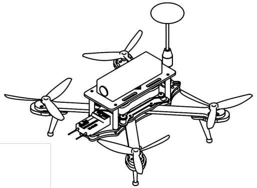
Innotech Internship Summary

Sophia J. Wang
with the *Indigenous Drone Team*: Sangay, Tshering, Tenzin, and John
11/20/24 – 1/10/25

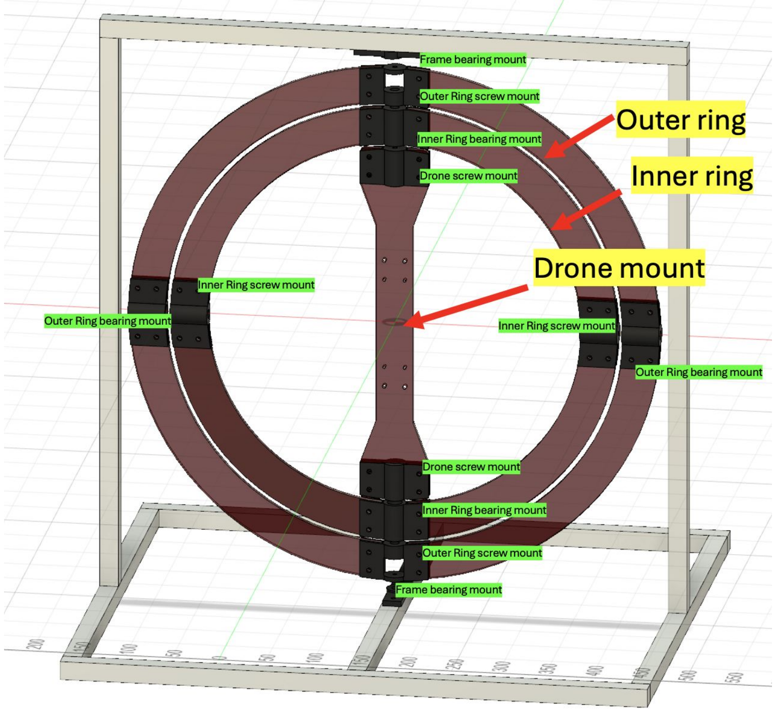


Gyroscopic Test Rig

Purpose
3-axis testing platform (yaw, pitch, roll) for tuning custom flight controller coefficients pre-flight.

Considerations

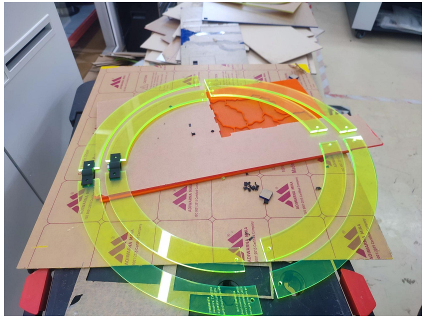
- v0 sizing
- Parametric design

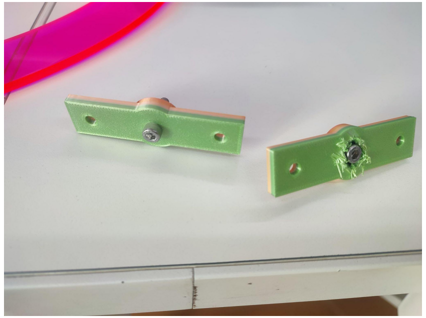


CAD Rendering

Prototype

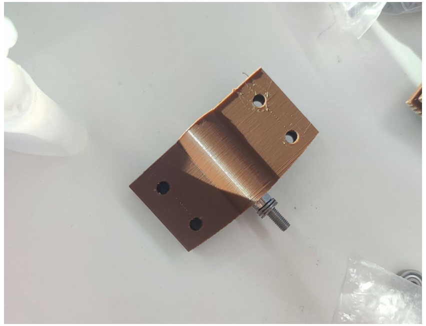
Process *with Tshering*





prototype 1

prototype 2



prototype 3

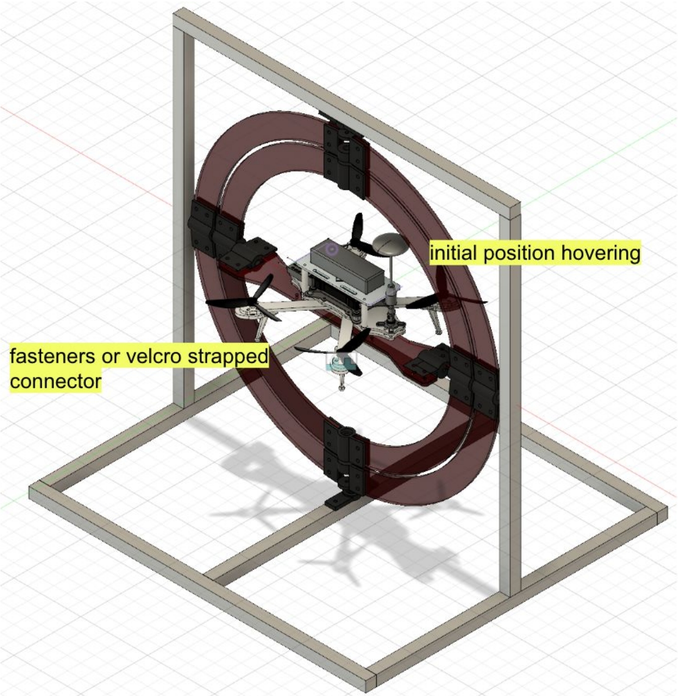
fun with the circular saw

Testing

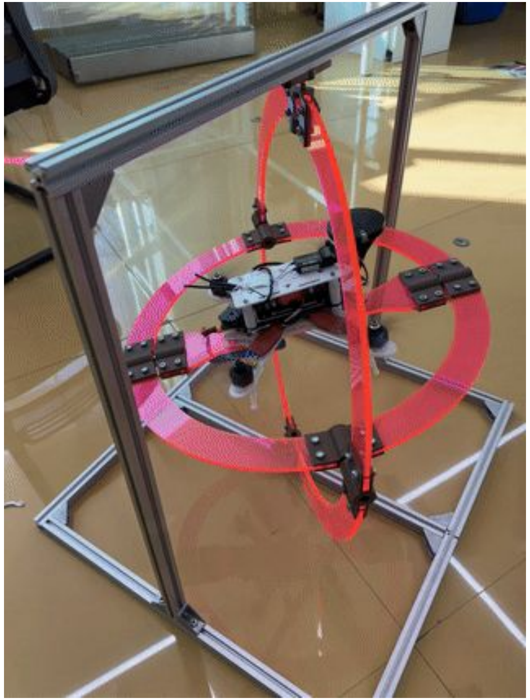
Demonstrates hovering stability* and quick correction for minor perturbations.

*need to correct for ground interference

Tenzin frame, Sangay & Tshering assembly with Cube Orange



CAD Rendering



Prototype

Documentation

github for replicability

sophiajwang / **Gyroscopic-Drone-Mount** Public

Code · Issues · Pull requests · Actions · Projects · Security · Insights

main · 1 Branch · 0 Tags · Go to file · Code

sophiajwang compress image · d1f1870 · last month · 4 Commits

cad	updated README and assemblies	last month
pics	compress image	last month
.DS_Store	compress image	last month
LICENSE	Initial commit	last month
README.md	updated README and assemblies	last month

special assembly instructions

1. aluminum extrusions are 20 mm x 20 mm, T-Slot 80/20
2. 5.5 mm acrylic
3. 30% infil
4. If nuts are difficult to find, you can thread a self-tightening nut with significant elbow grease.
5. We're working around the supply here. Better practice would be to use a fitted 5 mm shaft. Here, we're placing a loosely fitting 5 mm bolt through the shaft of the bearing, and securing with one nut at either end.
6. Again, working around supply. Best case would have been to find some M5x30 bolts, but we were only able to find M4 ones of sufficient length. Here, we're securing the bearing against the head of the bolt and the exacting pressure of the aluminum columns (better to add another nut to relieve precision of extrusions), then securing the screw mount with two nuts.

parts

Parts

Tools

Name	Purpose
Circular saw machine	aluminum extrusions
Sanding machine/sandpaper	aluminum extrusions
M4 and M5 allen keys	assembly
Wrench or needle nose plier	assembly

Frame

Section	Part	Details	Quantity
Base	Aluminum Extrusion [1]	52.5 cm	3
Base	Aluminum Extrusion	63 cm	2
Base	2020 Corner Bracket	30 mm x 30 mm	8
Base	M5x10, knurled cylinder head		16
Base	M5 T-nut		16
Column	Aluminum Extrusion	60.5 cm	2
Column	2020 Corner Bracket	30 mm x 30 mm	4
Column	M5x10, knurled cylinder head		8
Column	M5 T-nut		8
Top beam	Aluminum Extrusion	63 cm	1
Top beam	2020 Corner Bracket	30 mm x 30 mm	2
Top beam	M5x10, knurled cylinder head		4
Top beam	M5 T-nut		4

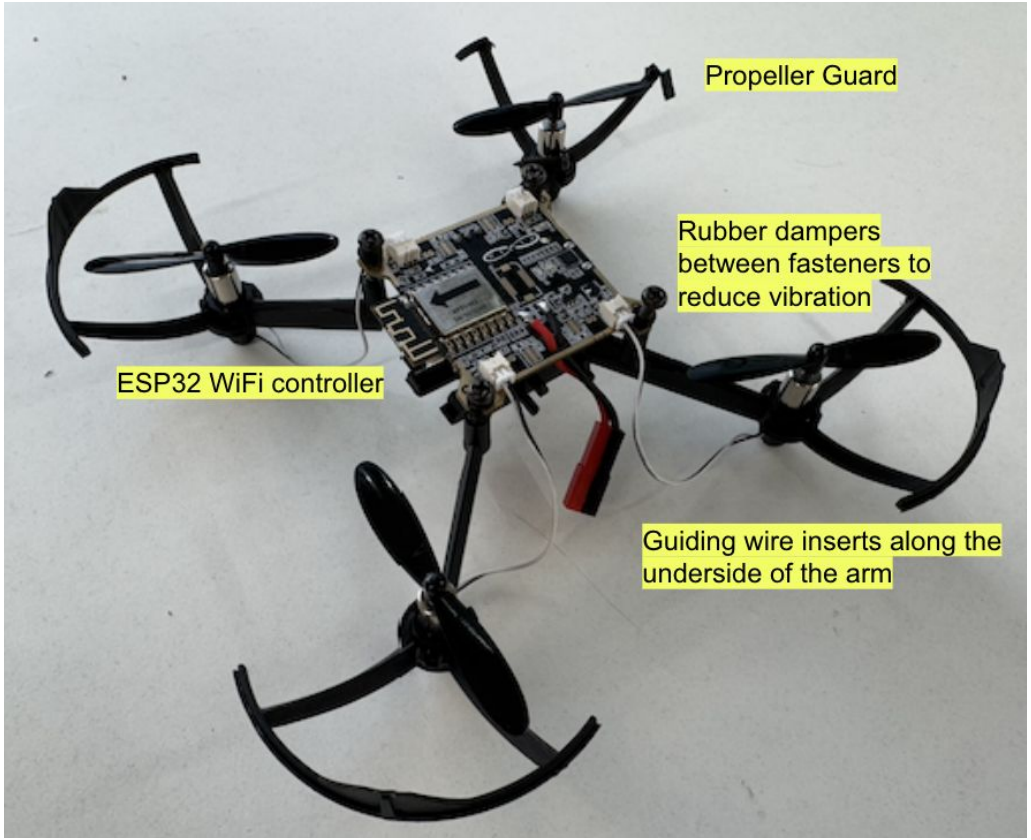
Rig

Section	Part	Details	Quantity
Mount	Drone Mount	Laser Cut [2]	1
Mount	Drone screw mount	3D print [3]	1
Mount	M5x15, knurled cylinder head		8
Mount	M5 nut [4]		8
Inner Ring	Inner Ring	Laser Cut	4
Inner Ring	Inner ring screw mount	3D print	2
Inner Ring	Inner ring bearing mount	3D print	2
Inner Ring	M5x15, knurled cylinder head	ring interconnects	16
Inner Ring	M5 nut	ring interconnects	16
Inner Ring	M5x25, knurled cylinder head	bearing shaft [5]	2
Inner Ring	M5 nut	bearing shaft	4
Inner Ring	Bearing (5x16x5mm)		2
Outer Ring	Outer Ring	Laser Cut	4
Outer Ring	Outer ring screw mount	3D print	2
Outer Ring	Outer ring bearing mount	3D print	2
Outer Ring	M5x15, knurled cylinder head	ring interconnects	16
Outer Ring	M5 nut	ring interconnects	16
Outer Ring	M5x25, knurled cylinder head	bearing shaft	2
Outer Ring	M5 nut	bearing shaft	4
Outer Ring	Bearing (5x13x4mm)		2
Frame	Frame Bearing Mount [6]	3D print	2
Frame	M4x30, button cap screw	bearing shaft	2
Frame	M4 nut	bearing shaft	6

“v0” Drone

Purpose:
Using open-source Pluto drone kit as platform for flight controller algorithm & design for manufacturing insights

"v0" Drone Hardware



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Design and Test of a Controller for the Pluto 1.2 Quadcopter

Nitika Jaggi * Dr. Koena Mukherjee ** Dr. Munmun Khanra ***

* *National Institute of Technology Silchar (e-mail: nitika.jaggi19@gmail.com).*
** *National Institute of Technology Silchar (e-mail: koena@ei.nits.ac.in)*
*** *National Institute of Technology Silchar (e-mail: munmun@ei.nits.ac.in)*

Abstract: Quadcopters are being utilized in varying applications like product delivery and surveillance. The controllers designed must be tested extensively in both simulations and flight tests before being deployed on the actual system. This paper presents a Proportional plus Derivative (PD) based Cascade control algorithm to allow the quadcopter to go to its goal location. The whole control is split into four subsystems- one to control each output. Simulation results of the same are presented to validate the proposed method. Further, Pluto 1.2, an open-source drone, is used as a testbed for the project. Since there was no prebuilt navigation support, a Vision-based Navigation system using an overhead camera and ArUco tags is developed. This estimated position is sent to Pluto 1.2 as a Multiwii Serial Protocol (MSP) packet via WiFi communication. For this, a new MSP command is written by modifying the drone's firmware. Finally, the complete navigation and communication system are tested in flight. The system developed for Pluto 1.2 is a novel one and, therefore, a contribution to the Open source aerial robotics community.

Keywords: Quadcopter, PD control, Cascade control, Pluto 1.2, Vision based navigation, ArUco, WiFi, Multiwii Serial Protocol.

1. INTRODUCTION

Quadcopters are being developed for use in various applications like medical aid delivery, as an emergency first responder, for surveillance, etc. They are helicopters with four counter rotating propellers placed in the same plane. They are controlled by differential adjustment of the angular velocities of the rotors. Quadcopters can move freely in 3D space i.e. they have 6 degrees of freedom(DOF). But they have only 4 rotors (actuators) to control all 6 DOF. Thus, they are underactuated systems. Independent control of 2 states namely x (forward/backward) ,y (right/left) translation is lost. These translations are coupled with the Roll & Pitch angles.

A mathematical model of the quadcopter is required for designing a controller for it. The dynamics of the system are derived from first principles by Gibiansky (2012). Papers by Bouabdallah and Siegwart (2005), Dydek et al. (2013), Luukkonen (2011) and Shi et al. (2020) all use the same equations of mo
model of the quadcopter b
ent ways due to use of diffe
strategies for control have
paper by Castillo et al. (2004)
all 12 states of the quadcopte
are linearised and then a hove
The system is practically imple
by Ajmera and Sankaranaraya...

of backstepping to control a quadcopter. It uses PD control for attitude stabilisation as well as position control. Özbek et al. (2016) compare different strategies i.e. PID, Sliding mode and fuzzy logic for controller design of a quadcopter. It compares them on the basis of tracking precision, applicability of control signals, quality of transient response and energy efficiency.

Just as important as testing the designed controllers in simulation, is to deploy the controller onto a hardware testbed. Pluto 1.2, an open source, programmable nano drone is an excellent choice for the same. It is small, robust to crashes and economical. It's firmware is a modified version of the popular, open source flight software, Cleanflight. It can be programmed in C using predefined functions (DronaAviation (2016)). It has only one disadvantage though, there is no navigation support inbuilt.

A controller requires real time feedback of the position of the drone. Many methods can be used for the same

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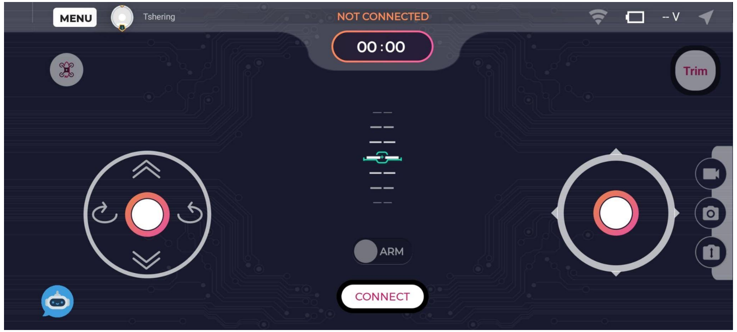
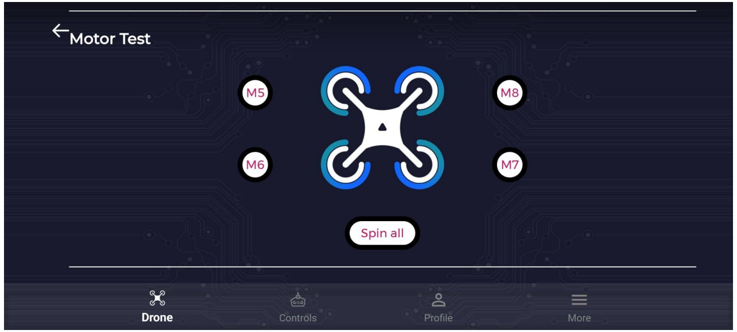
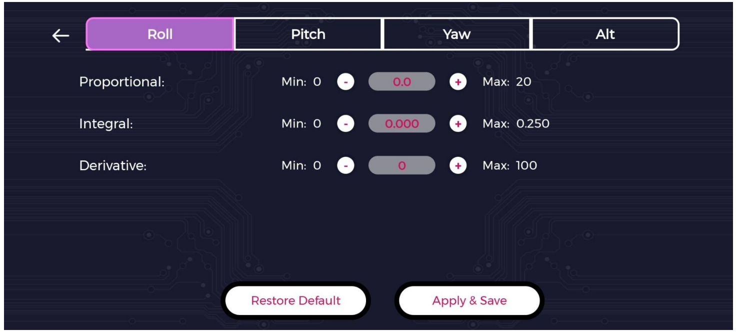
Existing papers on PD controller variants with augmented Pluto hardware (i.e. camera module)

“v0” Drone Software





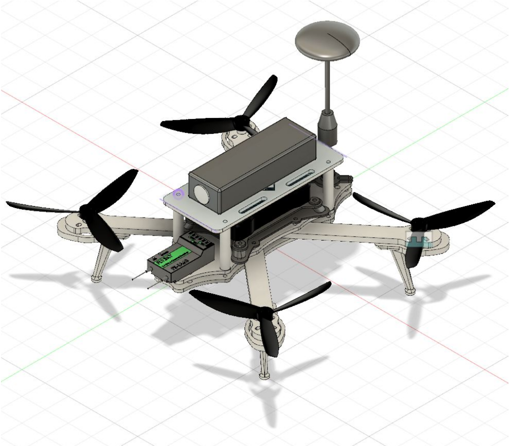


User interface with live data monitoring. Calibration pre-flight, programmable modes. Need to dampen the throttle.

v1 Drone Assembly

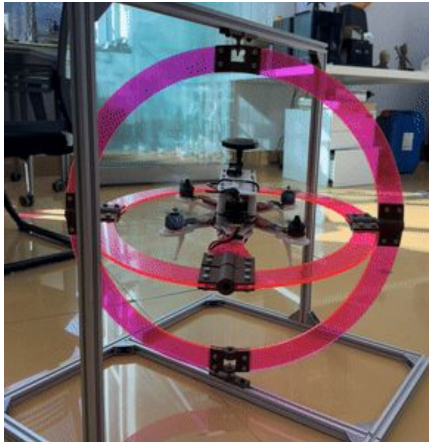
Purpose:

Testing the off-the-shelf cube flight controller (PixHawk CubePilot) as a viable base for further frame experimentation.



CAD Rendering (Tenzin)

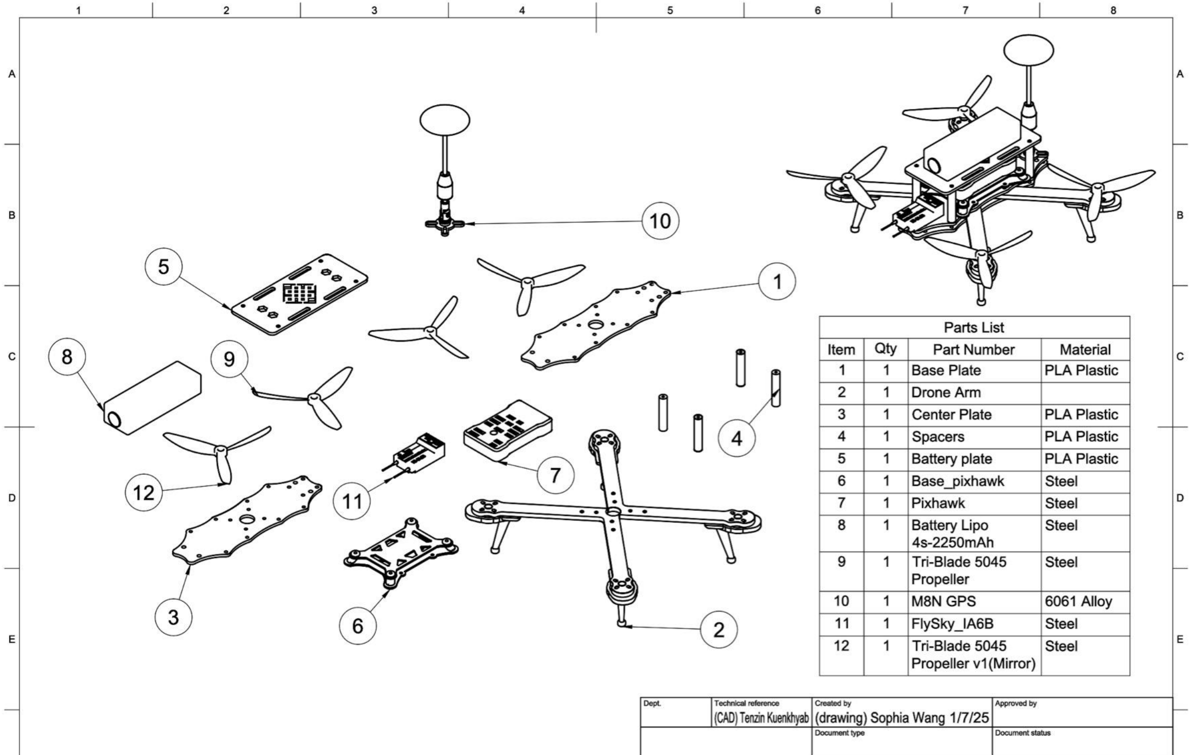
Prototype (assembly by Sangay and Tshering)



Testing with gyroscopic rig

Tethered Flight

Documentation

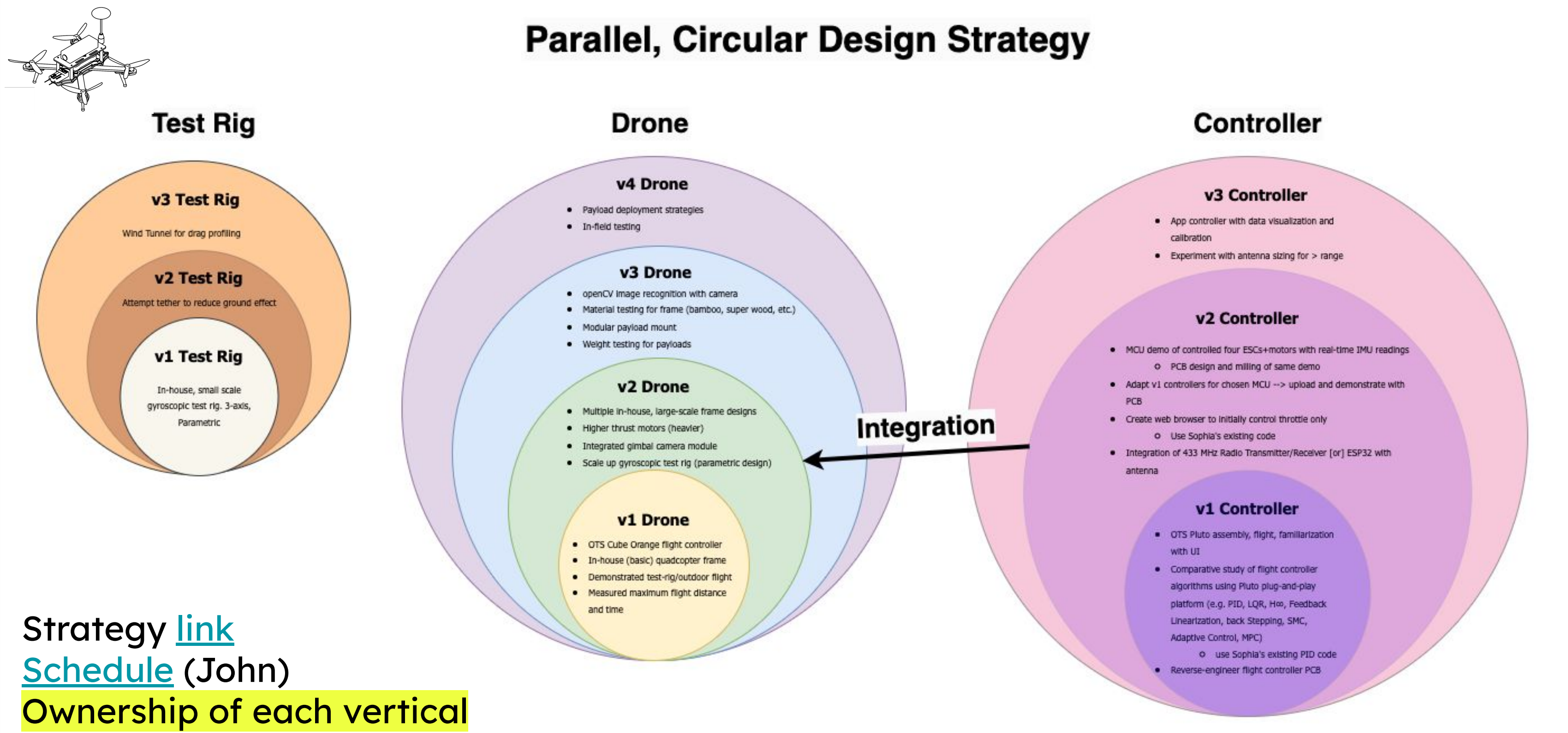


Parts List			
Item	Qty	Part Number	Material
1	1	Base Plate	PLA Plastic
2	1	Drone Arm	
3	1	Center Plate	PLA Plastic
4	1	Spacers	PLA Plastic
5	1	Battery plate	PLA Plastic
6	1	Base_pixhawk	Steel
7	1	Pixhawk	Steel
8	1	Battery Lipo 4s-2250mAh	Steel
9	1	Tri-Blade 5045 Propeller	Steel
10	1	M8N GPS	6061 Alloy
11	1	FlySky_IA6B	Steel
12	1	Tri-Blade 5045 Propeller v1(Mirror)	Steel

Engineering Drawing

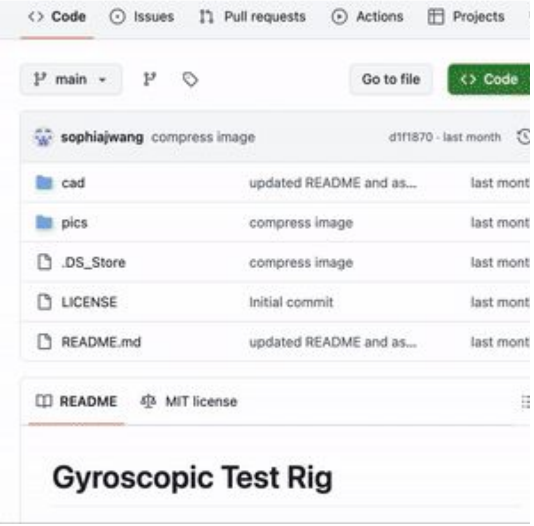
animation
(exploded view)

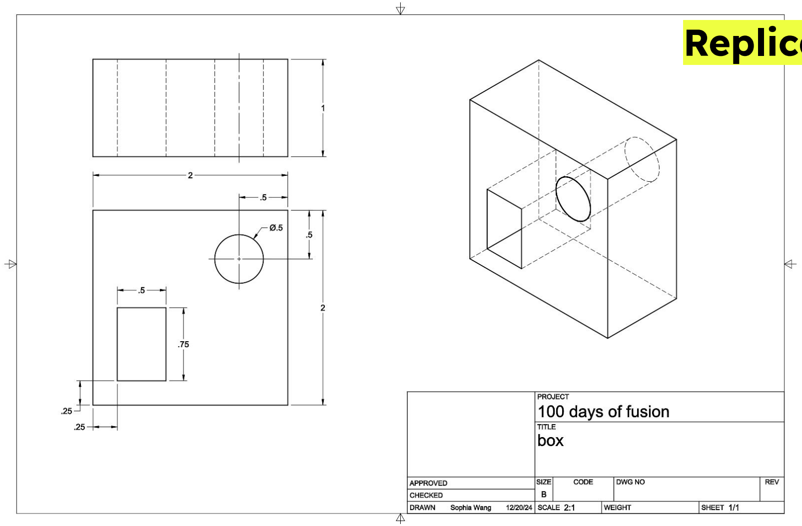
Next Steps



Strategy link
Schedule (John)
Ownership of each vertical

Documentation





Replicability and Standardization

Every project should have:

- Repository with all design files, relevant assembly instructions, Bill of Materials, process documentation
- Effective visualizations for communication to public:
  - Engineering Drawings
  - Animations

Design Process and Best Practices

Design process

- Thoughtful project objectives, design specifications, and milestones prior to starting
- Design choices based on careful trade studies
- Project tracking document
- Periodic design reviews
- Iterative, circular design processes to maintain functionality
- Testing at every step (validate datasheets – motor torques, current ratings)

Best Practices

- Parametric (for editing and scaling), constrained
- Documentation during (not after)
- Consistent communication across organization
    - Slack, public and private channels
    - Labwide Github – commit often

Learning Resources

- Fusion
  - Request personal license (may need to email customer support) – valid for 3 years, supports drawings, animations, manufacturing, and Eagle
  - 100 days of Fusion (link)
- Textbooks
  - *The Art of Electronics* Paul Horowitz and Winfield Hill (link)
  - *Practical Electronics for Inventors* Paul Scherz (link)
- Fundamental languages/software
  - Python
  - C++
  - KiCAD/Eagle/EasyEDA – circuit design & layout
  - CAD (Fusion, SolidWorks, OnShape, FreeCAD)
- Presentations
  - Diagrams (draw.io)
  - Figures (MATLAB, Python)
  - Gifs (ezgif.com)