DOMINANCE

Drone Mine Obstacle Avoidance

Group 18

Sponsored by Lockheed Martin

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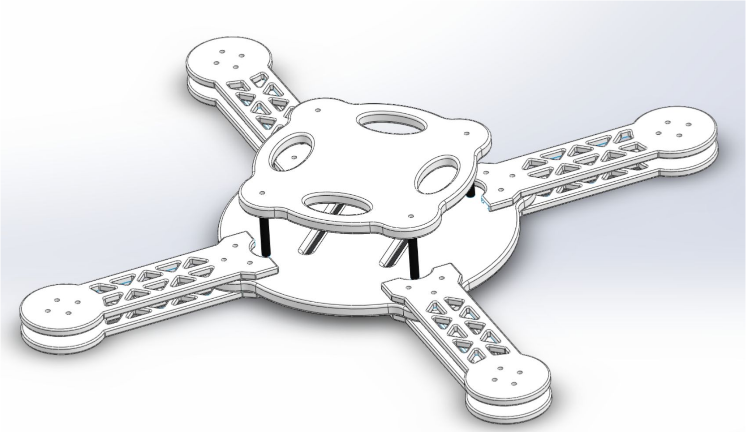
Project Objectives

- Create an autonomous drone
- Navigate all the obstacles in the obstacle course
- Avoid mine interference
- Return to starting position after navigating all obstacles
- Fly for at least 10 minutes (in standard operating conditions)

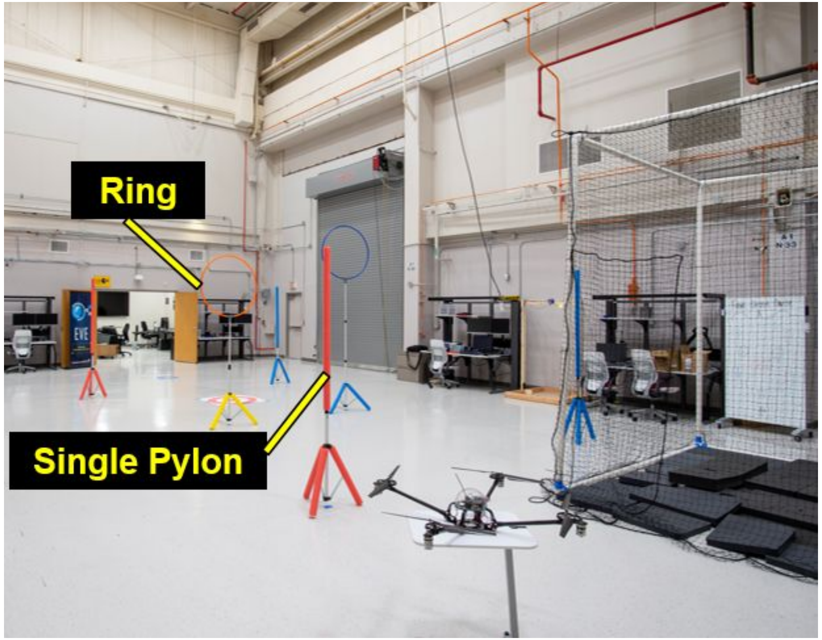


Project Motivation

- Reconnaissance or area scouting from military perspective
  - Useful to save lives of troops
- Exploration applications
  - Surveying forest regions
  - Exploring hard to reach areas of a cave system
  - Exploring tunnel systems
- Search and Rescue applications
  - lost/missing people
  - Fire search and rescue
  - Cave-ins
- Saves Money (Economical and Safe)

Project Competition Summary

- Sponsored project by Lockheed Martin
- Competition project (3 UAV teams and 1 Mine team)
- Compete to earn points
  - Ring = 1 point
  - Single Pylon = 2 points
  - Double Pylon = 3 points
  - Acoustic Waypoint = 4 points
  - Point multiplier for successful consecutive obstacle maneuvering
- Goal: Accumulate enough points to win the competition



Customer Requirements (Operational Modes)

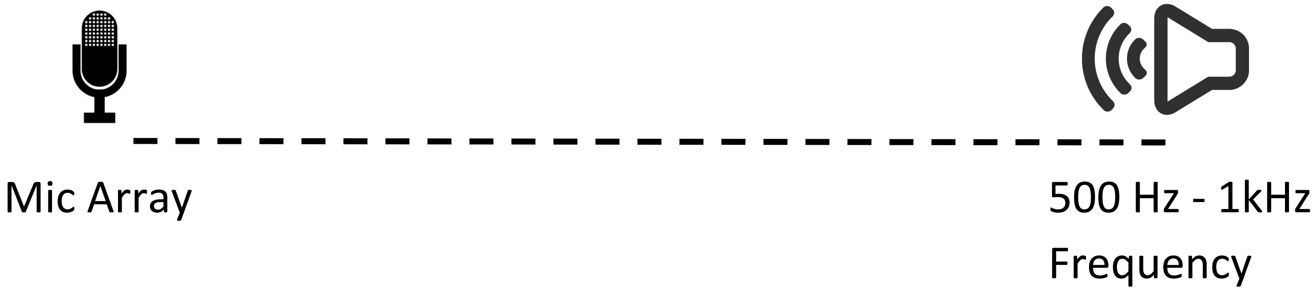
- Autonomous Mode: Autonomously Navigates an Obstacle Course
  - Auto Navigation (AutoNav) Submode: Navigate to obstacle
  - Auto Maneuver Submode: Maneuver around obstacle
  - E-Stop Submode: Immediately make a landing (safely stop UAV in case of emergency)
  - Take-off/Landing Submode: For taking-off and landing
- Manual Mode: Provides control to a human operator

Customer Requirements (Object Detection & Vision)

- Detect customer specific obstacles (Ring, Single and Double Pylons)
- Determine distance to target objects
- Determine confidence level of target object
- Mark targets with red “X” on video feed
- Calculate ETA to target object
- Detect acoustic Waypoints and land near waypoints
- Obstacle data along with live video feed
- Communicate with ground station (perform E-stop procedure; Manual Mode)
- Map course and return back to start point after end of run.

Customer Requirements (Sound Beacon Detection)

- The sound beacon will be placed at an unknown location in the competition
- Sound beacon will emit a noise within the frequency range of 500 Hz - 1 kHz



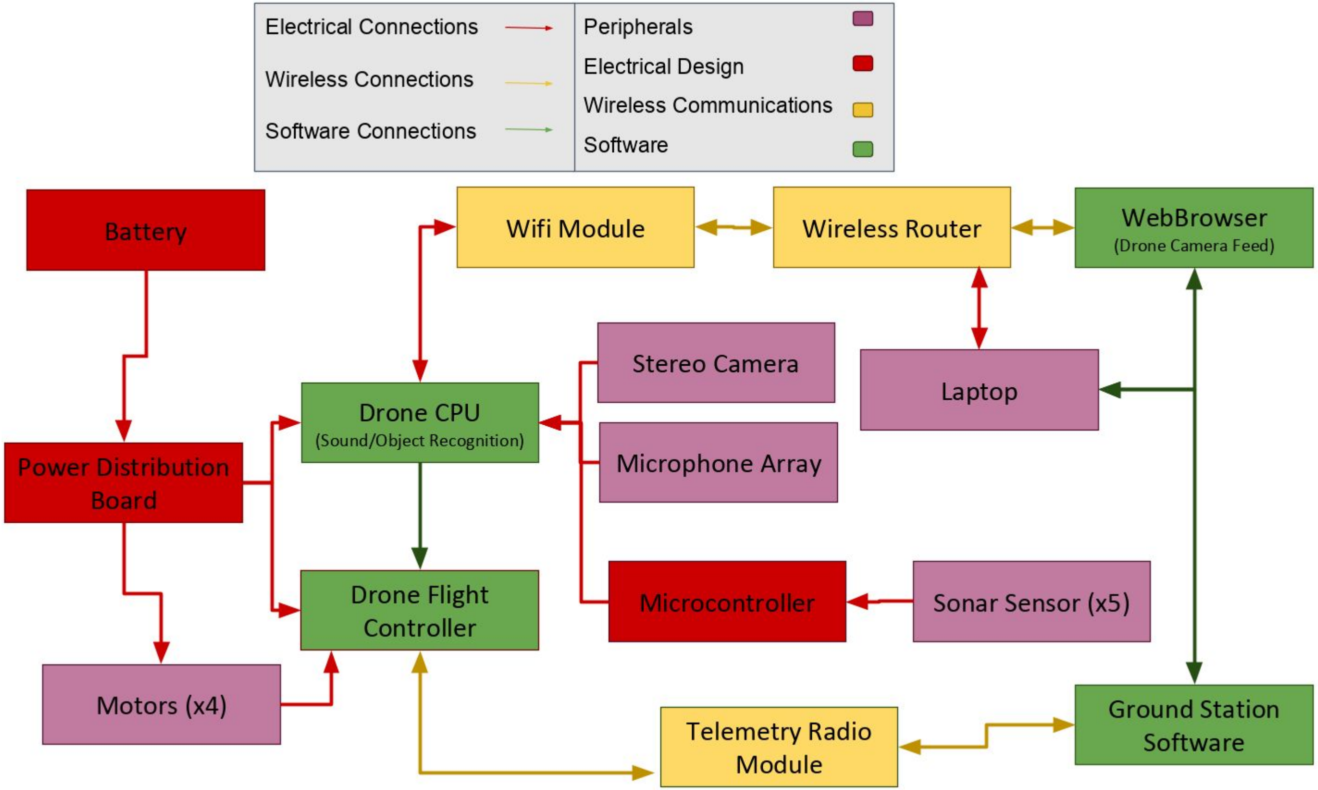
Customer Constraints

- GPS-denied navigation solution (needs to operate inside)
- Use of the YOLO vision algorithm is not allowed
- Budget: $1,650
  - $550 maximum for prototyping
  - $1100 maximum for final build
- Dimensional limits: 1.5ft x 1.5ft x 1.5ft
- Flight height limit: 45ft maximum height (to avoid ceiling collision)
- Maximum flight time: 15 minutes (for the competition)

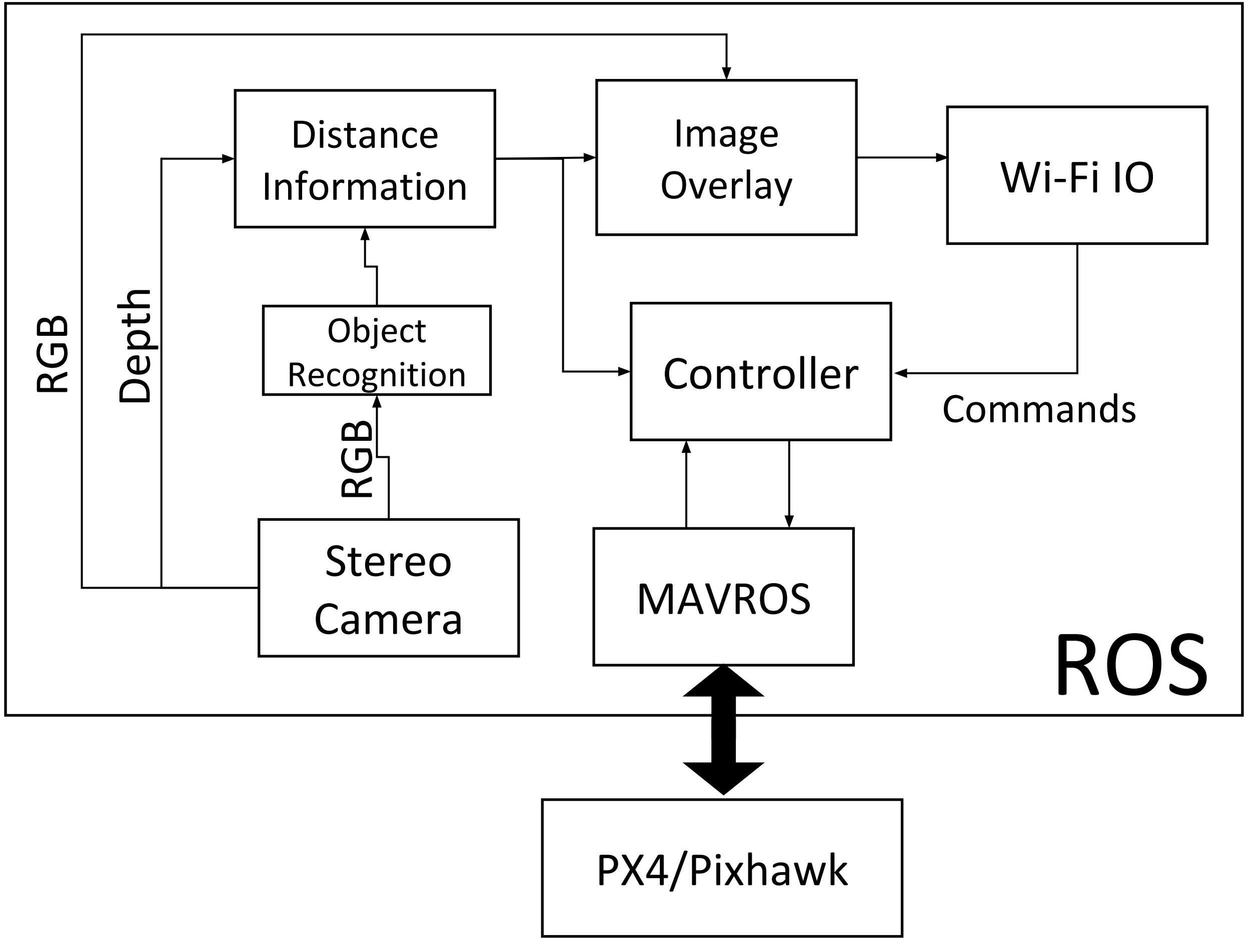
Design Overview

- A vision algorithm on the drone computer will use an RGB image from a camera to detect objects in its FOV
- A depth camera will provide depth information to determine the distance to the objects
- The drone computer using the position of the objects will determine flight path and send commands to the flight controller in charge of managing motor speed
- The drone computer will send a video stream overlaid with information on obstacles in view to the ground station via a WiFi connection
- The ground station will be able to send commands to change mode or direct drone flight via a WiFi connection

Project Diagram



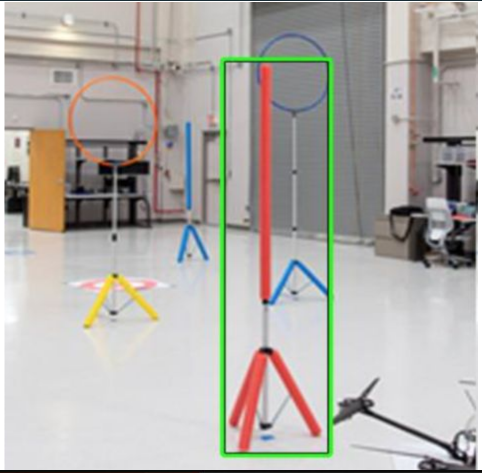
Drone Software Diagram

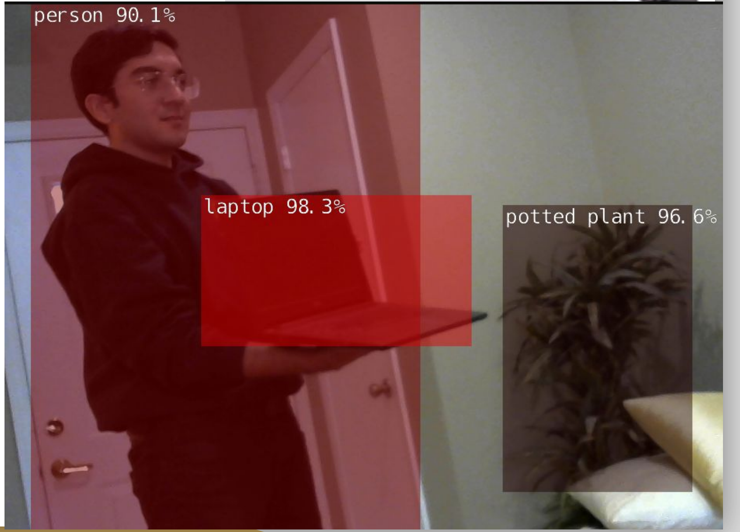


Obstacle Recognition

A computer object recognition algorithm running on the drone computer will take an RGB image from a computer and use this information to create bounding boxes around rings and pylons in view.

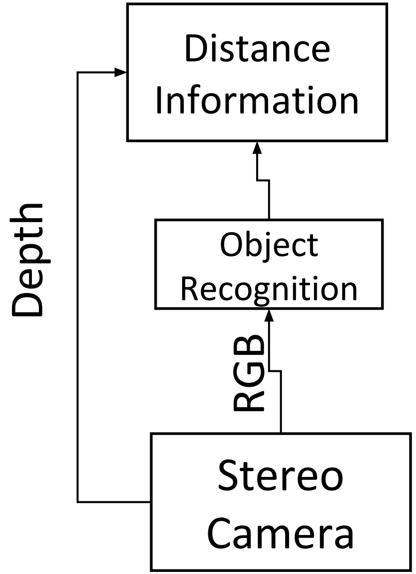
Based on benchmarks for object recognition models and software running on our hardware, we have decided to use a single shot detector (SSD).





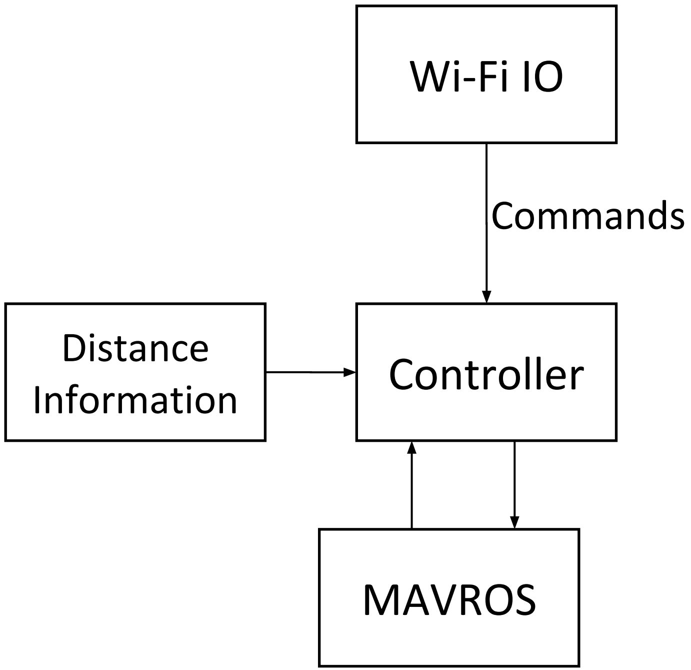
Obstacle Distance Processing

- This node is given the bounding boxes of each of the objects in the FOV of the RGB camera
- The bounding box will be translated from the RGB image to the depth image from the depth camera
- Based on the type of image, the node determines distance
- If two pylons are found to be close enough together, the drone will consider them to be a double pylon and average their positions



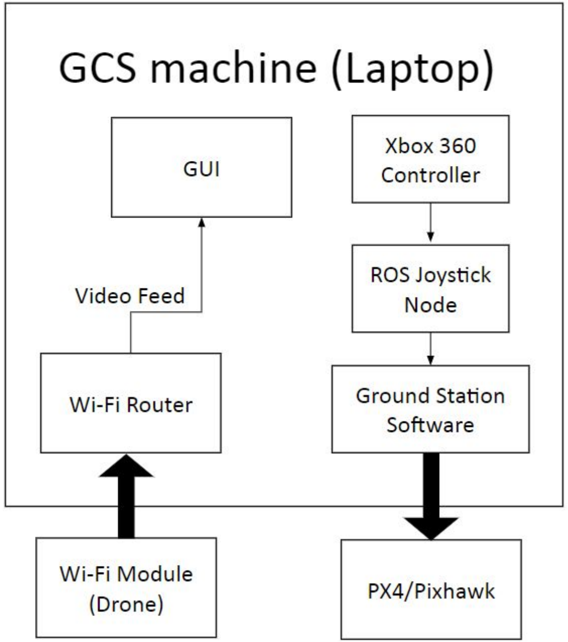
Drone Controller

- When in Autonomous Operation mode:
  - Controls what submode the drone is currently in based on received data
    - Most of the time in the AutoNav submode navigating to an obstacle
    - When positioned in front of obstacle, enters Auto Maneuver submode to navigate obstacle
    - When 0.5-1 kHz audio signal is picked up, enters Take-Off/Land submode
    - When E-Stop command is sent from ground station, enters E-Stop submode
- When in Manual Operation mode:
  - Relays flight commands received from the ground station to the flight controller via MAVROS



Ground Control Station Software

- Allows us to interact with the drone during operation.
  - View operational data, record data, manually control drone
- Drone will stream processed video over wifi
  - GCS will connect to stream over IP using a router
- Our selection choice: **QGroundControl**
  - Compatible with Windows, Mac OS, Android, and iOS
  - Supports our chosen flightstack, ArduPilot
  - Allows manual drone control via Xbox controller

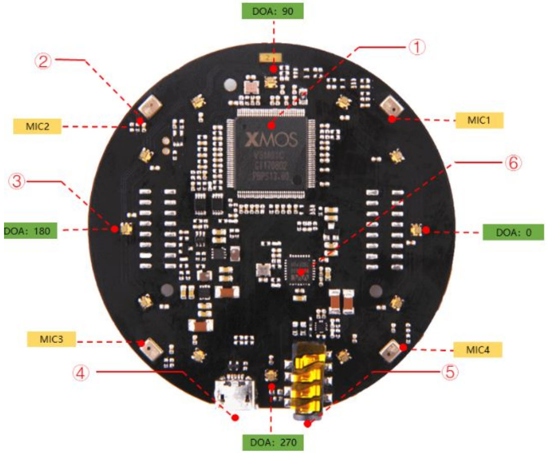


Microphone Array

Why The Seeed's ReSpeaker Mic Array v2.0:

- High quality Microphones
- Allows for Acoustic Echo Cancellation (AEC) and Direction of Arrival (DoA)
- Detects sound from 5 meters away (16.4 feet)
- Noise Filtering Parameters

Microphone	Mic Array v2.0	2-Mics Pi	4-Mics Pi
Sound Processor	XMOS-XVF3000 (stereo-AEC voice processor)	WM8960 (low power stereo codec)	X-Power AC108 ADC (x2)
Microphones	MP34DT01TR-M (x4) (digital)	MSM321A3729H 9CP (x2)(analog)	MSM321A3729H 9CP (x4)(analog)
Capture Radius	16.4 feet	10 feet	10 feet
Cost	$64.00	$9.90	$24.90



Seeed's ReSpeaker Mic Array v2.0

Flight Controller

Purpose:

- Maintain stability of the drone
- Translate user input into engine output
- Gather real-time data

ReadyToSky PixHawk Features:

- Inertial Measurement Units
- System-on-chip with backup system-on-chip
- Able to be flashed with new firmware
- Able to be controlled by an external computer
- ArduPilot Compatible

ReadyToSky Pixhawk

Flight Controller Comparison

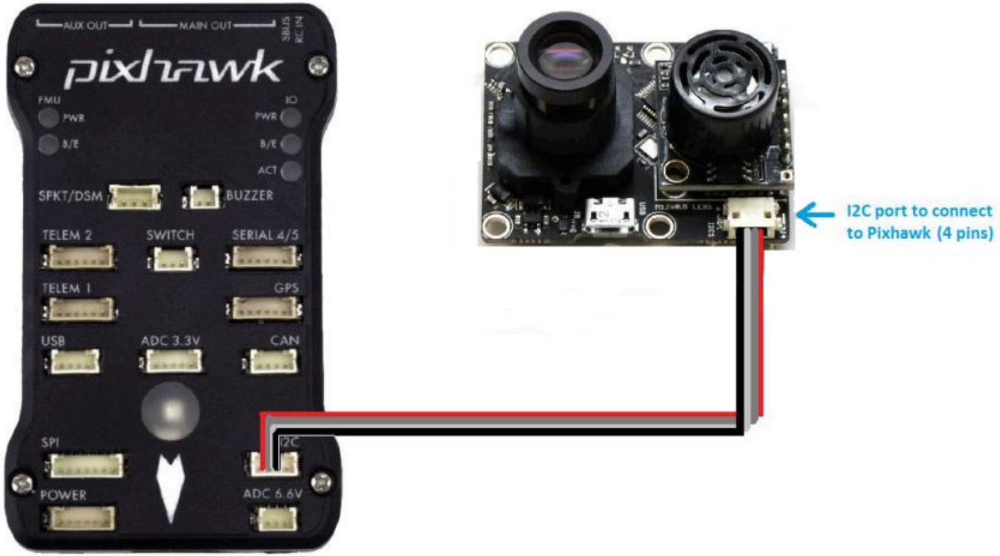
Flight Controller	HGLRC F4.V2	Readytosky Pixhawk
Processor	32-bit	32-bit
Flight Stack	BetaFlight	PX4 or Ardupilot
I2C	No	Yes
SPI	No	Yes
Price	$33.99	$72.99

Optical Flow & Height Sensor

PX4FLOW

- Provides an optical camera designed to be interfaced with the PixHawk
- Ultrasonic height sensor

- Gyroscope
- Flight controller firmware, aware of PX4FLOW
  - Determine height and groundspeed

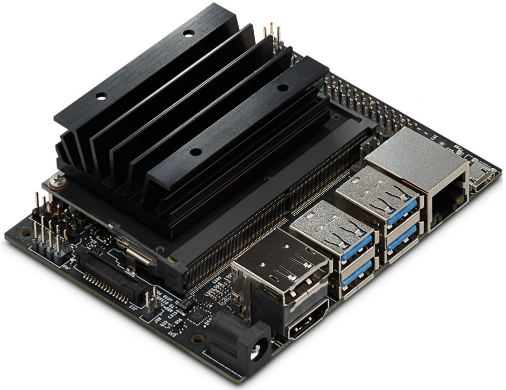


Drone Computer

Computer Requirements:

- Process images from camera to identify obstacles at a rate of at least 5 times per second
- Determine distances to objects using data from depth camera and vision algorithm
- Determine the flight path of the drone
- Send flight commands to the flight controller
- Transmit video and obstacle data to the ground station
- Receive and respond to commands from the ground station
- Support all necessary peripherals (wifi module, microcontroller, camera, microphone array, flight controller)

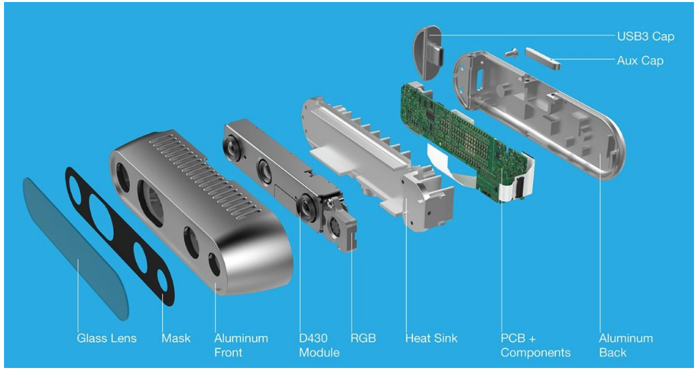
Drone CPU



Computer	Jetson Nano	Raspberry Pi 4B (4GB)
Processor	Cortex-A57 (4 cores)	Cortex-A72 (4 cores)
Clock Rate	1.42GHz	1.5GHz
Power Consumption	10 W	5 W
GPU	Maxwell (128 CUDA cores)	VideoCore VI
Weight	4.1 oz	1.6 oz
Price	$99	$55

- Large amount of computer vision resources (academic and otherwise) use Nvidia GPUs
- Nvidia provides their JetPack SDK for developing computer vision and AI applications

Depth Camera



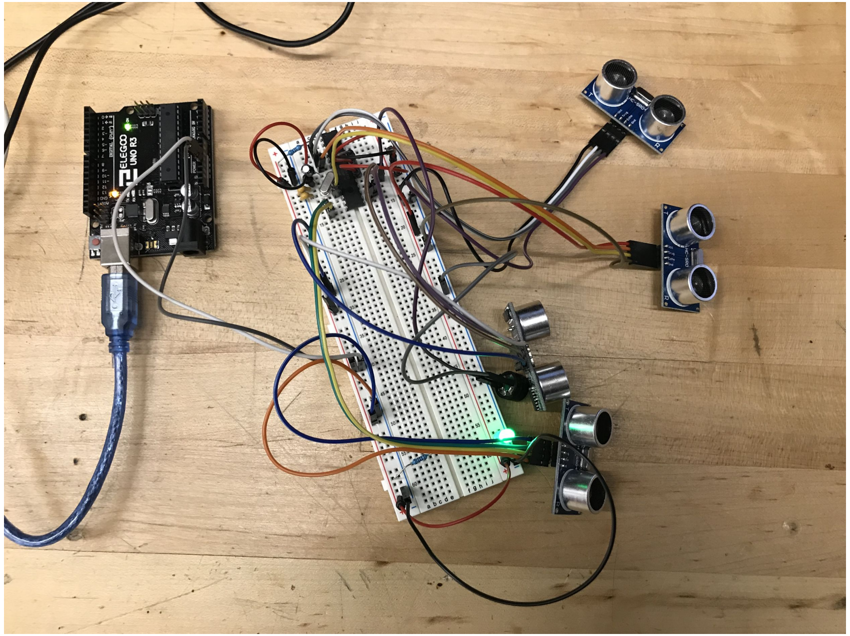
- A camera is necessary to provide a video stream for detecting objects and navigation
- The choice for a depth camera stems from the need to determine distance to the objects

Intel RealSense Depth Cameras

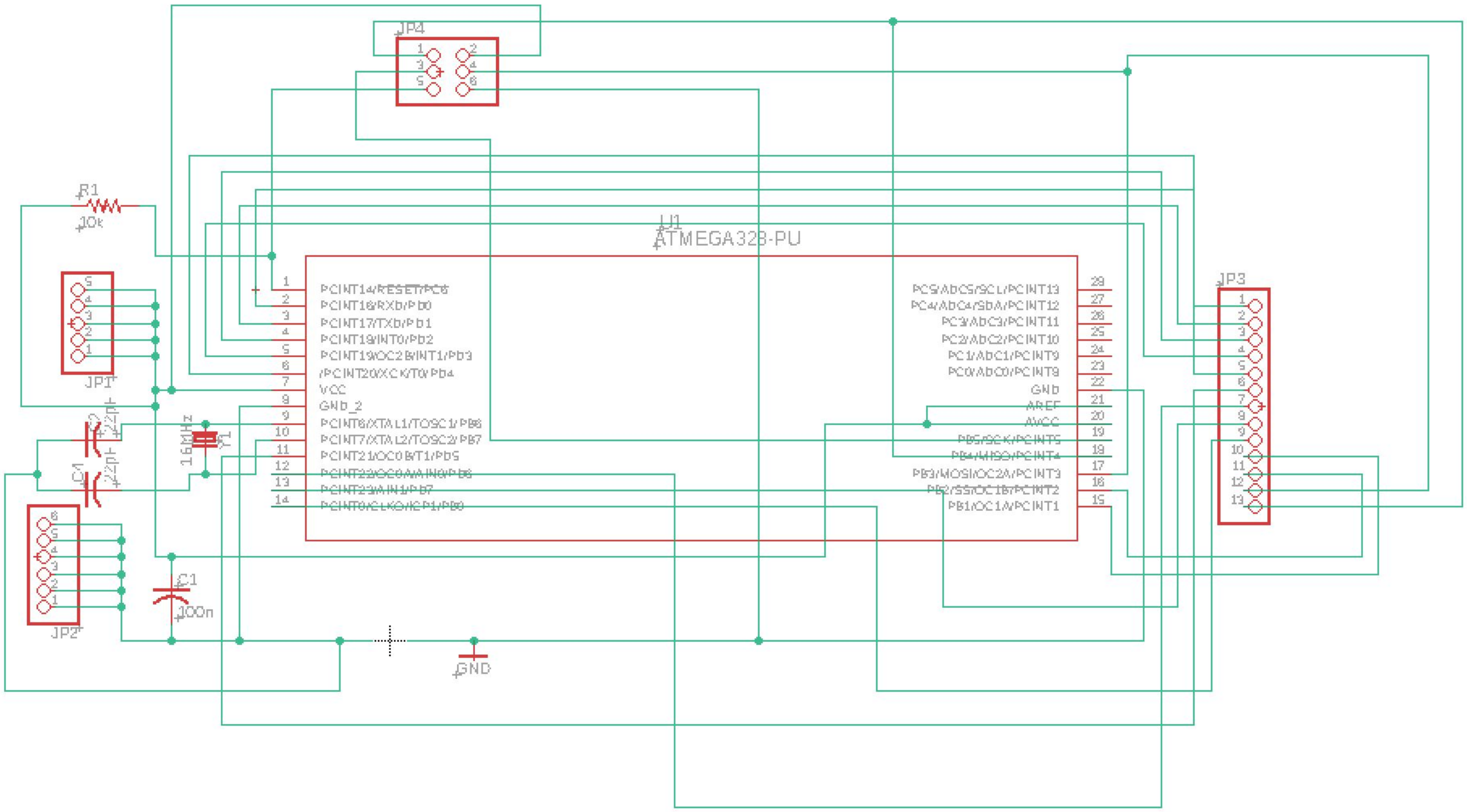
Camera	D415	D435	D435i
Depth FOV	63.4°x40.4°	85.2°x 58°	85.2°x 58°
Depth Resolution	720p @ 90fps	720p @ 90fps	720p @ 90fps
RGB FOV	70° x 42°	70° x 42°	70° x 42°
RGB Resolution	1080p @ 30 fps	1080p @ 30 fps	1080p @ 30 fps
IMU	No	No	Yes
Cost	$149	$179	$199

Hardware/PCB design

- Using an ATmega328pu to manage 5x ultrasonic sensors.
- Sensors will be placed toward the front, back, left, right, and bottom sides of the drone.
- Buzzer will indicate when drone is too close to an object.
- Proximity data will be relayed back to the Jetson Nano and used to assist autonomous flight.



Hardware/PCB design



Component Power Draw

Component	Voltage	Current	Power
Jetson Nano	5V	2-4A	10-20W
Intel RealSense Depth Camera	1.8V	83mA	150mW
Readytosky PixHawk	0.3-3V	0.83-8.3A	0.249-24.9W
Cobra CM-2206/17 2400kV Motors	6-8V	0.97-1.06A	5.82-8.48W
Cobra MR30 ESC	8-25V	30A	240W
PX4Flow Height and Ground Speed Sensor	5V	115mA	0.575W
Speed's ReSpeaker Mic Array v2.0	5V	180mA	0.9W
PCB with Distance/Proximity Sensors	5V	1mA	5mW

Motors

Cobra CM-2206-17 Motor Test Data, Kv=2400

Data Collected at 14.8 volts with HQ 5x4 Prop						
Throttle Setting	Motor Amps	Input Watts	Prop RPM	Thrust (Grams)	Thrust (Ounces)	Efficiency Grams/W
10%	0.64	9.46	6,756	49.9	1.76	5.28
20%	1.47	21.70	10,228	117.6	4.15	5.42
30%	2.62	38.70	13,038	192.1	6.78	4.96
40%	3.82	56.55	15,223	263.8	9.31	4.66
50%	5.07	75.07	17,084	332.8	11.74	4.43
60%	6.61	97.77	18,970	411.0	14.50	4.20
70%	8.75	129.44	21,200	512.2	18.07	3.96
80%	11.77	174.12	23,768	638.7	22.53	3.67
90%	15.59	230.70	26,185	779.3	27.49	3.38
100%	20.80	307.80	29,016	969.4	34.19	3.15

Prop Manf.	Prop Size	Li-Po Cells	Input Voltage	Motor Amps	Input Watts	Prop RPM	Pitch Speed in MPH	Thrust Grams	Thrust Ounces	Thrust Eff. Grams/W
HQ	4x4	4	14.8	15.29	226.3	30,758	116.5	650.9	22.96	2.88
HQ	4x4x3	4	14.8	19.18	283.9	29,469	111.6	776.5	27.39	2.73
HQ	4x4.5	4	14.8	11.62	172.0	31,938	136.1	475.0	16.75	2.76
HQ	4x4.5-BN	4	14.8	21.43	317.1	28,782	122.7	780.6	27.53	2.46
HQ	5x3	4	14.8	14.99	221.9	30,998	88.1	757.0	26.70	3.41
HQ	5x4	4	14.8	20.80	307.8	29,016	109.9	969.4	34.19	3.15
HQ	5x4x3	4	14.8	27.23	403.0	27,052	102.5	1146.8	40.45	2.85
HQ	5x4.5	4	14.8	23.17	342.9	28,320	120.7	978.2	34.50	2.85
HQ	6x3	4	14.8	22.46	332.5	28,513	81.0	1118.0	39.44	3.36

Cobra CM-2206/17 2400 kV

Approx diameter	Prop Size	Recommended stator size	Lowest kv	Highest kv
150-250mm	4”	1806	2600	2800
190-220mm	5”	2204-2206	2300	2600
220-270mm	6”	2204-2208	1960	2300
350mm	7”	2206-2210	1450	1600

Electronic Speed Controllers

- ESC and motor are a combination package and are directly compatible with each other.
- 30A maximum current draw
  - the 5x4 propellers draw 20A at max throttle
  - the 5x3 propellers draw 15A at max throttle

Batteries

Battery	Venom Fly	Dynamite Reaction	Tattu
Capacity (mAh)	3200	5000	10000
Voltage (V)	14.8	11.1	22.2
Discharge Rate (C)	30	50	25
No. Cells (S)	4	3	6
Weight (g)	330	204	1400
Price (USD)	59.99	74.49	185.00

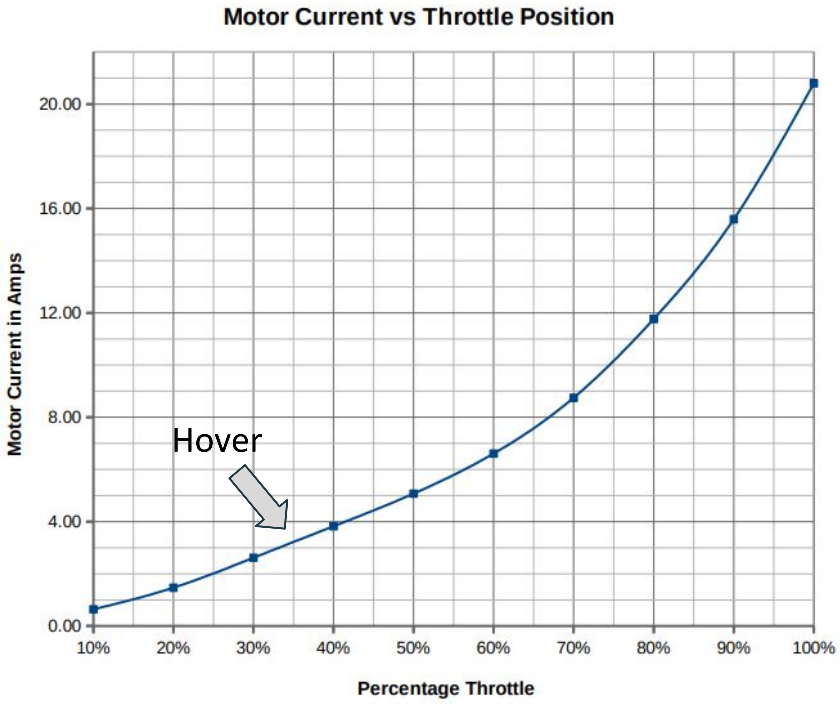
Power Supply

Max Current Draw Allowed :

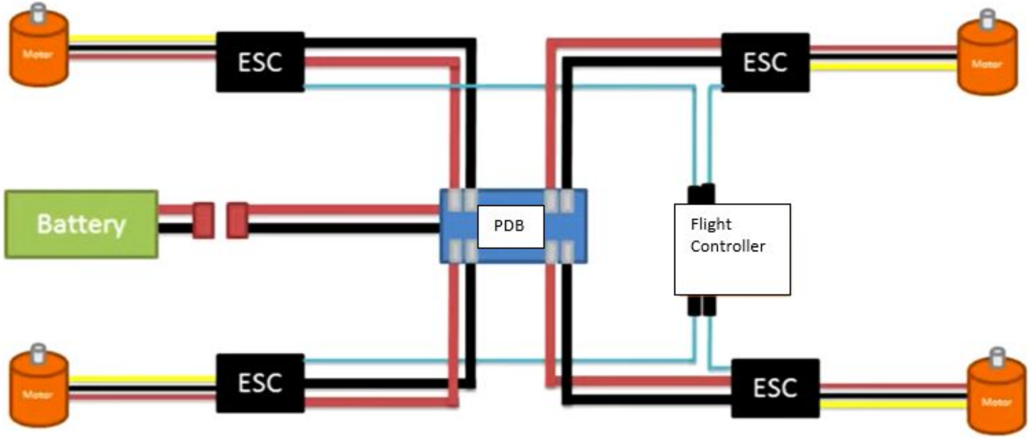
Capacity x C-Rating = 3.2 x 30 = 96A

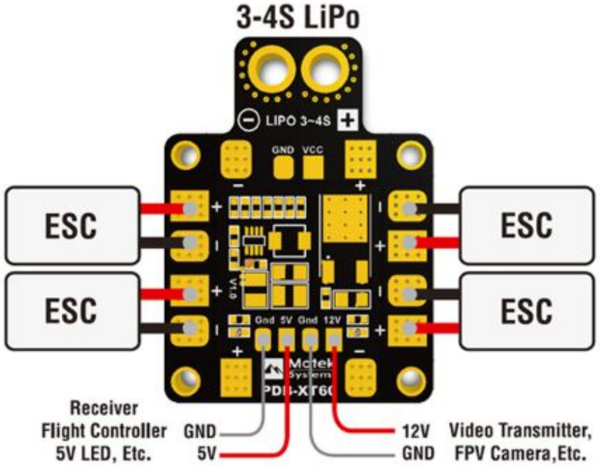
Flight Time for 85% Discharge :

$$\frac{(mah\ Battery/1000)\ x\ (.85)}{(21\ Average\ Amps)}(60)\ =\ 7.7\ minutes$$

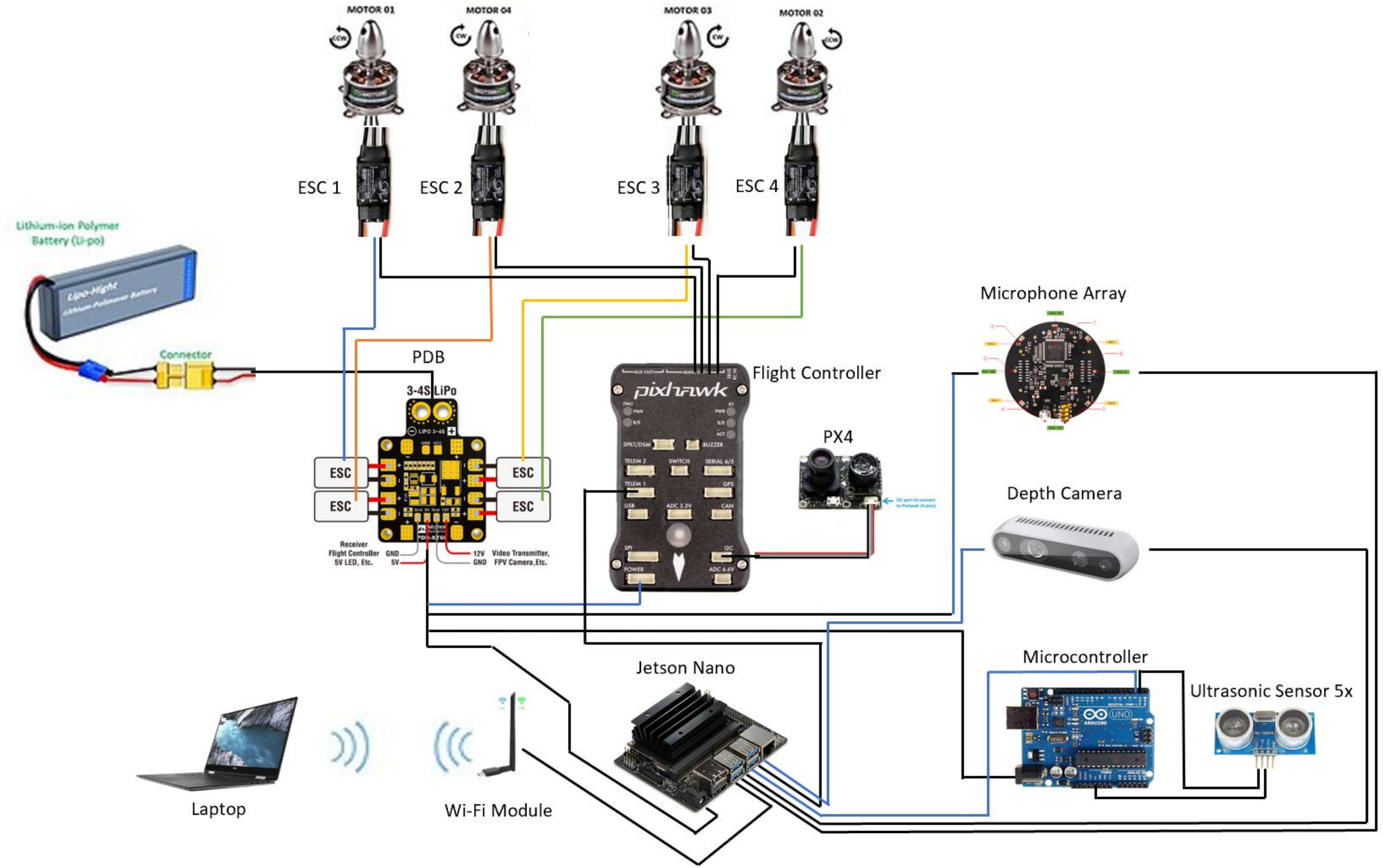


Power Distribution Board



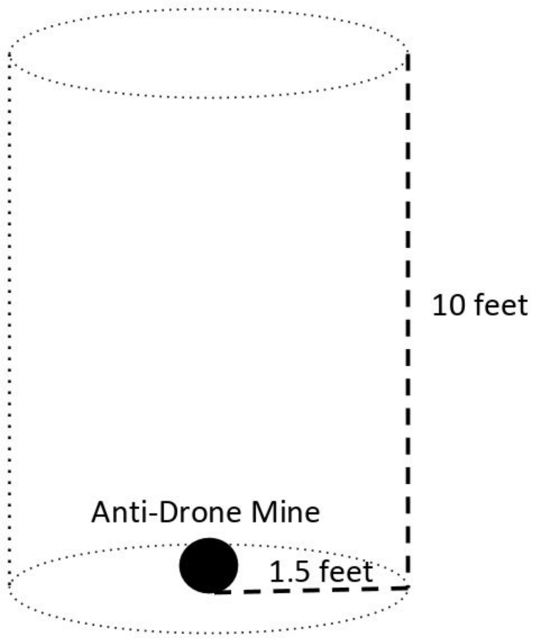


Component Connection Overview



Mine Avoidance

- Software Solutions
  - Use computer vision to detect mine (if it appears in field of view)
  - Compare drone distance to ground measurements using different sensors (barometer and ultrasonic) to avoid mine
  - If mine is detected, drone altitude increases past blast radius
- Hardware Solutions
  - Lightweight mesh to deflect projectiles
  - Propeller guards



Administrative Content

Division of Work

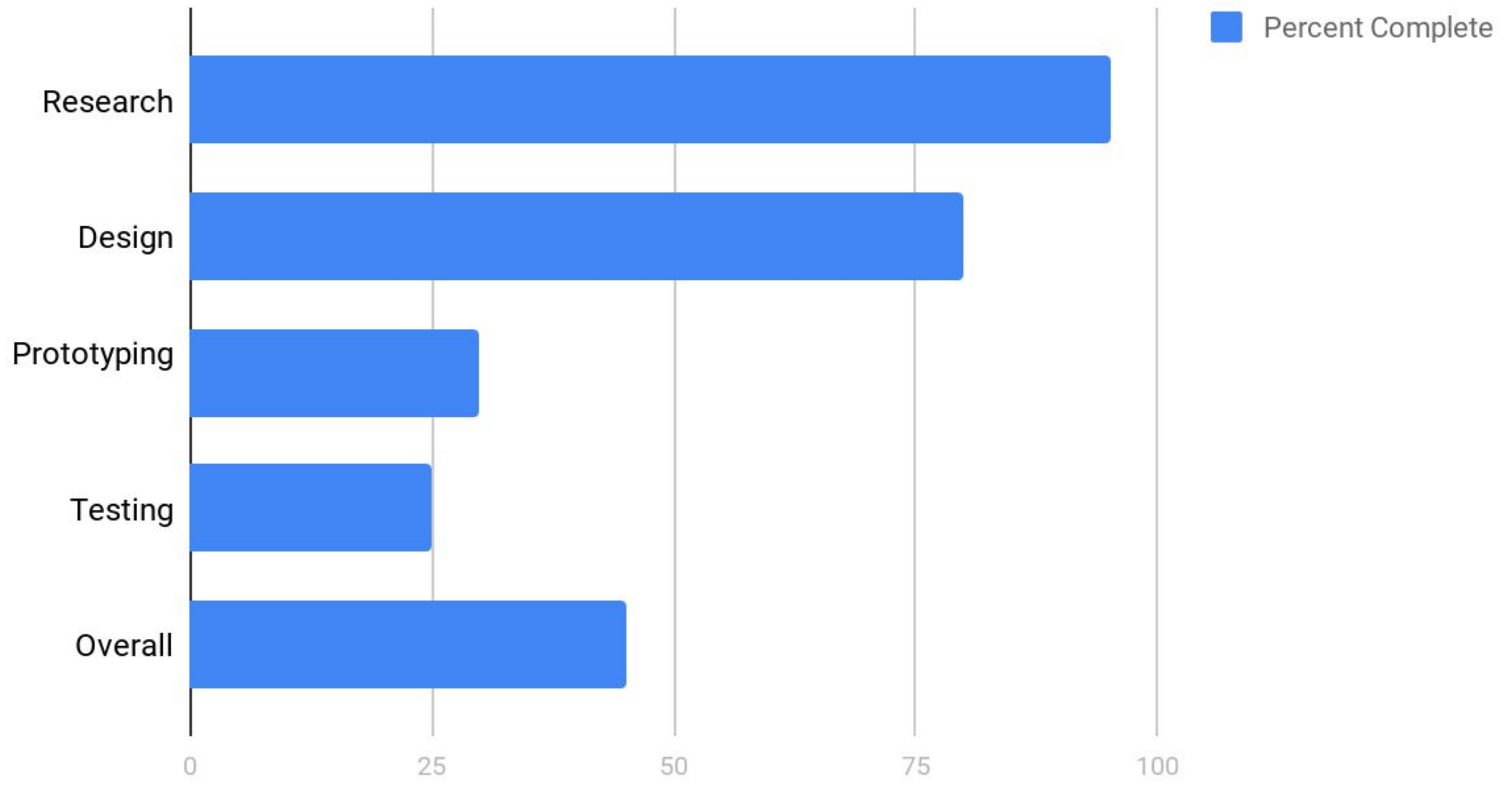
Electrical and Computer Engineering	**Mechanical and Aerospace Engineering**
• Ground Station Communication • CPU Integration • Object Recognition and Mapping Algorithm • Sound Recognition and Filtering • Data Processing • Power System • PCB/Microcontroller Development • Sensors	• Drone Frame Design • Sensor Mounts • Flight Controller • Electronic Speed Controllers • Motors • Propellers • Balancing

Division of Responsibilities

Component	**Responsibility**	**Assist**
Object recognition and mapping	Caleb	Hamza
Wireless communication, noise filtering, ground station data transfer	Hamza	Caleb
Power system, PDB, battery	Ryan	Rishi
PCB, Microcontroller, sensors	Rishi	Ryan

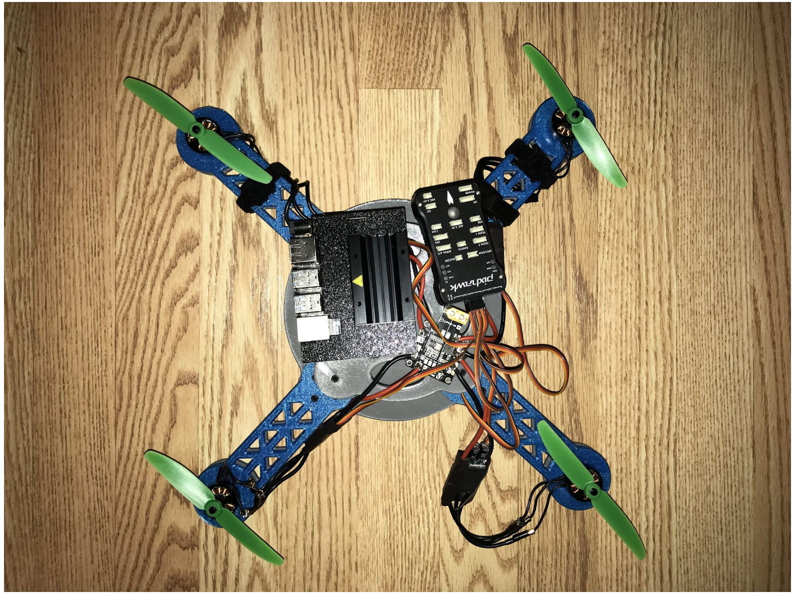
Component	Name	Unit Cost	Quantity	Cost
Jetson Power Cable	Adafruit 5V 4A Supply	$14.95	1	$14.95
Battery	Venom 4s 30c 3200mah14.8V LiPo battery	$59.99	1	$59.99
Drone Wifi Module	Geekworm NVIDIA Jetson Nano Wi-Fi Adapter	$16.79	1	$16.79
Companion Computer	NVIDIA Jetson Nano Developer Kit	$99.00	1	$99.00
Power Distribution Board	PDB XT60 Matek Power Distribution Board	$8.49	1	$8.49
ESCs	Cobra 30A Opto Multirotor ESC	$27.99	4	$111.96
Propellers	HQ Prop 5x3 Propellor (Black) (2) normal rotation	$0.49	2	$0.98
Propellers	HQ Prop 5x3 Propellor (Black) (2) reverse rotation	$0.49	2	$0.98
Motors	CM-2206/17-V2 MULTIROTOR MOTOR KV=2400	$22.99	4	$91.96
Standoffs	M3 Normal Standoff (1PC) - 35mm	$0.75	4	$3.00
Nuts & Bolts	M3 Black Steel 280 Piece Nut & Bolt Kit	$9.99	1	$9.99
Microphone	ReSpeaker Mic Array v2.0	$64.00	1	$64.00
Mounting Tape	Double Sided Tape	$6.74	1	$6.74
Cable Ties	Reusable Cable Ties	$3.99	1	$3.99
Power Connection	9V battery clip	$5.99	1	$5.99
SD Card	MicoSDXC	$19.49	1	$19.49
Depth Camera	Intel RealSense D435	$177	1	$177.00
Shipping and International Fees		$34.20	1	$34.20
			Total:	$729.50
			Remaining:	$920.50

Project Progress



Current and Potential Roadblocks

- Delays in shipping
- Defective parts on arrival
- Limited testing days at competition venue
- Damage from testing
- Model training



Plans Going Forward

Our goals are based on various milestones throughout the semester.

- 1st Competition Practice Run @ Lockheed Martin - Feb 14, 2020
- 2nd Competition Practice Run @ Lockheed Martin - Mar 13, 2020
- Midterm Demo @ UCF - Mar 17, 2020 - Mar 19, 2020
- Final Competition @ Lockheed Martin - Apr 9, 2020
- Final Project Presentation @ Lockheed Martin - Apr 10, 2020
- Final Project Presentation @ UCF - Apr 13, 2020 - Apr 16, 2020
- Senior Design Showcase @ UCF - Apr 17, 2020
- Final Documentation Due - Apr 21, 2020

Questions?