motor Drive Engine Accessory for RC Car Children Ride on Toys Replacement Parts | $13.58 | 2 | $27.16 | https://www.amazon.com/weelye-Universal-15000RPM-Accessory-Replacement/dp/B07HP965SS/ref=pd_sbs_21_4/140-5199111-9316403?_encoding=UTF8&pd_rd_i=B07HP965SS&pd_rd_r=23b4dd46-95d1-4c84-acb9-9b3e07d3851c&pd_rd_w=ZK1XR&pd_rd_wg=GIYzk&pf_rd_p=52b7592c-2dc9-4ac6-84d4-4bda6360045e&pf_rd_r=MQGGGTP83NMBR22H3BJF&psc=1&refRID=MQGGGTP83NMBR22H3BJF | YES | YES | NO | | | | |
| Trimmer Head | Better Heads LLC MaxPower's PivoTrim Universal Replacement 3317233 Head Uses .095-Inch Pre-Cut Trimmer Line, 11.25" L x 7.5" W x 4" H, Multi | $17.69 | 1 | $17.69 | https://www.amazon.com/Pivotrim-Maxpower-3317233-Trimmer-095-Inch/dp/B001AHAJXK?ref_=fsclp_pl_dp_2 | YES | YES | NO | | | | |
| Base Plate | Aluminum Sheet Plate 1/8" (.125) X 12" X 24" 5052 H32 | $49.99 | 1 | $49.99 | https://www.amazon.com/Aluminum-Sheet-Plate-125-5052/dp/B0055OO2GE | YES | Returned | N/A | | | | |
| Boundary Wire | DOGTEK 500ft Boundary Wire For Electronic Dog Fence System | $18.95 | 1 | $18.95 | | YES | YES | NO | | Mae | 672.1 | 460.82 |
| GPS Module | Adafruit Ultimate GPS Breakout - 66 channel w/10 Hz updates - Version 3 PRODUCT ID: 746 | $39.95 | 1 | $39.95 | https://www.adafruit.com/product/746 | YES | YES | NO | | | | |
| SMA to uFL/u.FL/IPX/IPEX RF Adapter Cable | SMA to uFL/u.FL/IPX/IPEX RF Adapter Cable PRODUCT ID: 851 | $3.95 | 1 | $3.95 | https://www.adafruit.com/product/851 | YES | YES | NO | | | | |
| GPS Antenna | GPS Antenna - External Active Antenna - 3-5V 28dB 5 Meter SMA PRODUCT ID: 960 | $14.95 | 1 | $14.95 | https://www.adafruit.com/product/960 | YES | YES | NO | | | | |
| IMU Sensor | Adafruit Precision NXP 9-DOF Breakout Board - FXOS8700 + FXAS21002 PRODUCT ID: 3463 | $14.95 | 1 | $14.95 | https://www.adafruit.com/product/3463 | YES | YES | NO | | | | |
| Shipping on Adafruit Items listed above | | $7.82 | 1 | $7.82 | NA | | | | | | | |
| Perimeter Wire Kit | RobotShop Perimeter Wire Generator and Sensor Soldering Kit | $9.95 | 1 | $9.95 | https://www.robotshop.com/en/robotshop-perimeter-wire-generator-sensor-soldering-kit.html?utm_source=rb-community&utm_medium=blog&utm_campaign=diy-perimeter-wire-generator-and-sensor | YES | YES | NO | | | | |
| Odroid XU4 | ODROID XU4 with active cooler and power supply | $77.88 | 1 | $77.88 | https://www.amazon.com/dp/B0761YJY27/ref=cm_sw_r_cp_api_i_ai2eEb6P3XCPB | YES | YES | | | | | |
| Bearing Pillow | | $15.95 | 1 | $15.95 | https://www.amazon.com/dp/B07MWBY7N9/ref=cm_sw_r_sms_c_api_i_yGAZDbX6MG2CA | YES | Waiting | | | | | |
| AmazonBasics 4-Port USB to USB 2.0 Ultra-Mini Hub Adapter | | $6.99 | 1 | $6.99 | https://www.amazon.com/AmazonBasics-4-Port-USB-2-0-Ultra-Mini/dp/B003M0NURK/ | YES | Waiting | | | | | |

# Budget

| Department | Cost Estimate |
|---|---|
| Mechanical Engineering | 579.29 |
| Electrical & Computer Engineering | 460.82 |
| Total | 1040.11 |

- Had to re-order the ODROID due to a mix up in the UCF purchase process

# Progress



## Progress Bar Chart

| Category | Progress as Percentile |
|---|---|
| Research | ~96% |
| Design | ~81% |
| Prototyping | ~72% |
| Software Development | ~51% |
| PCB Development | ~57% |
| Testing | ~41% |
| Total | ~72% |

Progress as Percentile