UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Distributed Species Tracker

Electrical & Computer Engineering

ECE 445 - SP 23

Group 10

April 26th, 2023

Introduction

Team Members

Jonathan Yuen [CompE]

- PCB Design
- Power Management Subsystem

Ryan Day [CompE]

- Firmware Development
- PCB Design
- Networking Subsystem

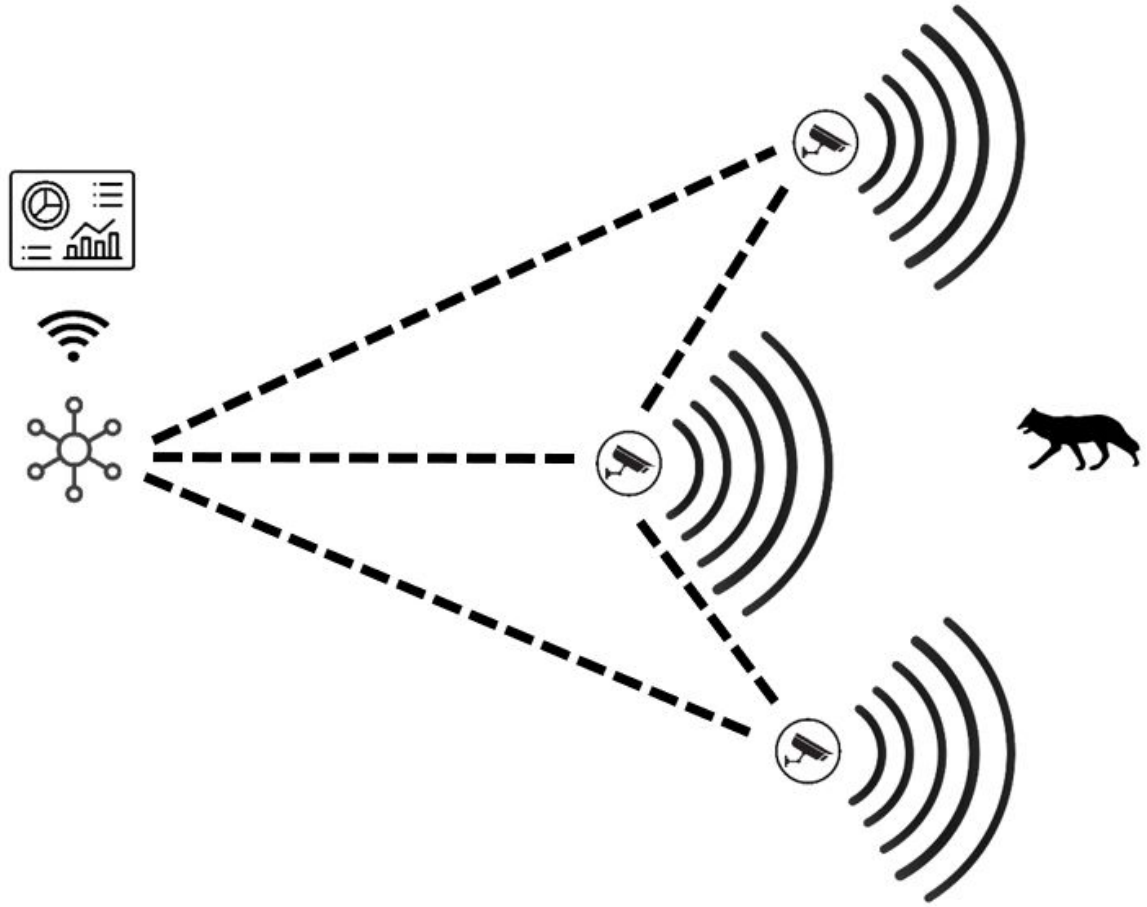
Max Shepherd [CompE]

- Software Development
- Image Classification Subsystem

Objective

Invasive and Endangered Species Tracking

- Remove overhead of tracking invasive species
- Aid in conservation efforts for study of endangered species
- Identify areas where species of interest have trafficked



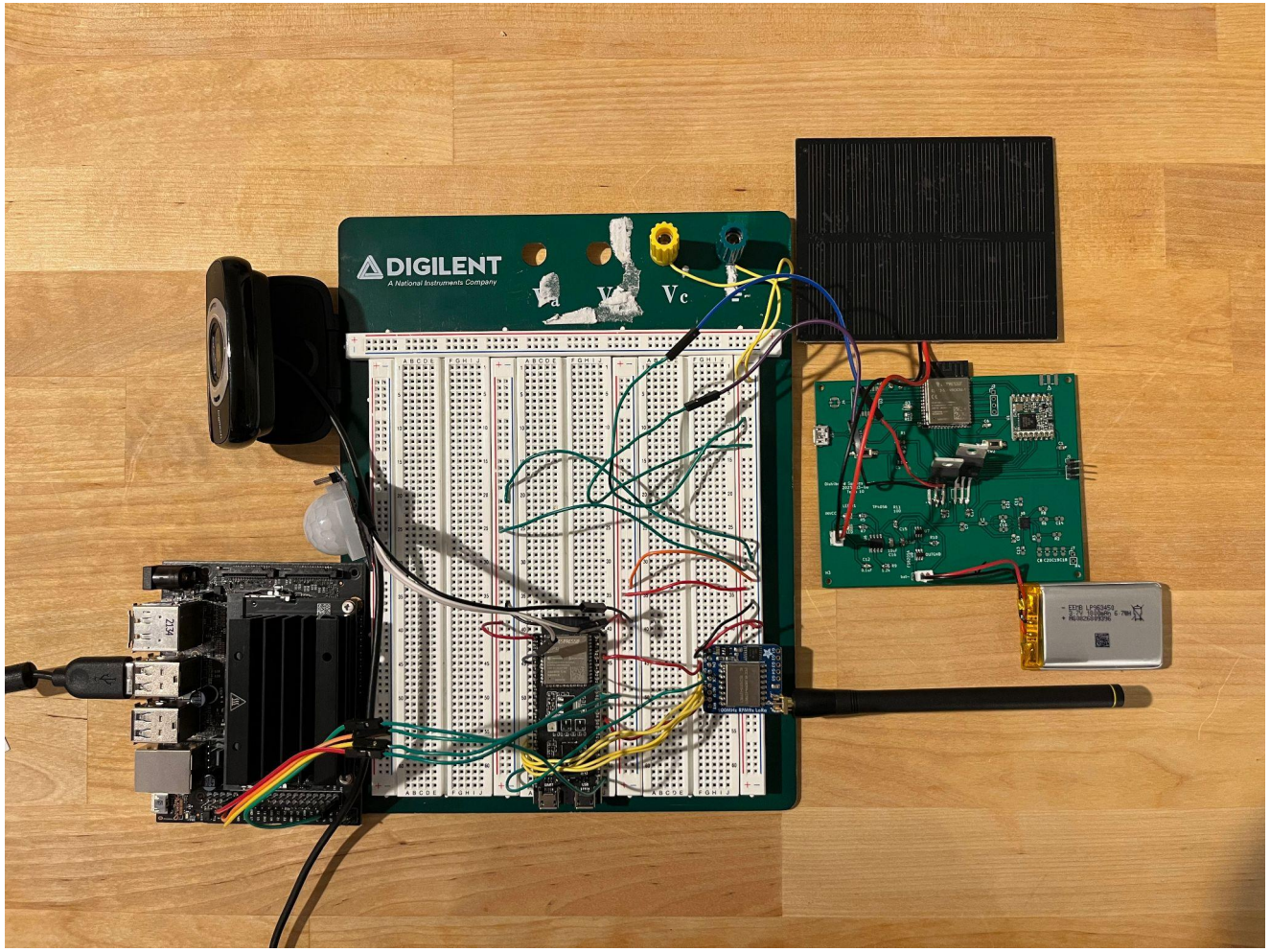
Functionality and Build

High Level Requirements

Data redundancy - We should be able to demonstrate that data gathered on any arbitrary node is reflected on the rest of the nodes in the network.

Accuracy - The system should be able to identify the presence of an animal with the infrared sensor and classify the animal we are monitoring with an accuracy of 70% or higher.

Power Ability - The system should be able to power a node with a 3.7V LiPo battery and charge the battery via solar energy.



Functionality and Build

Distributed Species Tracker

Node 1 Sightings:

- Node: 1, Animal Identified: human, GPS: (40.115278deg, -88.228367deg, 237.744m), Timestamp: 55946
- Node: 1, Animal Identified: human, GPS: (40.115278deg, -88.228367deg, 237.744m), Timestamp: 110370

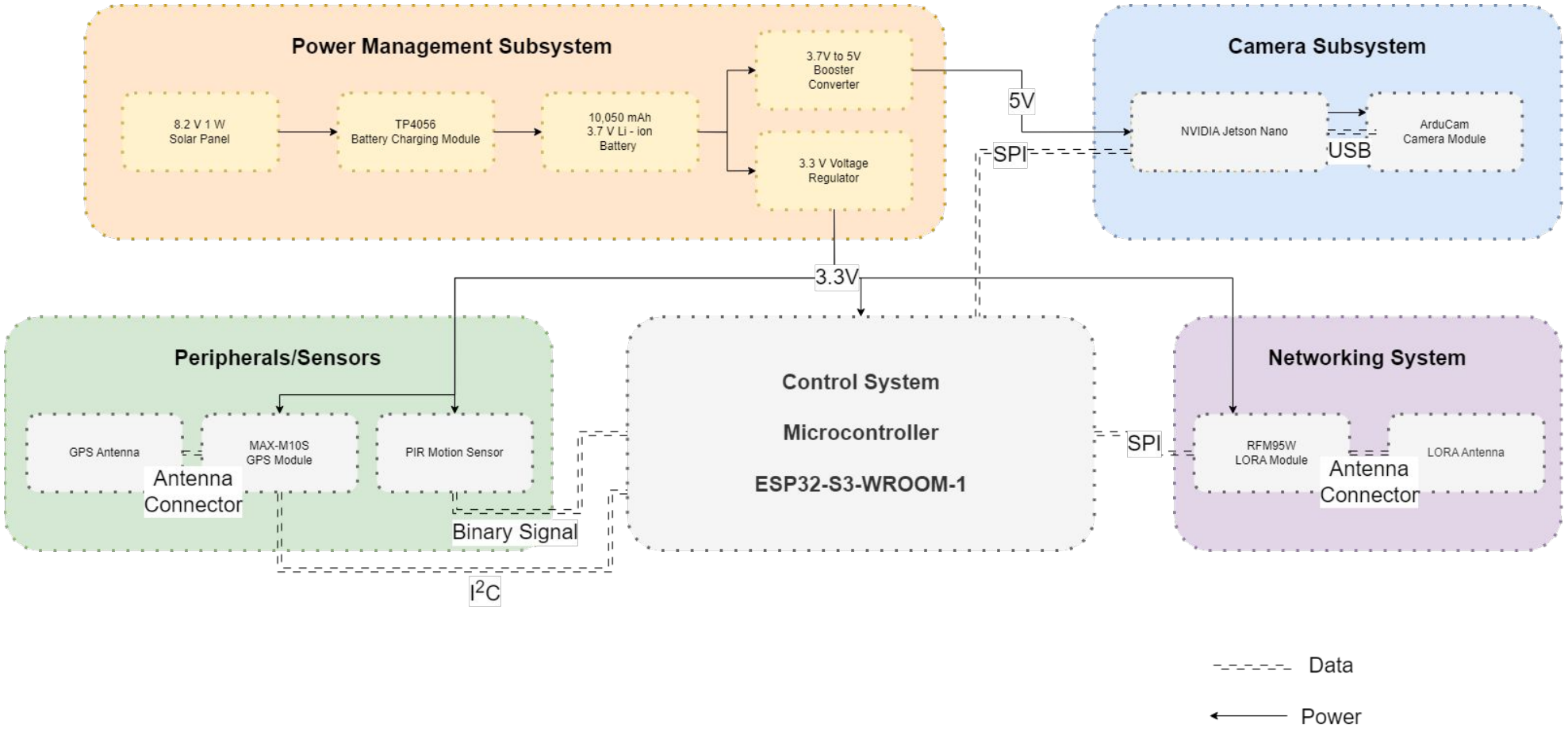
Node 2 Sightings:

- Node: 2, Animal Identified: human, GPS: (40.115278deg, -88.228367deg, 237.744m), Timestamp: 34467
- Node: 2, Animal Identified: human, GPS: (40.115278deg, -88.228367deg, 237.744m), Timestamp: 79456
- Node: 2, Animal Identified: human, GPS: (40.115278deg, -88.228367deg, 237.744m), Timestamp: 209456

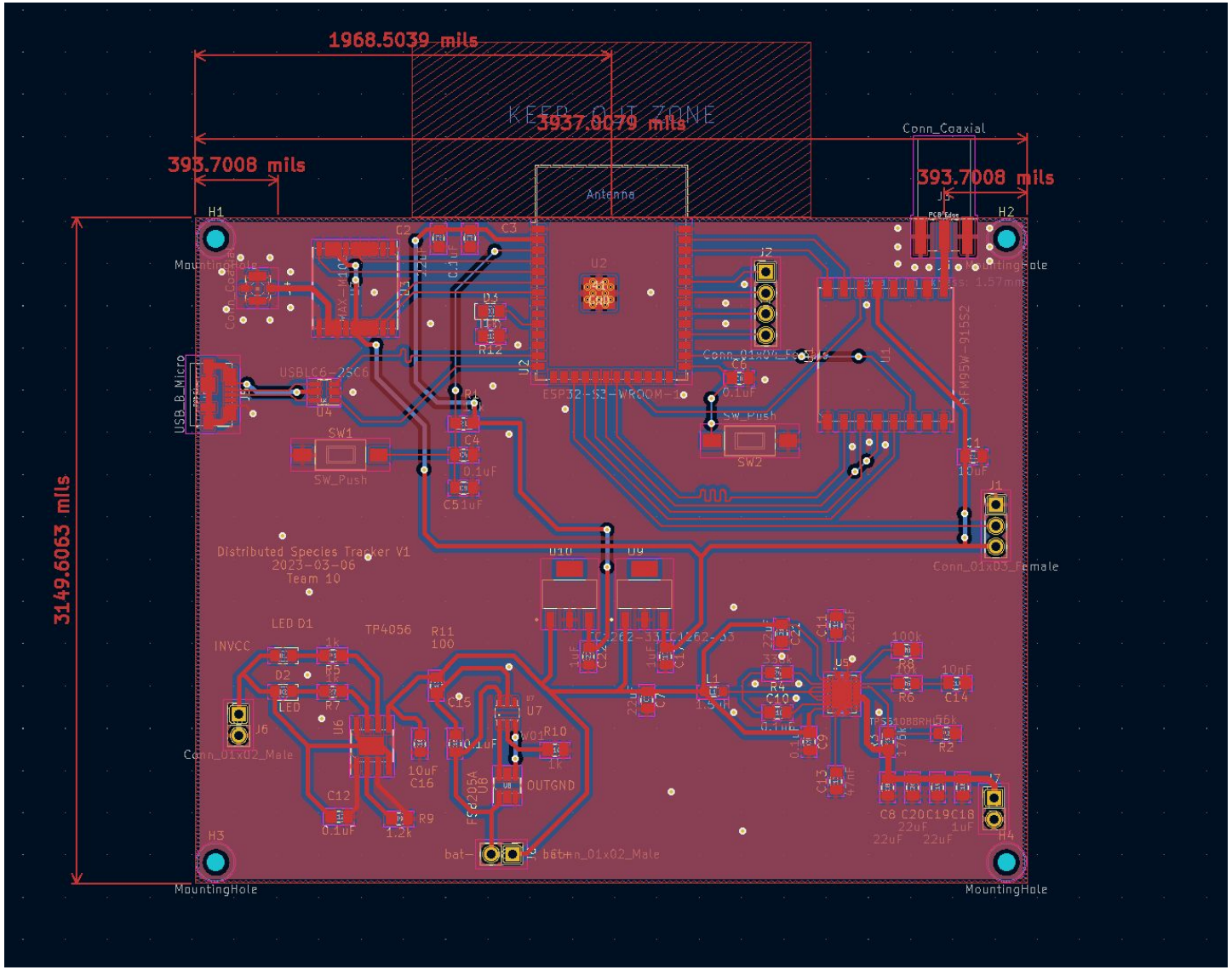
Node 3 Sightings:

- Node: 3, Animal Identified: human, GPS: (40.115278deg, -88.228367deg, 237.744m), Timestamp: 42298
- Node: 3, Animal Identified: human, GPS: (40.115278deg, -88.228367deg, 237.744m), Timestamp: 124539

Block Diagram

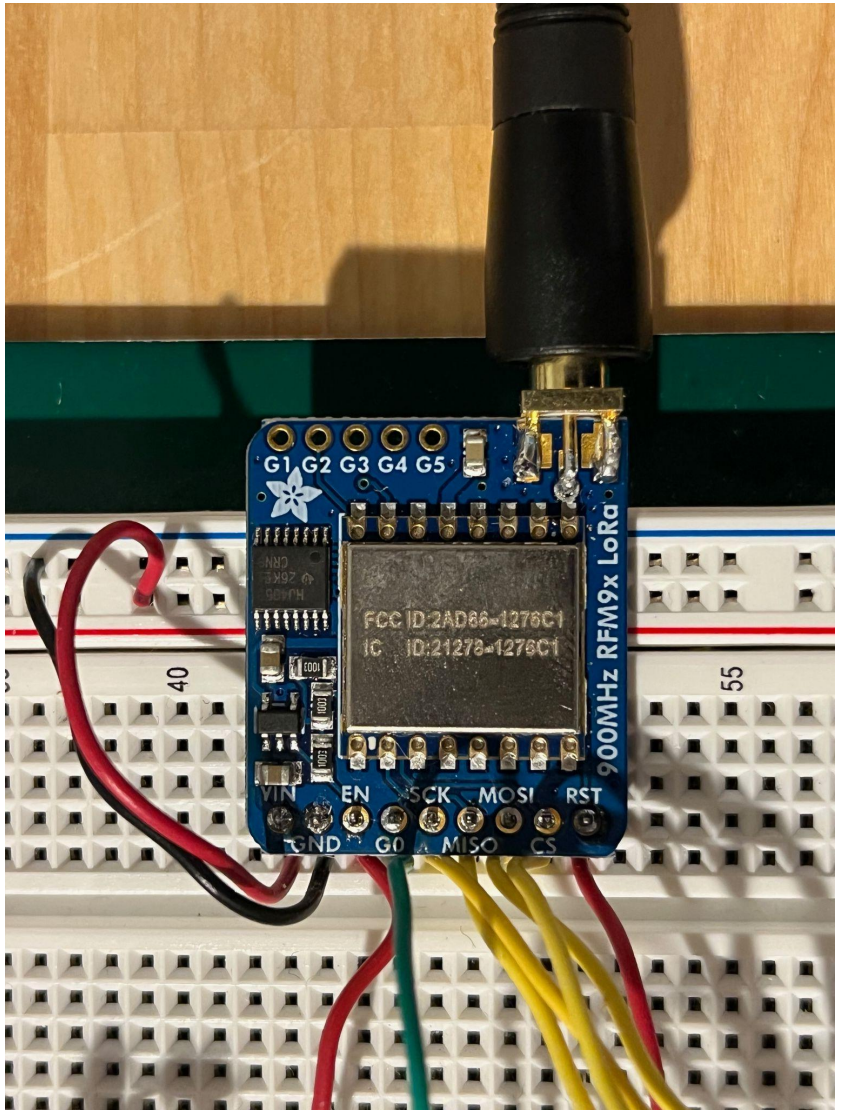


PCB Design


1968.5039 mils
3937.0079 mils
393.7008 mils
393.7008 mils
3149.6063 mils
KEEP OUT ZONE
Antenna
Conn_Coaxial
H1
H2
H3
H4
MountingHole
MountingHole
MountingHole
MountingHole
USB_B_Micro
USBLC6-2SC6
SW1
SW_Push
SW2
SW_Push
E5P32-S3-WROOM-1
Distributed Species Tracker V1
2023-03-06
Team 10
TP4056
LED D1
INVCC
LED
Conn_01x02_Male
Conn_01x03_Female
OUTGND
bat-
Conn_01x02_Male

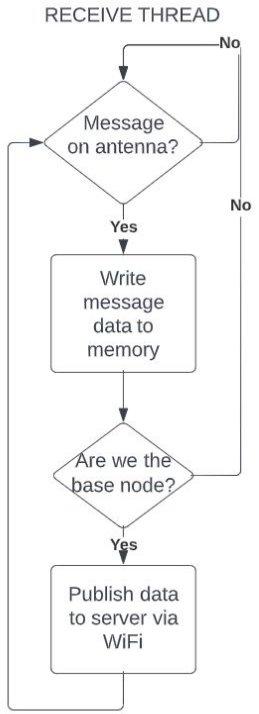
Networking Subsystem

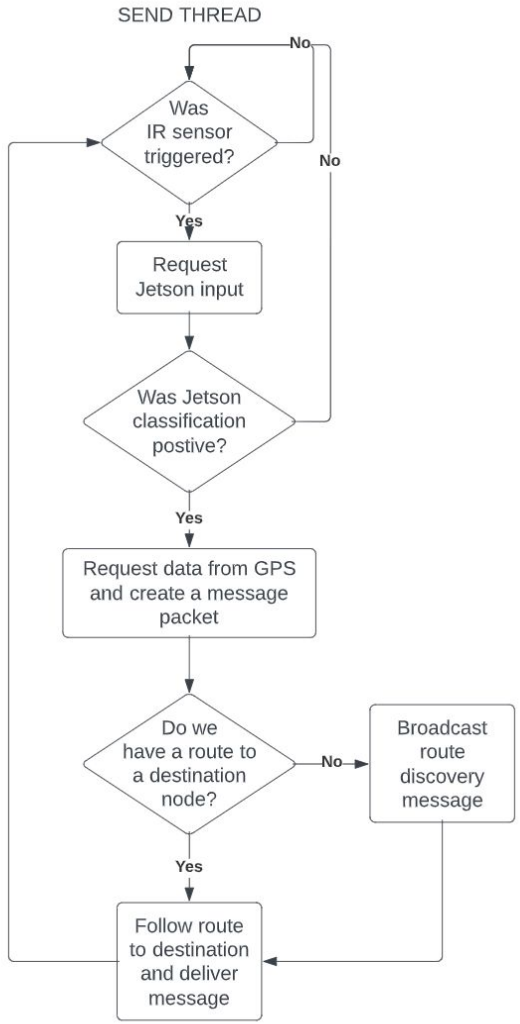
- Modulation scheme : LoRa
  - Spread spectrum
  - Long range / low power
  - Unrestricted 915 MHz range
  - Forward Error Correcting
  - Configurable spreading factor
- SPI communication with MCU
- Dipole whip antenna researched for best VSWR



ESP32 Software

- Parallelized receive and package/send threads
- Safe transmission over speed tradeoff
- Route Discovery
- Data stored locally and published if necessary

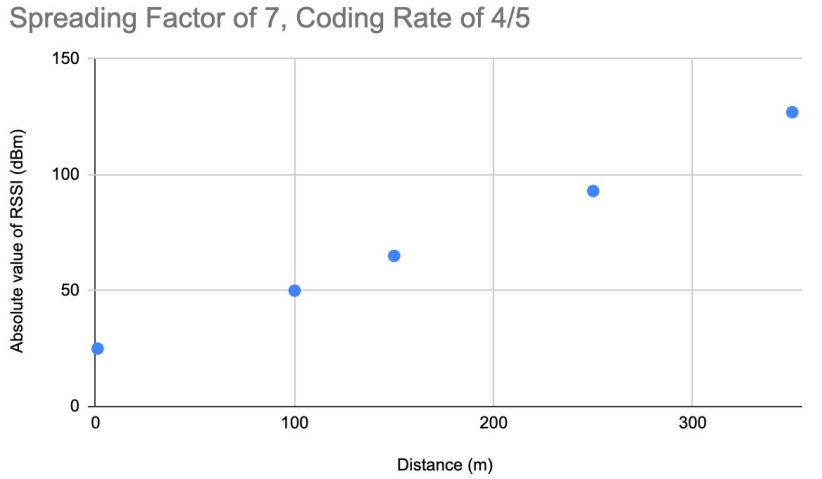


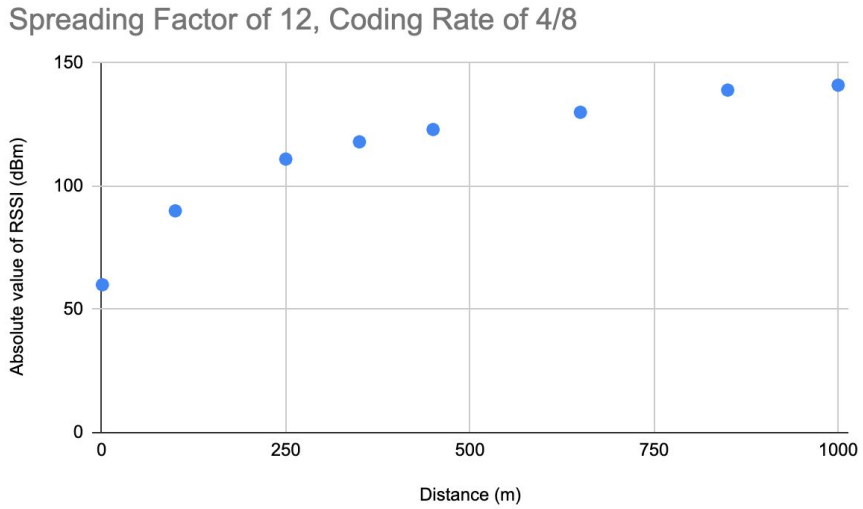


LoRa Data

- Successful message exchange at 1km with spreading factor (SF) of 12
- Expected relationship between SF/coding rate configurations and max distance

Spreading Factor	Coding Rate	Max Distance (m)	RSSI (dBm)	SNR (dB)
7	4/5	350	-127	-16
9	4/5	861	-137	-15
12	4/5	At least 1000m	-144	-20
7	4/8	342	-119	-13
9	4/8	850	-139	-15
12	4/8	At least 1000m	-141	-19



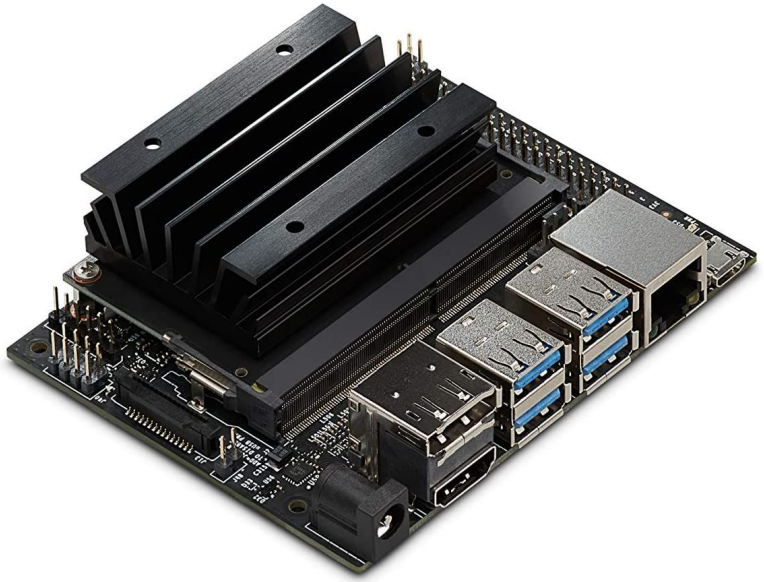


Networking/Jetson Software R&V

- Jetson image processing / handshaking was the biggest contributor to latency
- Consistent, fast picture-to-send latency

Trial #	Detection-to-Send Latency (ms)	Picture-to-Send Latency (ms)
1	2014	4
2	2234	5
3	1988	3
4	2055	2
5	2304	3
6	2111	3
7	2008	4
8	2047	5
9	1976	3
10	2289	4

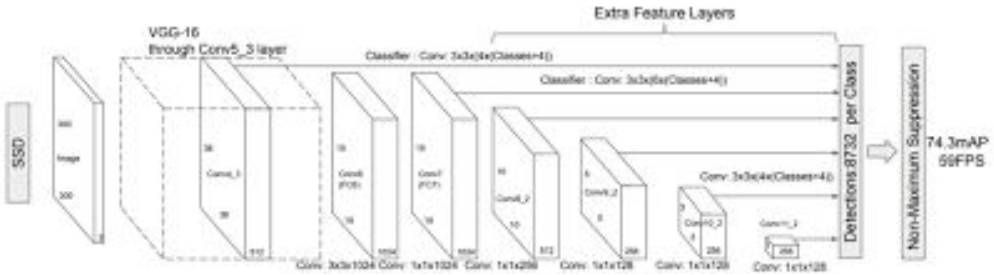
Image Processing Submodule

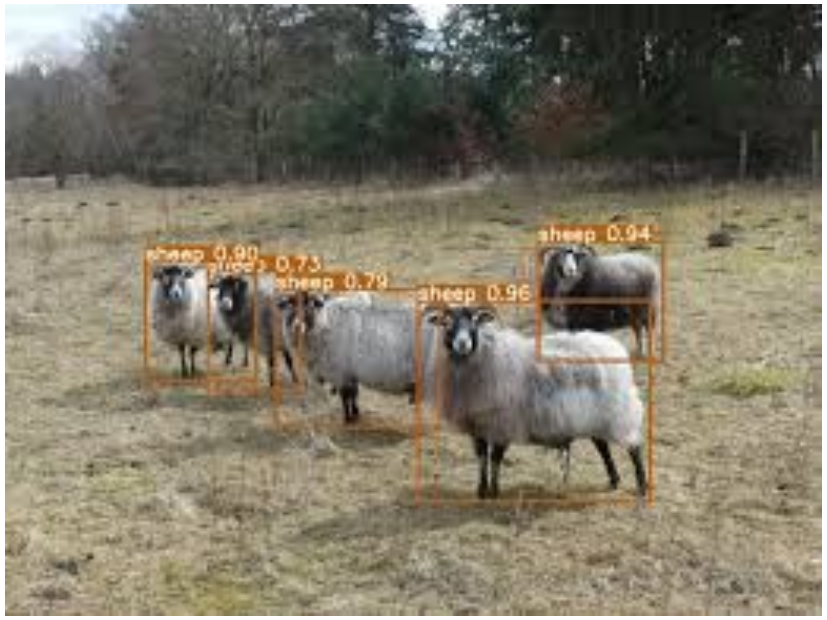


- Consists of Nvidia Jetson and USB Camera
- Notifies the MCU if the desired species is in frame or not
- Changes from original
  - Using external processor for inference
  - Using a two-wire output as opposed to SPI

Classification

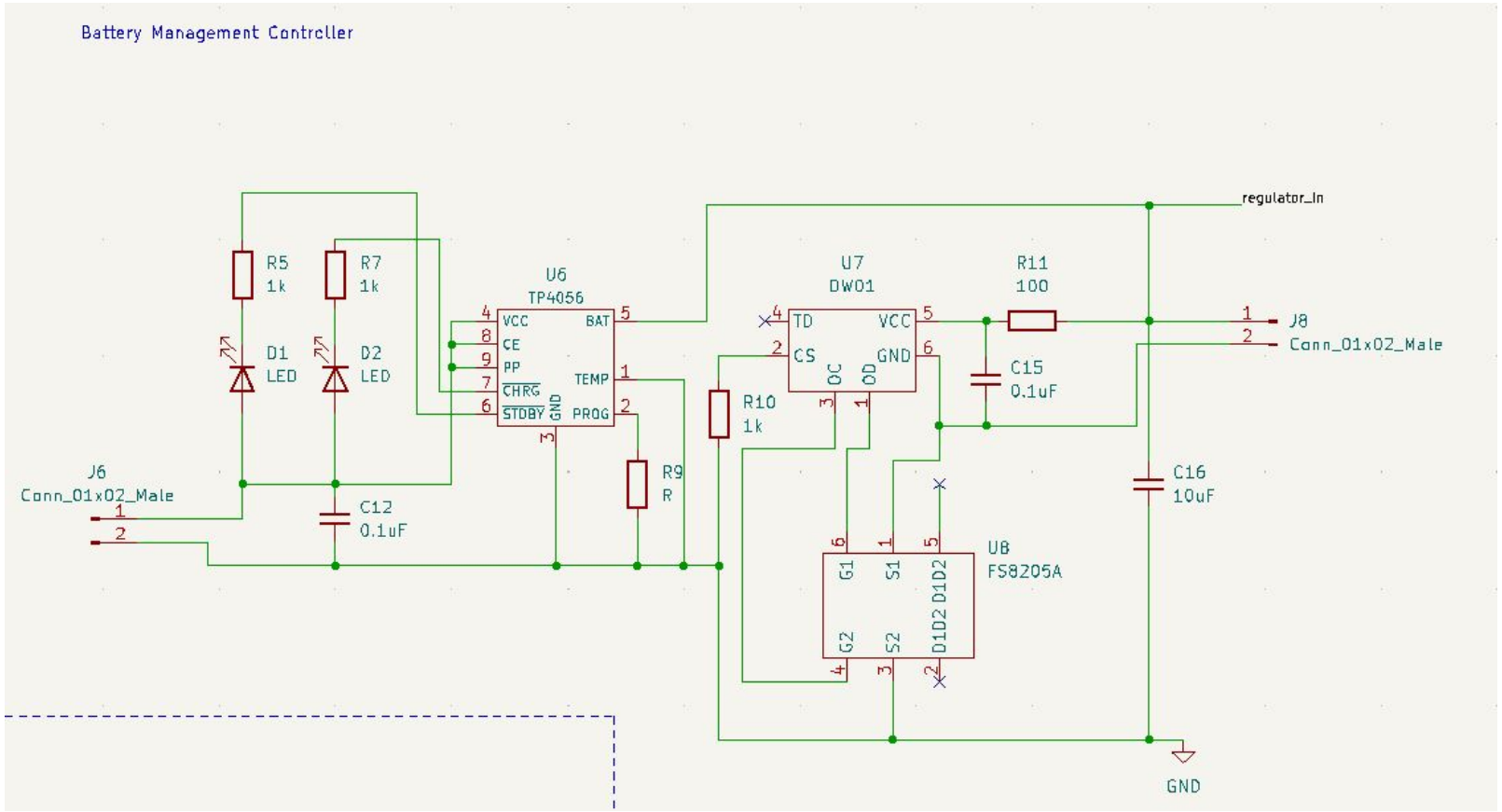
- Classification is done using object detection
- The model is SSD (single-shot detector) with a mobilenet backbone, a lightweight and fast model
- Model can detect up to 100 different classes of objects, and count how many of each object there are
- Final accuracy was 94% in the lab

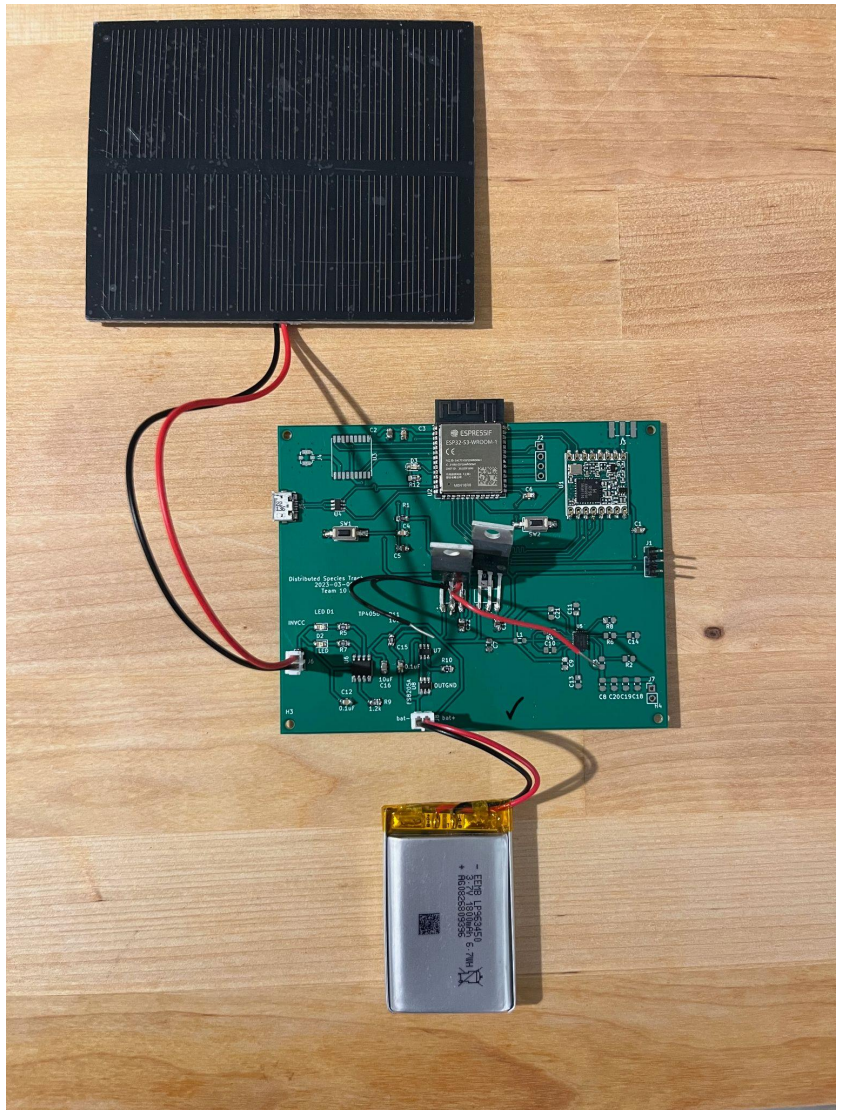




Power Management Subsystem

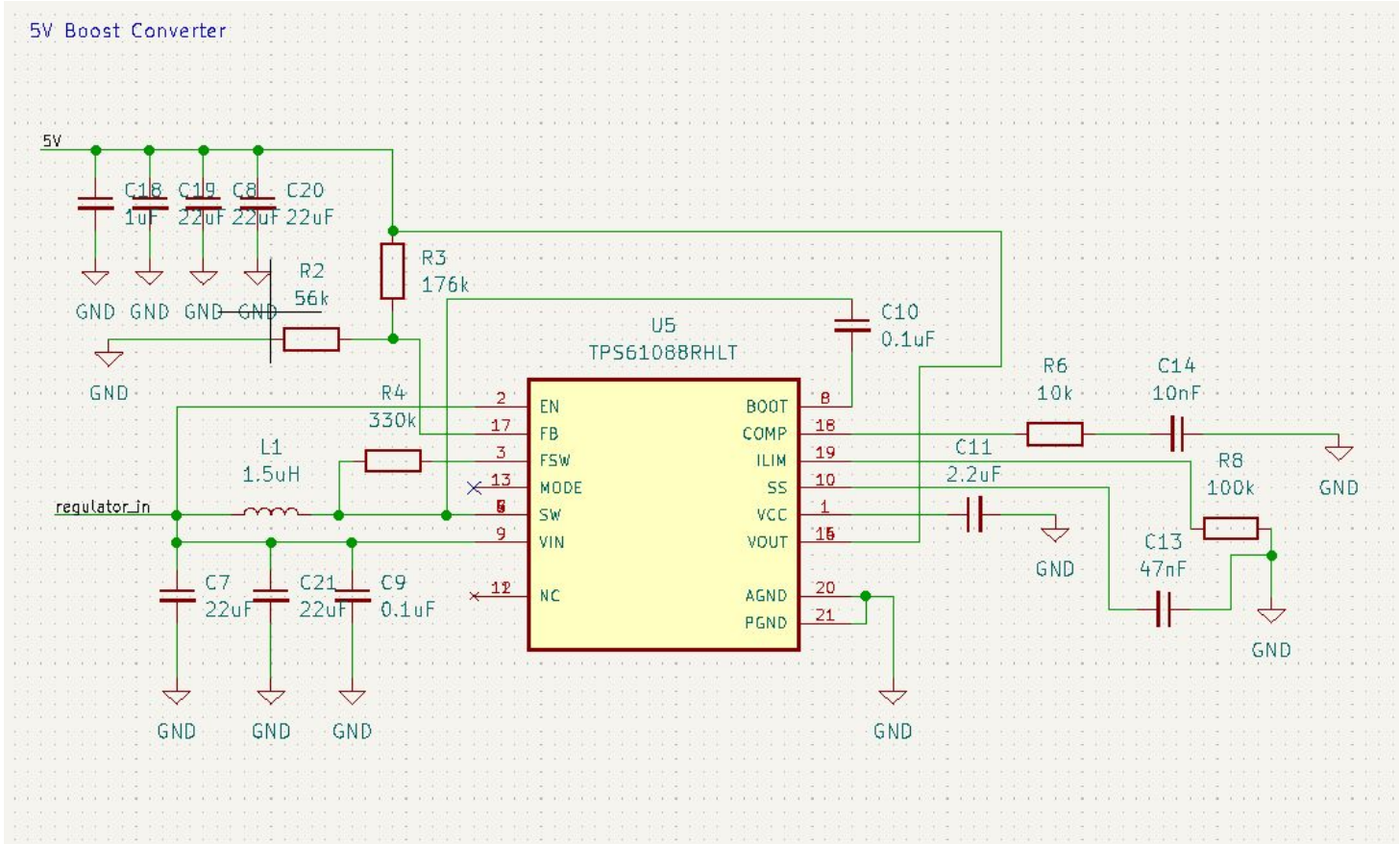
Solar Charging Circuit





Power Management Subsystem

5V Boost Converter Circuit



Changes to Design / Issues Encountered

- Scrapped the GPS module
- Replaced Jetson-to-MCU SPI connection with custom communication protocol
- Redundant 3.3V linear regulators
- Fine-pitched 5V boost converter
- MCU flash issues

Next Steps

Recommendations For Further Work

- Consolidate image processing to the MCU, reducing power consumption, size, and complexity
- Implement more robust failure detection and recovery
- Interactive map UI
- Weatherproof physical design
- Switch-Mode MPPT charging circuit

Conclusion

Accomplishments

- Functioning proof of concept design meeting most high level requirements
- Solar charging capabilities
- High accuracy image classification
- Dashboard
- PCB Design
- MCU Software
- RF theory and practice

Takeaways

- Use more well-documented chips
- Use hand-solderable IC’s
- Importance of IEEE and ACM Code of Ethics
- Plan ahead
- Hardware is difficult to debug

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