UNITED SENSORS

UCSB Computer Engineering | Capstone 2024

Mission Background

Drones help gather information, their versatility enable us to:

Explore Frontiers 	**Respond to Disaster** 
Mobilize Surveillance 	**Deliver Goods** 

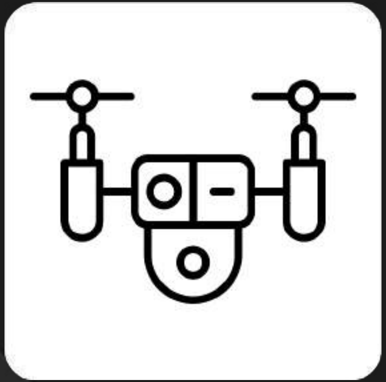
Anticipated Problems

Degradation - Extended use bounds sensors to failure

Inaccuracy	Compromise	Repair
Single Sensor Systems	Ripple Effect	Expensive Service
		

Proposed Solution

Sensor Redundancy - Multiple Sensors for the Same Operation

Precision	Tolerance	Reliability
Multi Sensor System	Versatile Function	Built-In Backup
		

Project Overview

Goal: Create sensor redundancy in quadcopters

1. Decide on a MCU that can handle larger amount of sensors and design a new firmware that Ardupilot will build from
2. Provide sensor redundancy for multiple sensor types on the open-source codebase by writing new drivers/editing filters
3. Create benchtop testing unit to test code/hardware without having to launch the quadcopter for ease of testing
4. Design/Print custom PCB with various redundant sensors types that aims for low power consumption

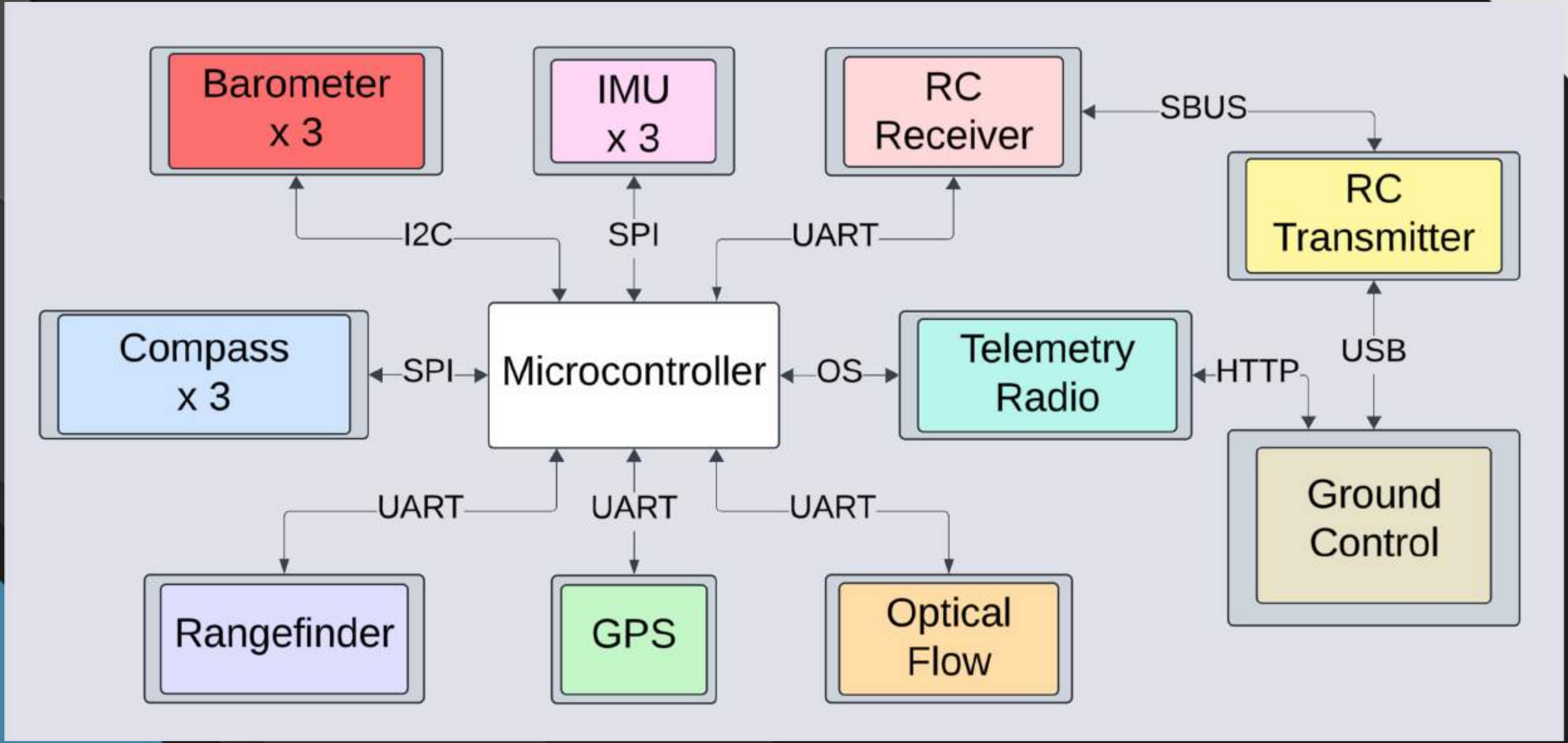
Engineering Team





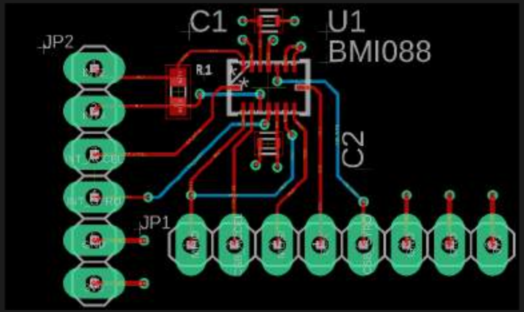
Edison Chen	Team Captain/Firmware and Sensor Integration
Ethan Nguyen	Software Development
Tim Qin	PCB Design
Hector Moreno	Motor Control
Shabeeb Reza	Telemetric Comm

Block Diagram



IMU - BMI088

- Communication Protocol: SPI
- 6 DOF IMU that consists of an accelerometer and a gyroscope
- Extended measurement range of up to ±24g
- Custom printed board with better sizing and defaulting to SPI



Compass - LIS3MDLTR

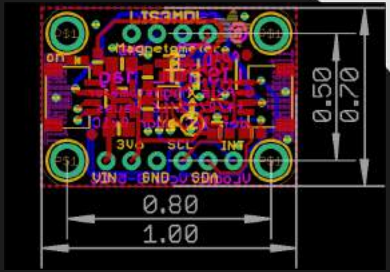
- 3-axis magnetometer
- Communication Protocol: SPI

Barometer - DPS310

- Connected via Stemma QT Cable
- Communication Protocol: I2C

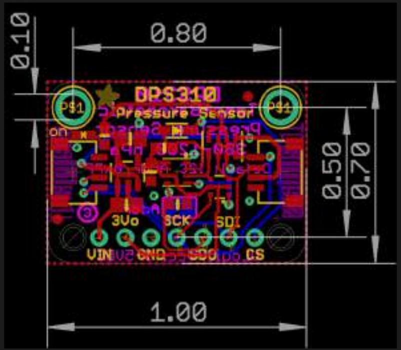
Driver Modifications

Compass - LIS3MDLTR



- Increase retries for initialization due to SPI lines working incorrectly

Barometer - DPS310

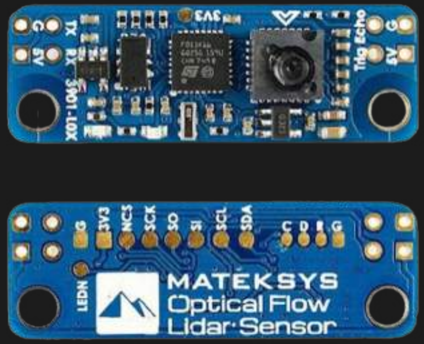


- Calibration had to be modified to work correctly
- AP_Baro configuration to support 3 instances

Rangefinder - TF-MiniS

- Communication Protocol: UART
- Swapped from VL53L0X for higher range (1m vs 10m)

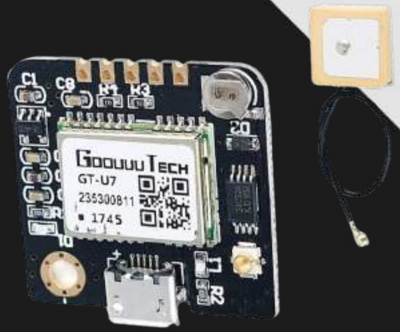
Optical Flow - Matek 3901-L0X



- Communication Protocol: UART
- Also contains a rangefinder if needed
- Swapped from PMW3901 since Matek was much better documented and built for drones

GPS - Neo-6M

- High sensitivity GPS that uses Satellite positioning
- Requires outdoor use in open area for accuracy
- Communication Protocol: UART



Motor - RtS 920kV Brushless

- Compact design that delivers 1lb of Thrust per unit
- Laced with magnets powered by electromagnetic field
- Utilizes PWM with a range of 50MHz to 100 MHz

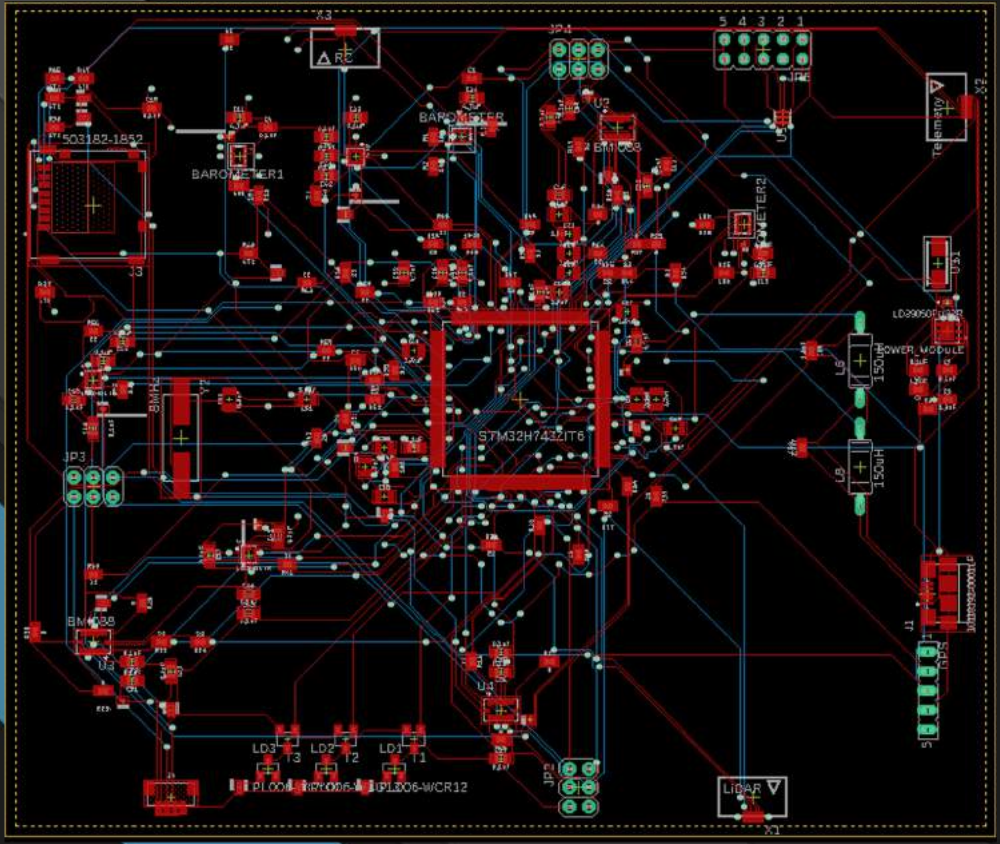
Speed Controller - RtS 40A ESC

- Acts as the middle ground between the motors and power signal
- Regulares rotation and direction by delivering timed electrical signals
- Connects to battery to increase motor velocity

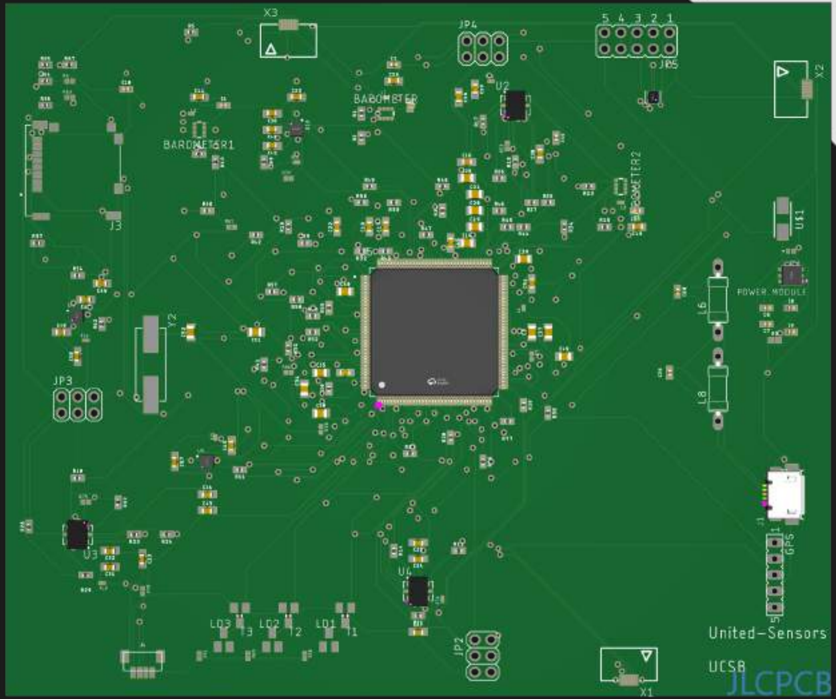
Receiver - FrSky RX6R

- Allows for communication with ground station
- High precision PWM featuring 16 Channels
- Communication Protocol: UART

Custom PCB

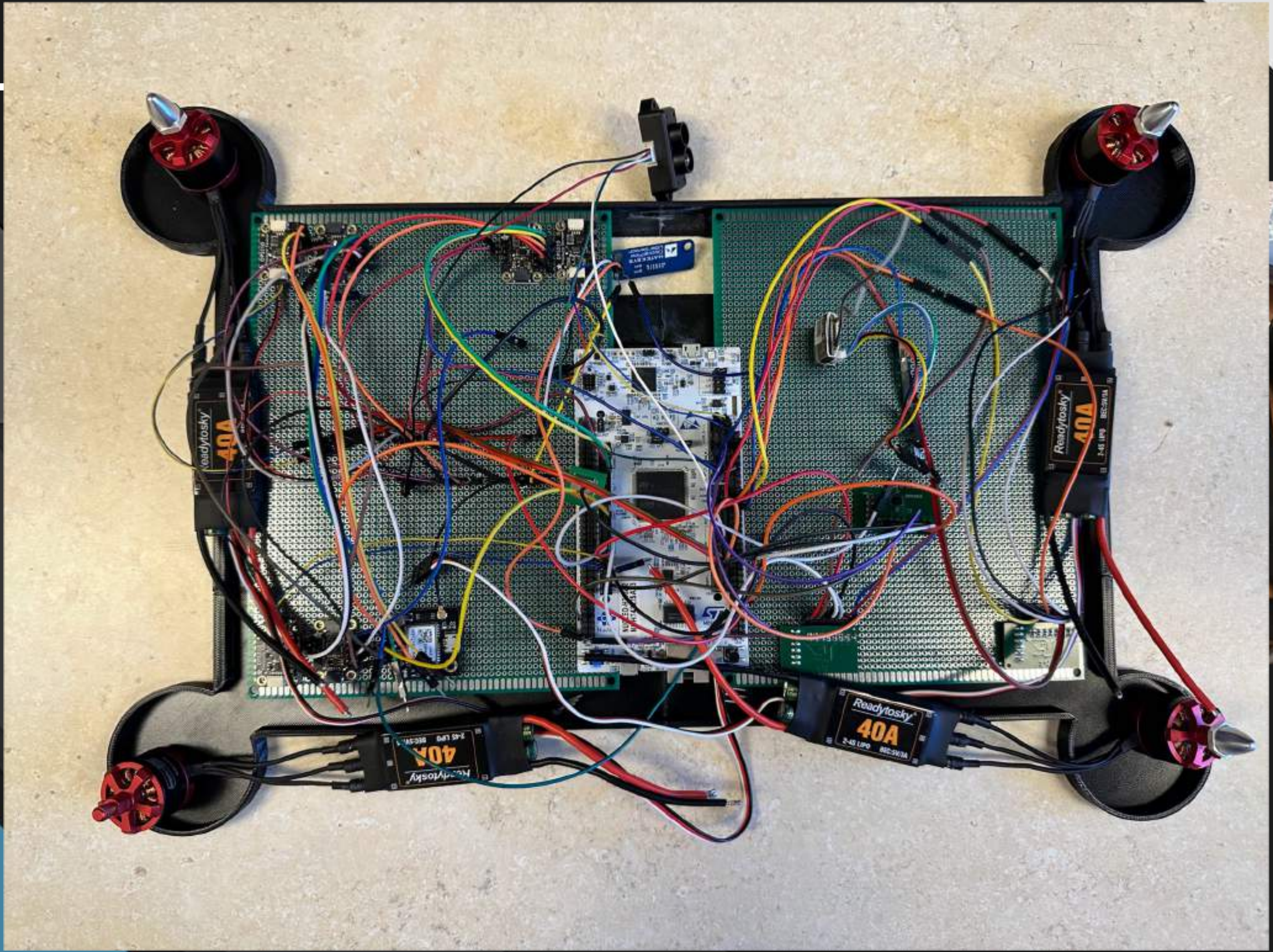


X3
RC
JP4
5 4 3 2 1
JP6
BAROMETER
U2
BMI088
503182-1852
BAROMETER1
BAROMETER2
Telemetry
X2
J3
U$1
LD39050PU33R
POWER_MODULE
L6
150uH
L8
150uH
Y2
BMI
STM32H743ZIT6
JP3
BMI088
U3
U4
J1
GPS
LD3
LD2
LD1
T3
T2
T1
JP2
LiDAR
X1



X3
JP4
5 4 3 2 1
JP5
X2
BAROMETER
U2
BAROMETER1
BAROMETER2
J3
U$1
POWER_MODULE
Y2
L6
L8
JP3
J1
GPS
U3
U4
LD3
LD2
LD1
T3
T2
T1
JP2
United-Sensors
UCSB
X1
JLCPCB

T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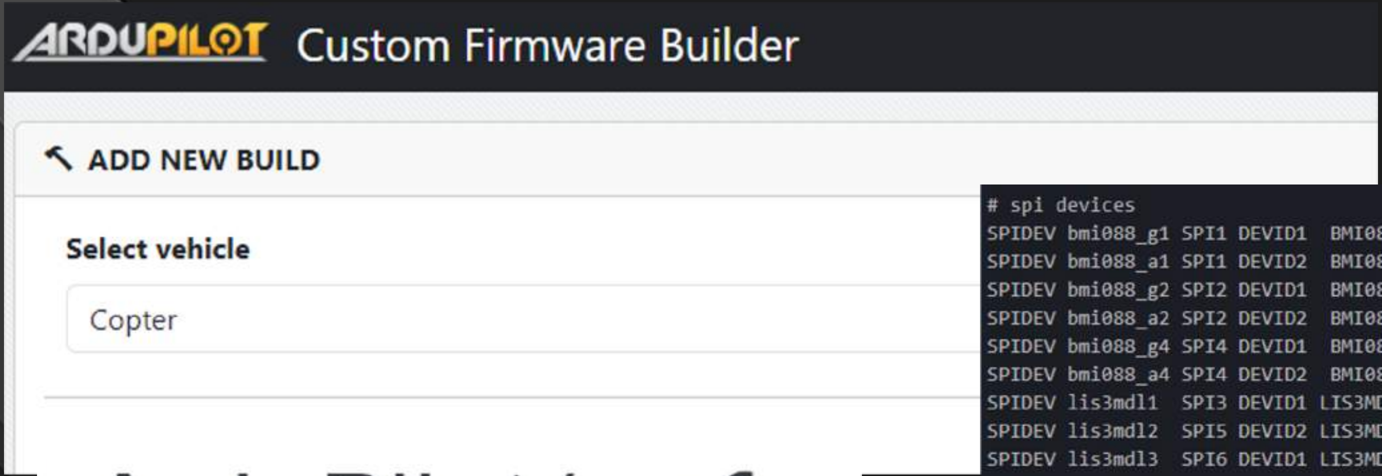
Firmware

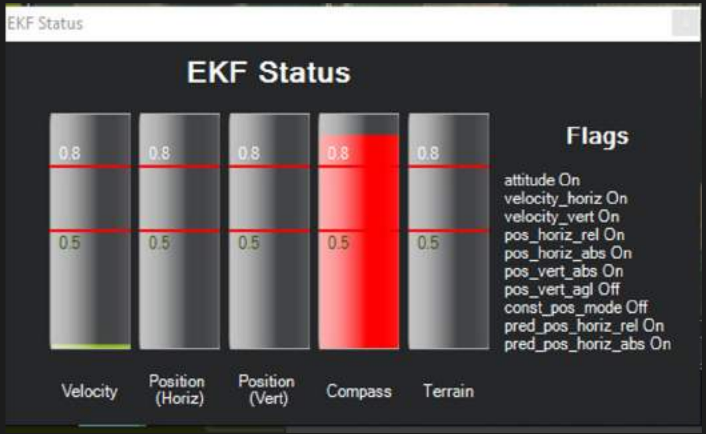



```
# spi devices
SPIDEV bmi088_g1 SPI1 DEVID1  BMI088_G_CS1  MODE3 1*MHZ 1*MHZ
SPIDEV bmi088_a1 SPI1 DEVID2  BMI088_A_CS1  MODE3 1*MHZ 1*MHZ
SPIDEV bmi088_g2 SPI2 DEVID1  BMI088_G_CS2  MODE3 1*MHZ 1*MHZ
SPIDEV bmi088_a2 SPI2 DEVID2  BMI088_A_CS2  MODE3 1*MHZ 1*MHZ
SPIDEV bmi088_g4 SPI4 DEVID1  BMI088_G_CS4  MODE3 1*MHZ 1*MHZ
SPIDEV bmi088_a4 SPI4 DEVID2  BMI088_A_CS4  MODE3 1*MHZ 1*MHZ
SPIDEV lis3mdl1  SPI3 DEVID1 LIS3MDL_CS1 MODE3  500*KHZ  1*MHZ
SPIDEV lis3mdl2  SPI5 DEVID2 LIS3MDL_CS2 MODE3  500*KHZ  1*MHZ
SPIDEV lis3mdl3  SPI6 DEVID1 LIS3MDL_CS3 MODE3  500*KHZ  1*MHZ

IMU BMI088 SPI:bmi088_a1 SPI:bmi088_g1 ROTATION_PITCH_180
IMU BMI088 SPI:bmi088_a2 SPI:bmi088_g2 ROTATION_PITCH_180
IMU BMI088 SPI:bmi088_a4 SPI:bmi088_g4 ROTATION_PITCH_180
BARO DPS310 I2C:0:0x77
BARO DPS310 I2C:1:0x77
BARO DPS310 I2C:2:0x77
COMPASS LIS3MDL SPI:lis3mdl1 false ROTATION_NONE
COMPASS LIS3MDL SPI:lis3mdl2 false ROTATION_NONE
COMPASS LIS3MDL SPI:lis3mdl3 false ROTATION_NONE
```

Why EKF + Lane Switching is needed

- One bad sensor can lead to larger amounts of error
- Choosing the reliable lane is better than taking the average of all
- Difficult to to detect when exactly was failure to rollback and recalculate
- EKF calculates variances by comparing results from other sensors



EKF (Extended Kalman Filter)

Used to get estimate vehicle position and states over a flight

1. Predict the next state based on the previous state and the action taken to go to the next state (Prediction)
2. Measure the current state using a sensor (Measurement)
3. Based on Affinity or sensitivity threshold of errors, estimate a new value based on the respective values (Estimation)
4. Repeat Step 1-3, continually using new values (Repeat)

Changes to ArduCopter

- EKF Changes
    - IMU defined lanes can now swap in other sensor iterations to compensate for failures
    - Only changes lane when IMU is faulty
    - Tries to get data from other sensor iterations
    - What is defined as a failure?
        - Power loss, Constant Values, Large Offset

Software Demo - IMU Failure and Recovery

Challenges

- Custom board was difficult to wire due to lack of labels on silkscreen
- Certain parts weren’t well documented on Arducopter
- Unnecessary risk taken with using a custom board as IMU is the most important sensor
- Working from chosen MCU instead of pre-built flight controller

Acknowledgements

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UCSB ECE

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THANK YOU!

Questions?