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# SkySnare: Drone Remote ID Detection and Tracking

## 2024 RRC Summer Internship Program

*Ashton Palacios, Brady Bowerbank, Jacob Hunter, Jude Koenig, Nate Osborne, Sarah Li*

*Tucson, Arizona - August 1, 2024*

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# Team Introduction

Ashton “PhD Boi” Palacios
BYU, PhD ECE
Has 3 Kids

Jude “Judecopter” Koenig
UNR, Bachelor’s CS
Likes to Waterski

Brady “papa cactus” Bowerbank
BYU, Master’s ECE
Has 3 Kids (Cats and Dog)

Nate “The Liar 2.0” Osborne
UA, Bachelor’s CS
Likes 2 travel

Jacob “The Liar” Hunter
UNR, Bachelor’s CS
Just an Angle Guy

Sarah “Sali” Li
UA, Bachelor’s SYE
Callsign is K7SLI

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# Motivation

- Why create a system that detects and track drones?
- Increasing number of drones entering the National Airspace System (NAS).
- Nefarious activities could include:
  - Smuggling
  - Trespassing
  - Attacks

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# Motivation

- Drone flew over college football stadium and suspended the game
- Aside from being a disruption, drones can potentially attack these vulnerable areas

# Background

- As of September 2023, the Federal Aviation Administration (FAA) requires all registered drones to follow the rule on **Remote ID**.
- Remote ID is the ability of drones in flight to provide identification and location information.
- Increase knowledge about drones' locations and increase airspace safety and security.

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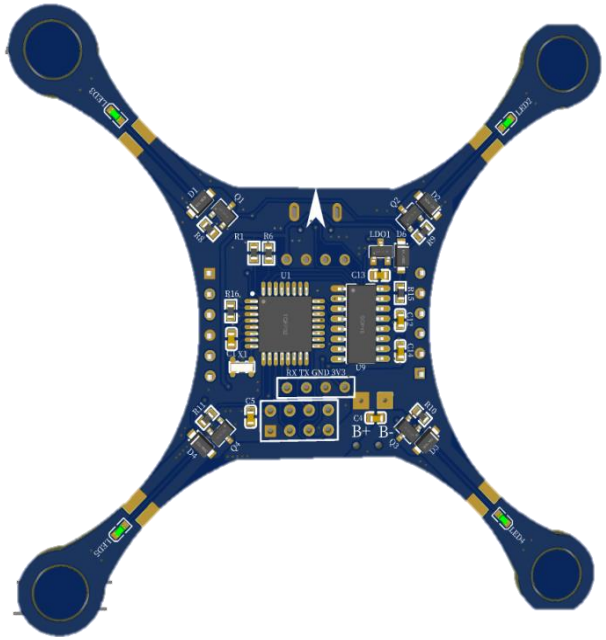
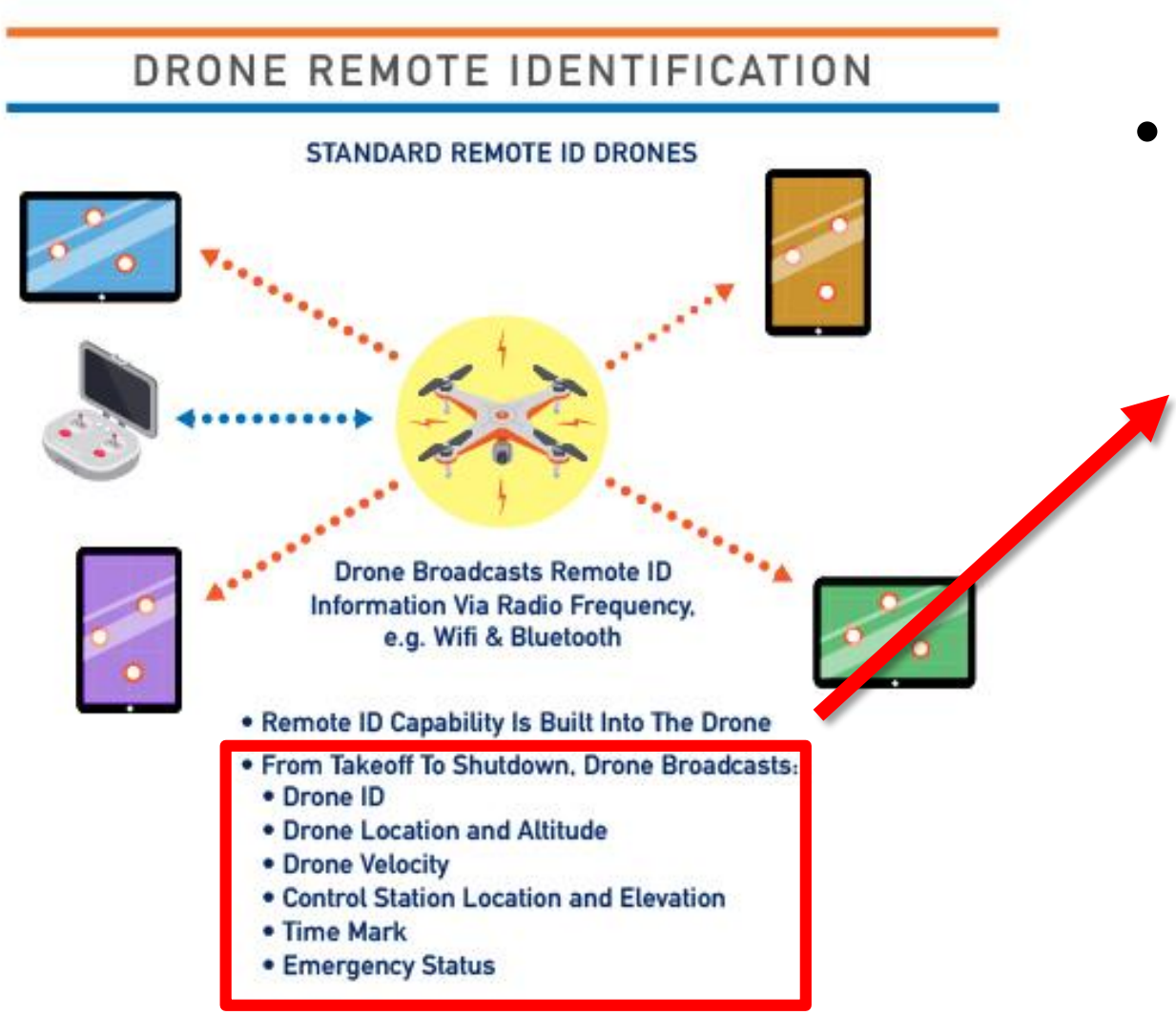
# What is Remote ID?

- Two module styles
  - Standard (built-in)
  - Broadcast (add-on)
- Transmits over WiFi or Bluetooth
  - Bluetooth Legacy
  - Bluetooth Low Energy (LE) including Long Range
  - WiFi Beacons
  - WiFi Neighborhood Aware Network (NAN)



# Remote ID Information




- Standard Remote ID Drone:
  - **Drone ID, Location, Altitude**
  - **Drone Velocity (horizontal & vertical)**
  - **Time Mark**
  - Control Station Location and Elevation
  - Emergency Status

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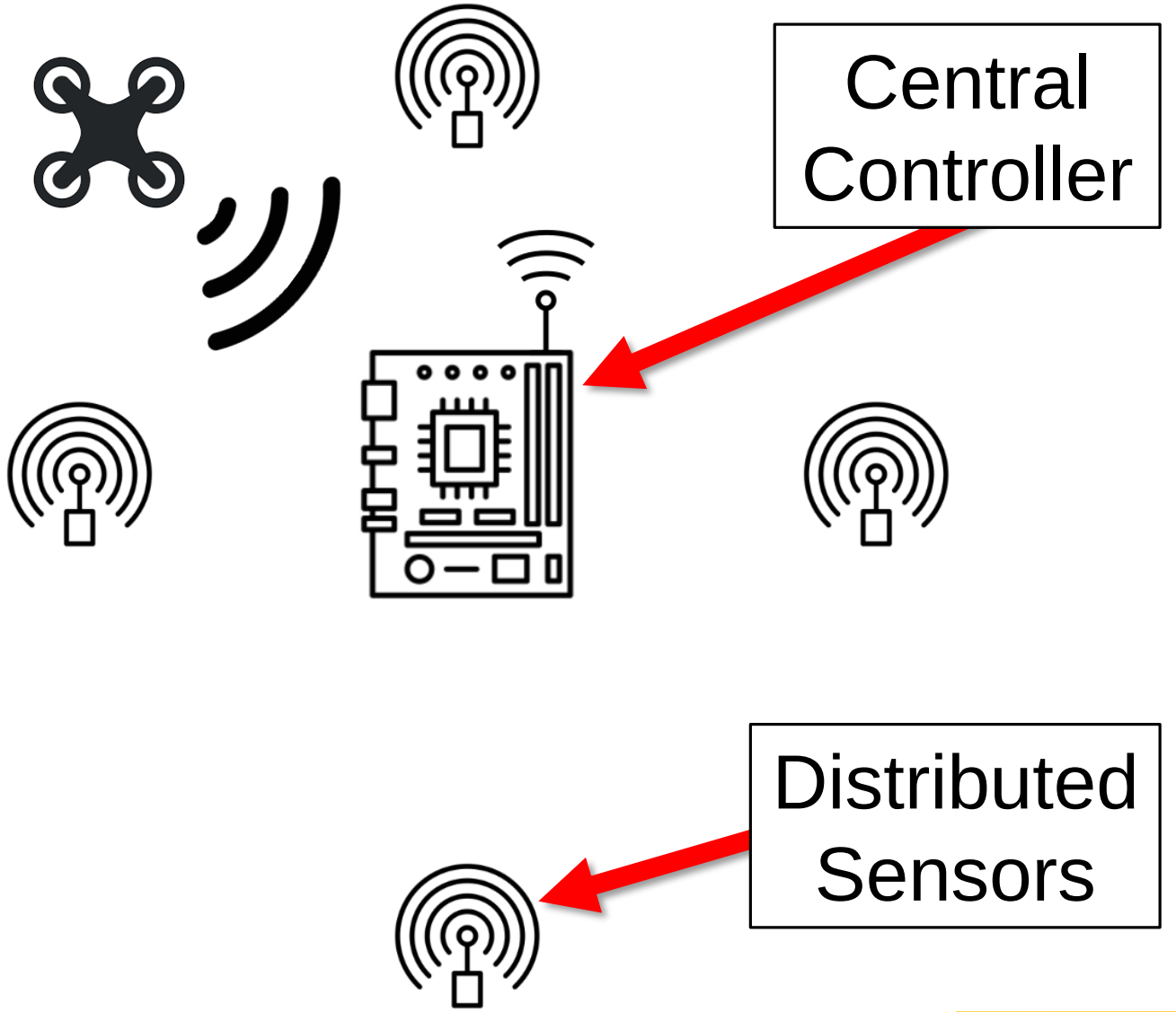
# Objective

- Design and test a system that can detect, track, and log drones broadcasting Remote ID information.

# System Overview

- SkySnare is a drone Remote ID detection and tracking system.
- RF sensors are distributed.
- Central controller manages information.



# System Overview

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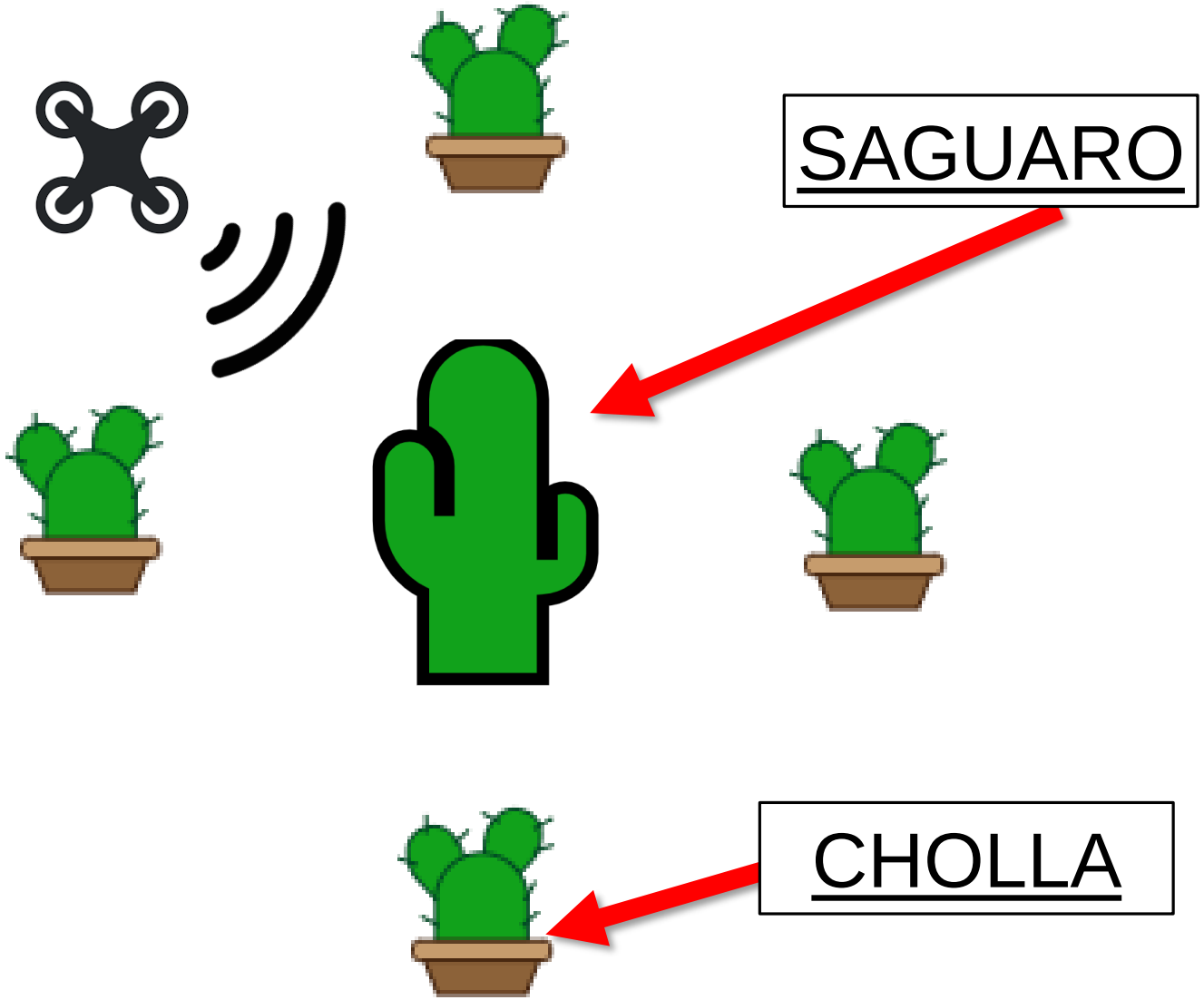

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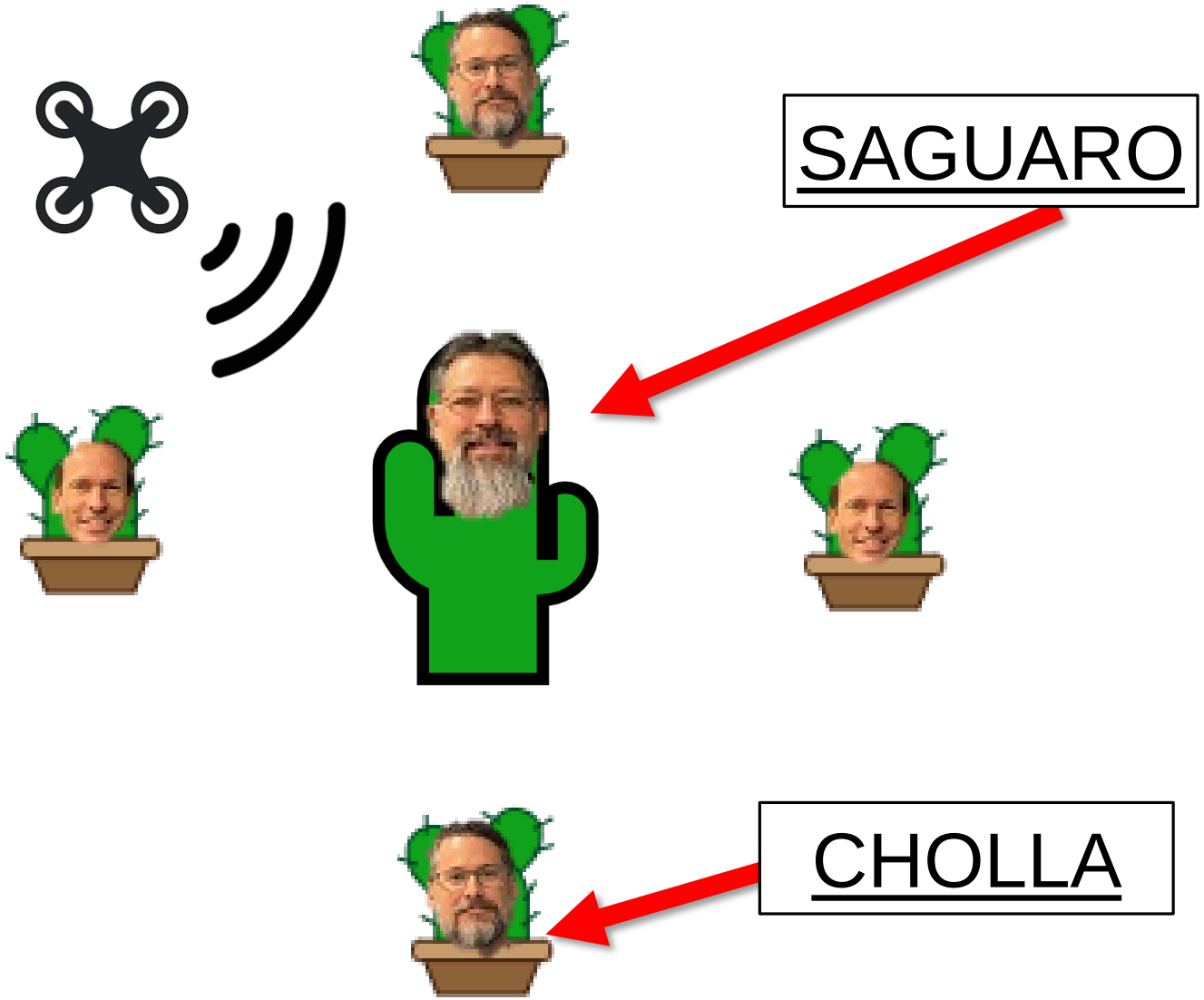
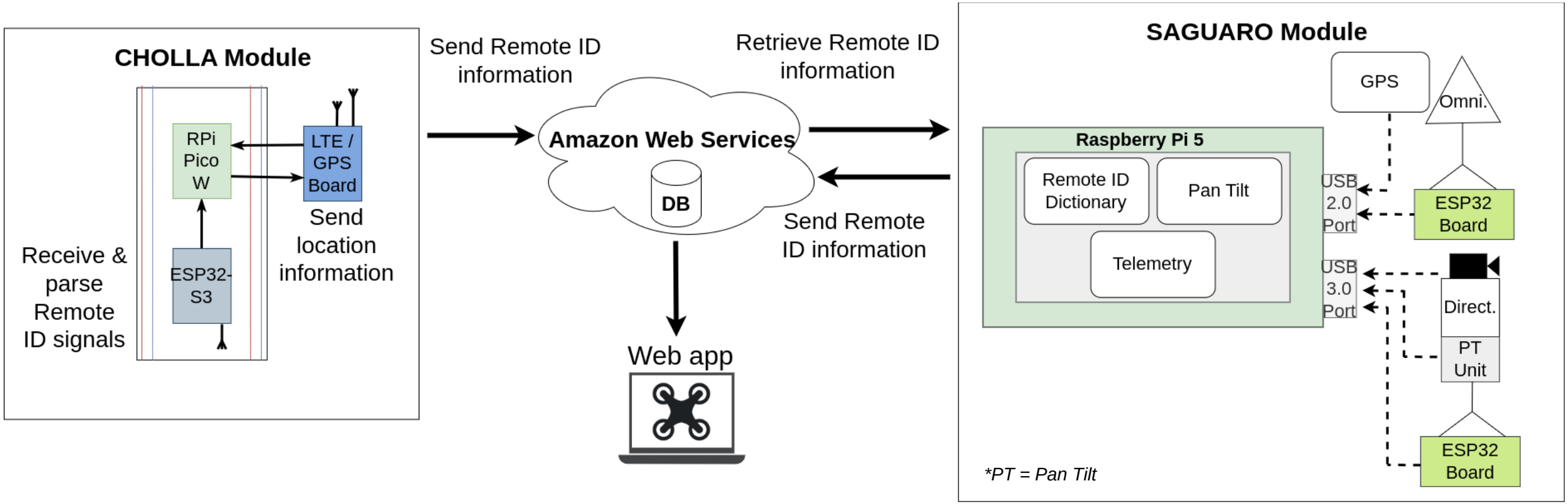
# CACTUS

**C**entralized
**A**utomated
**C**ontroller for
**T**racking
**U**nmanned
**S**ystems

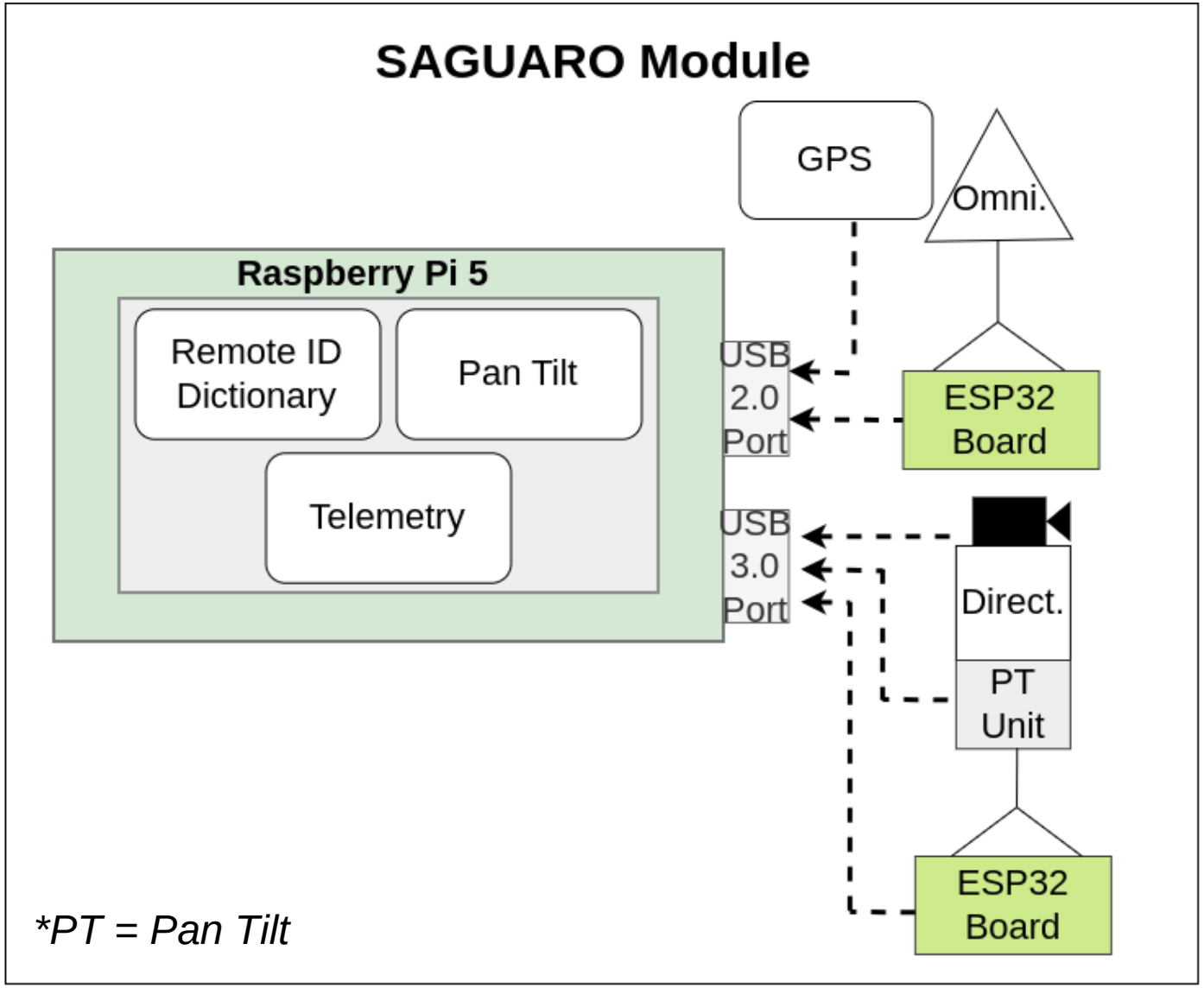


# System Details



# SAGUARO Hardware

**S**ystem
**A**djutant
**G**ateway for
**U**nifying
**A**rea
**R**emote
**O**perators



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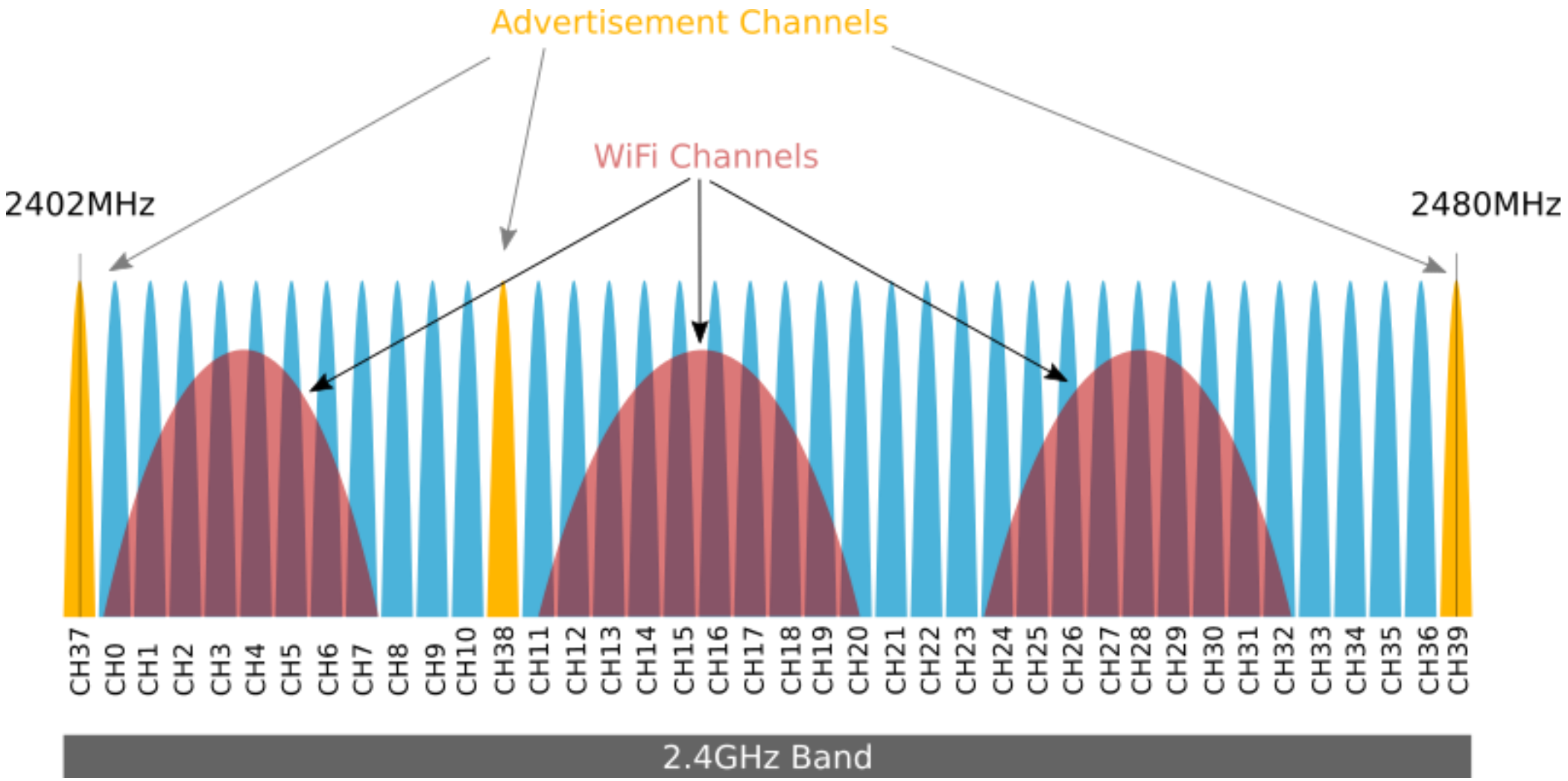
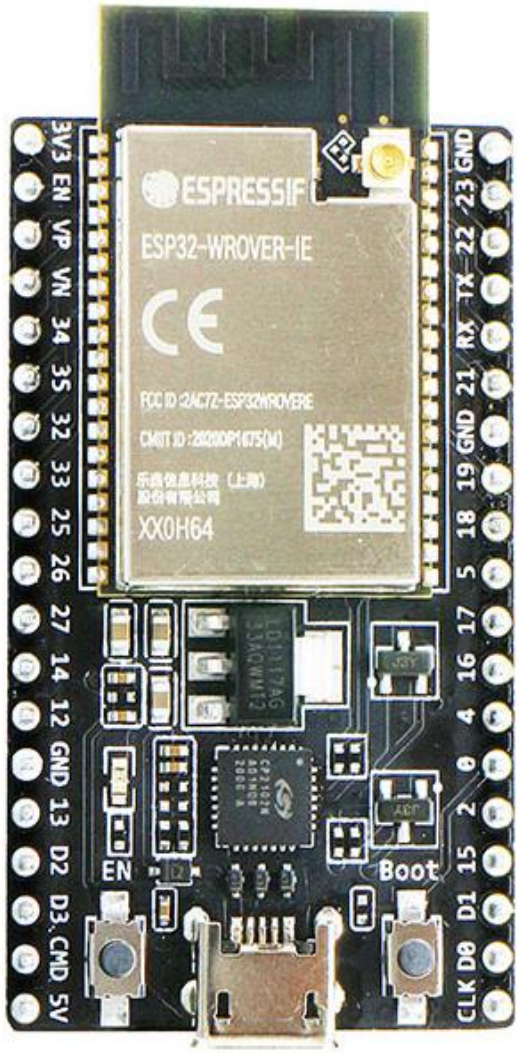
# Remote ID Detection



# Remote ID Detection

- ESP32
  - Low size, weight and power (SWaP)
  - Easy integration
  - Has WiFi and Bluetooth built in
  - External antenna port



# SAGUARO Antennas

- Omnidirectional
  - 3 dBi
  - 800-2500 MHz
- Directional
  - 13 dBi
  - 2400-2500 MHz
  - 3 dB beamwidth is 40 degrees

**Omnidirectional**

**Directional**

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# Remote ID Decode

- MAVLINK
  - Remote ID standard documentation
- ARDUPILOT
  - Implementation of Remote ID standard
- OpendroneID
  - Implementation that ARDUPILOT uses


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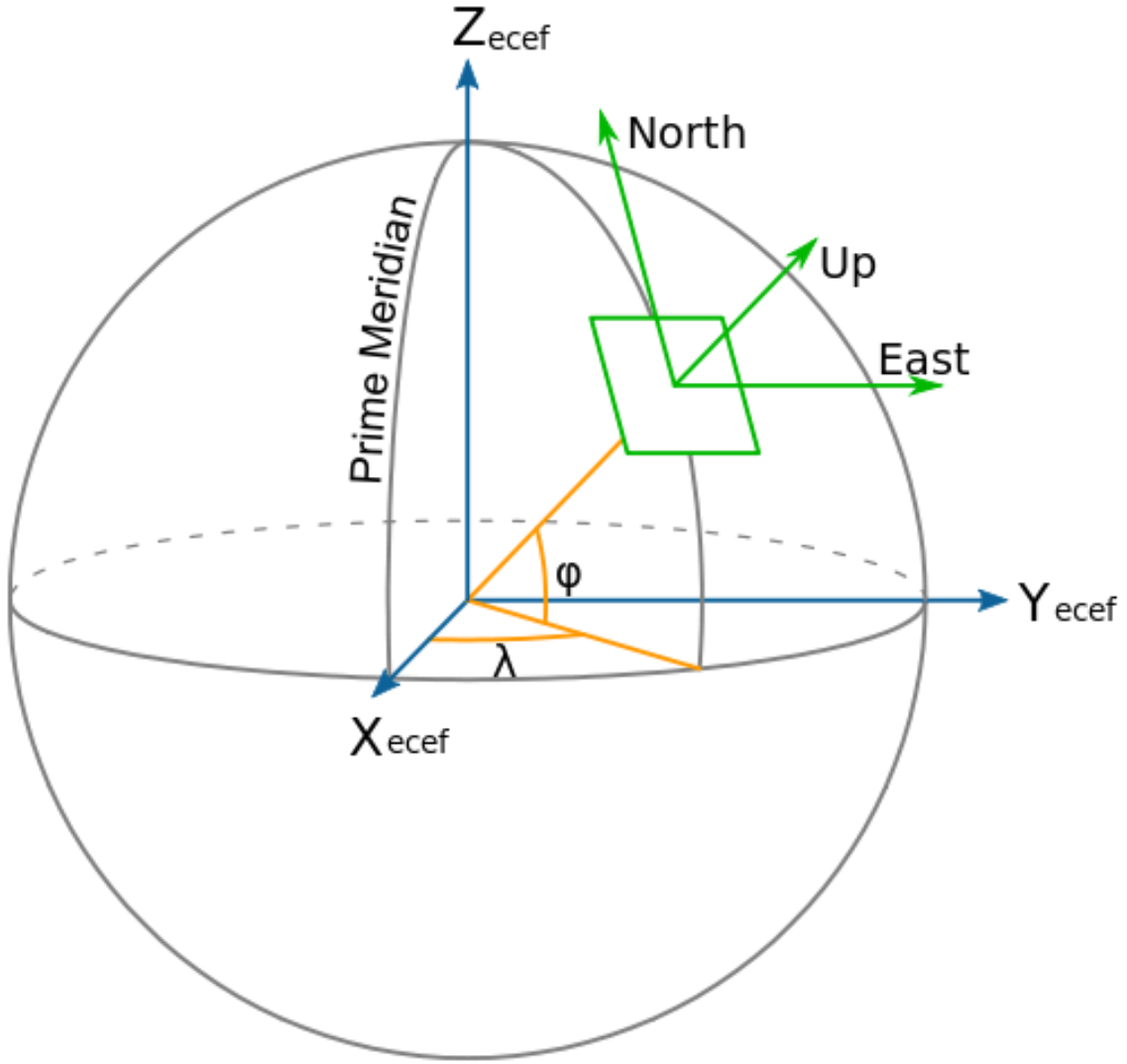
# World Coordinate System

- Need coordinate system for tracking
  - Earth-centered, Earth-fixed coordinate system (ECEF)
  - East, North, Up (ENU)
- ENU(green)
  - Localized plane is intuitive and easy to use
- Used PyMap3D Python library



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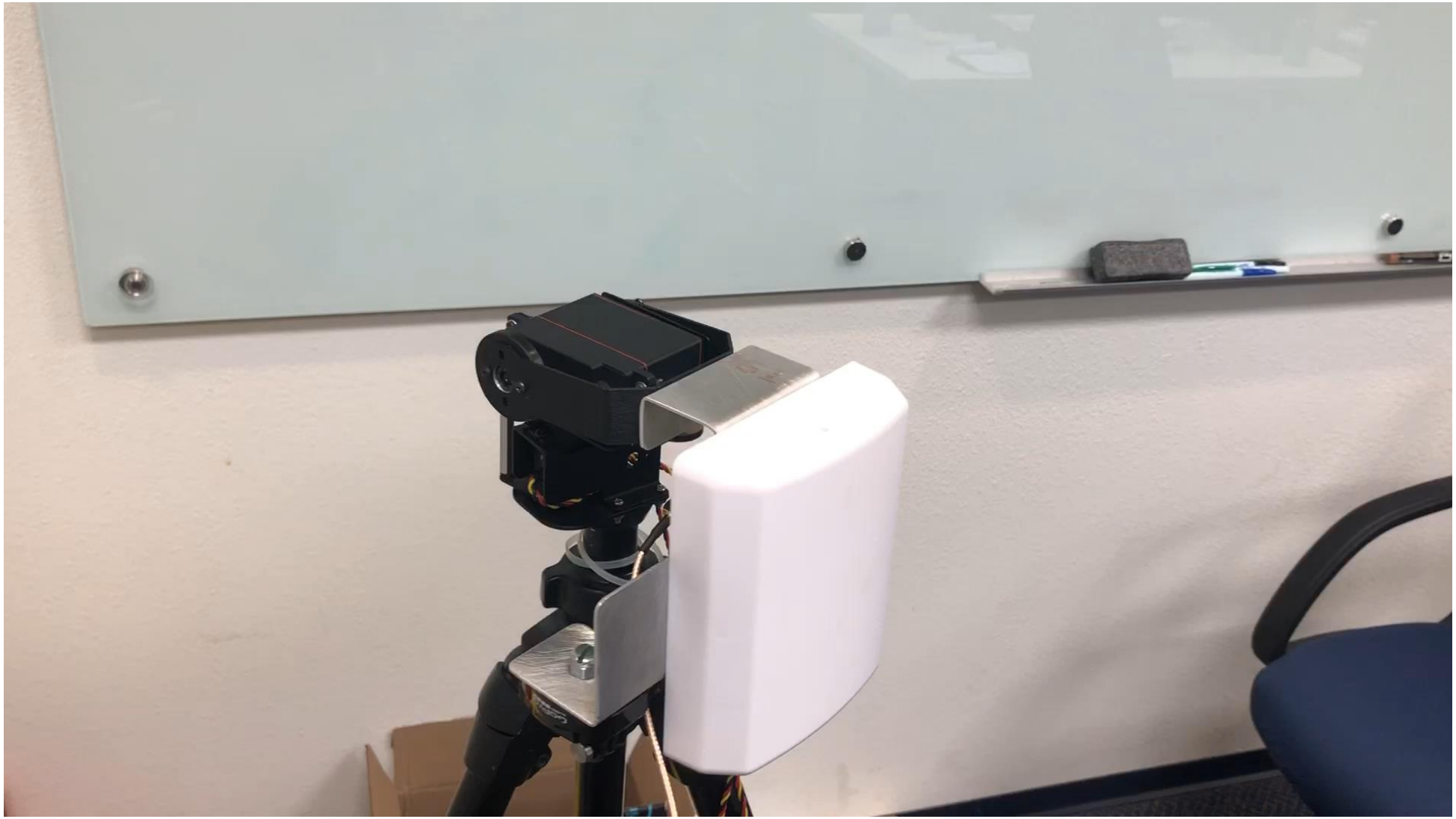
# Pan Tilt Unit Movement



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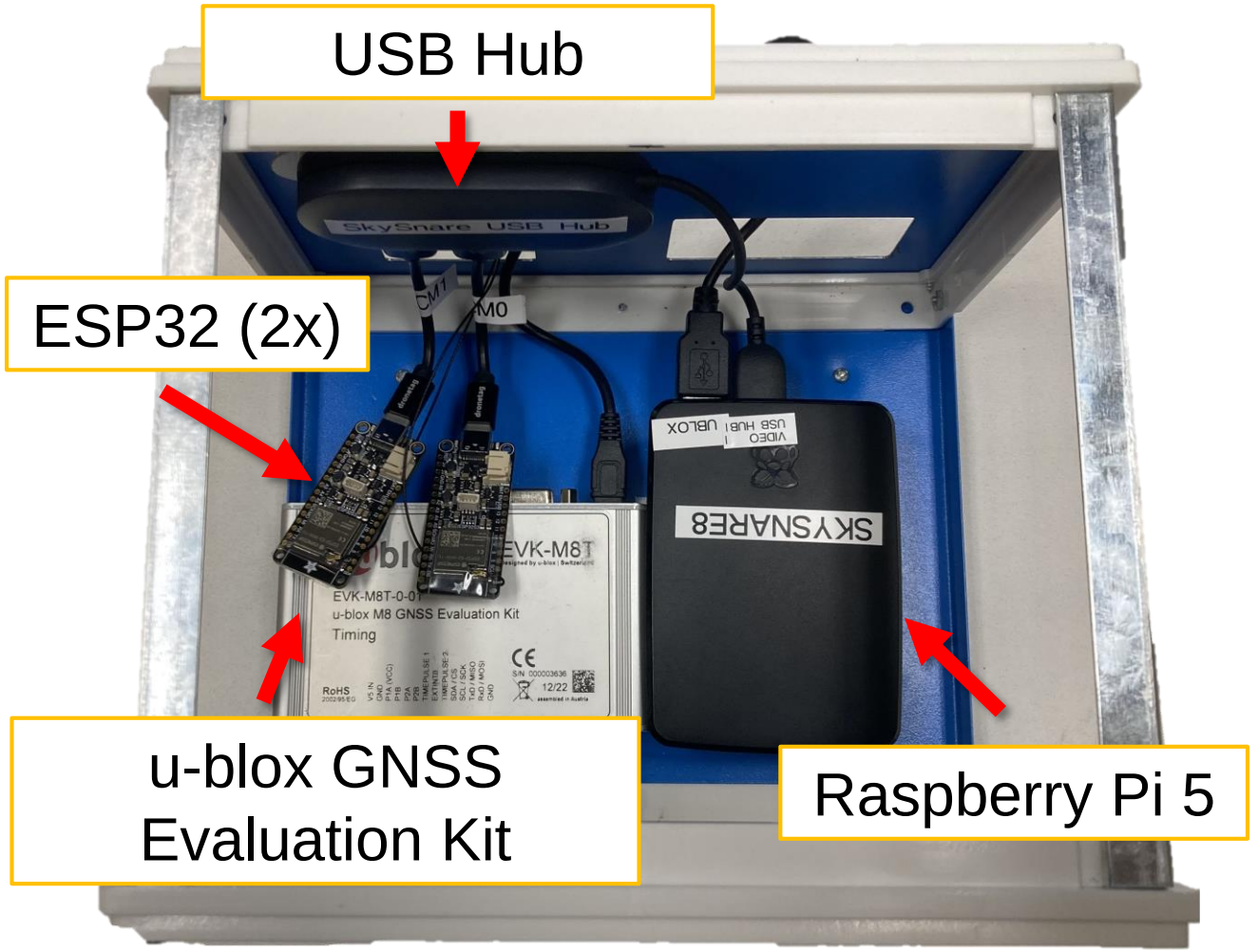
# SAGUARO Hardware


Front View




Top View

# CHOLLA Hardware

**CACTUS**

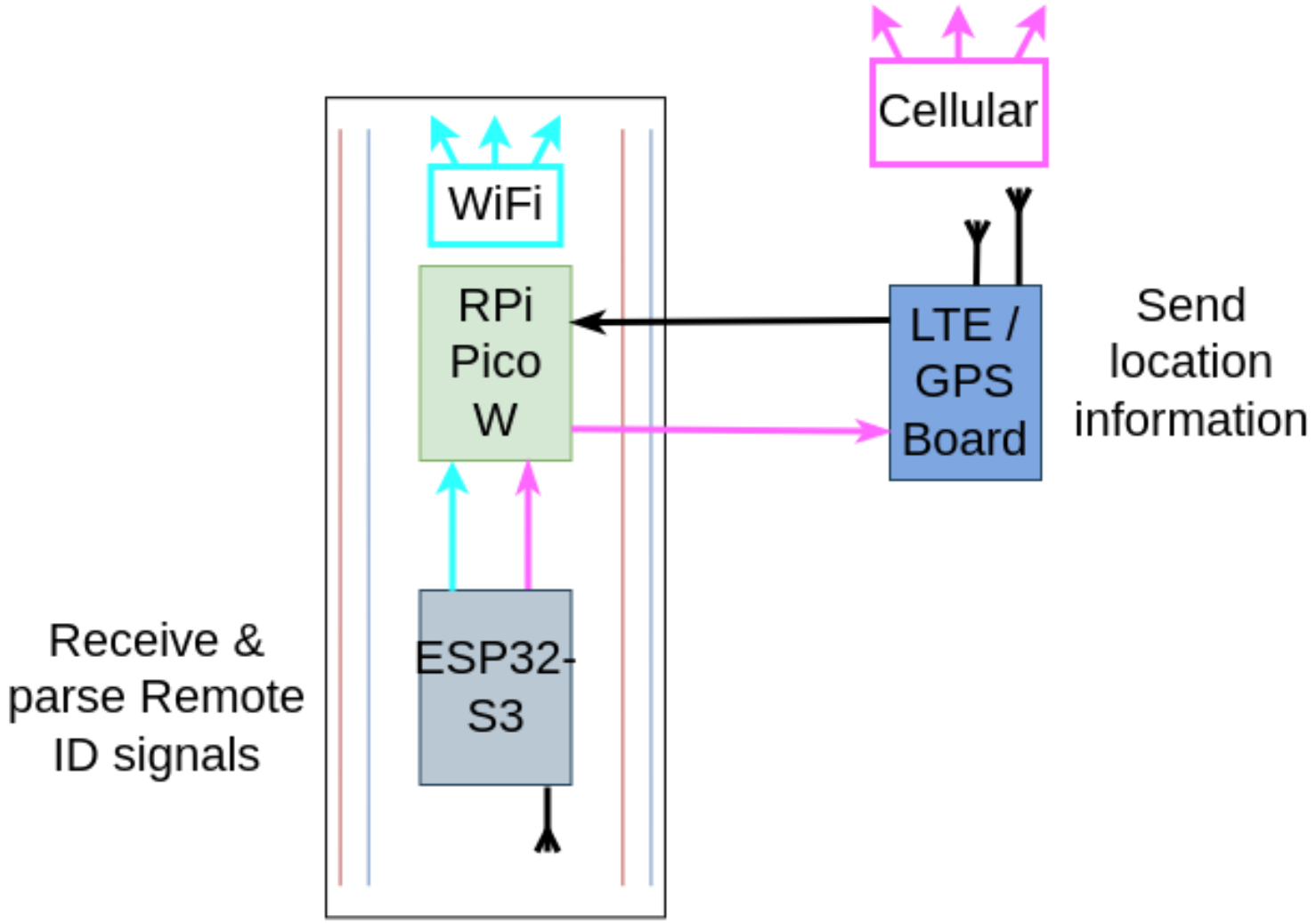
**H**ub for

**O**bserving and

**L**ogging

**L**ocal

**A**irspace



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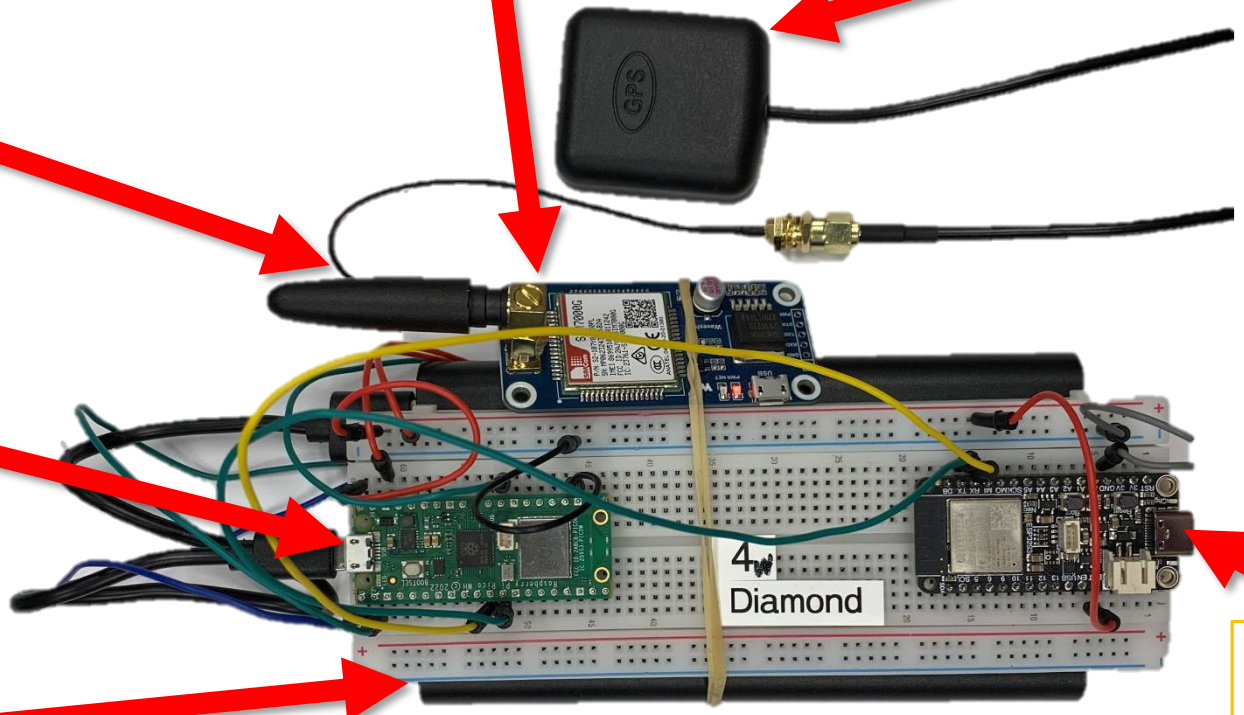
# CHOLLA Hardware



# CHOLLA Connectivity Options

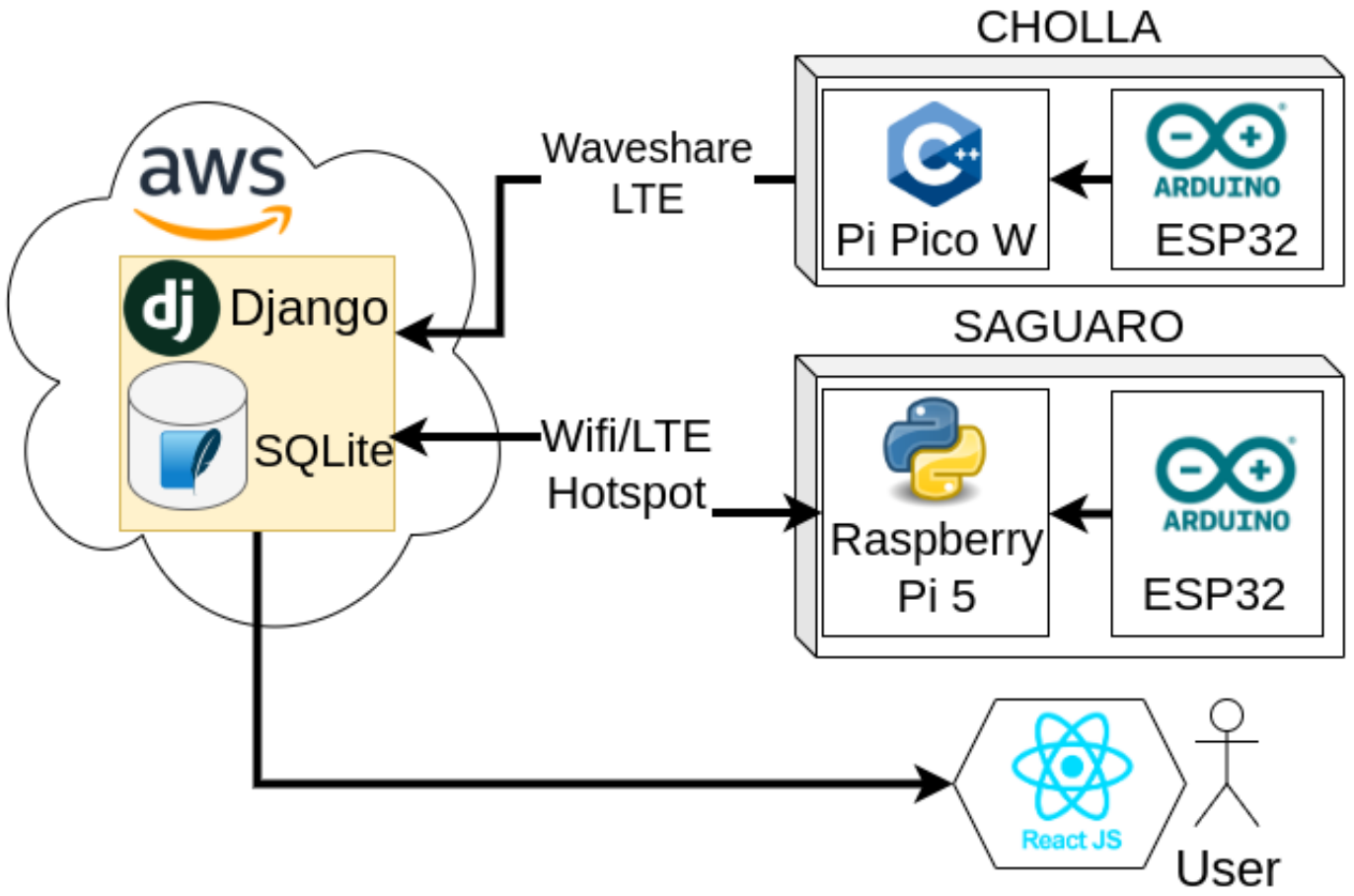
- WiFi Applications
  - Stadium
  - Home
  - Police Station
- LTE Applications
  - Airport
  - Park
  - Wildlife Preserve

# Application Software

Absolute Worst Software

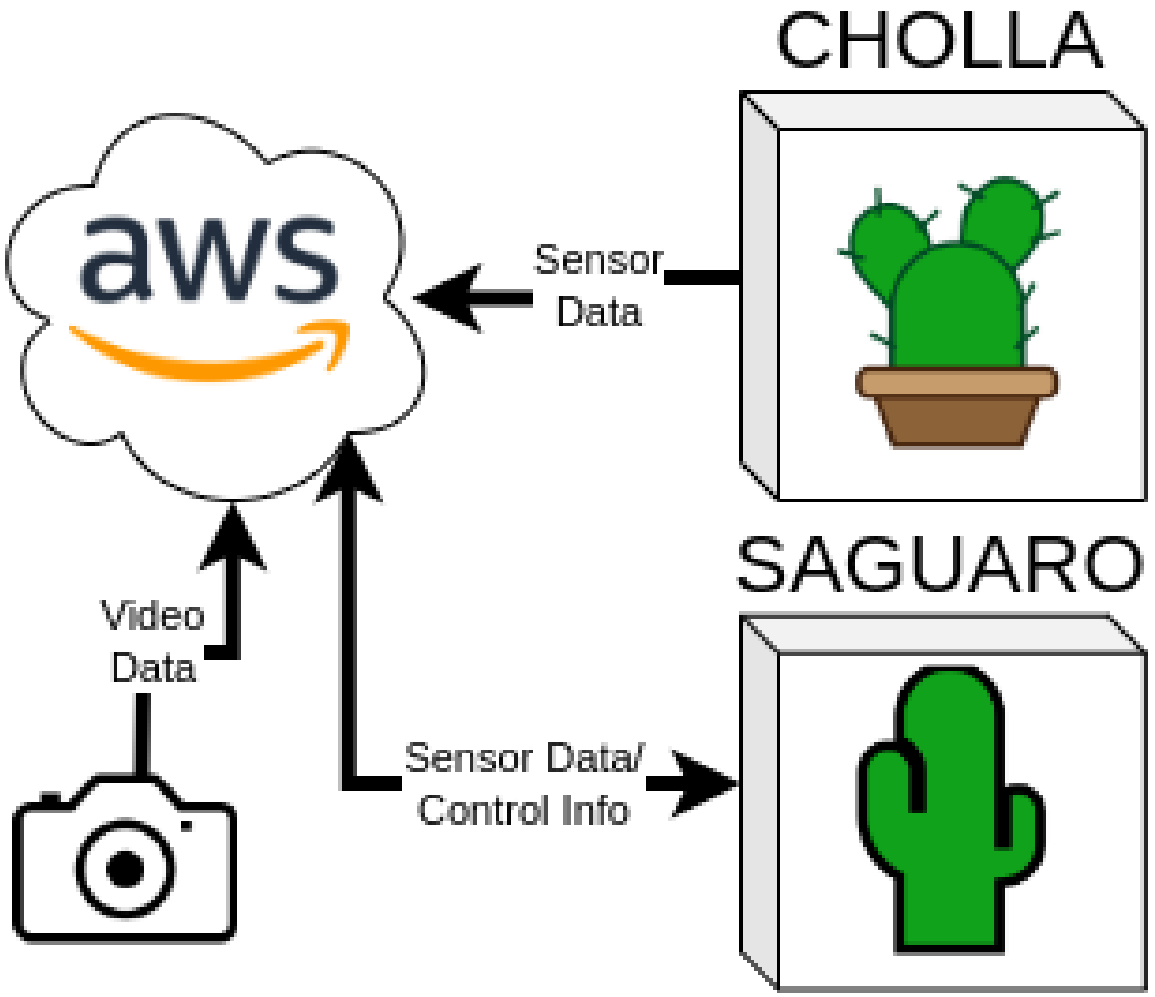
# Application Software

- Django
  - Web framework that manages Websockets and database via Python
- React
  - JavaScript framework for displaying webpages
- SQLite
  - Lightweight SQL database that is easy to manage



# Software Connections

- The SAGUARO utilizes Websockets to communicate with the server
  - Websockets are continuous connections between two computers
  - The camera and software controlling the pan tilt both communicate via Websockets



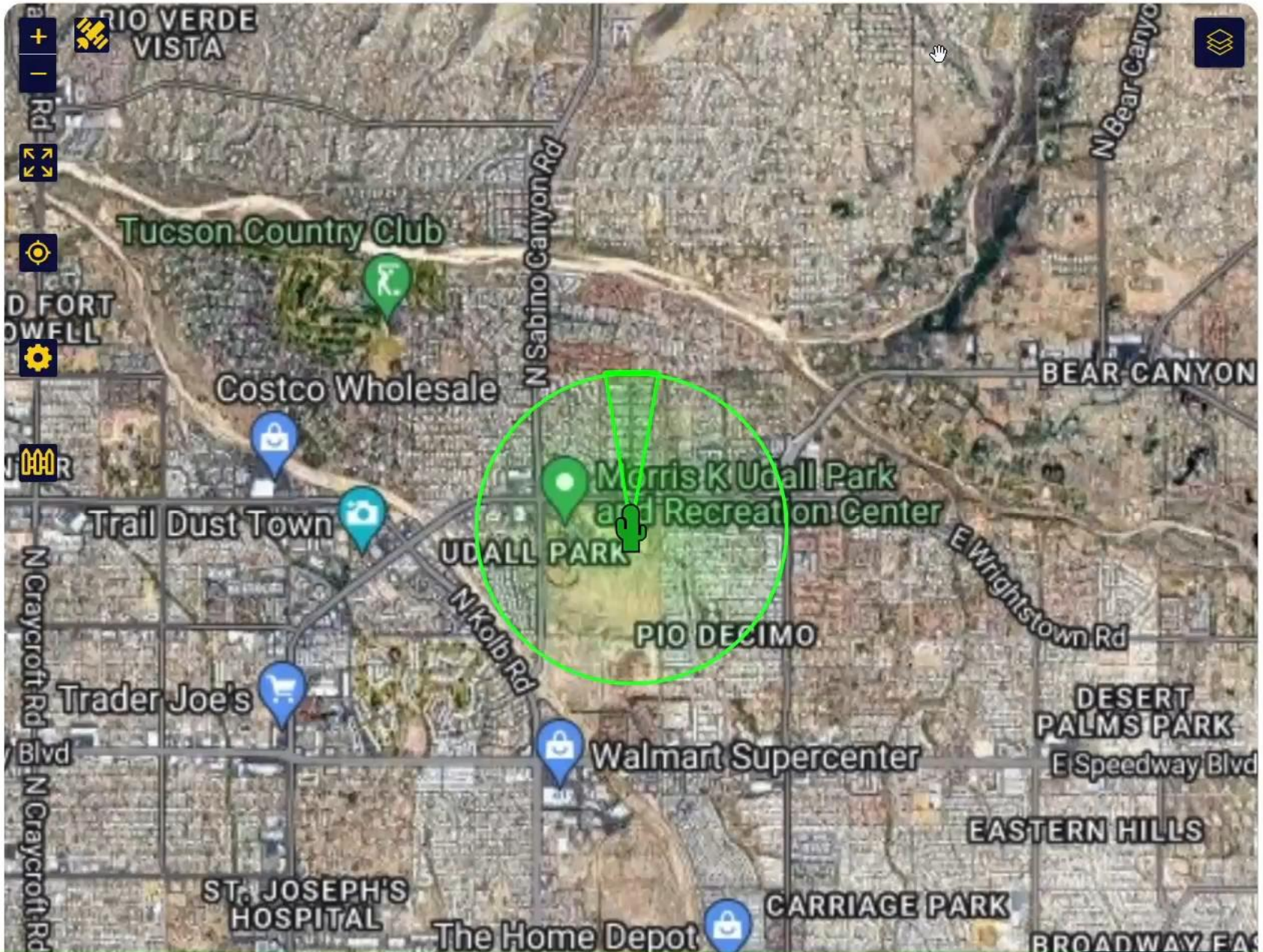
# Drone Camera

- A GoPro Hero (2018) mounted to the pan tilt was used to view the drone
- The GoPro Hero has a smoothing feature and automatically flips the video feed when turned over
- In future versions of the system this can be improved

SkySnare

To exit full screen, press F11

Data View




Data Overview | Data Table

**Drones**

| MAC | Color | Latitude | Longitude | Altitude | Time in Custody | Tracked |
|---|---|---|---|---|---|---|

**Saguaro**

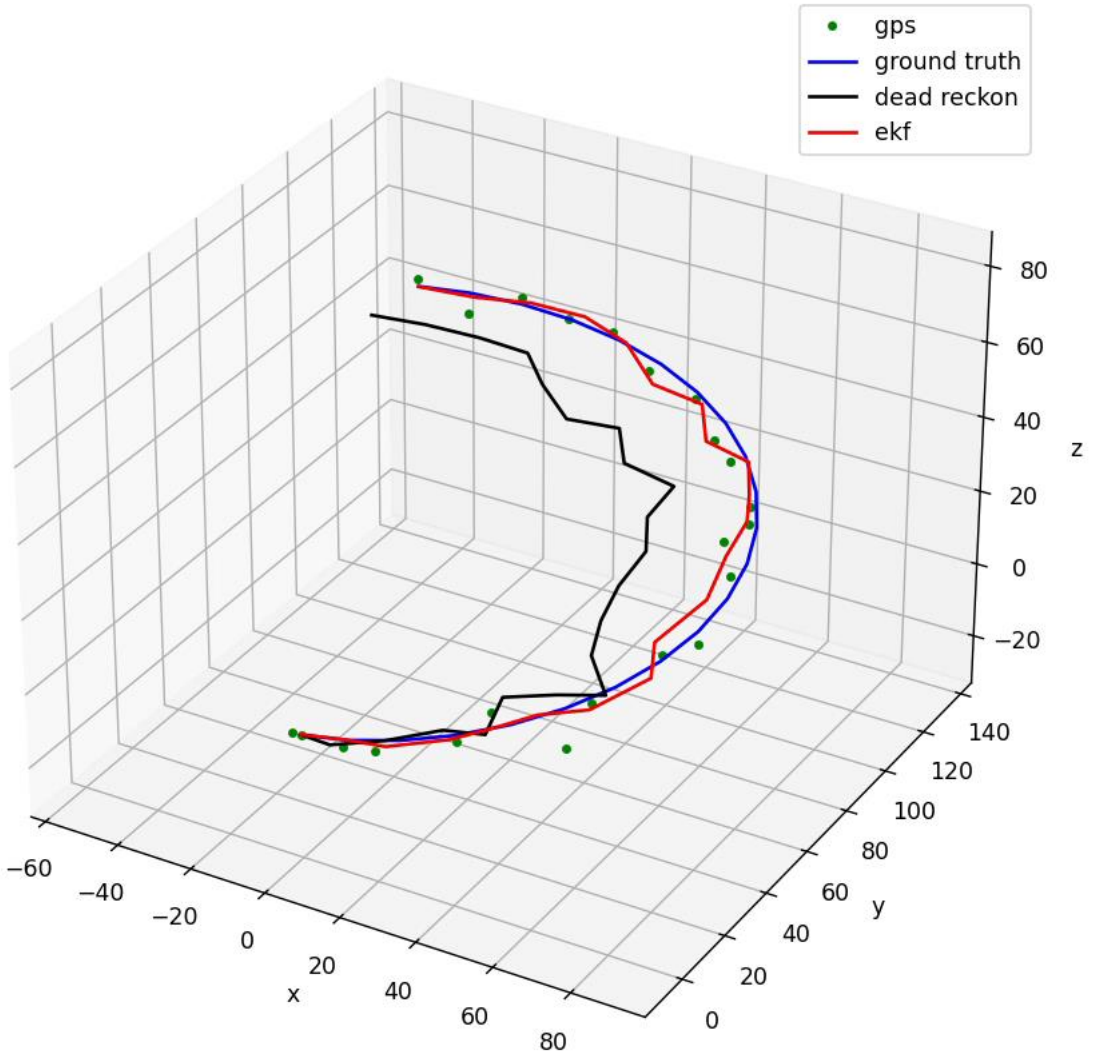
| | | |
|---|---|---|
| Rig Latitude: 32.2491 | Rig Longitude: -110.8345 | Rig Altitude: 772.7473 |
| PT Azimuth: 0 | PT Elevation: 0 | PT Error Code: 0 |
| Rec1 Connection: | Rec1 Temp: 48.2 | RPI Temp: 50.9 |
| Rec2 Connection: | Rec2 Temp: 49.8 | Tracking Mac: |

**Chollas**

| UUid | Latitude | Longitude | Altitude |
|---|---|---|---|

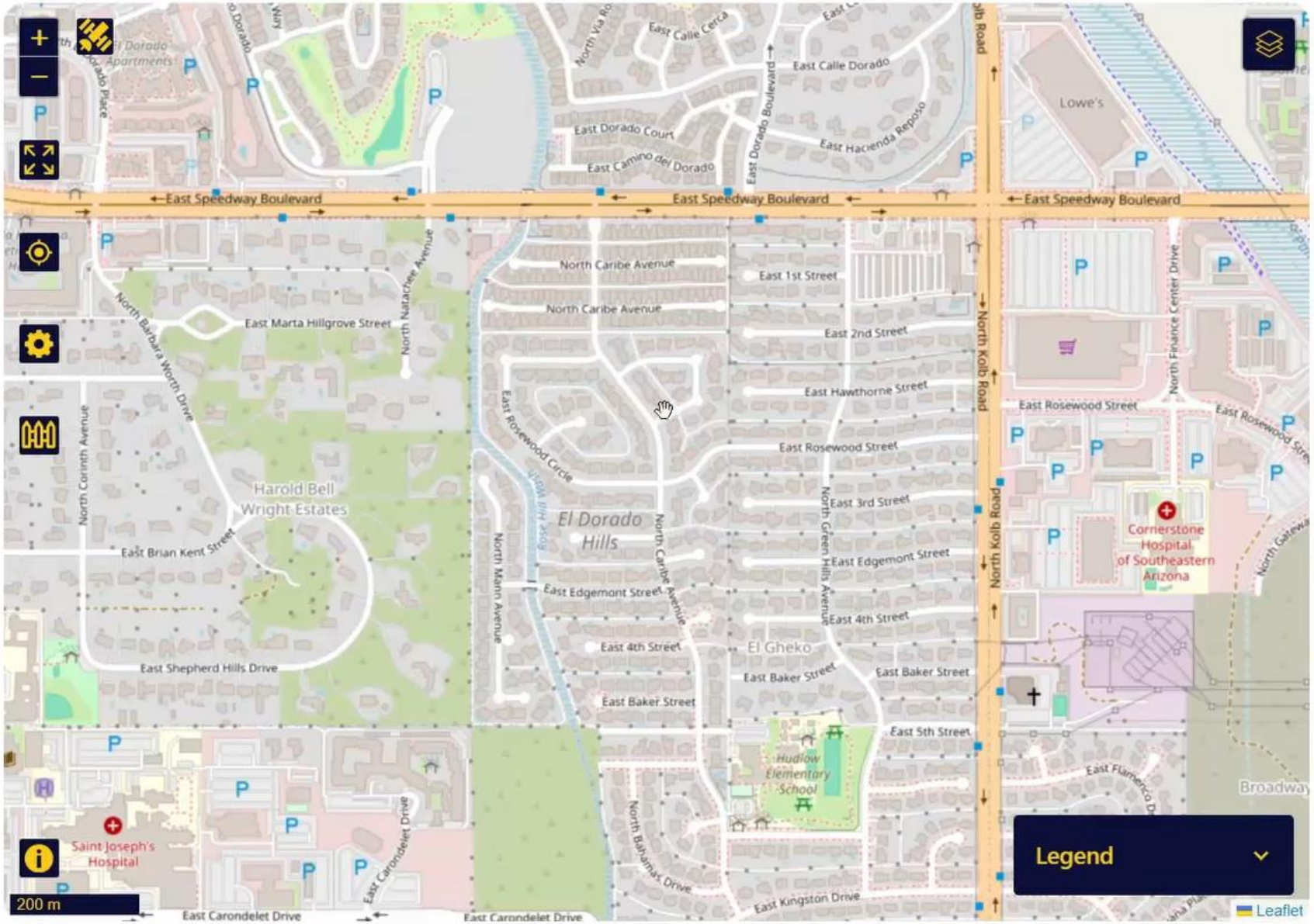
# Drone Camera

- Problem: We noticed that the pan tilt was lagging behind the drone
- Solution: We made a Extended Kalman Filter (EKF), which helped keep the drone in frame
- The EKF takes in historical data and uses it to predict the future movement of a drone



SkySnare

Data View




Data Overview | Data Table

**Drones**

| MAC | Color | Latitude | Longitude | Altitude | Time |
|---|---|---|---|---|---|
| de:ad:fa:af:de:ad | | 32.2251 | -110.8595 | 783.0017668663047 | 3 |

**Saguaro**

| | | |
|---|---|---|
| **Latitude: 32.2238** | **Longitude: -110.8586** | **Altitude: 783.0000** |
| PanTilt Azimuth: 0 | PanTilt Elevation: 0 | PanTilt Error Code: 0 |
| Omni Connection: | Omni Temp: -100 | RPI Temp: 50.6 |
| Directional Connection: | Directional Temp: -100 | Tracked Mac: |

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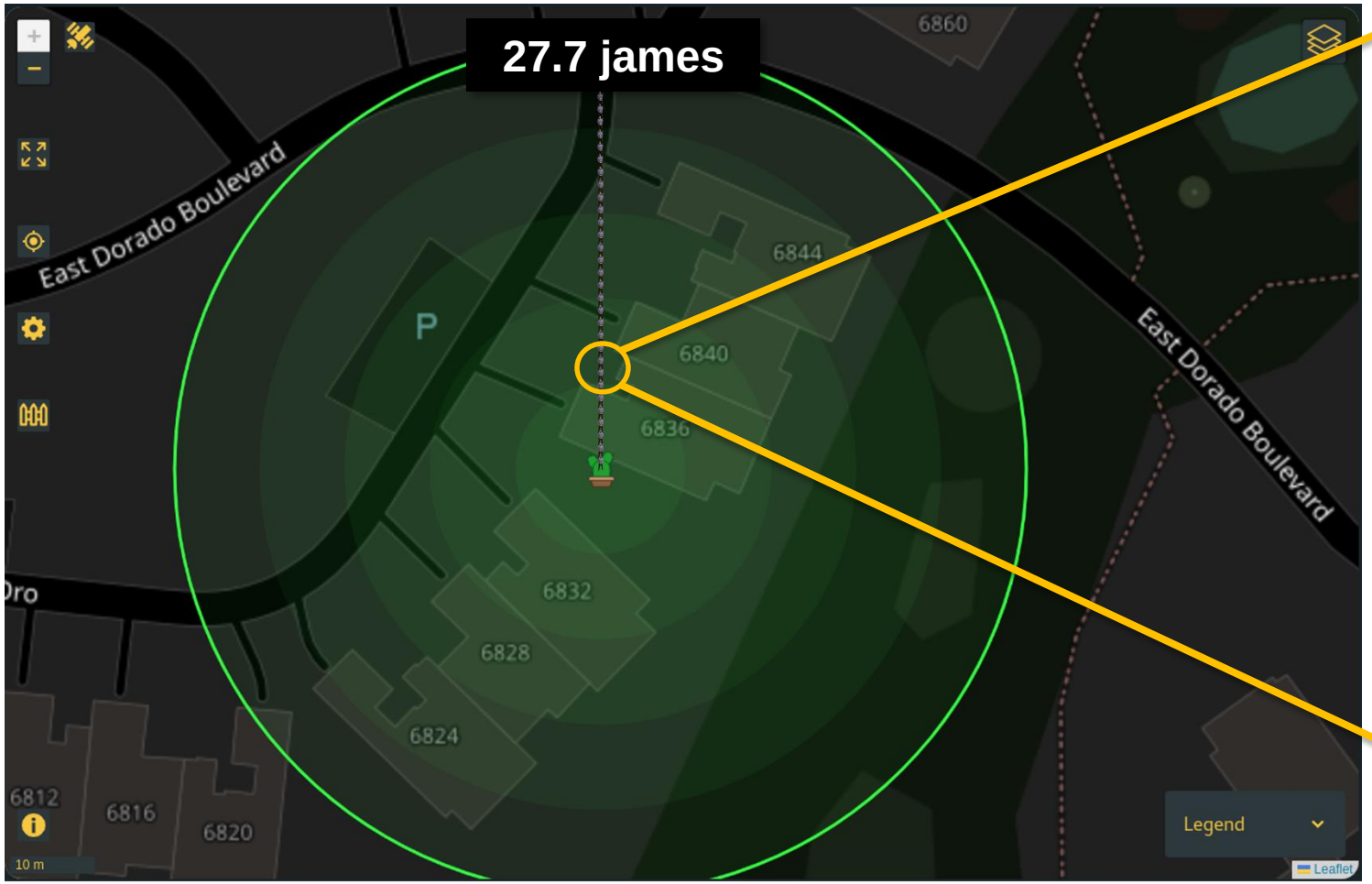
# James Range Circles

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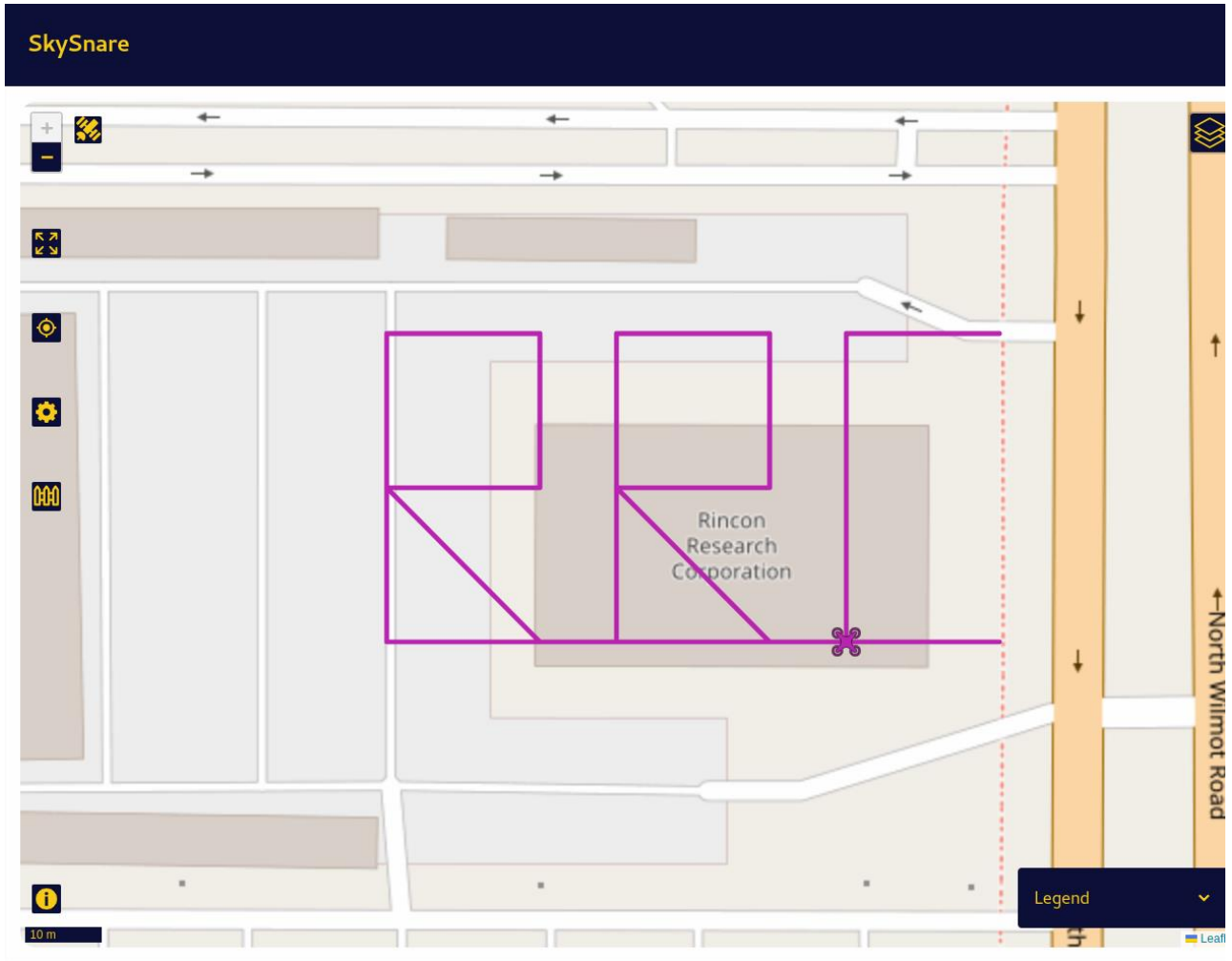
# Evaluations

- Problem:
  - Integration testing a system with this many pieces proved to be difficult
- Solutions:
  - Simulated tests
  - Incremental testing in the field
- We did 7 tests, all at Udall park

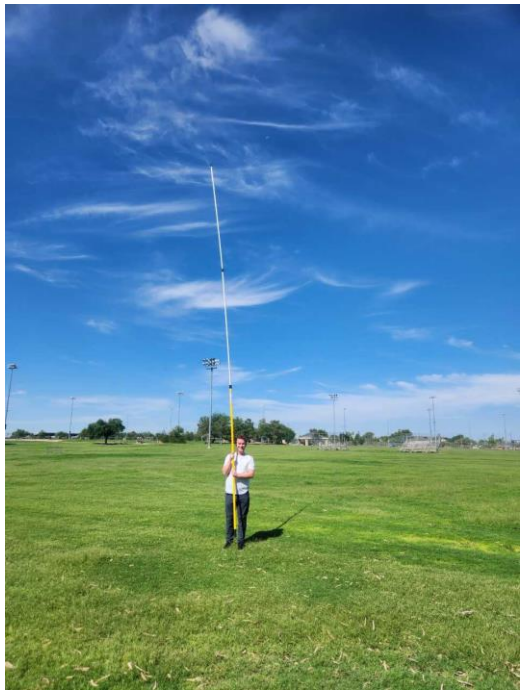
# Simulations

- The two main simulators we used were:
  - A physics based simulator for only the web app
  - A point to point simulator for testing the EKF



# Human Drones

- For someone from Rincon to fly a drone for us, we need them to have a part 107 license
- So we weren't constantly taking other people's time, we found PIG BOLE ™
- All of this testing was done at Udall park



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# Antenna Ranges

- What we measured was:
  - Directional measured at 1371 ft
  - Omnidirectional measured at 1029 ft
- We were unable to observe our antenna max range due to obstructions

# Drones

- We were able to test our system with a real drone twice
- Due to this still being at Udall park, we were not able to fully test our range
- We were able to request certain patterns and view them on the map via the drone path

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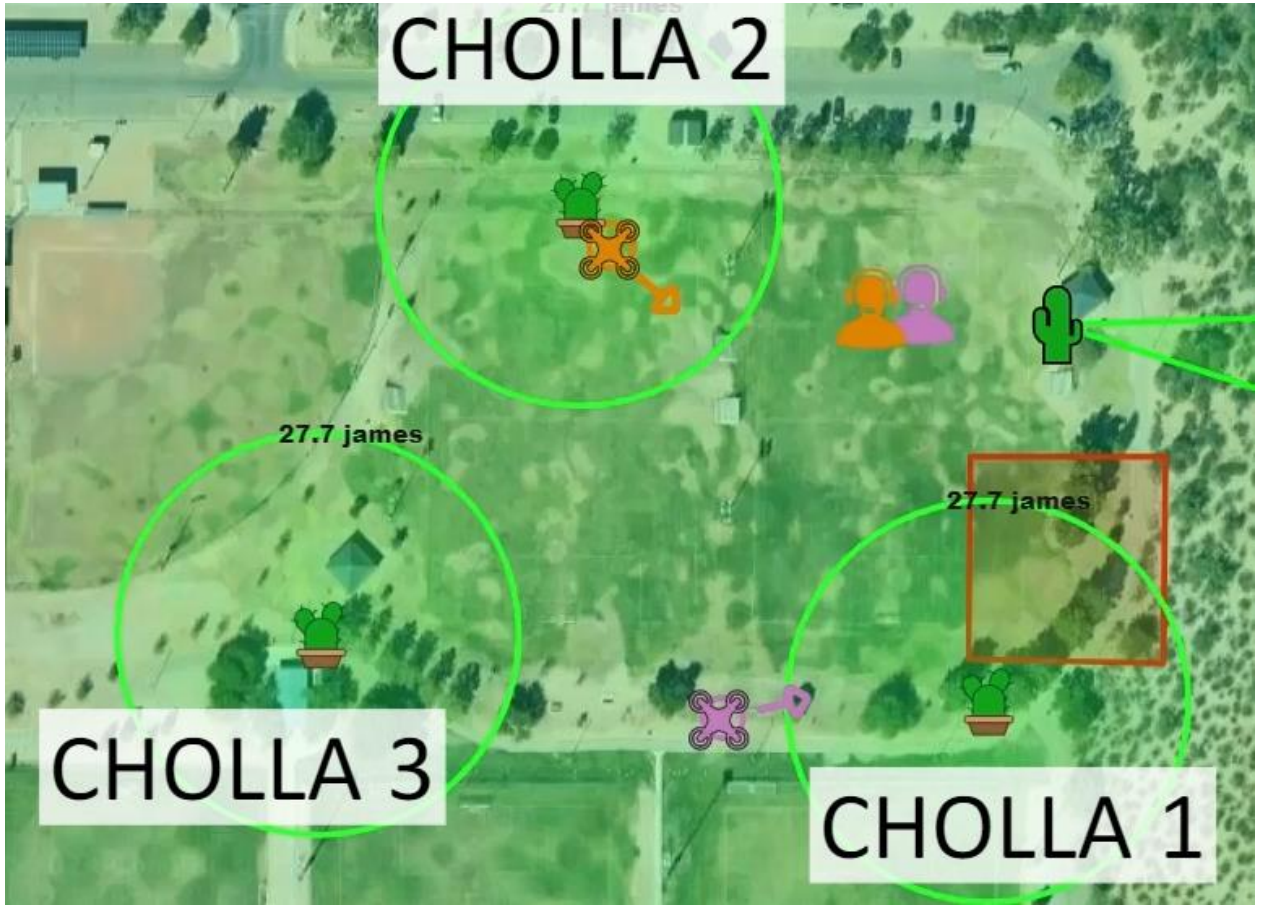
# Playback Mode Demo

# Extending CACTUS

- We finished SAGUARO during week 4 of our 10 week program
- We identified one limitation in SAGUARO: obstructions to its range
- To solve this issue, we created CHOLLA



SkySnare

Data View

Trim

Data Overview | Data Table

### Drones

| C | Color | Latitude | Longitude | Altitude | Time in Custody | Tracked |
|---|---|---|---|---|---|---|
| 7:30:63 | | 32.2499 | -110.8335 | 747 | 684 (s) | |
| a:f6:b2 | | 32.2499 | -110.8334 | 748 | 686 (s) | |

### Saguaro

| | | |
|---|---|---|
| Rig Latitude: 32.2498 | Rig Longitude: -110.8334 | Rig Altitude: 781.0021 |
| PT Azimuth: 103 | PT Elevation: 0 | PT Error Code: 0 |
| Rec1 Connection: | Rec1 Temp: -100 | RPI Temp: 50.5 |
| Rec2 Connection: | Rec2 Temp: 50.8 | Tracking Mac: |

### Chollas

| UUid | Latitude | Longitude | Altitude |
|---|---|---|---|

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# Future Works

- LoRa(Long Range)
  - ARRMI
- VTX/Telemetry
- Flight Tracker

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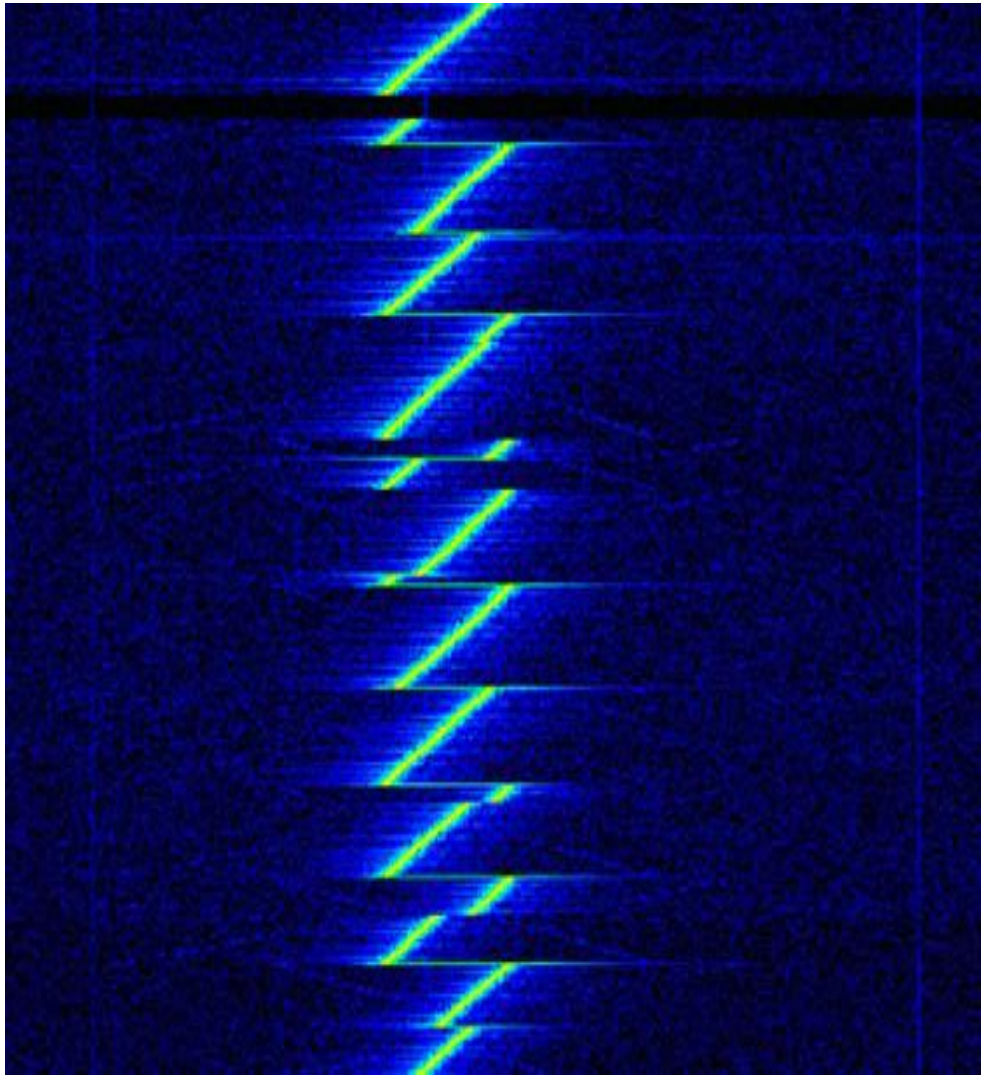
# LoRa

- Benefits of LoRa radio
  - Low power
  - Long range
- Unique Problems
  - LoRa has a low bit rate
    - Condense Remote ID message from 128 bytes to 32 bytes
  - Create a unique protocol to suit our needs
    - ARRMI



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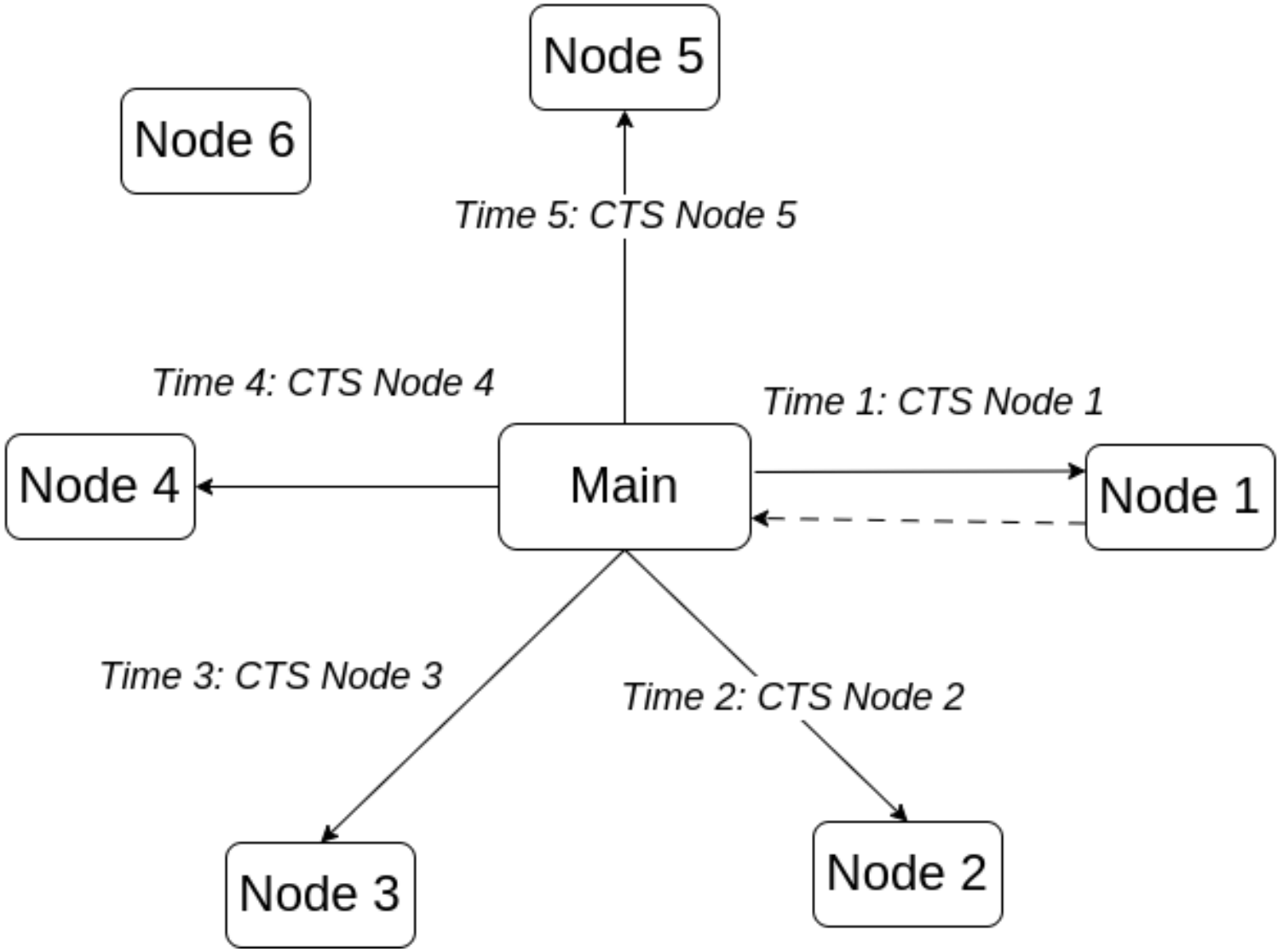
# ARRMI

**A**ggressively
**R**egimented
**R**emote
**M**odule
**I**nterface



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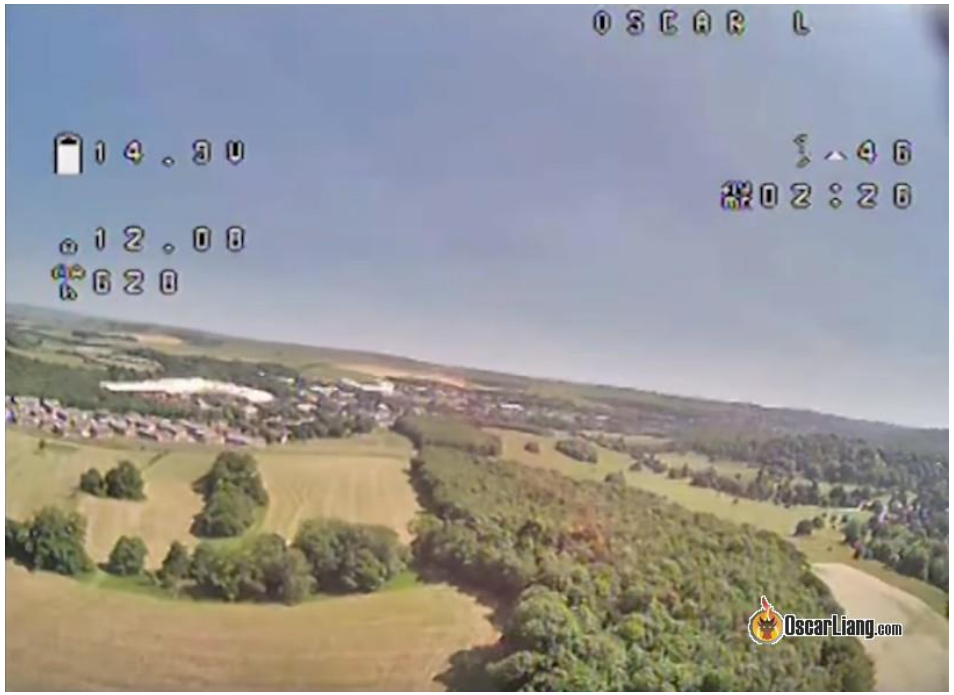
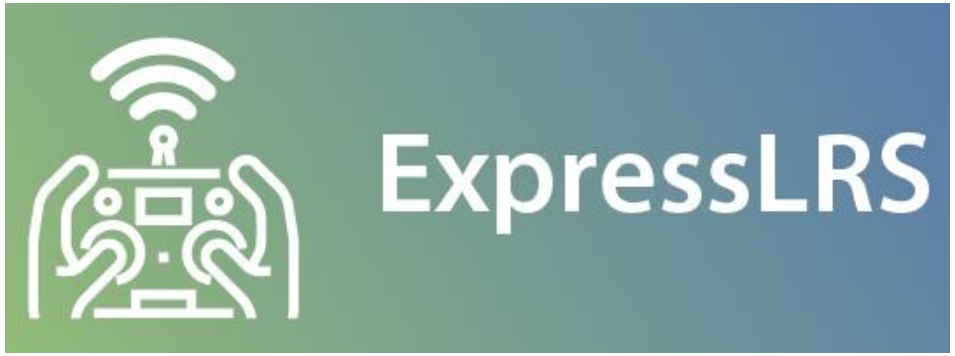
# Decode VTX/Telemetry

- Benefits of decoding Video Transmission (VTX)/Telemetry
  - Drones transmit more than just Remote ID
  - Decoding other signals gives more data
- Unique Problem
  - Many telemetry and video protocols exist
    - Sweep through known protocols until one works



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# Flight Tracker

- Distributed System
  - Crowdsourcing
  - Buy In Module
- Neighborhoods
  - Property Privacy
- Global Connectivity
  - Already on AWS

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# Lessons Learned

- It works the first time every time
- Prickly pears are not cholla
- Microcontrollers are difficult
- Presentations should not be made by committee

**The real Remote ID was the friends we made along the way ☺**

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# Us.png


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# Acknowledgements & Thank You


Mark Kross

Mike Garcia

Dan Evans

James Goodall

Chris Zurita

Madelyn Moulden

Mridul Bansal

**And RRC as a whole!**

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# Condensed Message

| Byte | 0 | | | | | | | | 1 | | | | | | | | 2 | | | | | | | | 3 | | | | | | | | 4 | | | | | | | | 5 | | | | | | | | 6 | | | | | | | | 7 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bit | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Field | Header | | | | Unused | | | | Status | | | | Hori Acc | | | | Vert Acc | | | | Speed Acc | | | | Direction | | | | | | | | Vertical Speed | | | | | | | | Horizontal Speed | | | | | | | | RSSI | | | | | | | | MAC[0] | | | | | | | |

| Byte | 8 | | | | | | | | 9 | | | | | | | | 10 | | | | | | | | 11 | | | | | | | | 12 | | | | | | | | 13 | | | | | | | | 14 | | | | | | | | 15 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bit | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Field | Drone Altitude | | | | | | | | | | | | | | | | Operator Altitude | | | | | | | | | | | | | | | | Timestamp | | | | | | | | | | | | | | | | MAC[1] | | | | | | | | MAC[2] | | | | | | | |

| Byte | 16 | | | | | | | | 17 | | | | | | | | 18 | | | | | | | | 19 | | | | | | | | 20 | | | | | | | | 21 | | | | | | | | 22 | | | | | | | | 23 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bit | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Field | Drone Latitude | | | | | | | | | | | | | | | | | | | | | | | | Drone Longitude | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | Operator Latitude | | | | | | | |

| Byte | 24 | | | | | | | | 25 | | | | | | | | 26 | | | | | | | | 27 | | | | | | | | 28 | | | | | | | | 29 | | | | | | | | 30 | | | | | | | | 31 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bit | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 3 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Field | Operator Latitude Cont. | | | | | | | | | | | | | | | | Operator Longitude | | | | | | | | | | | | | | | | | | | | MAC[3] | | | | | | | | MAC[4] | | | | | | | | MAC[5] | | | | | | | |

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# Other tools used

- Caddy
  - Cross-platform web server
- Daphne
  - Allows us to deploy the application asynchronously, which is required for Websockets
  - The recommended way to deploy a Django application with channels
- SQLite
  - Initially used because it is one of the faster SQL based databases, a switch the PostgreSQL would be good for the future for it’s extra features
- Redis
  - An in-memory database that is used to communicate between Websockets.

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# WOOO DATABASE MODELS