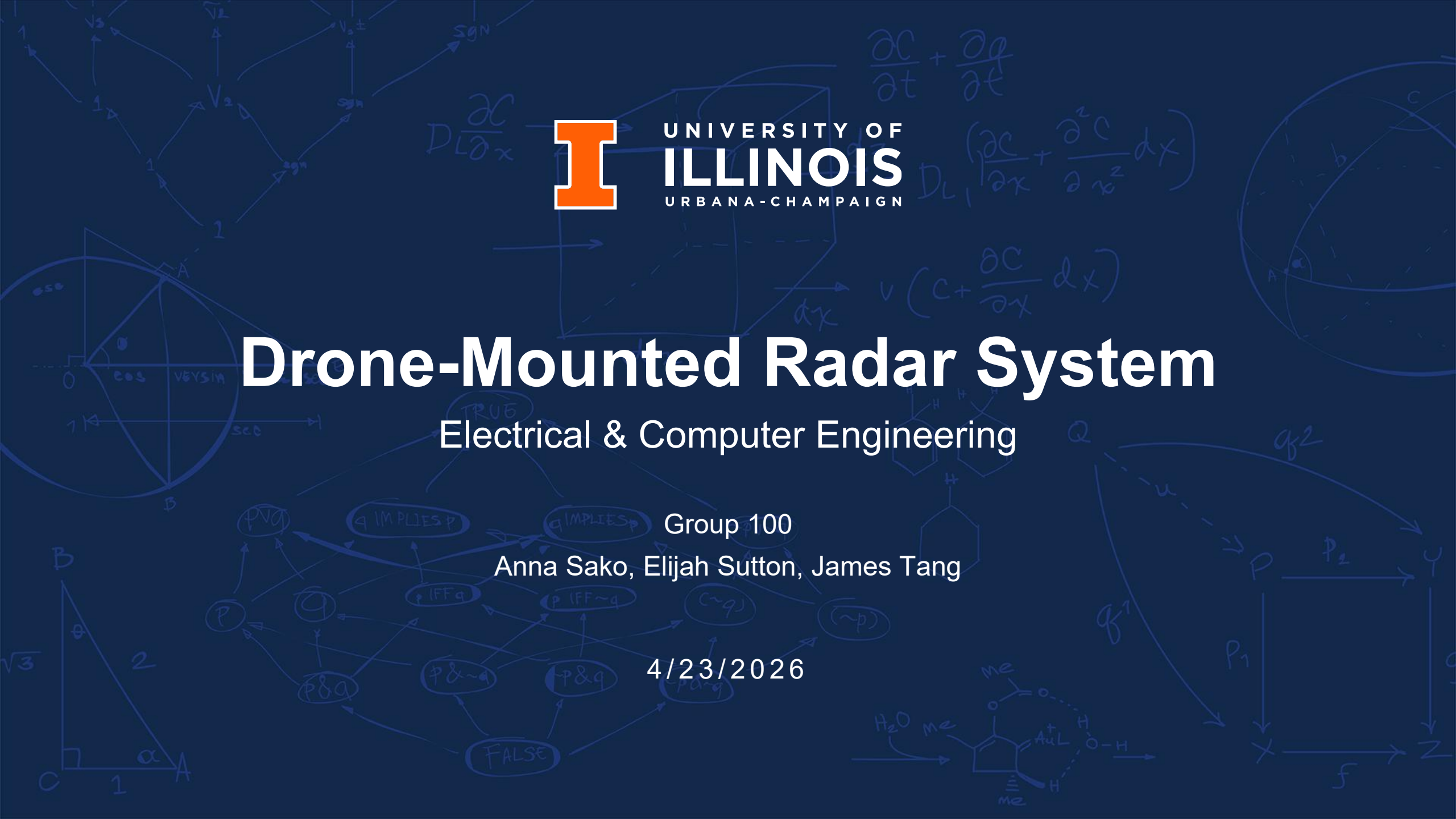


UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Drone-Mounted Radar System

Electrical & Computer Engineering

Group 100

Anna Sako, Elijah Sutton, James Tang

4/23/2026

Objective

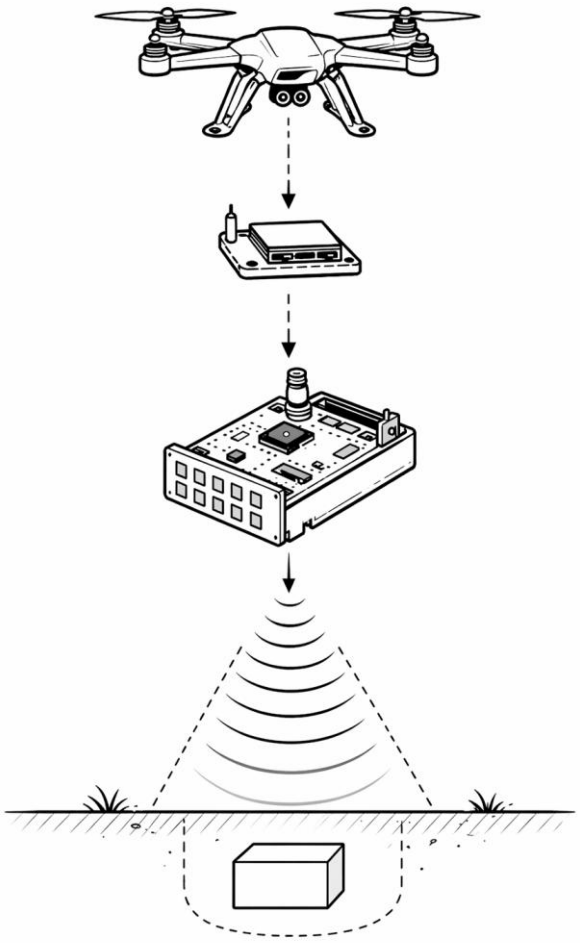
General reconnaissance in hazardous environments is often:

- **Dangerous** for human operators
- **Expensive** to deploy at scale
- **Difficult** to implement on a low-cost platform

Semester Goal: A scalable proof of concept for low-cost aerial reconnaissance

Over the semester, we refined the project scope to match what could be realistically achieved. Rather than forcing a fully developed final system, we narrowed the design into a **working proof of concept** that demonstrates:

- Radar to drone to ground station integration
- Basic autonomous flight routes
- Radar surveying and localization
- A foundation for future expansion

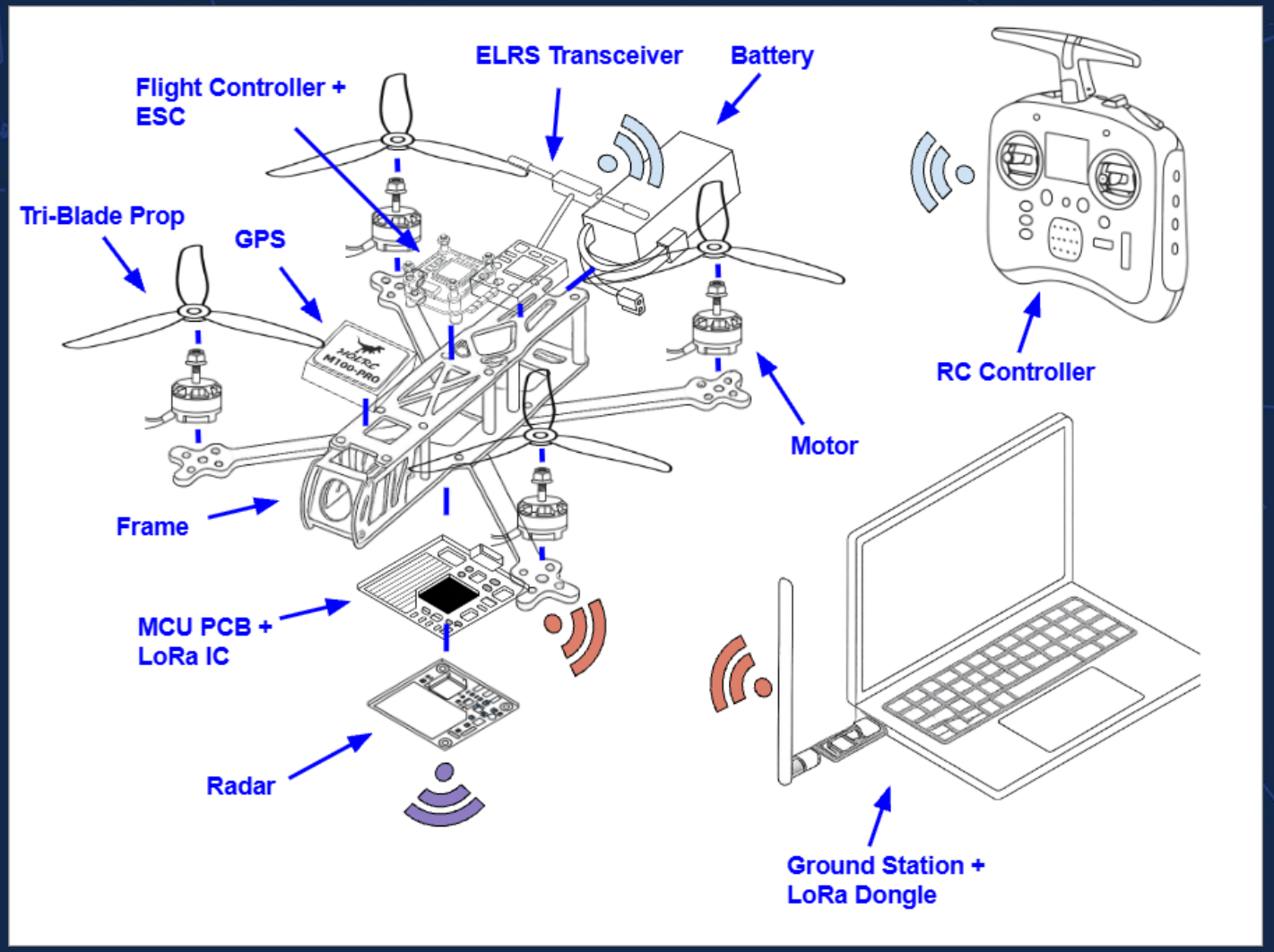


Project Overview:

Our project is a **low-cost drone reconnaissance proof of concept** that collects flight data and sends it to a ground station for visualization. Because wireless transmission speed was more limited than originally planned, the system does not provide fully instantaneous feedback. Instead, the project shows that even with communication constraints, the collected flight data can still be used in a meaningful way for **reconstruction, visualization, and future sensing-system expansion**.

- **Manual + Semi-autonomous flight** to control the drone from the ground station
- **GPS data collection** to estimate the drone's location over a mapped area
- **Gyroscope data collection** to track motion and orientation during flight
- **Ground station visualization** to place recorded coordinates on a map, with expected position error on the order of **± meters**

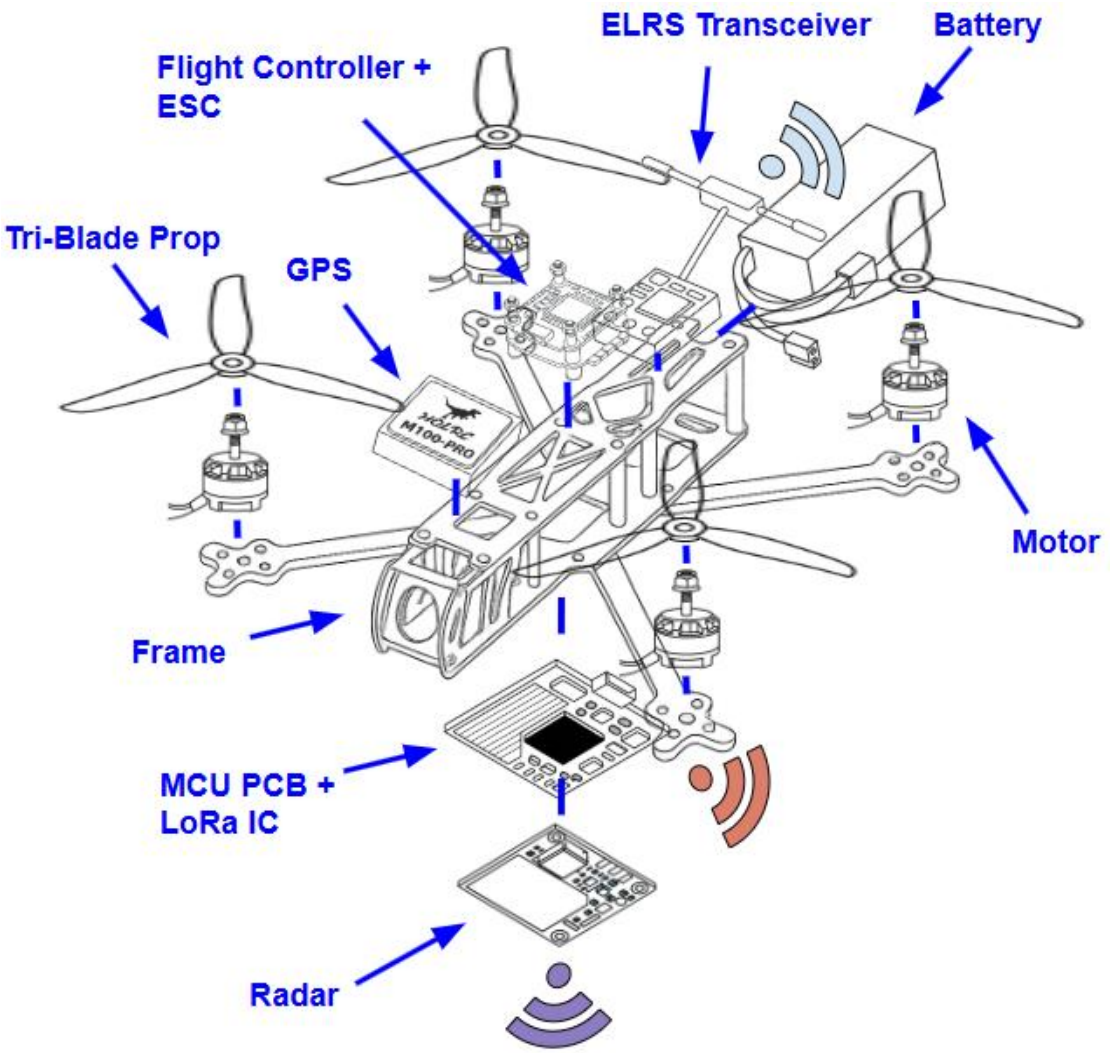
DESIGN OVERVIEW



DESIGN OVERVIEW
High/low level requirements

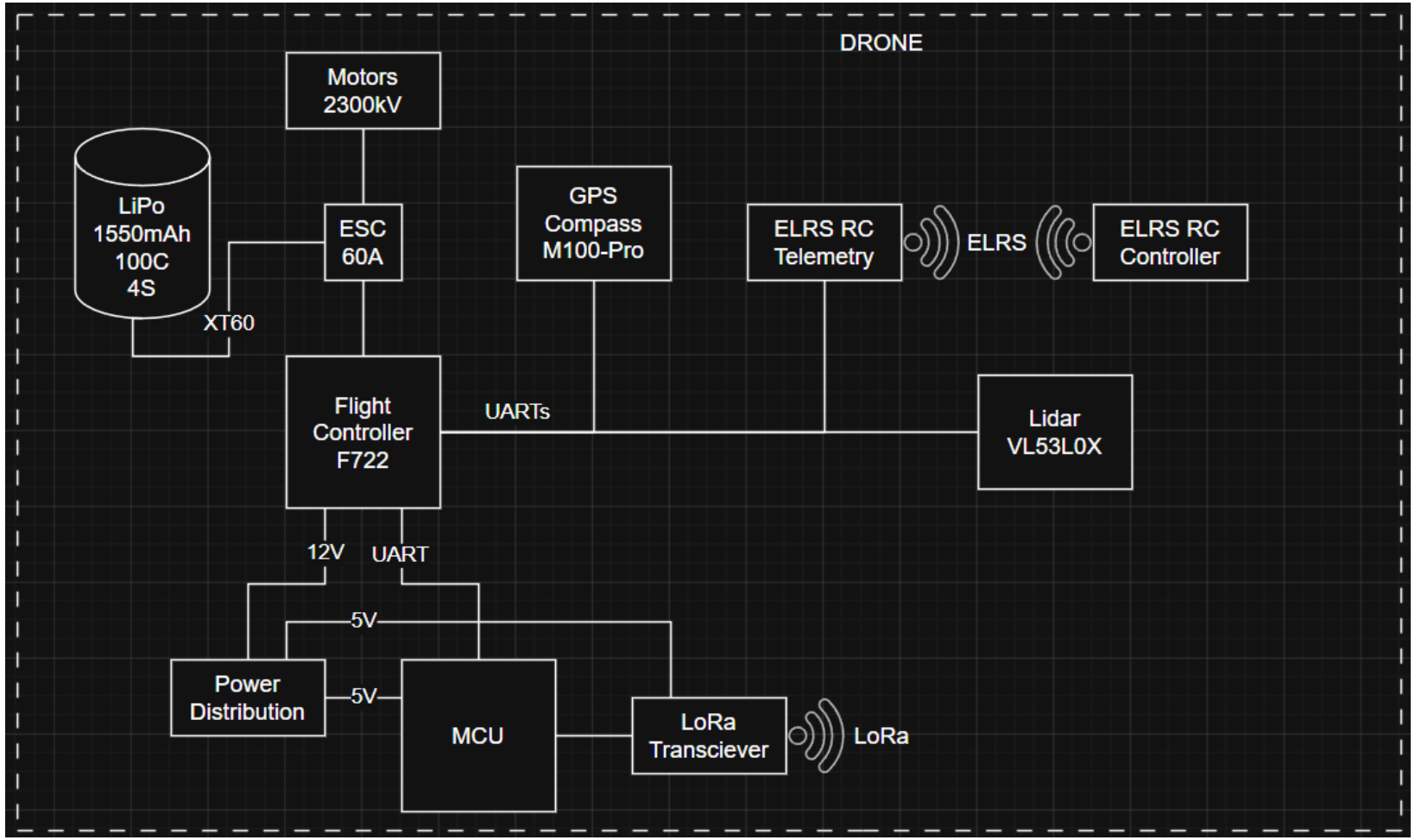
Drone: Criteria

- Efficient
  - Peak efficiency at ~20mph with payload
- Cheap
  - 5" drone platform
  - Very modular
- Payload Capacity
  - Drivetrain tuned to maximize flight time with payload
- Fast
  - ~11.7 thrust-to-weight ratio

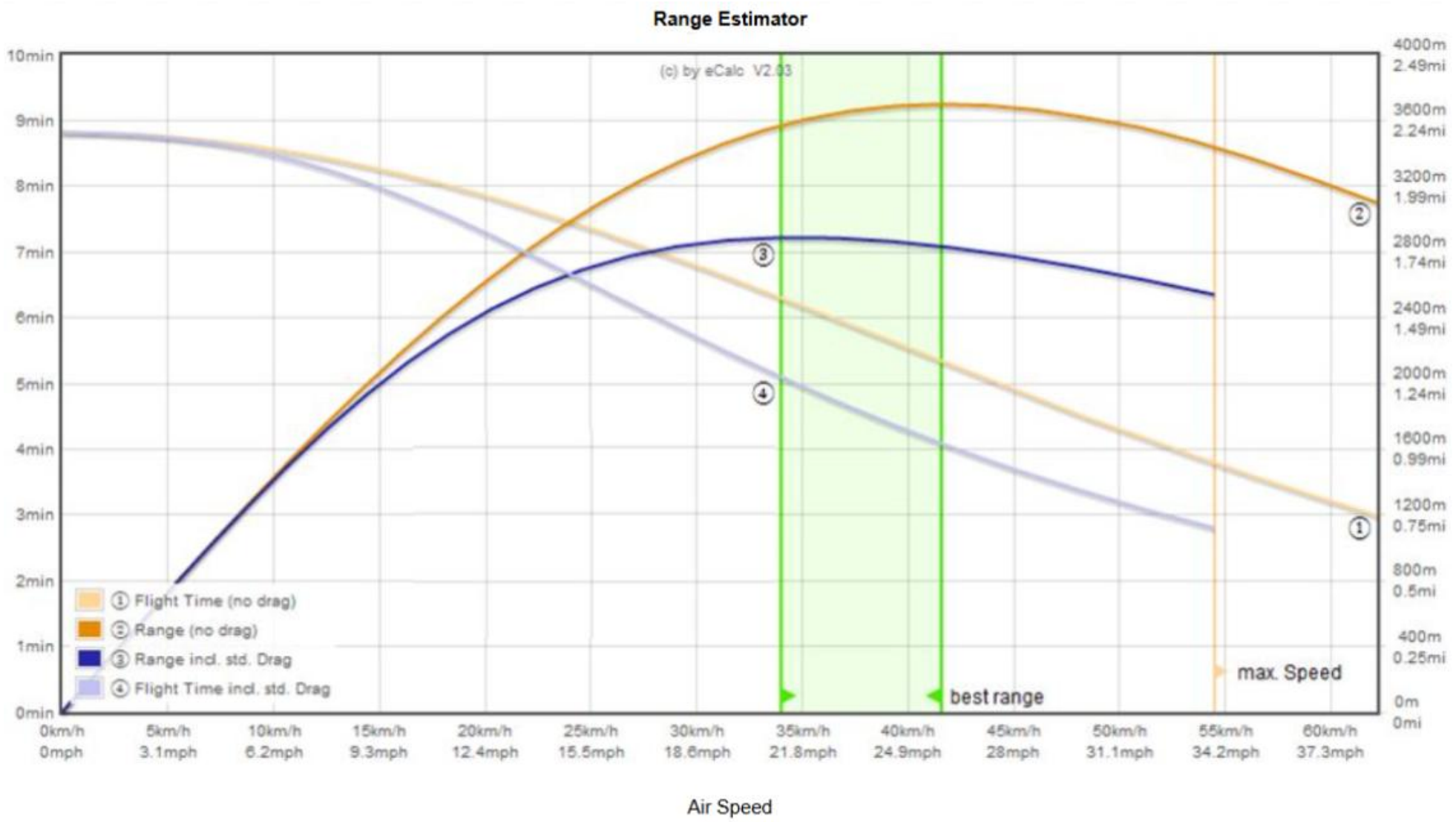


Drone: Electrical Design

- Drivetrain
  - Battery
  - ESC
  - Motors
- Telemetry
  - GPS
  - ELRS
  - Lidar
- Autonomy
  - MCU
  - Power Distribution
  - LoRa

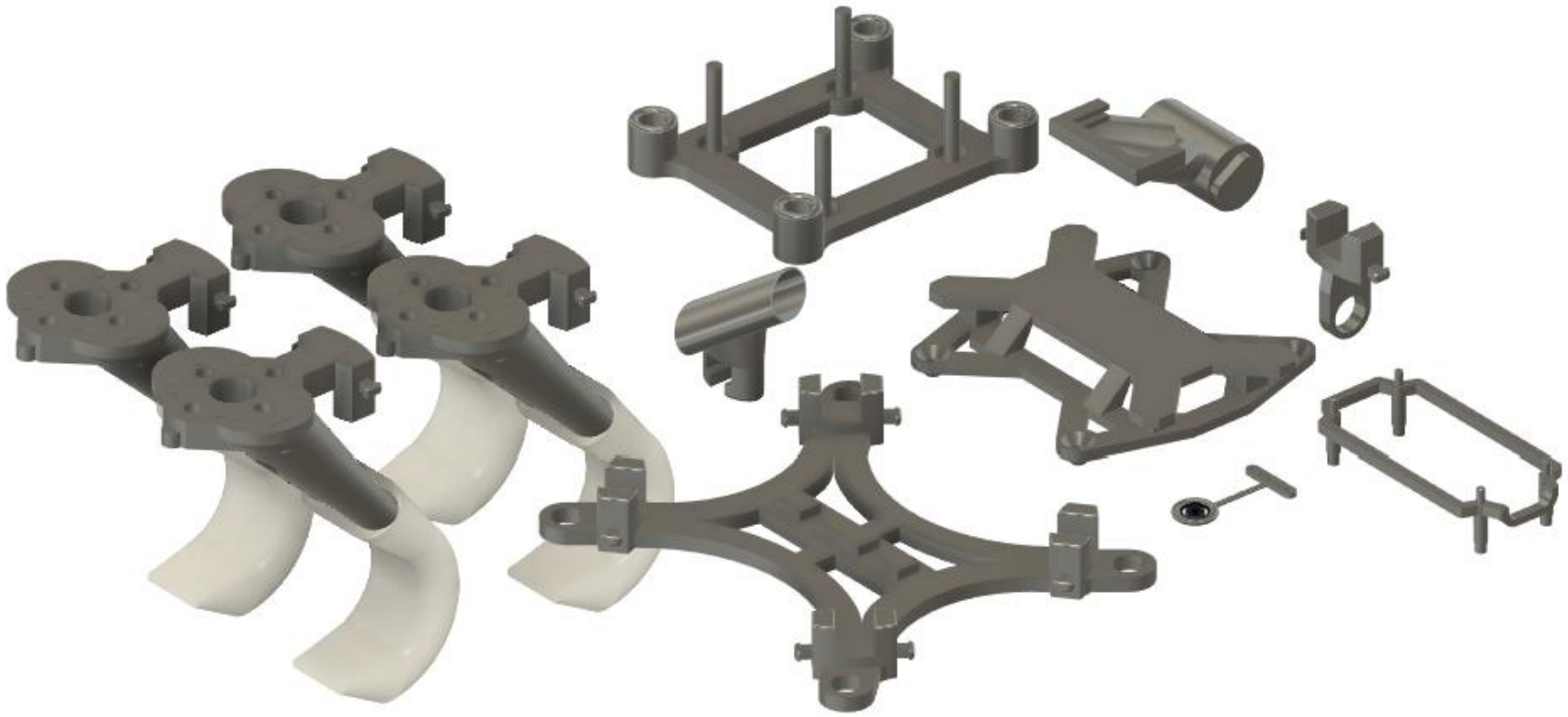


Drone: Design Optimization



Drone: Mechanical Design

- Mounts / Electronics Protection
  - FC + ESC
  - GPS
  - ELRS Receiver
  - LoRa Transceiver
  - Battery
  - PCB
- Adaptors
  - Motor Sizing
- Landing
  - PLA Legs
  - TPU Feet

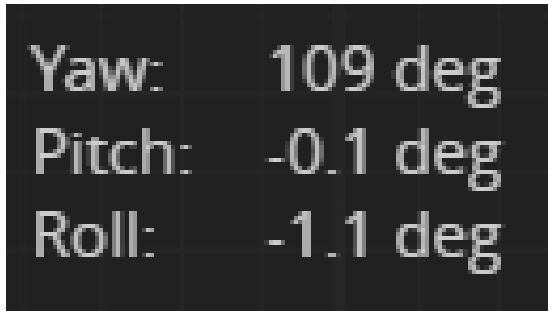


Drone: Software Design

Ground Station Control

- Telemetry
  - GPS Coordinates
  - Gyro/Acc
  - Flight Controller State

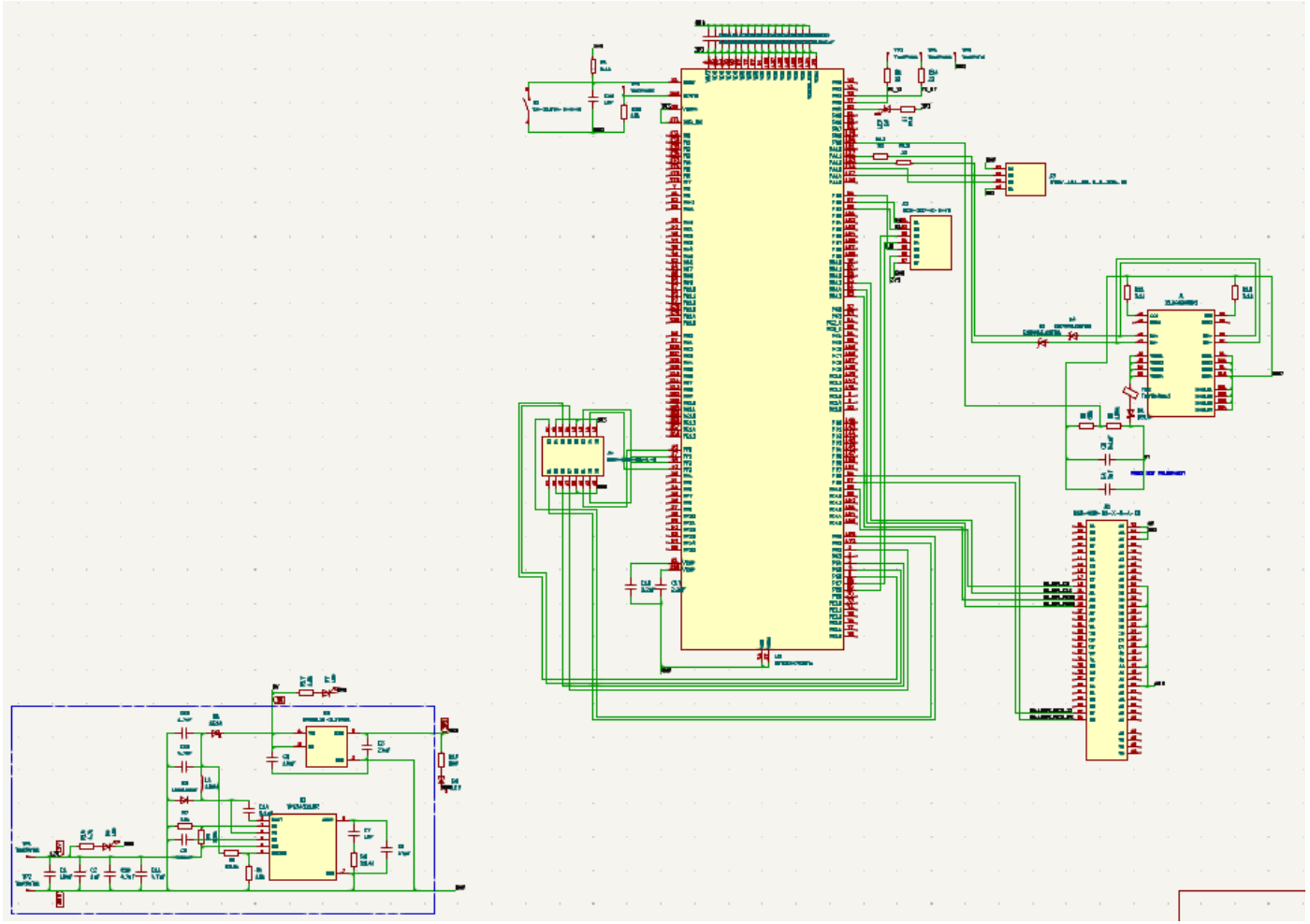
- Commands
  - ARM/DISARM
  - Flight Mode
  - WASD, up/down
  - Fly route



```
>> SYSTEM STATUS
DISARMED
>> IMU DATA
Accel: [-8, -26, 2079] | Gyro: [0, -1, 6] | Mag: [-155, 1392, 1926]
>> GPS DATA
Sats: 0 | Fix: 0 | Lat: 0.0000000 | Lon: 0.0000000 | Alt: 0m
```

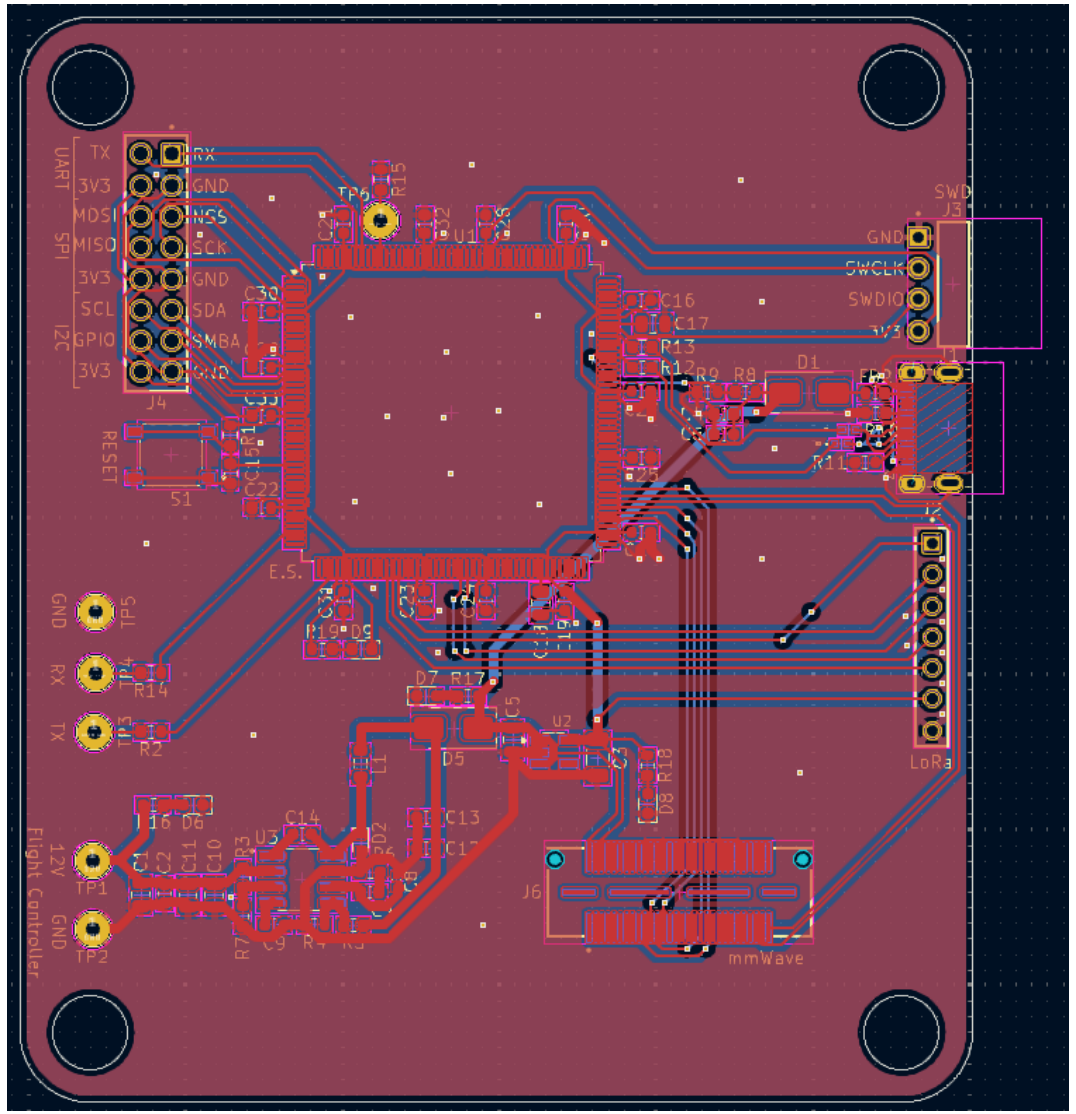
PCB: Design Criteria

- Integrate All Subsystems Together
  - Direct Radar
  - Command Drone
  - Relay Data to Ground Station
- Processing Power
  - STM32H7 – 480MHz+
- Modular
  - 5V/3V3
  - High Pin Count

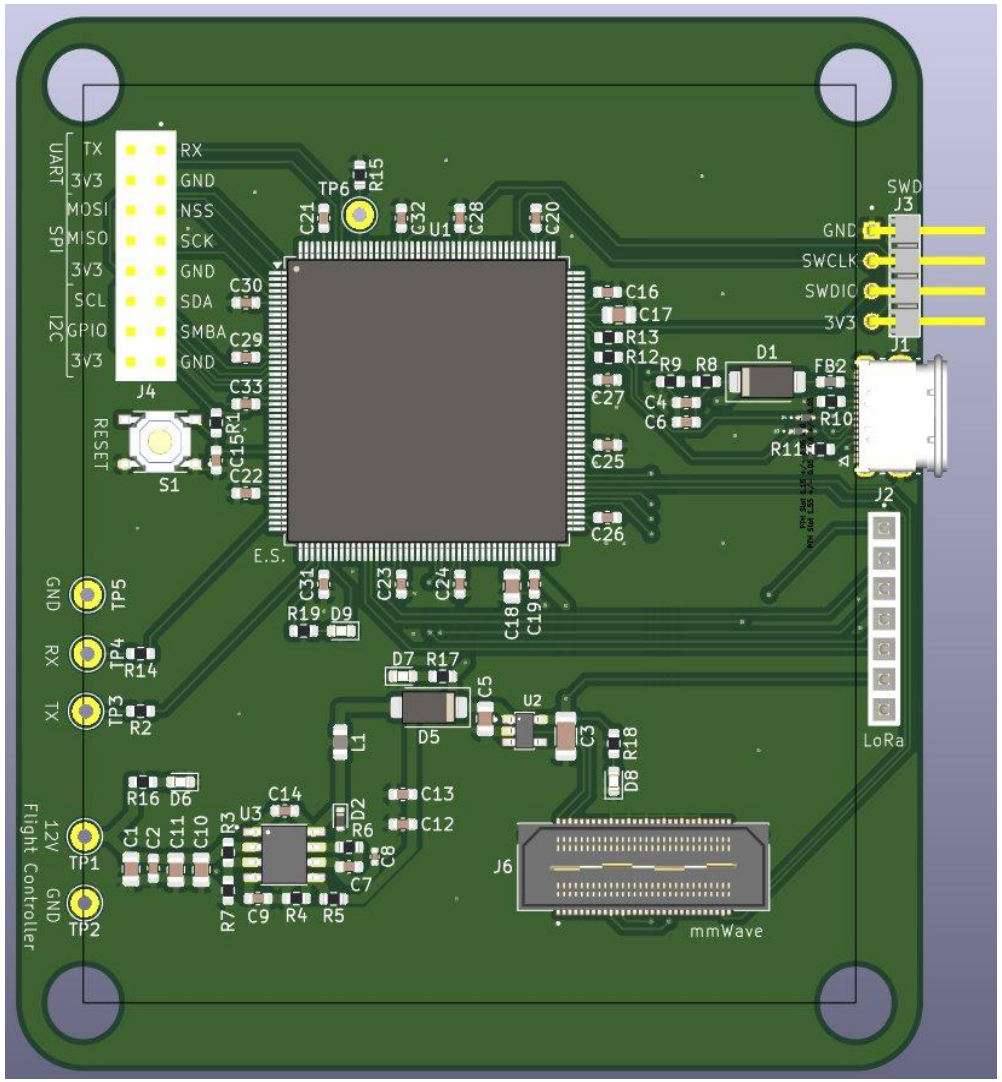


PCB: Design Overview

- Power Distribution
  - 12V/5V/3V3
  - Buck
- Programming
  - SWD (STM standard)
  - USB-C
- Radar
  - 60-pin Direct (UART + SPI)
- LoRa
  - UART
- Flight Controller
  - UART

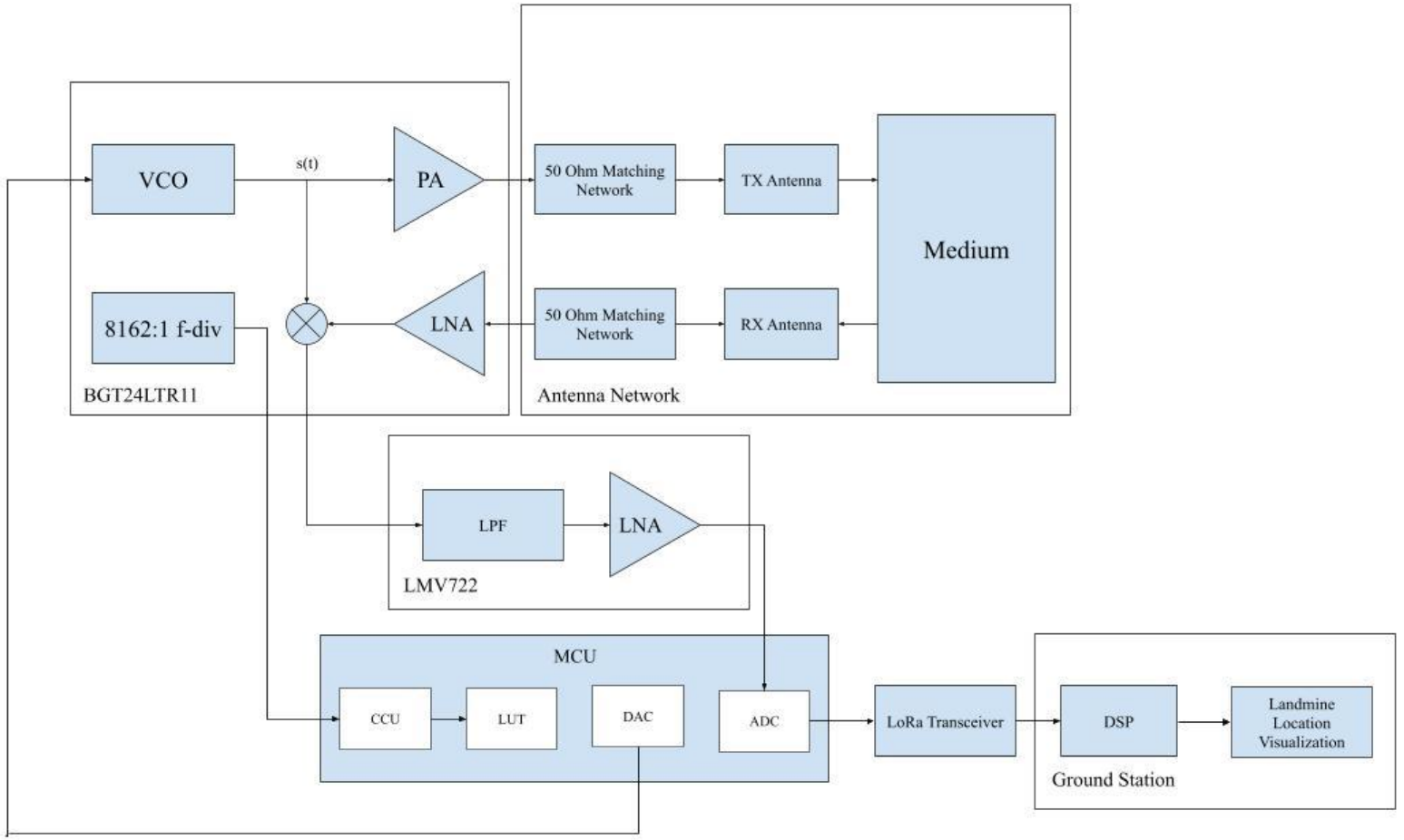


PCB: Design Details

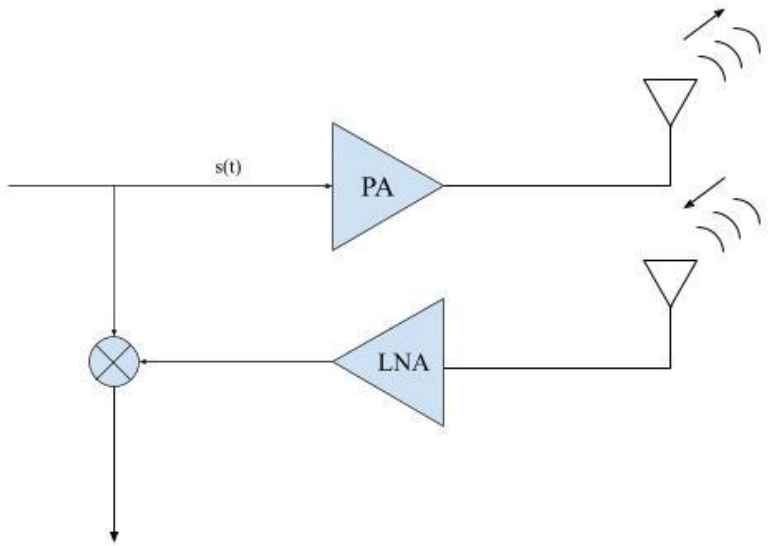


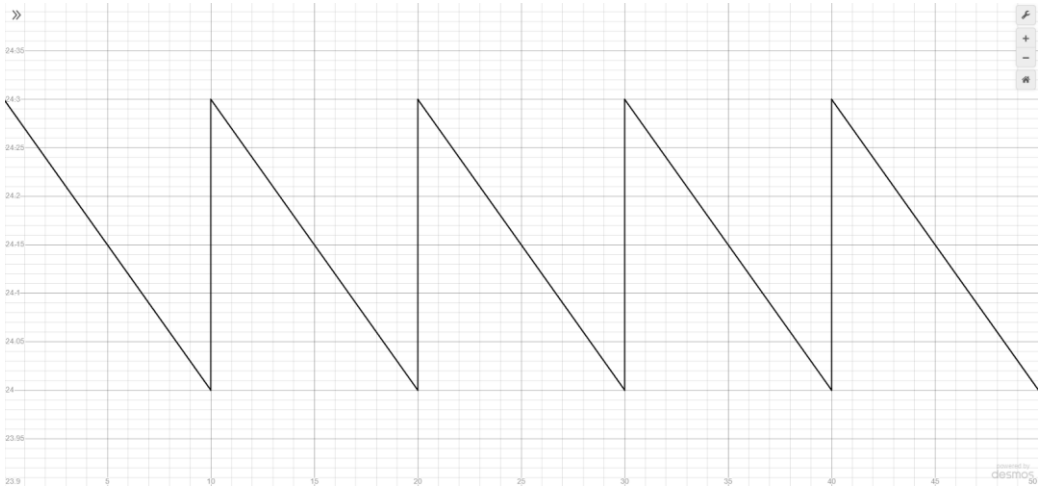
- LED Indication
  - Power
  - GPIO
- Programming Redundancy
  - SWD
  - USB-C
- Additional Pins (Lidar)
  - SPI
  - UART
  - I2C
  - Power
- Test Points
  - Boot0

Original Design of FMCW Radar



FMCW Radar: Design





$$s_t(t) = \cos\left(2\pi f_{\max} t - \pi\gamma t^2\right)$$

$$s_r(t) = s_t(t - t_d) = \cos\left(2\pi f_{\max}(t - t_d) - \pi\gamma(t - t_d)^2\right).$$

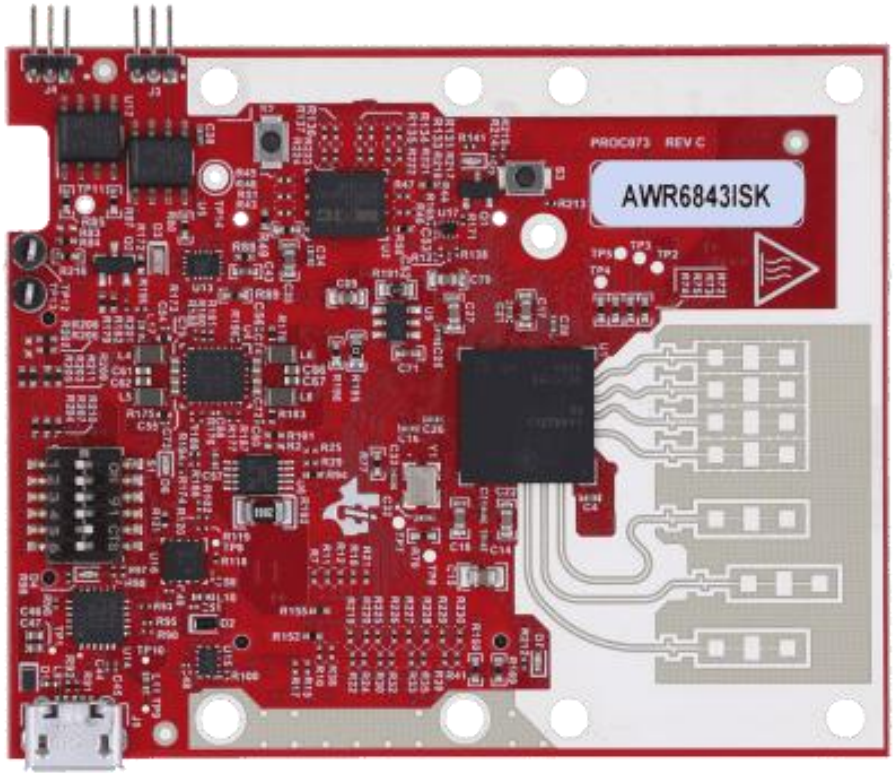
$$s(t) = s_t(t)s_r(t) = \cos\left(2\pi\gamma t_d t - \pi\gamma t_d^2 - 2\pi f_{\max} t_d\right)$$

Frequency of the chirp contains information about the position of the object.

$$f_{out} = 2\pi\gamma t_d$$

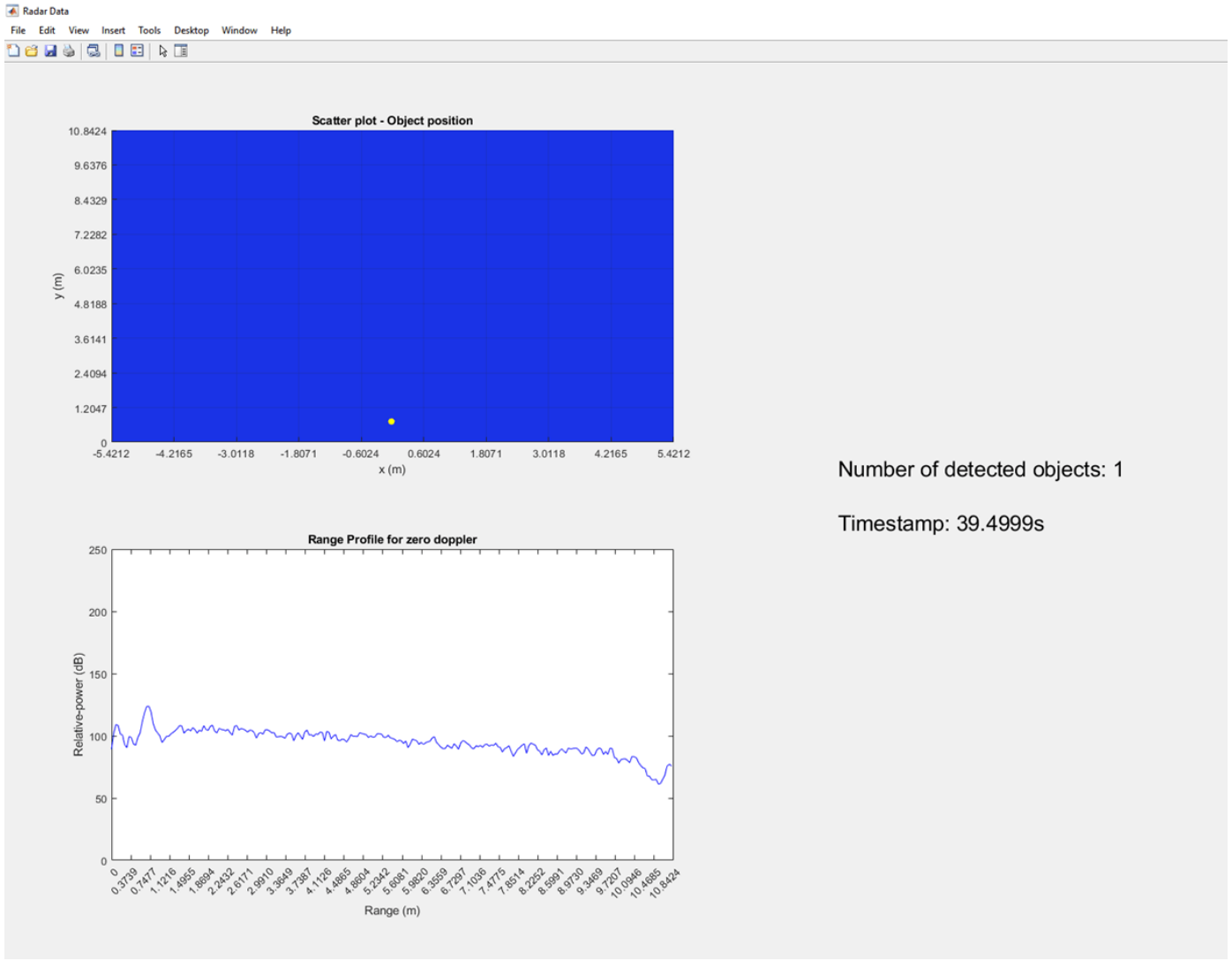
$$t_d = \sqrt{(x - x_T)^2 + y^2 + z^2}$$

FMCW Radar: Design



- Replaces the function of the BGT24LTR11 chip and the MCU logic to generate MCU
- Extracts chirp frequency from the radar

Point Cloud Data of FMCW Radar



Project Overview

Overall, we were able to achieve:

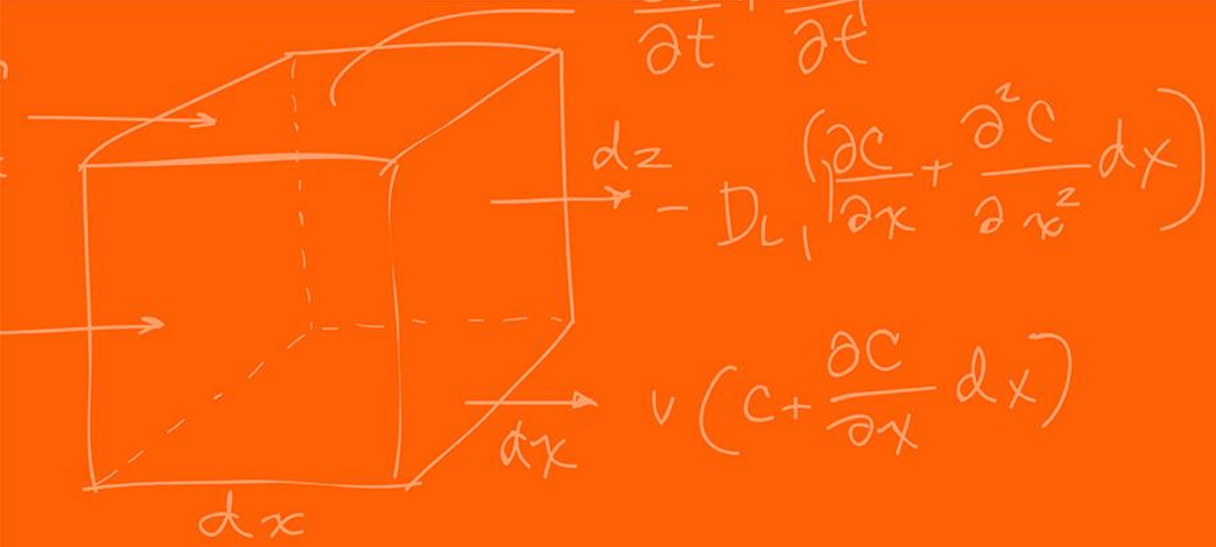
- Controllable Drone Flight
- GPS & Gyroscope Data Collection
- MCU to Flight Controller Communication
- Basic Design Framework Capable of Supporting Future Work

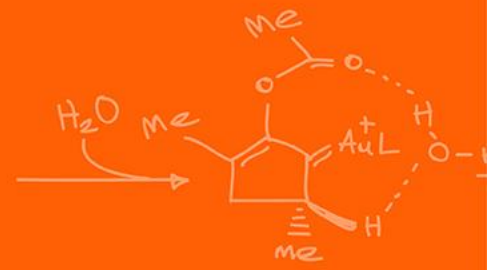
Future Work

The biggest limitation we faced is the time and budget constraints placed on us by the class structure; if we were to continue this project beyond this class, some possible extensions could include:

- Advanced Autonomous Drone Flight
- Radar Feedback to Ground Station
- Radar Data Visualization
- Ground Station App-Based User Interface

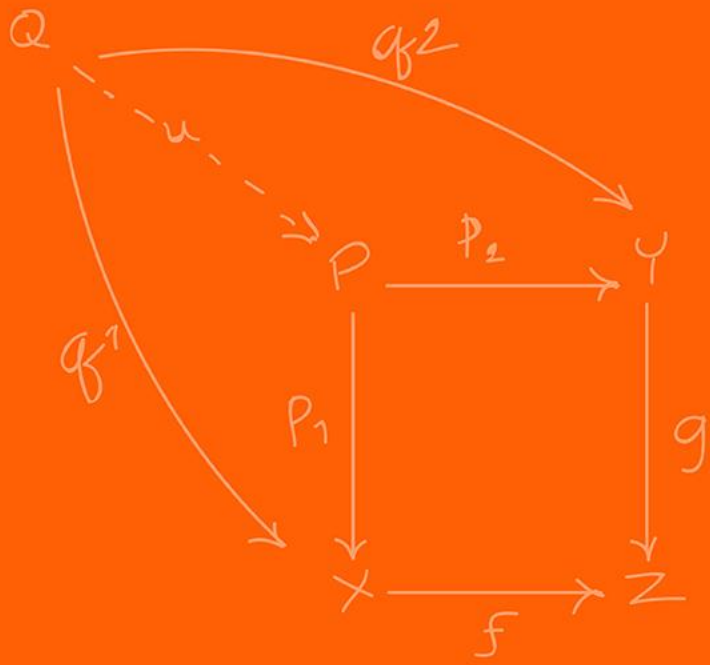
Thank You!
Questions?





The Grainger College of Engineering

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN



FMCW Radar: Point Cloud Data

PCB: Design

- LED Indication
  - Power
  - GPIO
- Programming Redundancy
  - SWD
  - USB-C
- Additional Pins (Lidar)
  - SPI
  - UART
  - I2C
  - Power
- Test Points
  - Boot0

IMAGE (Send to back so Block I is not covered.)

(Text here relevant to the photo for a larger call out on a given idea or message.)
(Keep this text simple and short on one or two lines.)

BOYS READ ME

Lets do an overview and THEN

And then 2-3 slides on each subsystem

2-3 slides on RADAR design, requirements and verification (should include block diagram, math, graphs, figures, tables).

2-3 slides on DRONE design, requirements and verification (should include block diagram, math, graphs, figures, tables).

2-3 slides on GROUND SYSTEM + PCB design, requirements and verification (should include block diagram, math, graphs, figures, tables).

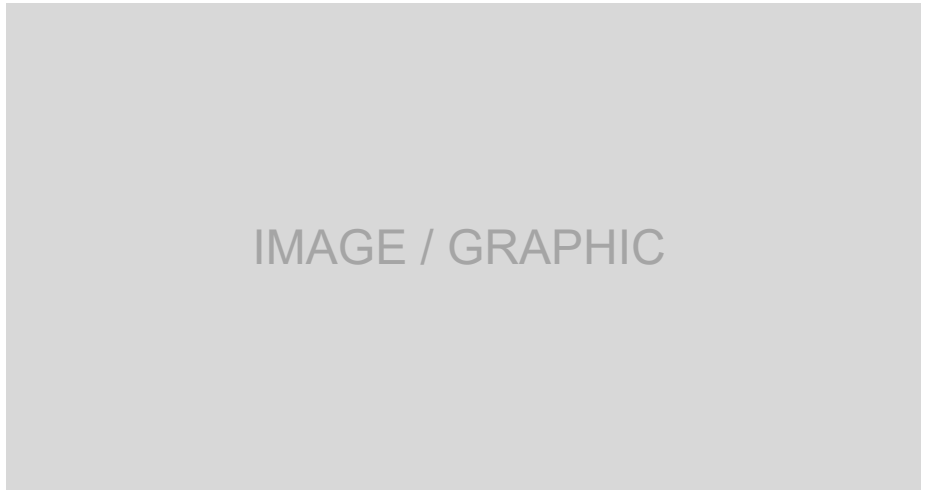
Lorem Ipsum Dolor Sit Amet Consectetur Adipiscing

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Lorem Ipsum Dolor Sit Amet Consectetur Adipiscing

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Slide Title



Lorem Ipsum Dolor Sit Amet Consectetur Adipiscing

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat.

Lorem Ipsum Dolor Sit Amet Consectetur Adipiscing

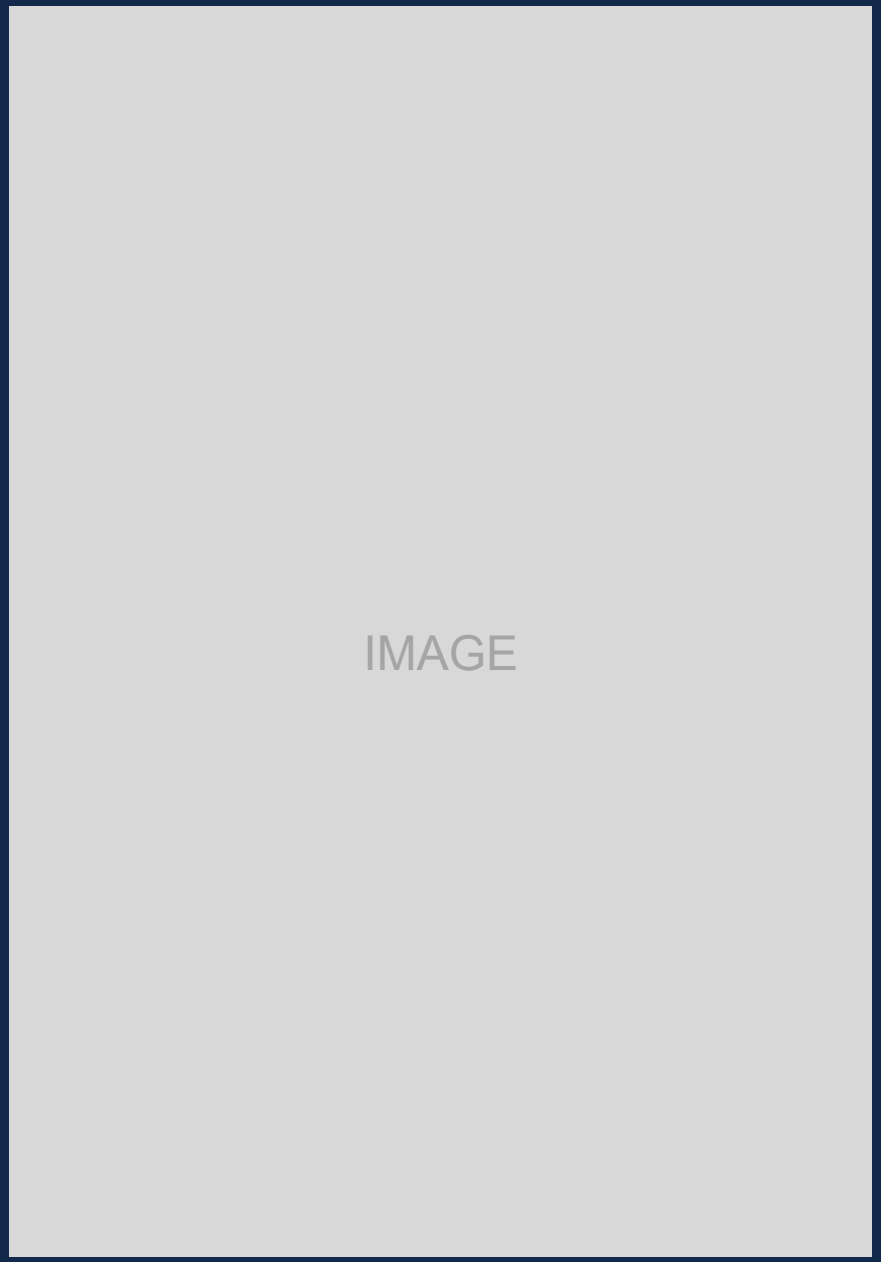
Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

Lorem Ipsum Dolor Sit Amet Consectetur Adipiscing

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat.

Lorem Ipsum Dolor Sit Amet Consectetur Adipiscing

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.



Lorem ipsum dolor sit amet consectetur adipiscing elit

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat.

Lorem ipsum dolor sit amet consectetur adipiscing

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

Slide Title

Lorem Ipsum Dolor Sit Amet Consectetur Adipiscing

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat.

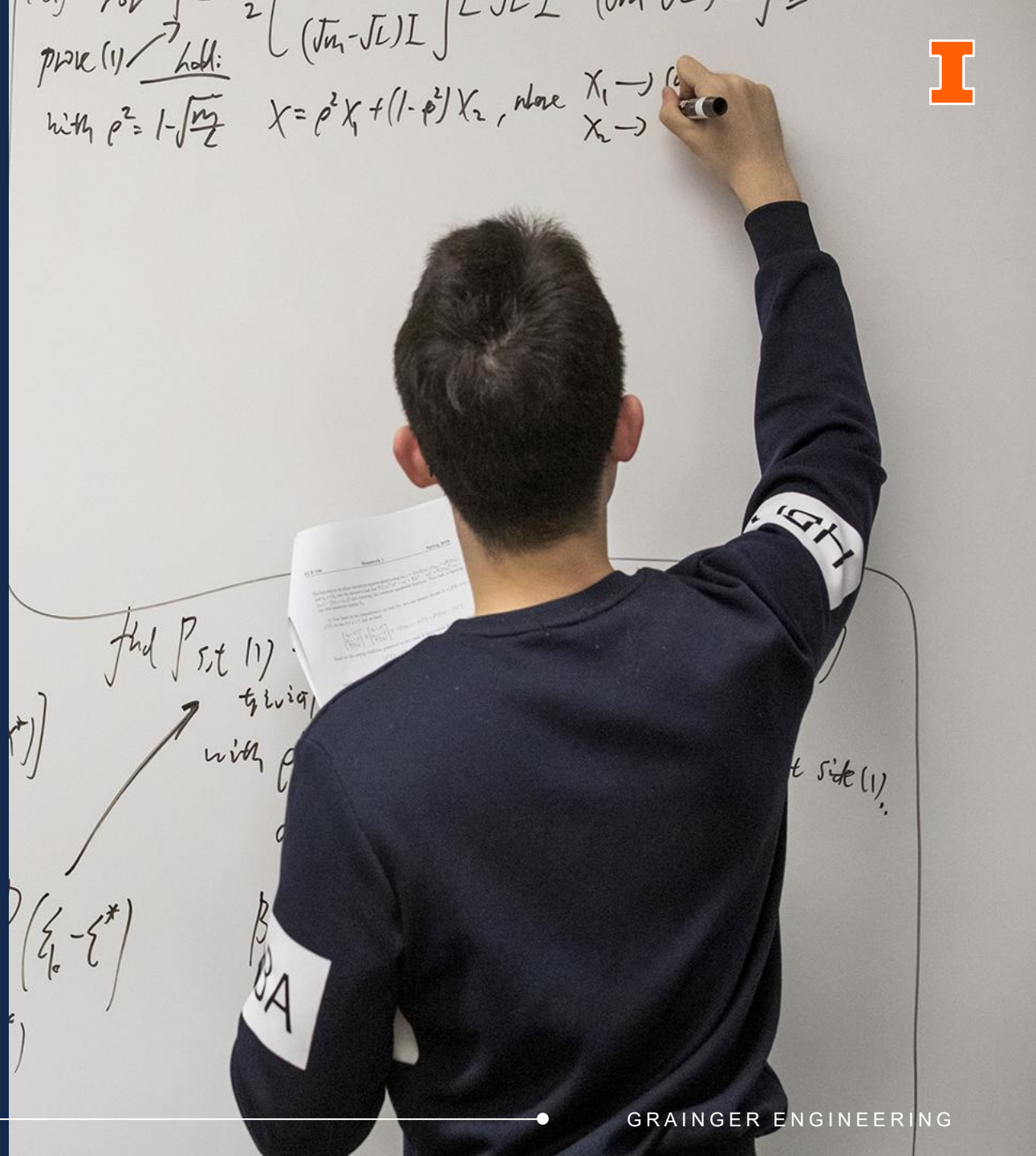
Lorem Ipsum Dolor Sit Amet Consectetur Adipiscing

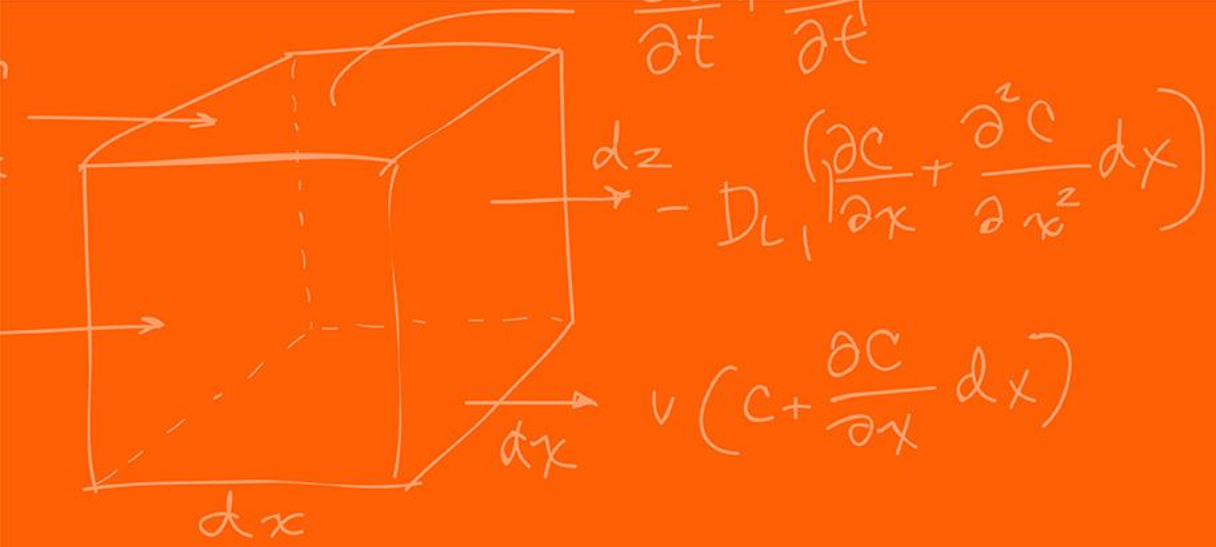
Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

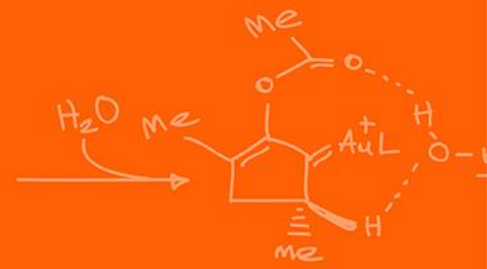
IMAGE

(Use a photo for the entire slide like the example shown here. Send the photo to the back so the Block I and footer text is not covered.)

(Slide the blue box and the text left or right to fit over your background image. Use this text box for a call out or caption to the image.)







Heading

(Main section divider slide option two, or transition slide.)