# Lockheed Martin Autonomous Drone

# Group 4


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- Other Interdisciplinary Teams

# What is a RoboCopter?

- Autonomously search for other “enemy” drones
- Intentionally collide with them in a game-like environment to score points.
- Allow us to take out existing drone threats before they become a problem.
- Explore object detection algorithms and how they can be used within military applications.
- Deploy drones to save human lives in threatening conditions.

# Project Goals

- - Maneuverable and durable, system
- - Continuous flight for at least 10 minutes.
- - Object Detection Algorithms
- - Drone must return to its starting point within the playing field.
- - Live stream, wifi-based, camera mode
- - Coordinate a variety of sensors to determine when a collision has occurred.
- - Recover quickly from head-on collisions with enemy drones or other obstacles.
- - Autonomous flight path to navigate among obstacles with minimal collisions.

# Measurable Specifications

| | |
|---|---|
| 1.0 | The quadcopter must not fly beyond the 30ft x 30ft x 30ft field. |
| 1.1 | The quadcopter must support at least at least 2 pounds of electronics. |
| 1.2 | The quadcopter must fly at least 10 miles per hour. |
| 1.3 | The quadcopter must fit within a 4 ft x 4 ft x 4ft box, including the dimensions of the cage. |
| 1.4 | The quadcopter must include a processor that is at least 400 MHz and quad-core, in order to effectively use the object detection algorithms. |
| 1.5 | The power supply must support voltages in the range of 11 volts to 14 volts. |
| 1.6 | The printed circuit board must be capable of delivering 3 to 5 Volts. |

# Rough Budget - 2000$ Total

1. Pixhawk - $240
2. DJI Flame Wheel Kit - $300
3. PCB - $50
4. TX2 - $300
5. Custom Drone - $700
6. Sensors - $50
7. Batteries - $300
8. Last Minute Repairs - $60

# Weekly Progress

- PCB parts are on their way.
- All parts have arrived, except for the TX2 chip.
- Decided that TX2 suits our needs better for neural network detection than Raspberry Pi.
- Ensured compatibility between batteries and converters.
- Almost a finalized custom drone design from Mechanical and Aerospace Teams.
- Test Drone has successfully taken flight.
- Weekly meetings, Weekend meetings, all coming together for the success of this project.

# Flight Controller Software - Ardupilot

- Open-source flight control software which runs on the Pixhawk
- Allows for autonomous flight and waypoint navigation
- Well tested and documented
- Allows the drone to work outdoors and during bad weather conditions

# DroneKit

- Open-source software development framework which allows developers to get info about vehicle state, guide the vehicle to a specific destination or program a mission
- Python scripts are loaded on to a companion computer such as a Raspberry Pi 3
- Developers can create object detection and path planning applications which require a lot of processing power
- Raspberry Pi 3 and Pixhawk transfer messages using a communication protocol called MAVLink

# Overview

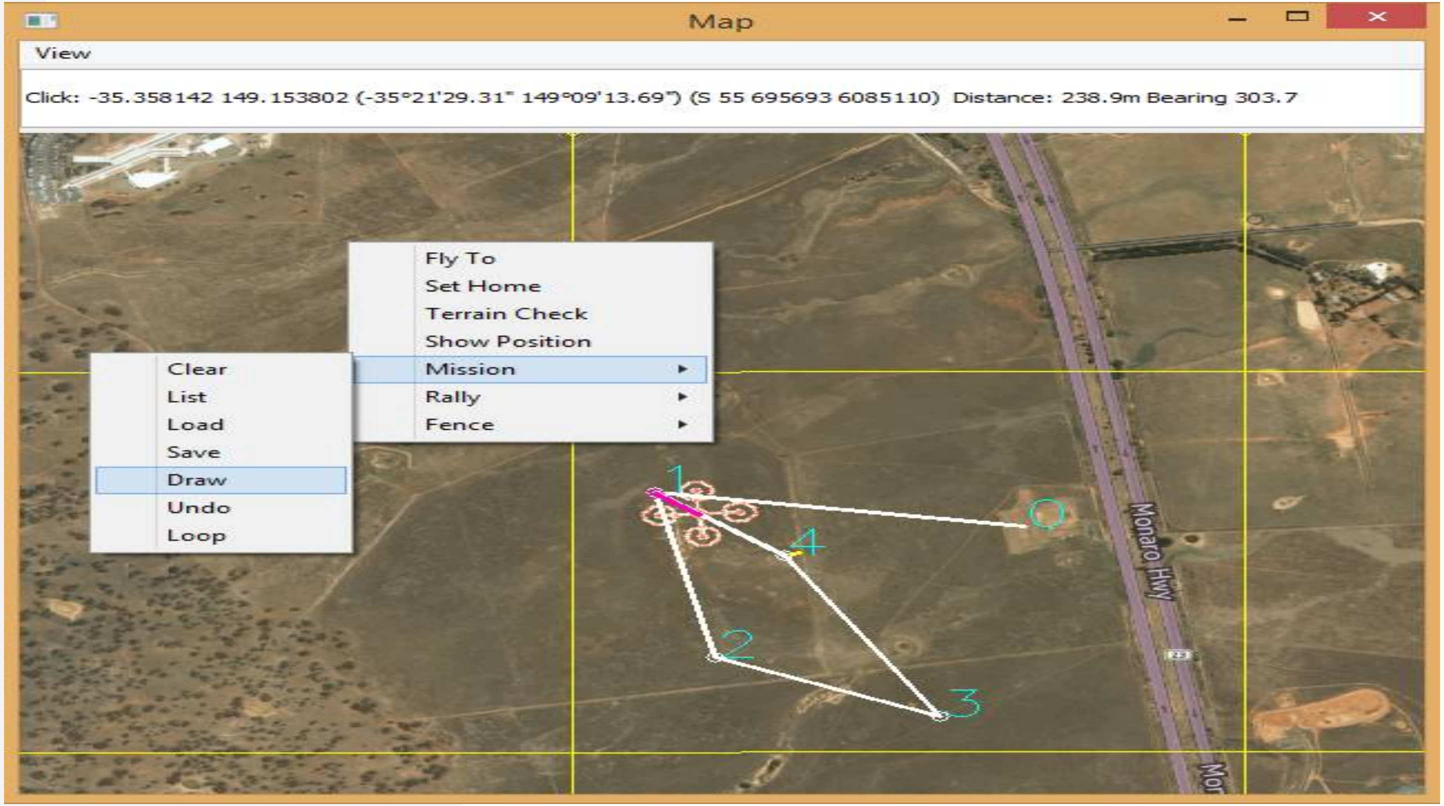
- Ardupilot running on Pixhawk calibrates the machine, controls the motors, stabilizes flight, and transfers sensor data

- DroneKit running on the Raspberry Pi 3 analyzes sensor and image data and changes the path of the drone accordingly

# Simulation - DroneKit SITL

- Ardupilot code is loaded on a PC and there is no need for a flight controller
- Provides a testing environment for quadcopter flight patterns and missions
- Environmental conditions and failure of units can be simulated
- A Ground Control Application can be connected so it’s easier to visualize the simulated commands

# Simulation - DroneKit Software In the Loop(SITL)



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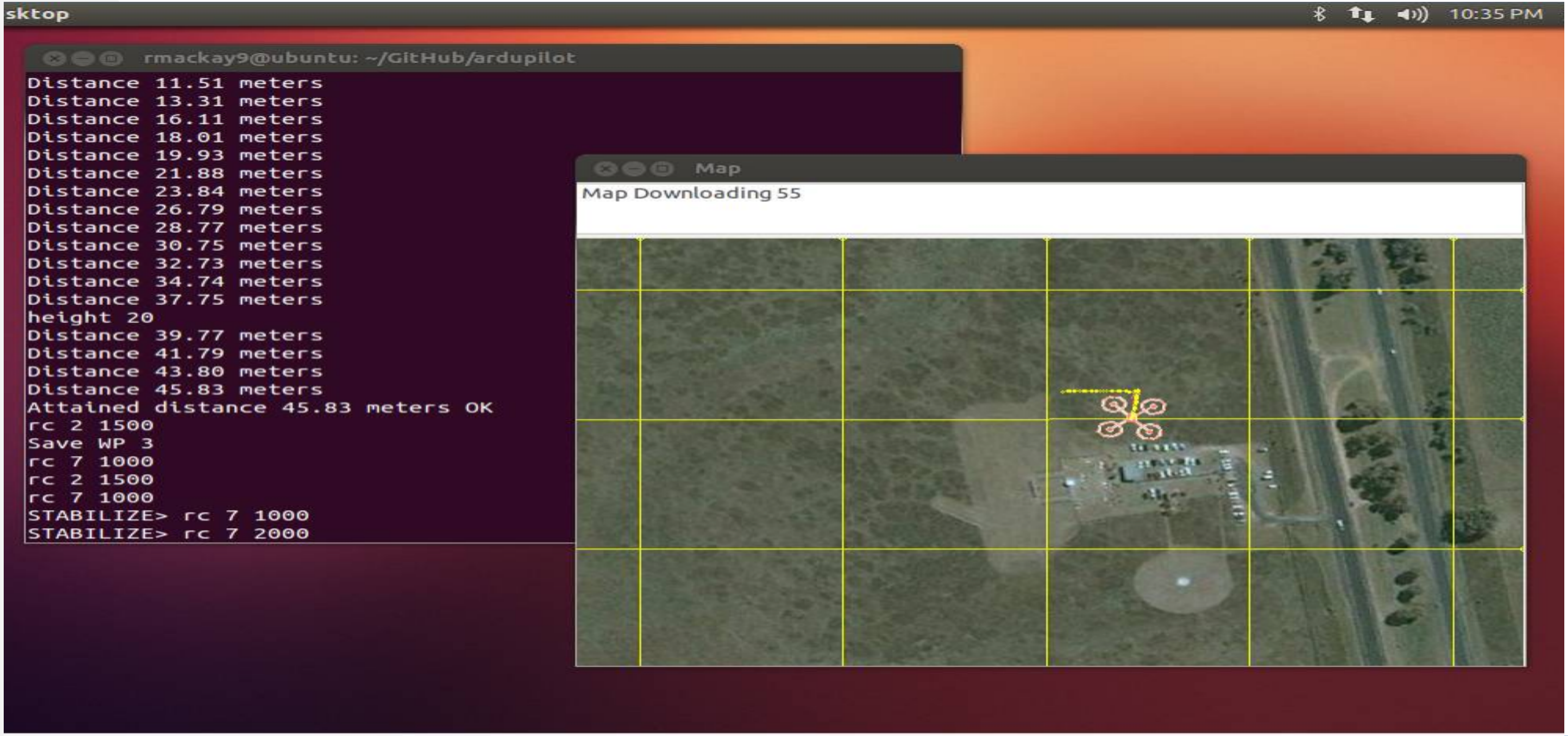


# Autonomous Flight Software Strategies

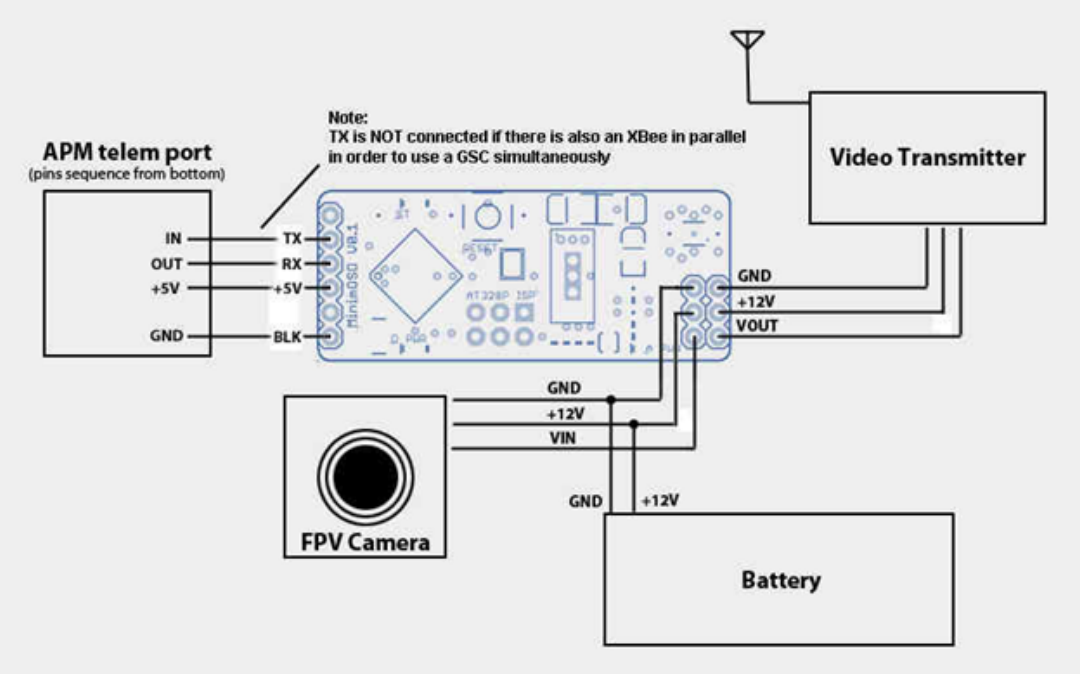
- *Search mode* options:
  - Circle outer perimeter and slowly move inwards
  - Travel in irregular patterns such as a combination of zigzag, straight, and circular
  - Hover in one position for a specific amount of time to increase chances of detecting an enemy drone flying by
  - Start scanning at a higher altitude, then lower altitude when enemy has been detected; this solution helps the drone scan more of the surroundings at once
- *Pursue mode* options:
  - Increase acceleration of drone when an enemy has been detected
  - Tap an enemy drone once and move on to pursue other enemy drones
  - An alternative option is to follow the target after tapping once for 10 seconds and then tap again

# Live Feed

- Mounted Camera with pivoted support
- On Screen Display (OSD) for displaying telemetry from the flight controller
- Used in conjunction with detecting and tracking algorithms to display targeting overlays

# On Screen Display (OSD)

- Minim OSD
- Altitude, flight time, battery life, etc.
- Via Telemetry
- DF13 6-pin
- Video transmitter / receiver or WIFI



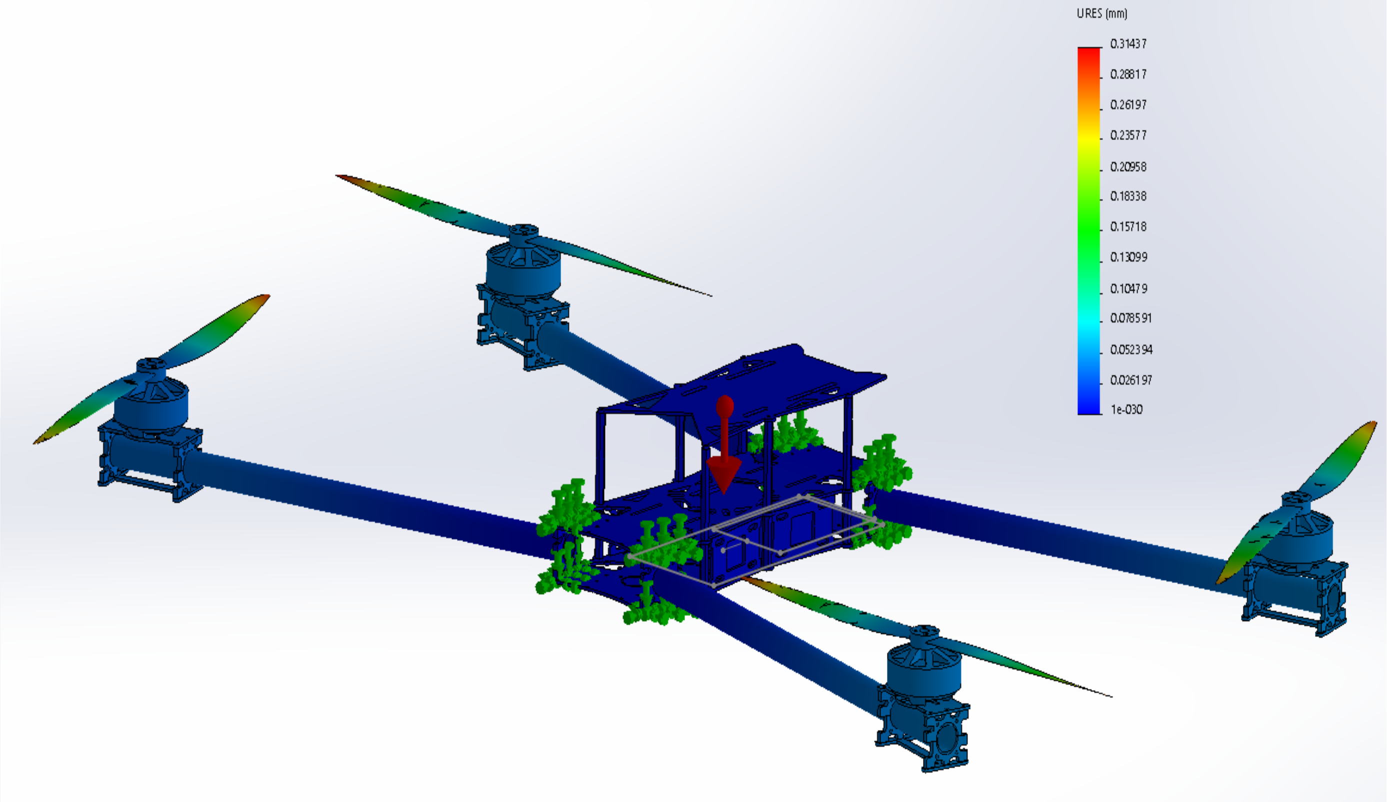
# OSD Specifications

| Specs | Minim OSD v1.1 | Micro Minim OSD v1.1 | Skylark Tiny OSD III Board | Betaflight OSD | Hobbyking E-OSD | RedRotor RROSD Mini PDB | Matek HUBOSD |
|---|---|---|---|---|---|---|---|
| Dimensions | 58 x 18 x 8mm | 15 x 15mm | 41 x 24 x 11mm | N/A | 34 x 17 x 4mm | 36 x 36mm | 51 x 36 x 4mm |
| Weight | 9g | 1.2g | 22.5g | N/A | 3.3g | N/A | 4g |
| Input Voltage | 5v – 12v | 5v – 12v | 7.4v – 12v | N/A | 7.2v – 12v | 12v | 8v – 21v |
| Cost | ~$12.30 | ~$7.00-$14.00 | ~$48.00 | N/A | ~$15.00 | ~$25.00 | ~$19.00 |

# Pi Camera Module

- IMX219 8-megapixel sensor
- Easily compatible via a 15cm ribbon cable to a camera serial interface port
- MMAL and V4L APIs
- Picamera Python Library and other third party libraries

# Mechanical / Aerospace



# Protective Cage

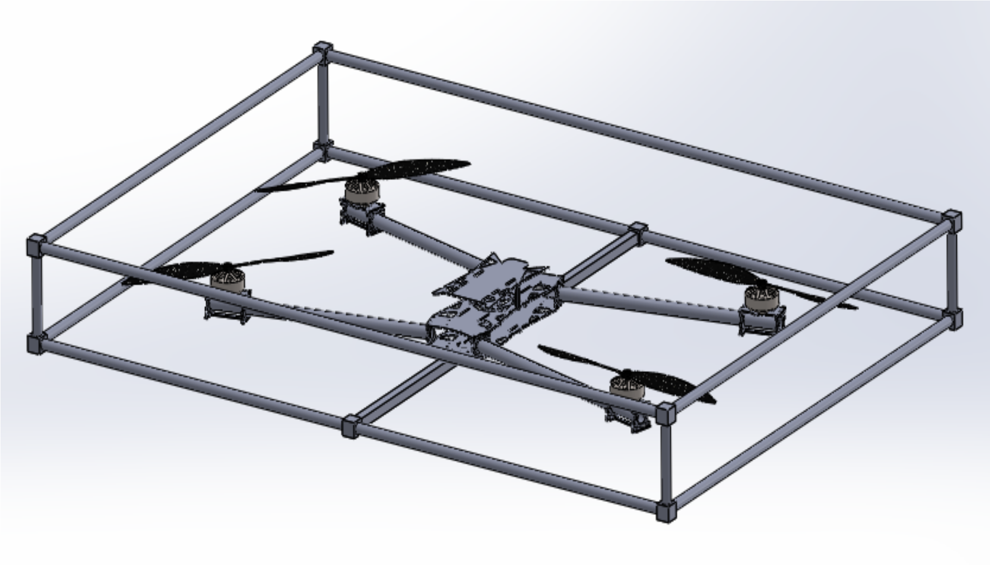
Shape: Cuboid

Weight: 0.674 kg

Volume: 0.21 m^3

Materials:

- Clear Polycarbonate
- Carbon Fiber
- Zip Ties
- Velcro Ties



# Propeller Selection

- Xoar PJP-T 1245
- Matches propeller/motor combination
- Large diameter
- Large pitch ratio with varying angle of attack of airfoils
- Rounded tip
- Carbon Fiber

# Motor Selection

- A motor able to produce plenty of torque was necessary to turn the 12 inch diameter propellers
- The relatively low KV indicates high torque
- KV = RPM / Voltage
- Motor efficiency is 78.9% when producing a thrust of 1kg, which results in an acceptable power draw

| | |
|---|---|
| KV: | 550 KV |
| Stator Diameter: | 40mm |
| Stator Thickness: | 10mm |
| Rm: | 0.054 Ohms |
| Io: | 1.25 Amps |
| Mass: | 124 grams |

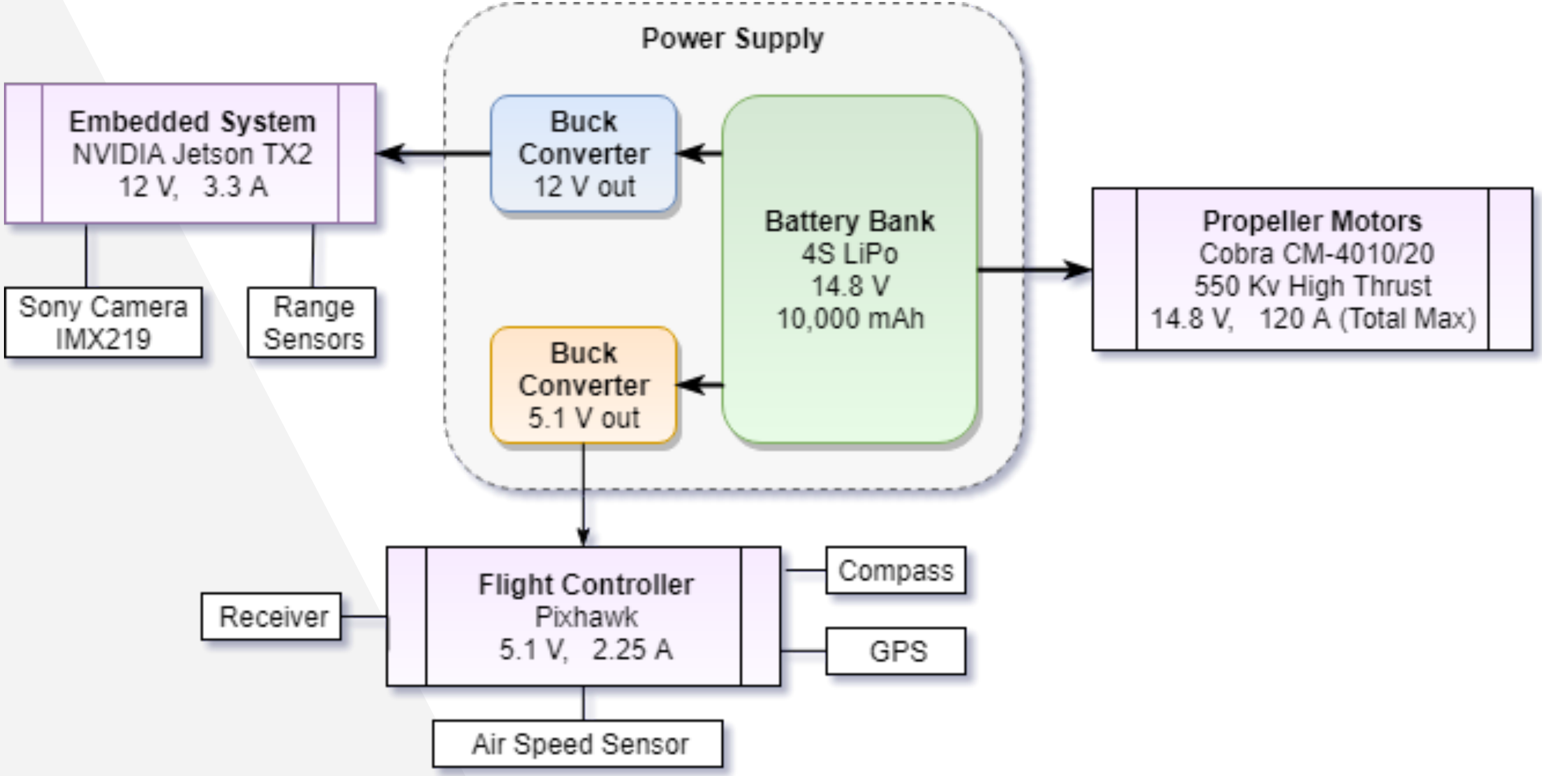
$$e_{motor} := \frac{Power - R_m \cdot I^2 - V \cdot I_o}{Power}$$

# Motor / Propeller Output

## Cobra CM-4010/20 Motor Test Data, Kv=550

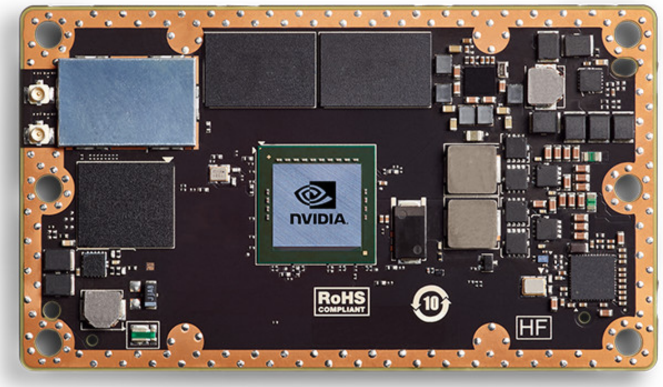
| Data Collected at 22.2 volts with APC 12x4.5-MR Prop | | | | | | |
|---|---|---|---|---|---|---|
| Throttle Setting | Motor Amps | Input Watts | Prop RPM | Thrust (Grams) | Thrust (Ounces) | Efficiency Grams/W |
| 10% | 0.33 | 7.35 | 1,889 | 85.2 | 3.01 | 11.59 |
| 20% | 0.85 | 18.83 | 2,928 | 205.6 | 7.25 | 10.92 |
| 30% | 1.56 | 34.54 | 3,757 | 347.4 | 12.25 | 10.06 |
| 40% | 2.99 | 66.42 | 4,817 | 595.9 | 21.02 | 8.97 |
| 50% | 5.50 | 121.99 | 5,948 | 951.4 | 33.56 | 7.80 |
| 60% | 8.75 | 194.25 | 6,950 | 1329.7 | 46.90 | 6.85 |
| 70% | 12.89 | 286.11 | 7,859 | 1737.6 | 61.29 | 6.07 |
| 80% | 17.88 | 396.96 | 8,678 | 2161.8 | 76.25 | 5.45 |
| 90% | 24.18 | 536.75 | 9,461 | 2629.1 | 92.74 | 4.90 |
| 100% | 28.32 | 628.79 | 9,918 | 2883.7 | 101.72 | 4.59 |

# Hardware Block Diagram



# Embedded System - NVIDIA Jetson TX2

- Will handle all processing of sensor and camera data
- Will utilize machine learning to identify prey drones
- Will run autonomous flight program which controls the drone motors

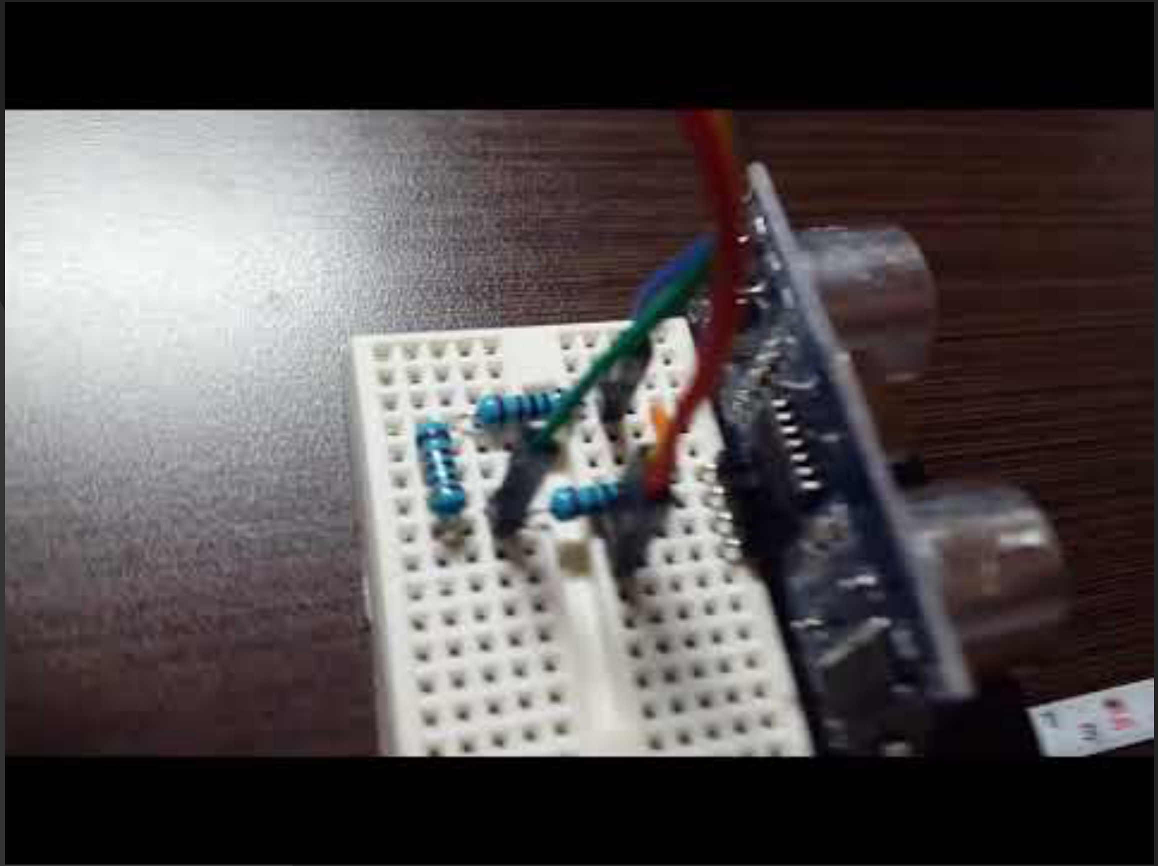


# Why the NVIDIA Jetson TX2

| System | NVIDIA Jetson TX2 | Rasp. Pi 3 | BeagleBoard |
|---|---|---|---|
| **CPU** | Dual Denver + Quad ARM | ARM Cortex-A53 | ARM Cortex A-8 |
| **Dedicated GPU** | 256 CUDA Cores | none | none |
| **RAM** | 8 GB | 1 GB | 256 MB |
| **Storage** | 32 GB eMMC | Flash | Flash |

# Range Sensor Demo

https://youtu.be/oN95_7mMeZM



# **Object Detection** - Feature Matching

Template

Failed to Detect Drone

## Pros:

- Easy to implement
- Efficient algorithm

## Cons:

- Rarely ever works
- Cannot detect rotated objects
- Affected by lighting

# Object Detection - Color Histogram Analysis

## Pros:

- Easy to implement
- Efficient algorithm
- Detects rotated objects

## Cons:

- Drastically affected by lighting
- False positives triggered by objects of similar colors

Template

Successful Identification

# Object Detection - Affine SIFT

## Pros:

- Can detect slightly rotated objects well

## Cons:

- Cannot detect drastically rotated objects
- Highly resource-intensive

Template

Failed to Identify

# **Object Detection** - Machine Learning

## Pros:

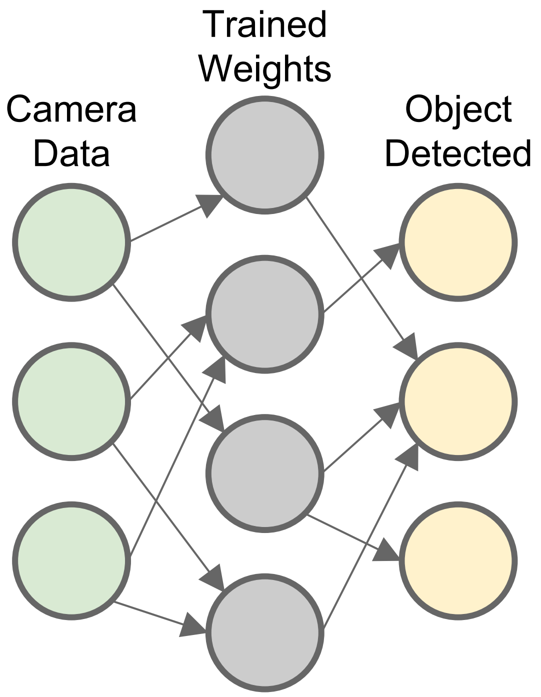
- Best possible object detection

## Cons:

- The most resource-intensive

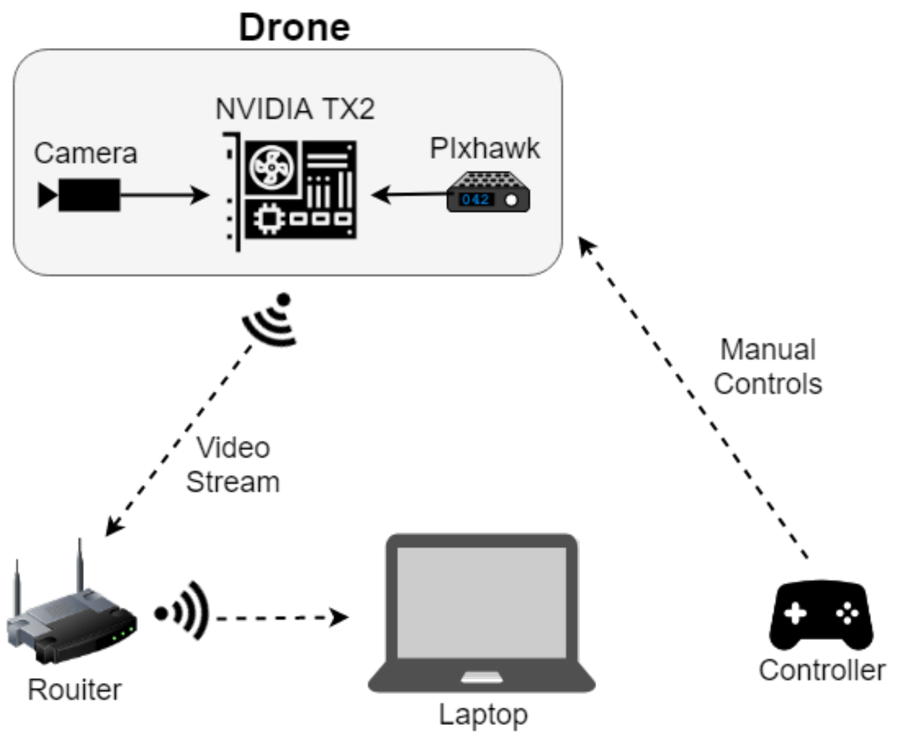
## Verdict:

- Use Machine Learning for Object Detection



# Robot Operating System (ROS)

- ROS is a software framework which makes it easier to perform tasks commonly needed for robotics projects
- We will use ROS to stream camera video to a laptop
- The drone will fly autonomously, but a controller can be used to take full control of the drone at any time

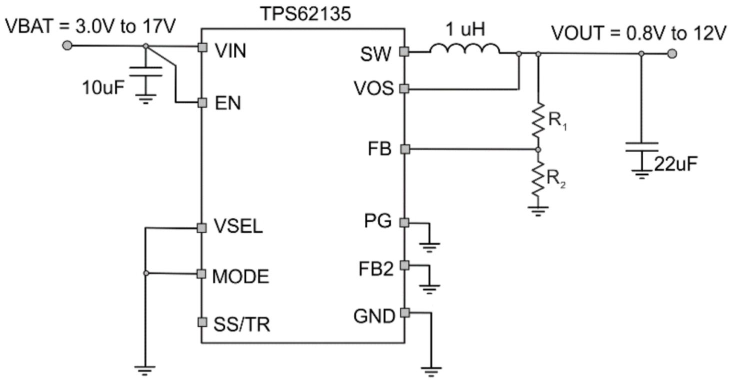


# Choosing a Test Drone Prototype

- Integrable parts that are guaranteed to work with any DJI part.
- Includes the frame, motors, and propellers.
- Test and reconnect our software and hardware components.
- Reputable company with efficient and powerful parts (like the motors).
- Find errors before they occur.
- Practice Programming Pixhawk.
- Analyze Drone Dynamics.

# TPS62135 Printed Circuit Board Design

- Create a printed circuit board to manage power across the internal embedded systems.
- Prevent system failure and allow for steady flight.
- Facilitate varying voltage levels across the system.
- (PCB) will also stabilize voltage spikes, ensuring that components don't get damaged.
- Buck converter allows for a wide range of voltages.

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# Power Management Integration

- Motors used to power our quadcopter have a battery independent of the PCB.
- Power the Pixhawk with approximately 5 volts, as well as other microcontrollers with both 5 and 3.3 volts.
- TX2 Chip uses a minimum of 5.5 Volts which is well within our range of conversion.
- Raspberry Pi is also supported.
- Can actively select voltage levels based on PCB layout.

# Specifics of TPS62135

- Texas Instruments provides free reference designs that can be openly used for development.
- TPS62135 reference design so we can use a battery with a higher voltage to allow our embedded systems to run continuously for at least 10 minutes.
- Voltage error of only 1%, which fits well within our error range.
- Decided to start with a reference design and adapt as necessary.
- Power any new sensors.
- Ensure that voltage requirements are met.

# Challenges we have faced

- Flipped wiring between electronic speed controllers and motors.
- Interdisciplinary communication / compromise.
- Hardware incompatibilities (Raspberry Pi)
- Lack of experience within drone creation.
- Funding limits (2000$ from Lockheed Martin)
- Wide Variety of Ideas.
- Time limits.
- Rules of the competition (Must wait 10 seconds after collision to score points against opposing drone).

# Sources


- http://python.dronekit.io/about/overview.html
- http://ardupilot.org/dev/docs/sitl-simulator-software-in-the-loop.html#sitl-simulator-software-in-the-loop

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