Final Product Presentation
Precision Landing
Team 3

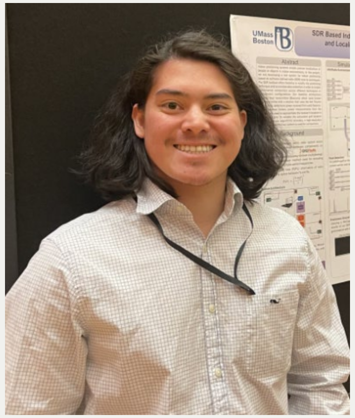
Team Roles and Assessments

Anas Asha

- Researcher of ToF and TDoA methods
- Helped in setting up beacons

Joy Georgie

- Builder and tester of the drone
- Configured beacons



Miguel Chang-Mera

- PCB designer and tester
- Integrator of software with hardware

Project Description

- Our project is to design a landing algorithm so that a drone can land on a selected platform
- **Motivations:**
  - Currently there are no commercial solutions to an automated high-precision landing drone system.
  - We believe that our system is unique by using Ultra-Wideband (UWB) beacons that locate our drone and the target location with a high degree of accuracy.
  - Similar systems are used for indoor positioning of objects or people, but we plan for our system to be adaptable to any location

- **Customer Requirements:**
  - Calculation of the flight must be done in real time
  - The components must not weigh down the drone
  - The beacons must communicate with the calculation computer
  - Our system must implement machine learning
- **Engineering Requirements:**
  - Integrate beacons to calculate a flight path and land on a designated platform
  - The beacons we are using are Decawave's DWM1001
    - Utilizes Ultra-Wideband radio technology
    - Enables the accurate measure of the time of flight with centimeter landing accuracy

5 Project Specific Success Criteria

- **PSSC 1:** Design landing path using the TDoA method
- **PSSC 2:** Test the beacons and verify their functionality
- **PSSC 3:** Set up the Intel Board and interface it with the beacons to determine the landing path
- **PSSC 4:** Set up a MAVLINK protocol between the Intel Board and the Pixhawk
- **PSSC 5:** Land on Team 5's platform and verify the landing algorithm's functionality

Updates on our PSSCs

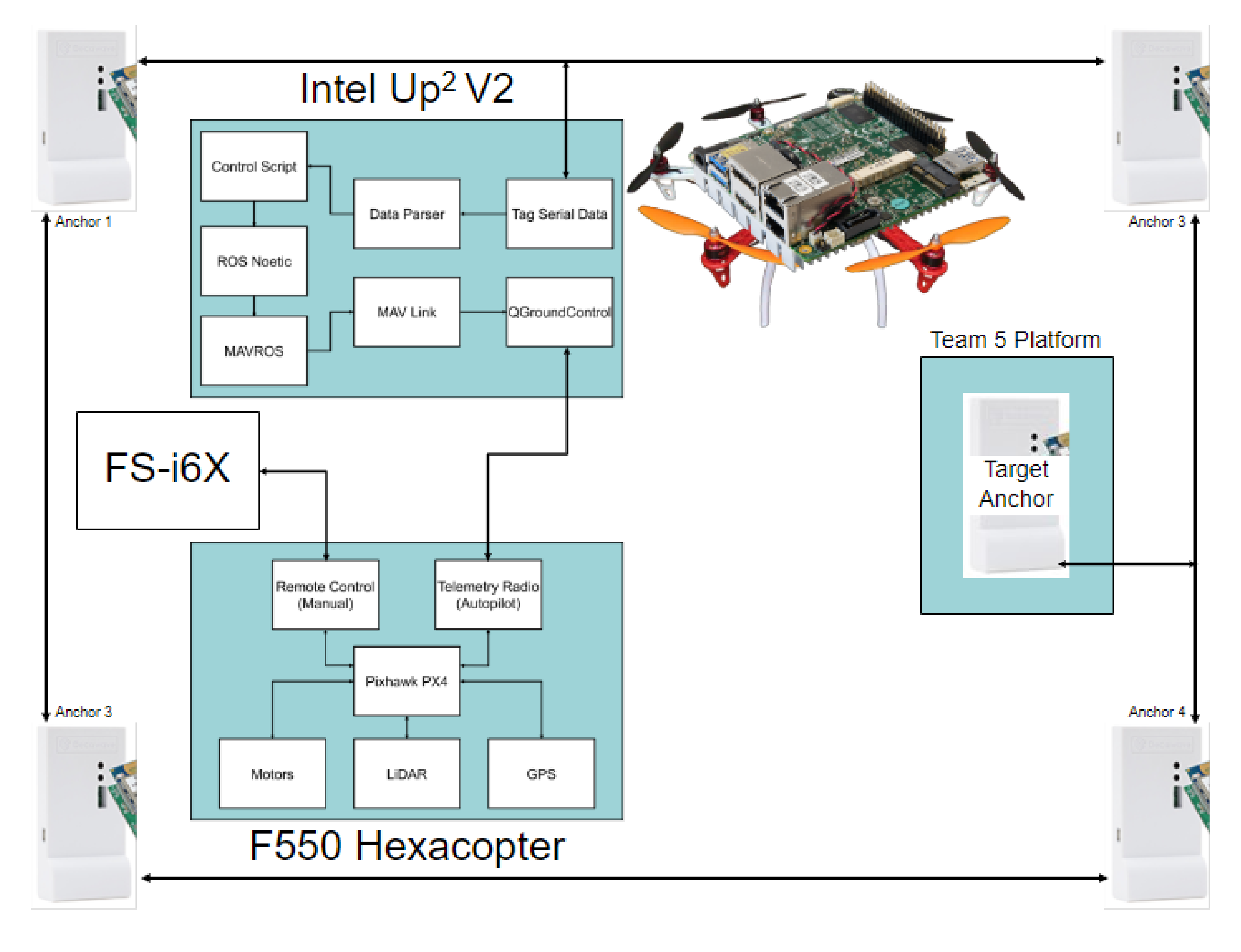
- **PSSC 1:** We designed the path using a simulation; We also connected the controller to the drone and were able to set up the commands with the different switches (80%)

- **PSSC 2:** Each beacon performs its respective job, either as an anchor or as a tag (100%)

- **PSSC 3:** We interfaced the beacons with the Intel Board and were able to record distance (100%)

- **PSSC 4:** MAVLINK Protocol was set up between the Intel Board and the Pixhawk (100%)

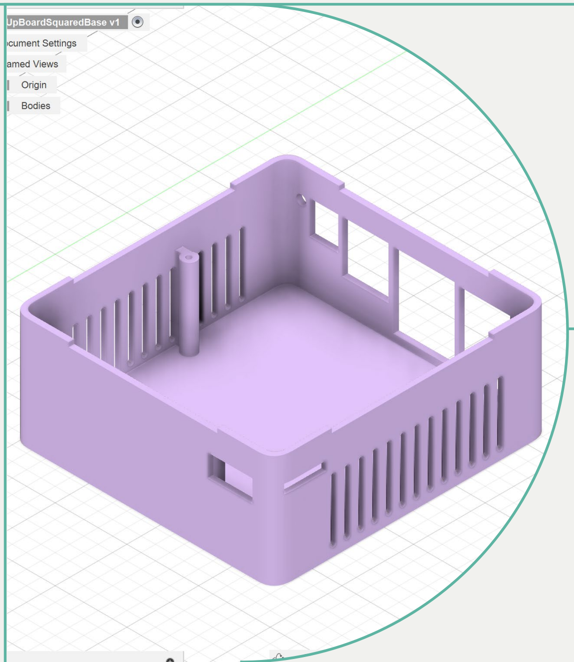
- **PSSC 5:** Although we were able to connect the controller to the drone, we had some issues with our drone and getting to fly (60%)

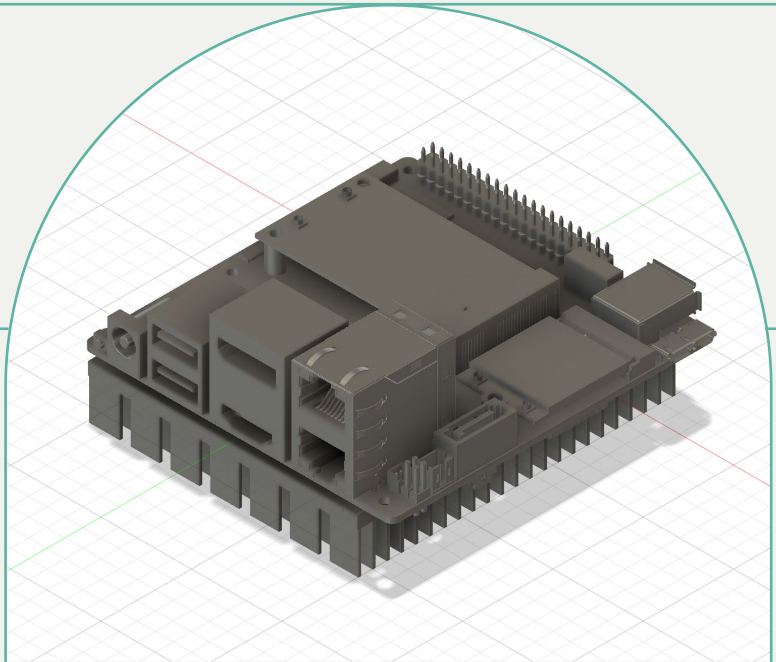


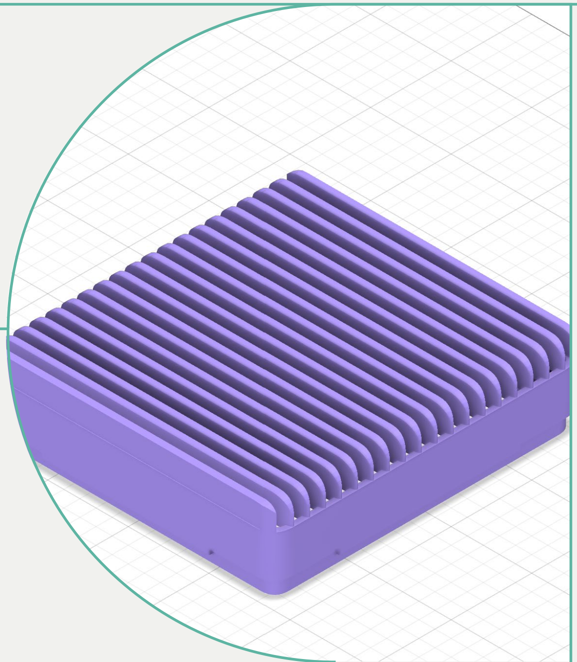
Intel Up² V2
Control Script
Data Parser
Tag Serial Data
ROS Noetic
MAV Link
QGroundControl
MAVROS
Anchor 1
Anchor 3
FS-i6X
Team 5 Platform
Target Anchor
Remote Control (Manual)
Telemetry Radio (Autopilot)
Pixhawk PX4
Motors
LiDAR
GPS
Anchor 3
Anchor 4
F550 Hexacopter

Computer Graphics of Important Design Components

- We made a case for our intel board. We made the base and the top separate to ensure we prioritize the heat sink that is attached.

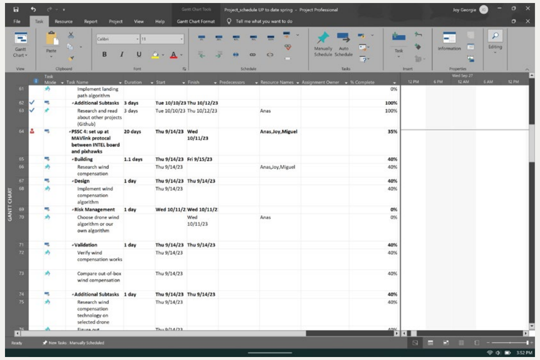


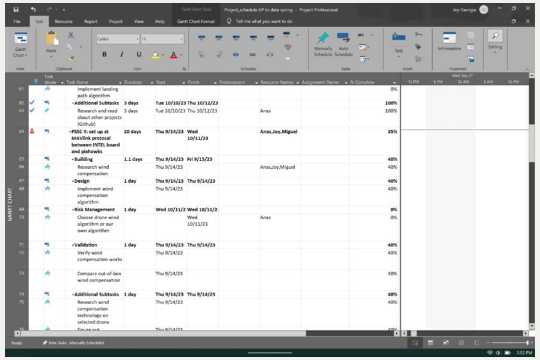


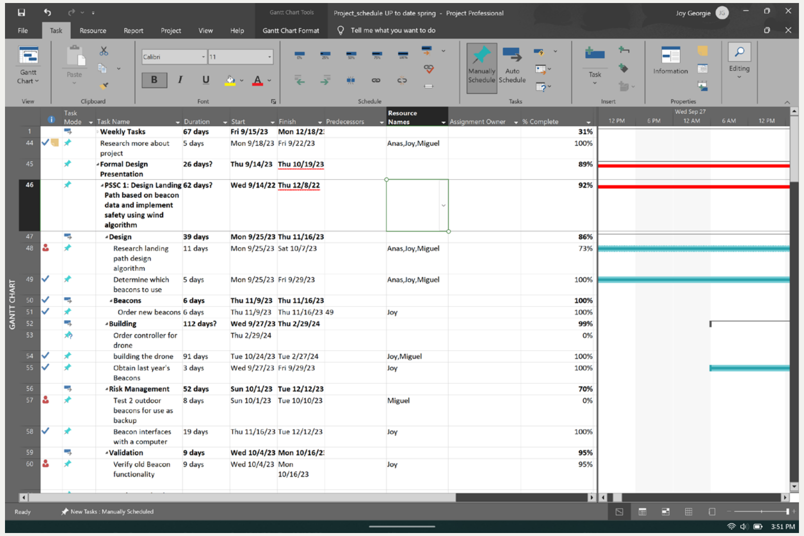


Updated MS Project

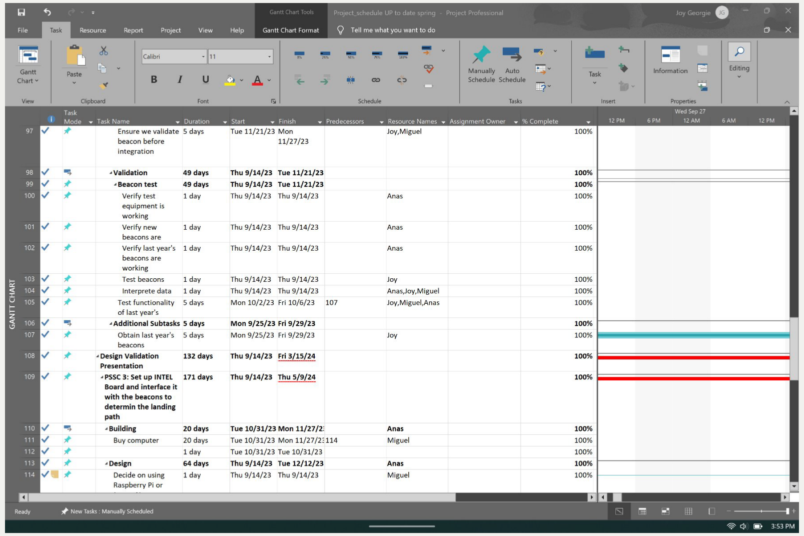
- Weekly reports are done every week by the team lead of the week with help from the other groupmates if needed
- Everything relevant to our project is uploaded into our Microsoft Teams in its folder
- Microsoft Project is used to organize our project, writing out what tasks we need to do, who they are assigned to, as well as a completion percentage.



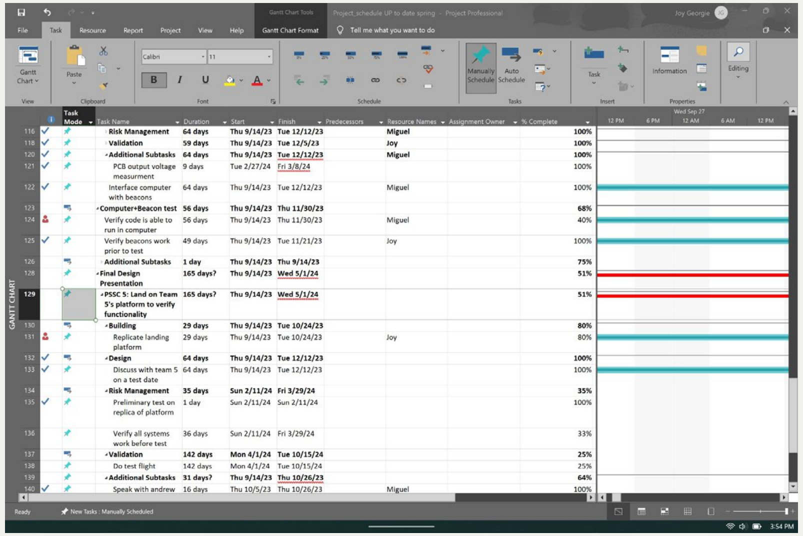




MS Project Continued



	Task Name	Duration	Start	Finish	Predecessors	Resource Names	Assignment Owner	% Complete
97	Ensure we validate beacon before integration	5 days	Tue 11/21/23	Mon 11/27/23		Joy,Miguel		100%
98	**Validation**	**49 days**	**Thu 9/14/23**	**Tue 11/21/23**				**100%**
99	**Beacon test**	**49 days**	**Thu 9/14/23**	**Tue 11/21/23**				**100%**
100	Verify test equipment is working	1 day	Thu 9/14/23	Thu 9/14/23		Anas		100%
101	Verify new beacons are	1 day	Thu 9/14/23	Thu 9/14/23		Anas		100%
102	Verify last year's beacons are working	1 day	Thu 9/14/23	Thu 9/14/23		Anas		100%
103	Test beacons	1 day	Thu 9/14/23	Thu 9/14/23		Joy		100%
104	Interprete data	1 day	Thu 9/14/23	Thu 9/14/23		Anas,Joy,Miguel		100%
105	Test functionality of last year's	5 days	Mon 10/2/23	Fri 10/6/23	107	Joy,Miguel,Anas		100%
106	**Additional Subtasks**	**5 days**	**Mon 9/25/23**	**Fri 9/29/23**				**100%**
107	Obtain last year's beacons	5 days	Mon 9/25/23	Fri 9/29/23		Joy		100%
108	**Design Validation Presentation**	**132 days**	**Thu 9/14/23**	**Fri 3/15/24**				**100%**
109	**PSSC 3: Set up INTEL Board and interface it with the beacons to determin the landing path**	**171 days**	**Thu 9/14/23**	**Thu 5/9/24**				**100%**
110	**Building**	**20 days**	**Tue 10/31/23**	**Mon 11/27/2**		**Anas**		**100%**
111	Buy computer	20 days	Tue 10/31/23	Mon 11/27/2	114	Miguel		100%
112		1 day	Tue 10/31/23	Tue 10/31/23				100%
113	**Design**	**64 days**	**Thu 9/14/23**	**Tue 12/12/23**		**Anas**		**100%**
114	Decide on using Raspberry Pi or	1 day	Thu 9/14/23	Thu 9/14/23		Miguel		100%



	Task Name	Duration	Start	Finish	Predecessors	Resource Names	Assignment Owner	% Complete
116	**Risk Management**	**64 days**	**Thu 9/14/23**	**Tue 12/12/23**		**Miguel**		**100%**
118	**Validation**	**59 days**	**Thu 9/14/23**	**Tue 12/5/23**		**Joy**		**100%**
120	**Additional Subtasks**	**64 days**	**Thu 9/14/23**	**Tue 12/12/23**		**Miguel**		**100%**
121	PCB output voltage measurment	9 days	Tue 2/27/24	Fri 3/8/24				100%
122	Interface computer with beacons	64 days	Thu 9/14/23	Tue 12/12/23		Miguel		100%
123	**Computer+Beacon test**	**56 days**	**Thu 9/14/23**	**Thu 11/30/23**				**68%**
124	Verify code is able to run in computer	56 days	Thu 9/14/23	Thu 11/30/23		Miguel		40%
125	Verify beacons work prior to test	49 days	Thu 9/14/23	Tue 11/21/23		Joy		100%
126	**Additional Subtasks**	**1 day**	**Thu 9/14/23**	**Thu 9/14/23**				**75%**
128	**Final Design Presentation**	**165 days?**	**Thu 9/14/23**	**Wed 5/1/24**				**51%**
129	**PSSC 5: Land on Team 5's platform to verify functionality**	**165 days?**	**Thu 9/14/23**	**Wed 5/1/24**				**51%**
130	**Building**	**29 days**	**Thu 9/14/23**	**Tue 10/24/23**				**80%**
131	Replicate landing platform	29 days	Thu 9/14/23	Tue 10/24/23		Joy		80%
132	**Design**	**64 days**	**Thu 9/14/23**	**Tue 12/12/23**				**100%**
133	Discuss with team 5 on a test date	64 days	Thu 9/14/23	Tue 12/12/23				100%
134	**Risk Management**	**35 days**	**Sun 2/11/24**	**Fri 3/29/24**				**35%**
135	Preliminary test on replica of platform	1 day	Sun 2/11/24	Sun 2/11/24				100%
136	Verify all systems work before test	36 days	Sun 2/11/24	Fri 3/29/24				33%
137	**Validation**	**142 days**	**Mon 4/1/24**	**Tue 10/15/24**				**25%**
138	Do test flight	142 days	Mon 4/1/24	Tue 10/15/24				25%
139	**Additional Subtasks**	**31 days?**	**Thu 9/14/23**	**Thu 10/26/23**				**64%**
140	Speak with andrew	16 days	Thu 10/5/23	Thu 10/26/23		Miguel		100%

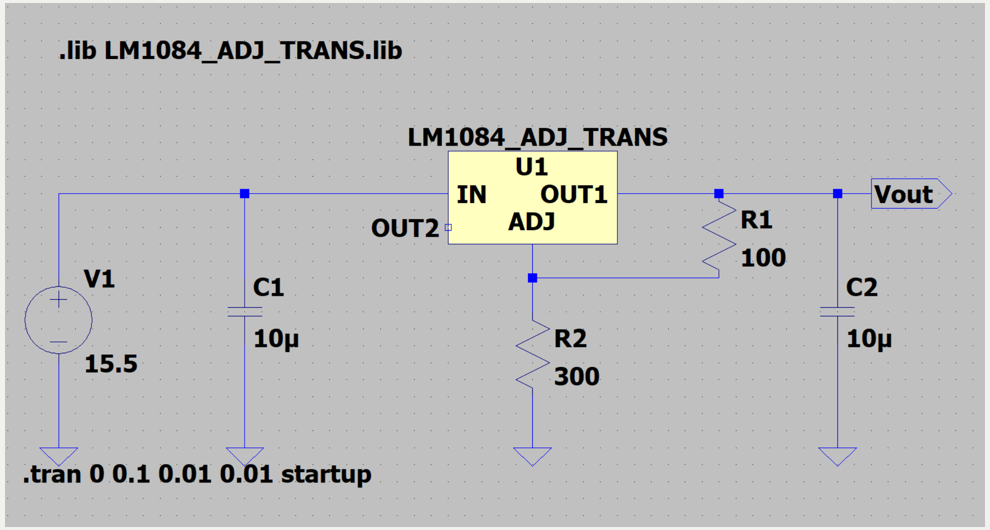
Budget, Parts, Tool, Equipment

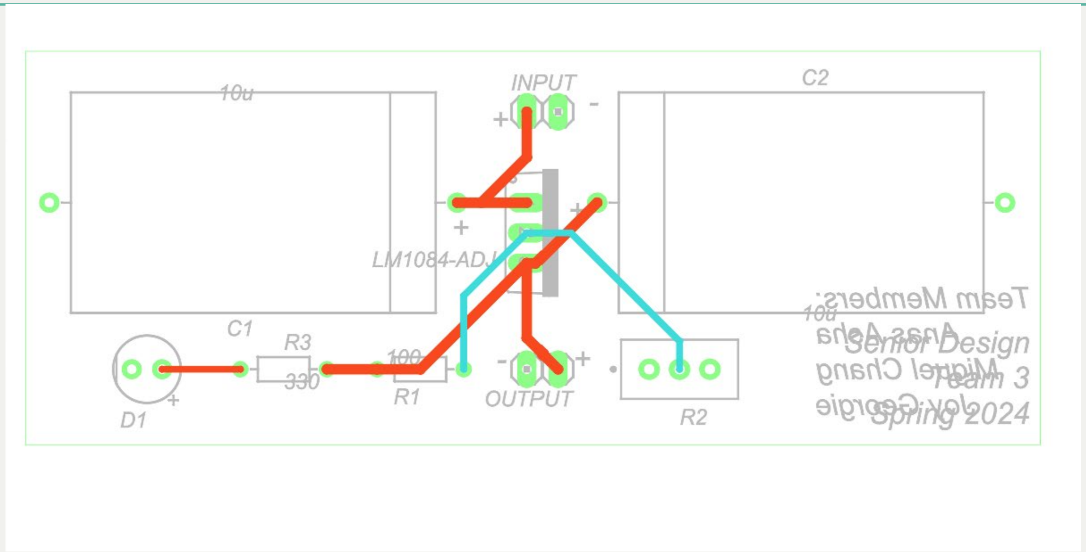
- F550 Hexacopter: $285.99
- INTEL up board V2: $289.99
- MDEK1001 ultra-wide beacons: $299.99
- PCB components and printing: $48.11
- HRB 2 Packs 4S 3300mAh 14.8V Lipo RC Battery: $79.99
- Telemetry Air and Ground Data Transmit Module: $67.89
- WiFi Antenna: $8.99
- Intel Wireless AC 9260 Single Pack: $15.99
- CR123A Rechargeable Batteries 8 Packs: $29.99
- Voltage Regulator Support: $8.99
- 5V 6A Power Supply: $13.99
- TFMini-S - Micro LiDAR: $42.95

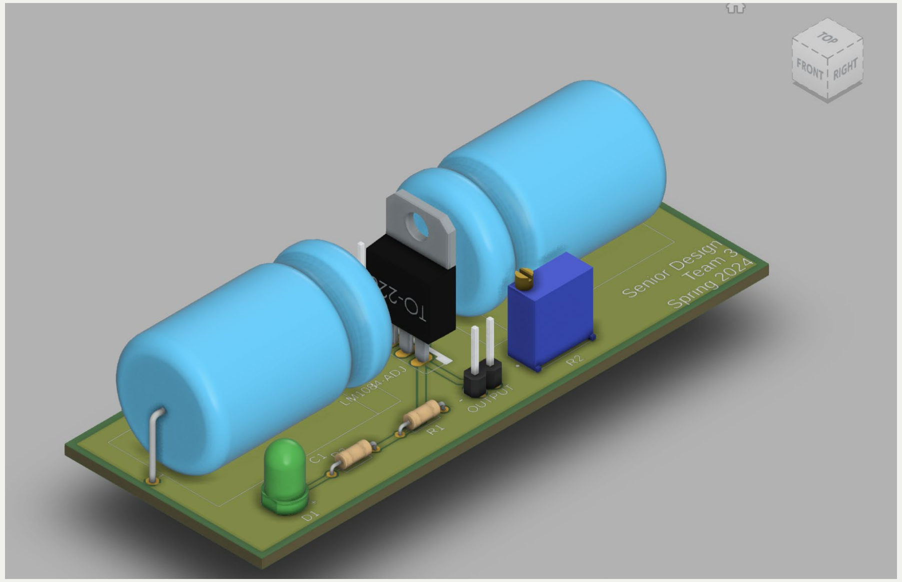
Total spent: $1192.86

Total remaining: $307.14

PCB







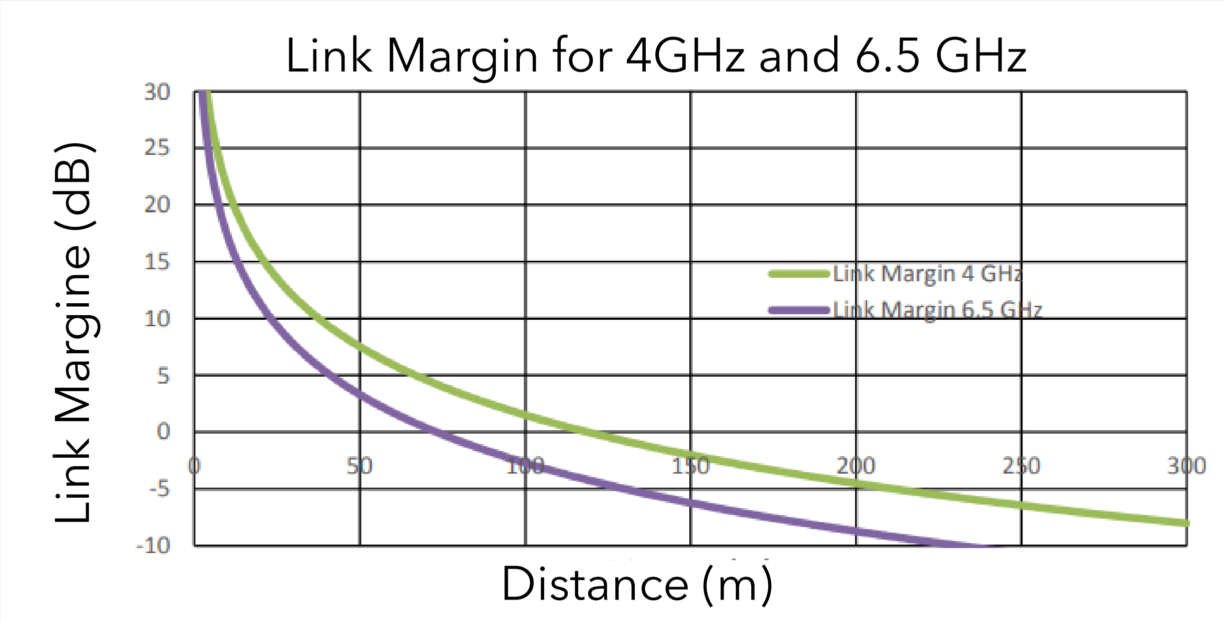
- We design a voltage regulator for our PCB.
- Its purpose is to regulate the voltage going into the INTEL Up Board from the drone battery.
- The computer takes in 6 volts and 6 amps.

Design Validation
PSSC 1

- Each beacon took the role of initiator once and calculated its distance with all other anchors one at a time before the next one becomes an initiator
- The initiator will send a frame, wait for the response from the receiver, and calculate the distance
- When an anchor is in responder mode it waits to receive a frame from an initiator and sends the corresponding answer
- We connected the controller to the drone and were able to set up the commands with the different switches

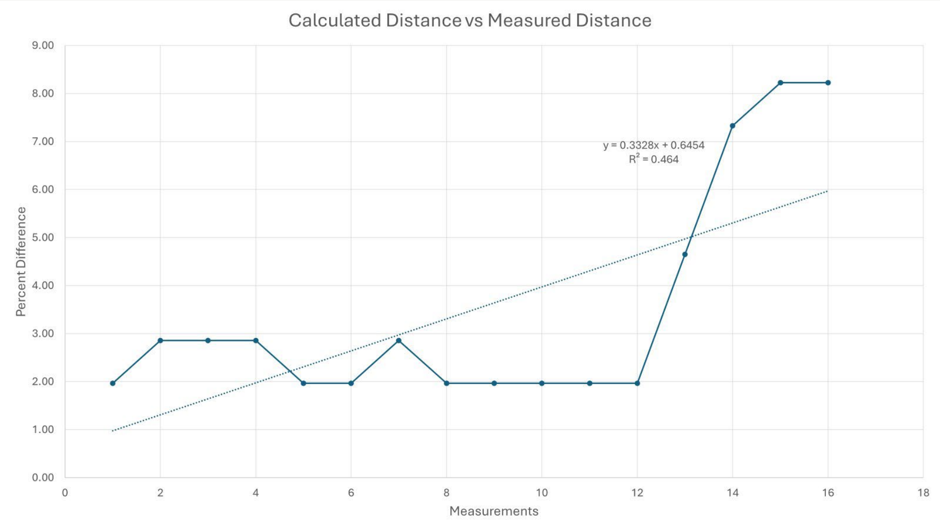
PSSC 2

- Link Margin is a way to measure all the gain and losses in a communication system from transmitter to receiver
- The range of the beacons reduces with increasing channel frequency



Validation Data

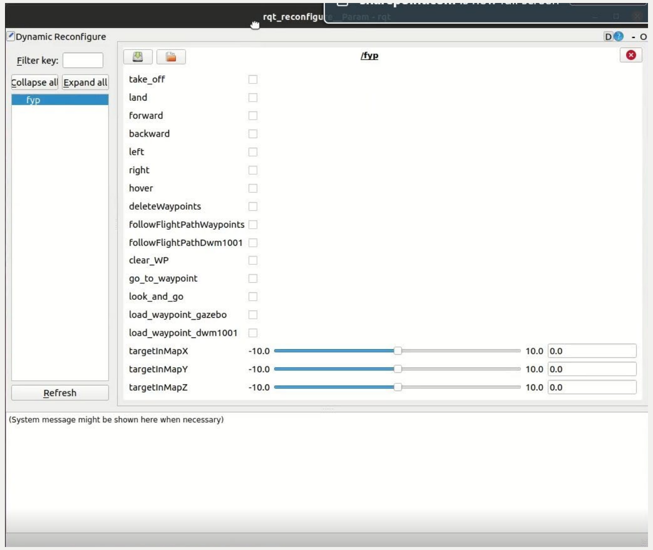
PSSC 2:

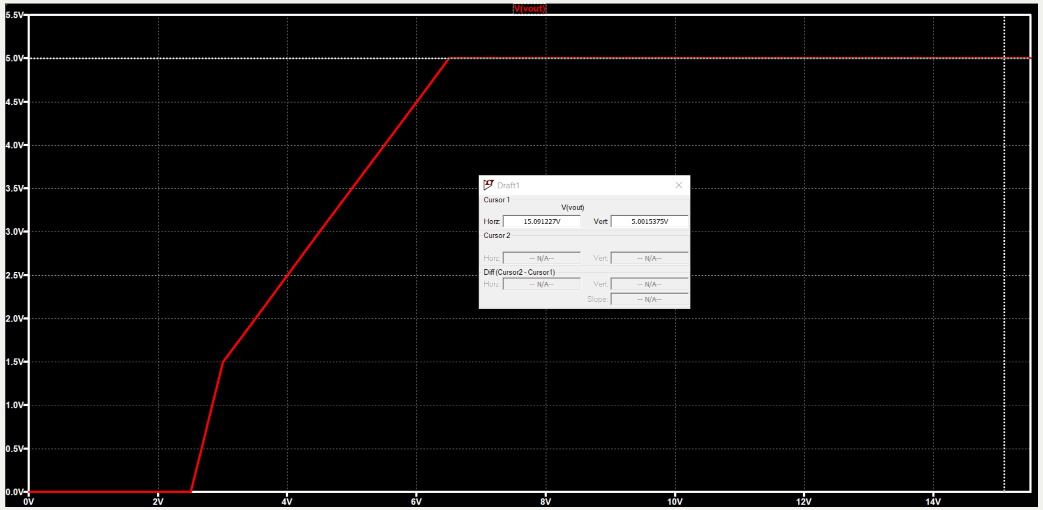


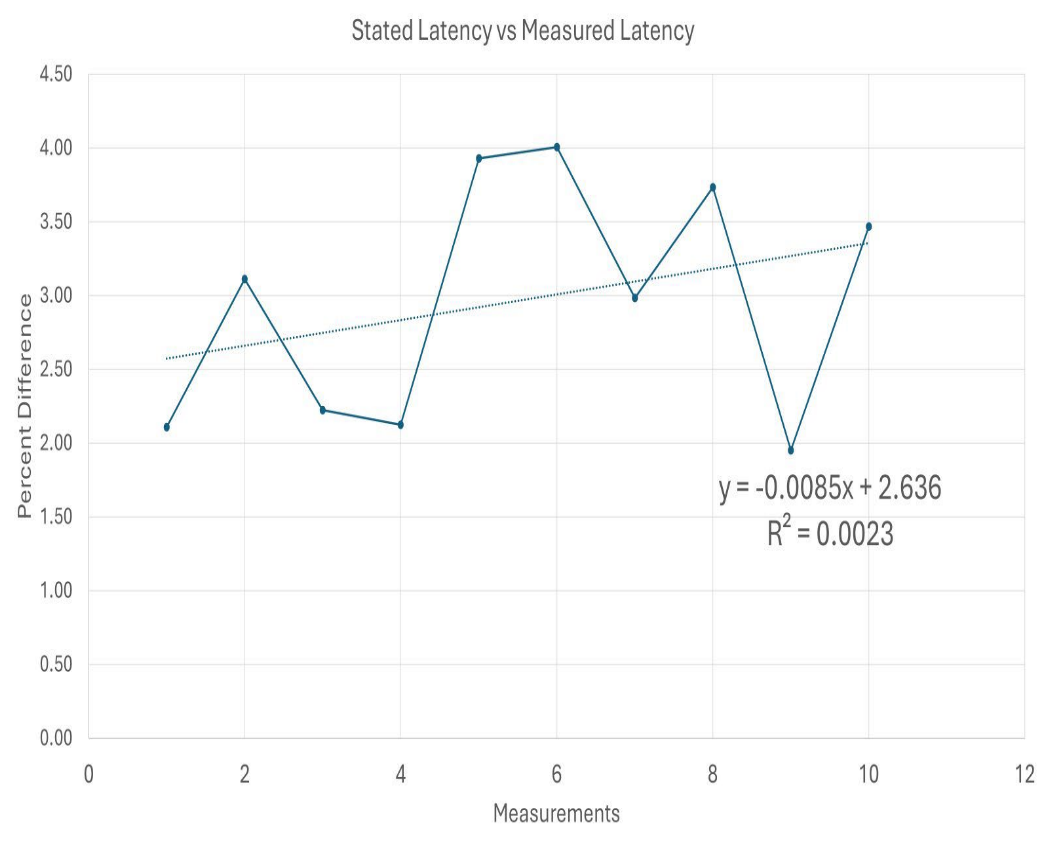
Measured distance purple (cm)	Actual distance (m)	Percentage Difference
114	1.12E+02	1.96
115	1.12E+02	2.86
115	1.12E+02	2.86
115	1.12E+02	2.86
114	1.12E+02	1.96
114	1.12E+02	1.96
115	1.12E+02	2.86
114	1.12E+02	1.96
114	1.12E+02	1.96
114	1.12E+02	1.96
114	1.12E+02	1.96
114	1.12E+02	1.96
117	1.12E+02	4.65
120	1.12E+02	7.33
121	1.12E+02	8.23
121	1.12E+02	8.23

PSSC 3

- We set up the intel board and interfaced it with the beacons to determine the landing path.
- We downloaded all the necessary programs like QGroundControl and synced it to the drone.
- We will test the PCB output. specifically, we will measure the range of voltage to power the Intel board. another way is to test the tag position update latency.



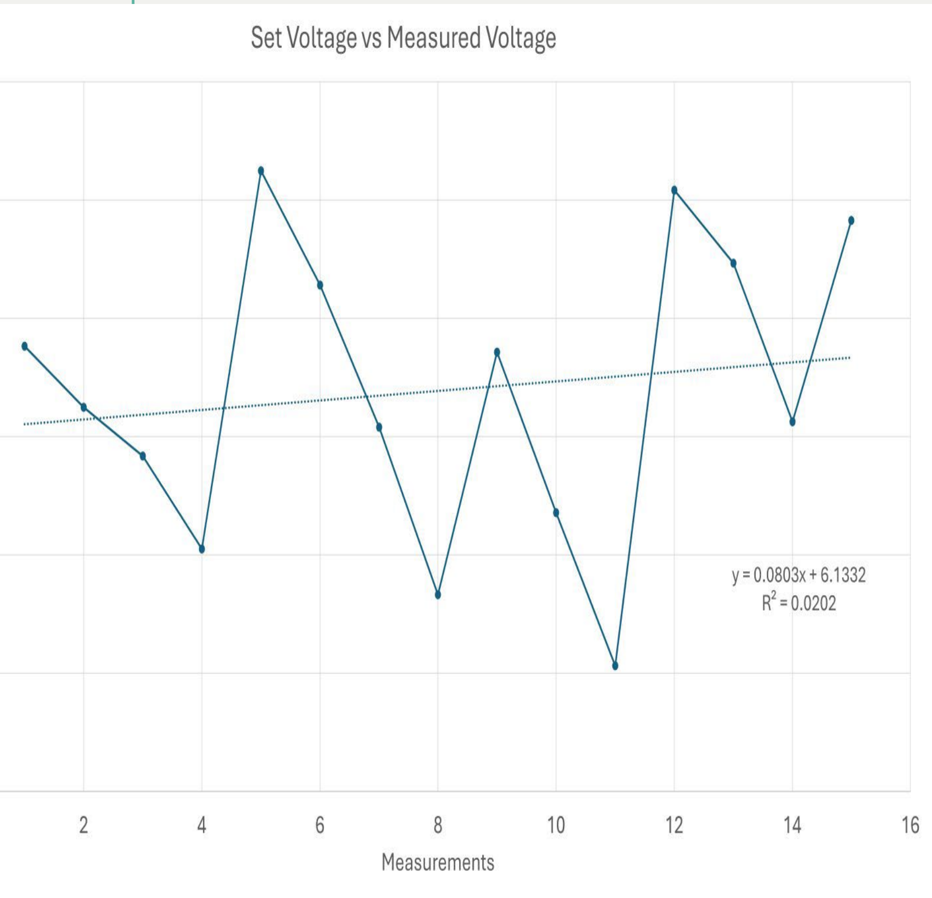




PSSC 3:

Manufacturer latency static (s)	Measured latency static (s)	Percent Difference
10	9.76	2.45
10	9.62	3.97
10	9.80	2.04
10	9.61	4.07
10	9.64	3.71
10	9.82	1.79
10	9.81	1.98
10	9.78	2.22
10	9.69	3.23
10	9.60	4.13

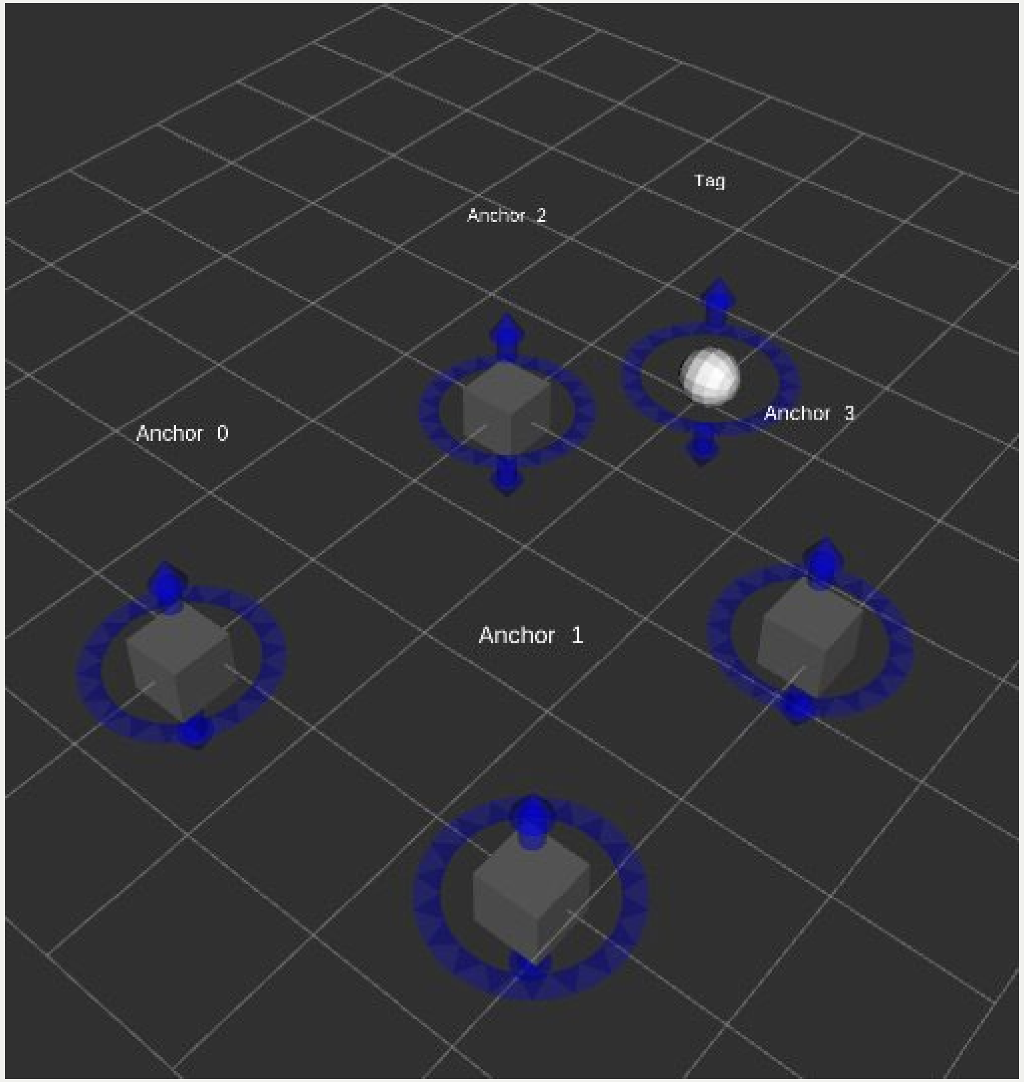
PSSC 3:



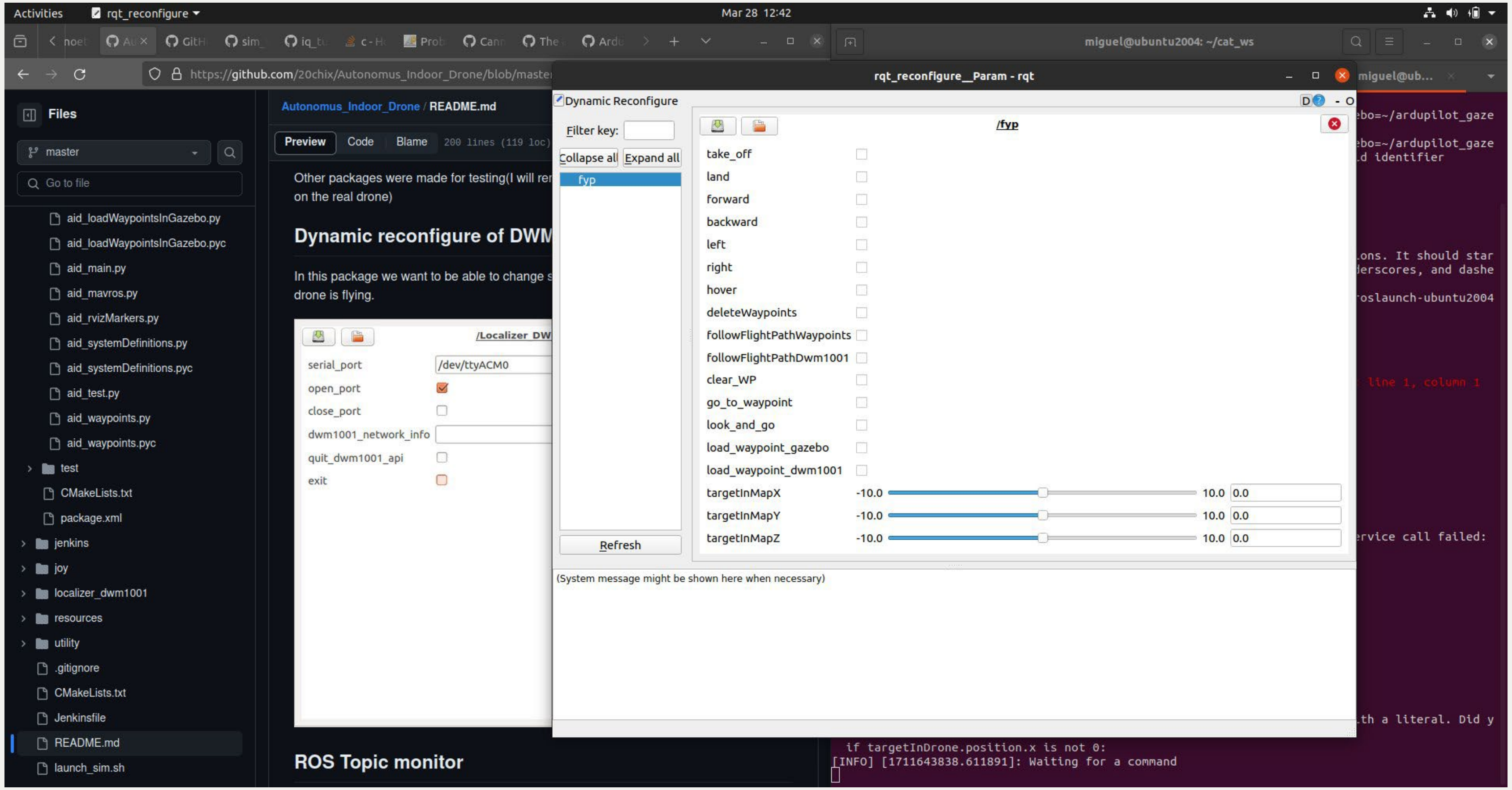
Set voltage (V)	Measured voltage (V)	Percent difference
5	4.65	7.53
5	4.70	6.50
5	4.73	5.67
5	4.80	4.10
5	4.52	10.50
5	4.61	8.56
5	4.71	6.16
5	4.84	3.33
5	4.65	7.43
5	4.77	4.71
5	4.90	2.13
5	4.54	10.17
5	4.59	8.94
5	4.71	6.25
5	4.56	9.66

PSSC 4

- Set up MAVLINK Protocall between the Intel Board and the Pixhawk.
- Implement a small scale Mav link tests.
- Have the MAVLINK automatically collect data such as motor currents,
  system temperature, battery life, and fan status



PSSC 4 continued



PSSC 5

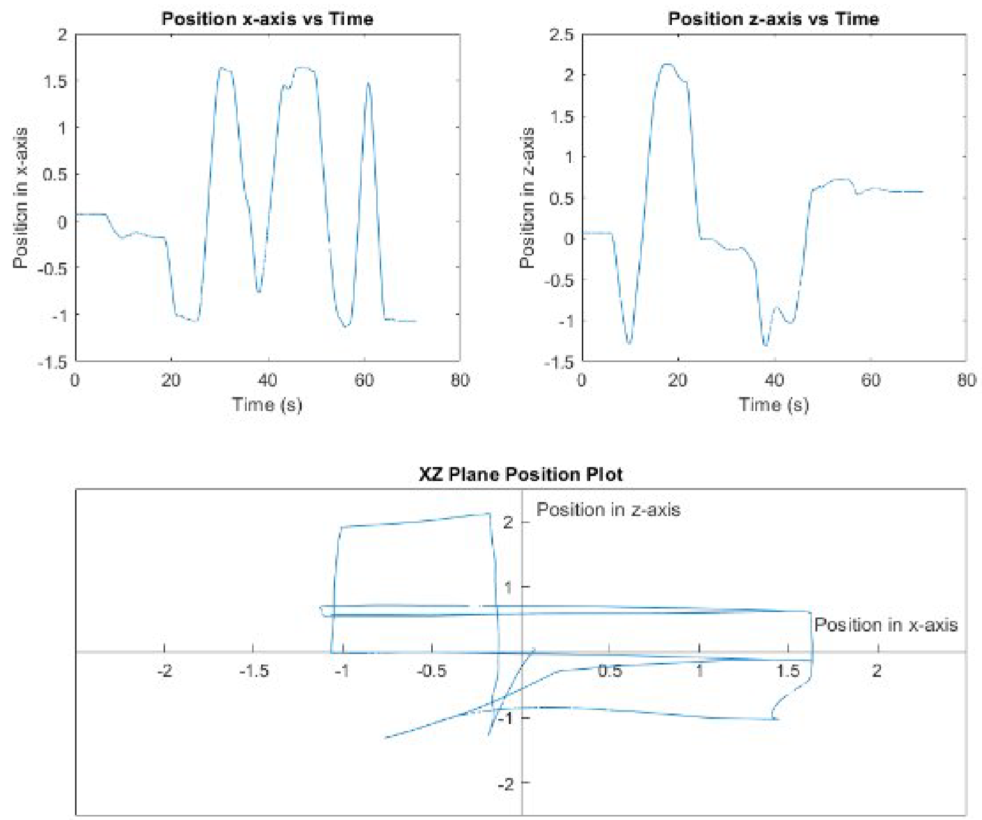
- We were unable to get the drone to fly stably
- ROS and Beacon functionality test
- Landing on replicated top of the platform.
    - I) Test integrity of drone post-landing.
    - II) Determine damage to platform.(least impotant)
    - III)Determine accuracy of landing by measuring how far off the drone landed from the center of the platform. (most important)
- Land the drone on the team 5 platform.

ML Problem

- Wanted to predict the location of the drone
- Used a regression learning model
- Time is our independent, or predictor, variable
- The location is our dependent, or continuous, variable
- Solving this problem will allow us to obtain accurate and precise landing

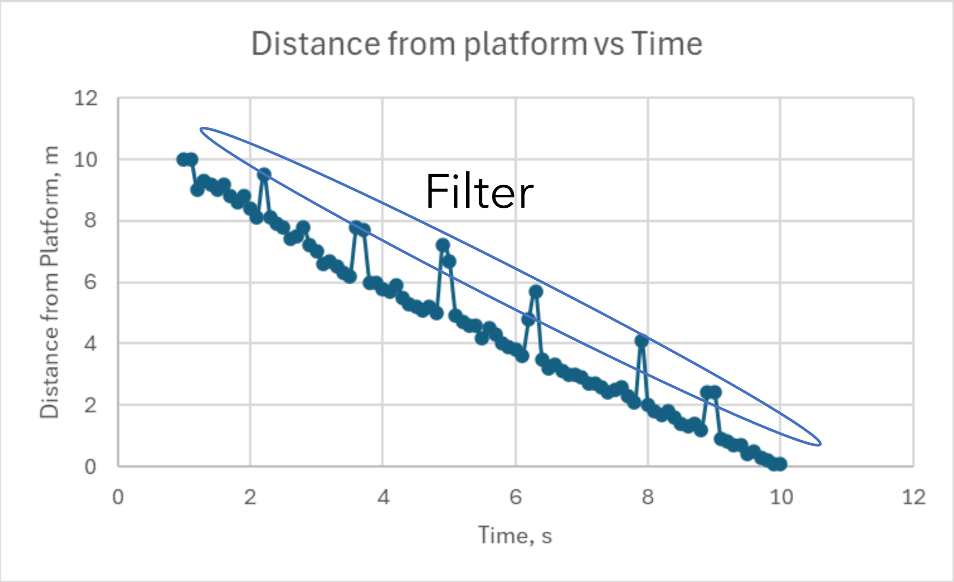
Data Collection

	Type	Rigid Body	Rigid Body	Rigid Body	Rigid Body	Rigid Body	Rigid Body	Rigid Body
	Name	usrp	usrp	usrp	usrp	usrp	usrp	usrp
	ID	83CD646A	83CD646A	83CD646A	83CD646A	83CD646A	83CD646A	83CD646AE54711EE6
		Rotation	Rotation	Rotation	Position	Position	Position	Mean Marker Error
Frame	Time (Secc	X	Y	Z	X	Y	Z	
0	0	-0.01755	-0.04972	0.012825	0.071428	0.855582	0.066454	0.000028
1	0.008333	-0.01158	-0.06331	0.037443	0.071431	0.855585	0.066439	0.000038
2	0.016667	-0.02368	-0.07456	0.042773	0.071434	0.855586	0.066443	0.000048
3	0.025	-0.01263	-0.06395	0.041472	0.071422	0.855592	0.06645	0.000036
4	0.033333	-0.01145	-0.0391	0.01312	0.071426	0.855587	0.066452	0.000035
5	0.041667	-0.01356	-0.0639	0.028701	0.071446	0.855588	0.066434	0.000046
6	0.05	-0.01537	-0.08101	0.044925	0.07143	0.855587	0.066439	0.000042
7	0.058333	-0.01919	-0.08216	0.041657	0.071422	0.855593	0.066449	0.00003
8	0.066667	-0.00268	-0.06288	0.011196	0.071424	0.855598	0.06645	0.000034
9	0.075	0.001033	-0.06054	0.040435	0.071444	0.855585	0.06643	0.000046
10	0.083333	-0.01846	-0.07073	0.027331	0.071428	0.855593	0.066428	0.000048
11	0.091667	-0.01096	-0.08215	0.03637	0.071438	0.855592	0.066447	0.000049
12	0.1	-0.00973	-0.03789	0.025203	0.071421	0.855591	0.066451	0.00003
13	0.108333	-0.01054	-0.0499	0.007985	0.071447	0.855572	0.066439	0.000033
14	0.116667	-0.0064	-0.0562	0.030584	0.071435	0.855582	0.06643	0.000049
15	0.125	-0.046	-0.06284	0.027048	0.07144	0.855578	0.066445	0.000053
16	0.133333	-0.00805	-0.04787	0.029319	0.071423	0.855588	0.066447	0.00004
17	0.141667	-0.00884	-0.03382	0.022788	0.071434	0.855575	0.066452	0.000032
18	0.15	-0.01713	-0.05654	0.024977	0.07143	0.855585	0.06642	0.00004
19	0.158333	-0.01565	-0.07069	0.046649	0.071442	0.855592	0.066432	0.000047
20	0.166667	0.011538	-0.0681	0.067852	0.071429	0.855591	0.066439	0.000037

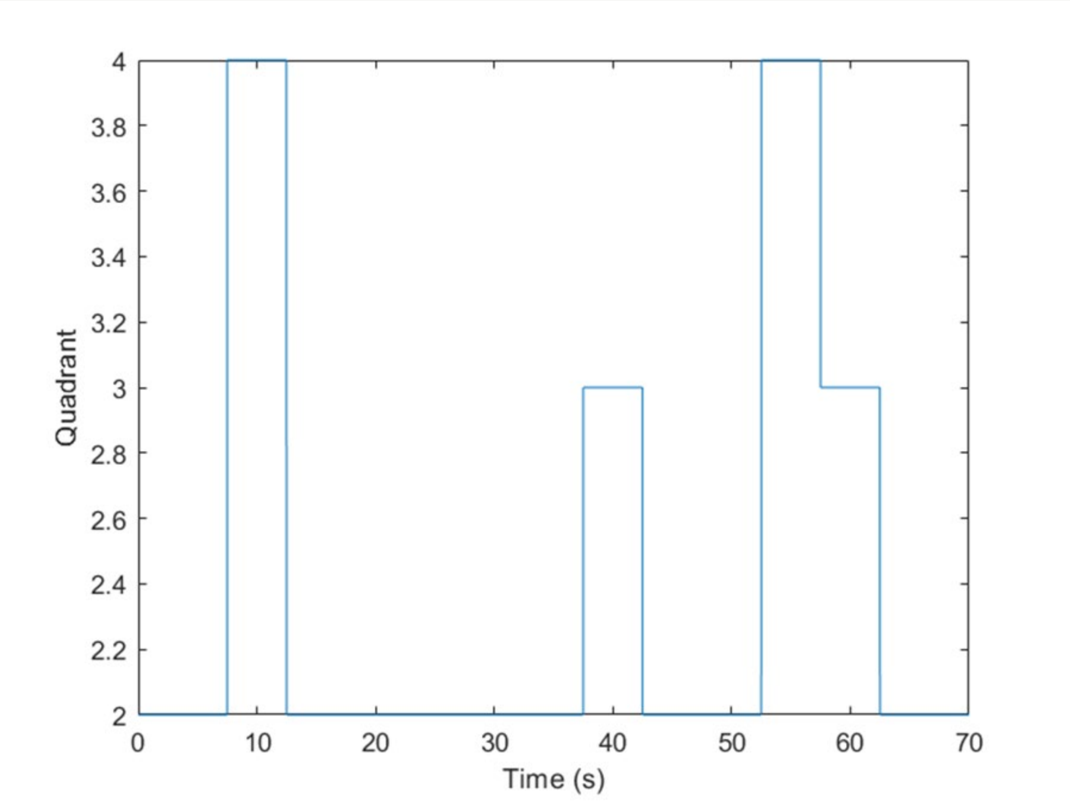


Feature Selection

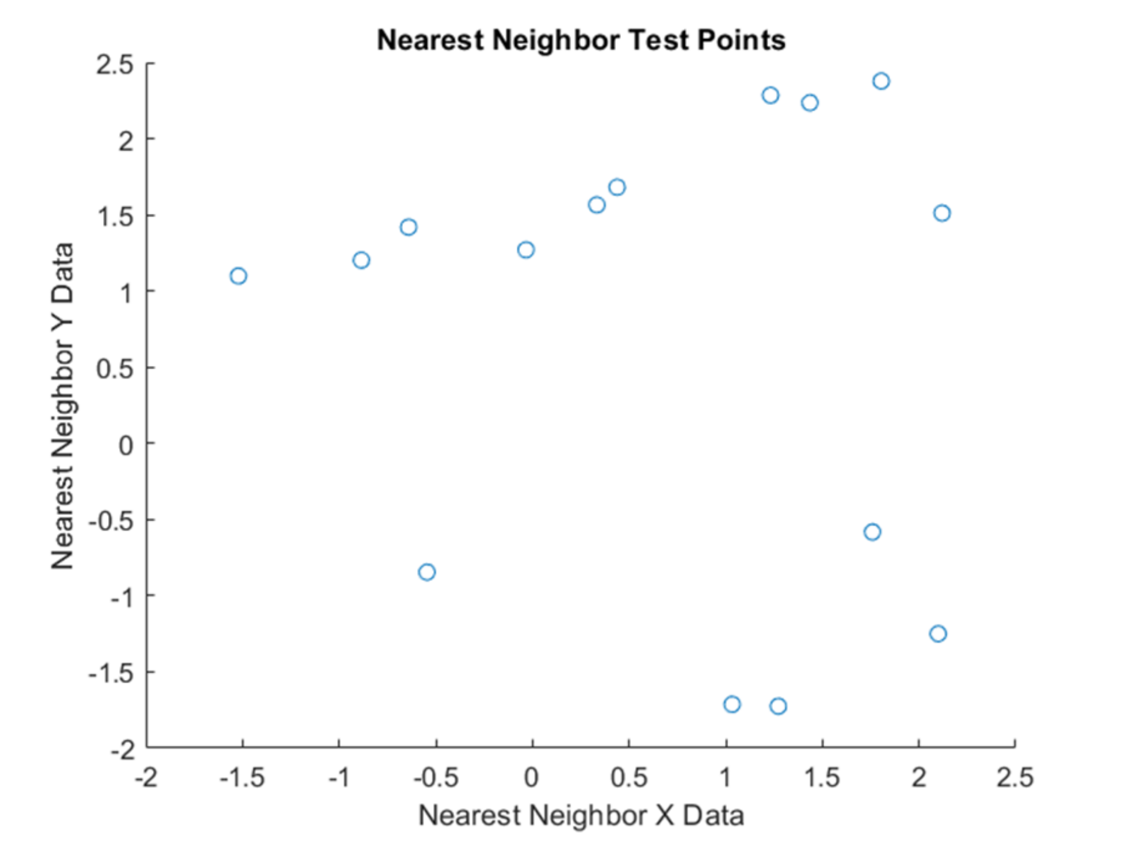
- Want to select relevant and linear data
- Use a variation threshold to remove unwanted data



Training



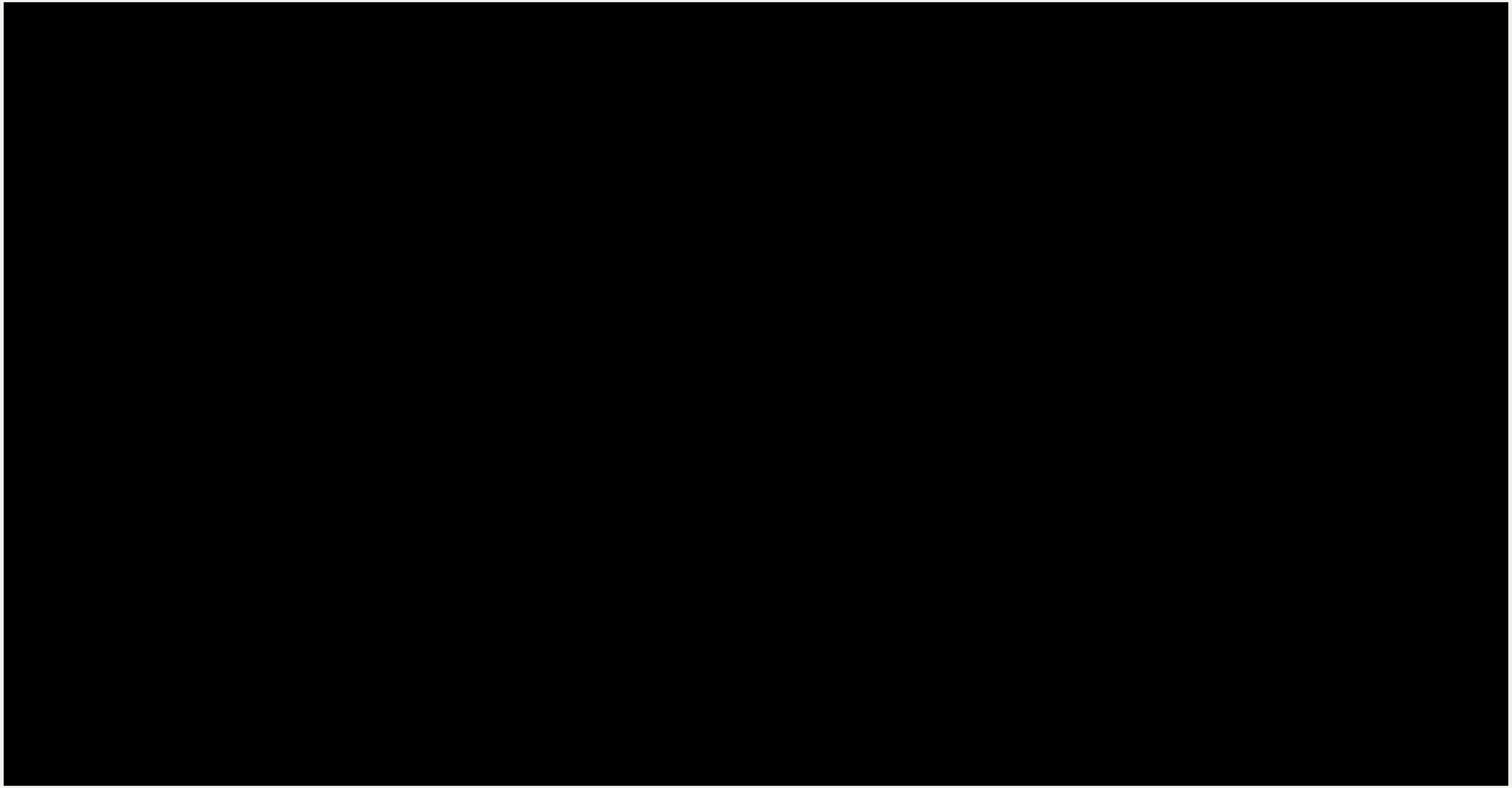
Quadrant
Time (s)
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
0
10
20
30
40
50
60
70



Nearest Neighbor Test Points
Nearest Neighbor Y Data
Nearest Neighbor X Data
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5

Prediction

- We used a 80-20 split of our data where 80% is the training and 20% is the Testing.
- Based on the data the module predicts, we measure its accuracy on precision accuracy.
- We use the prediction obtained from MATLAB and compare it to the actual physical location of our test object.
- The data had a low mean error so we can confidently use it to compare the results of the prediction.



Future work

- Obtain more data for the Machine Learning to improve the algorithm and run more prediction tests
- Fix drone motors
- Test fly the drone with manual and automated control.

Closing Remarks

We would like to show our gratitude to the Department's Director of Technical Ops, Andrew Davis; Prof. Matthew Bell; Prof. Kiersten Kerby-Patel; Prof. Michael Rahaim; Prof. Tomas Materdey; and fellow classmates.