Department of Electrical Engineering and Computer Science

Howard University, Washington, DC 20059

EECE 401: Senior Design

Spring 2024

Final Report

By.

Adebola Babatunde-Lawal

Lauren Dewberry

Phillips Akinbami

Emmanuel Igban

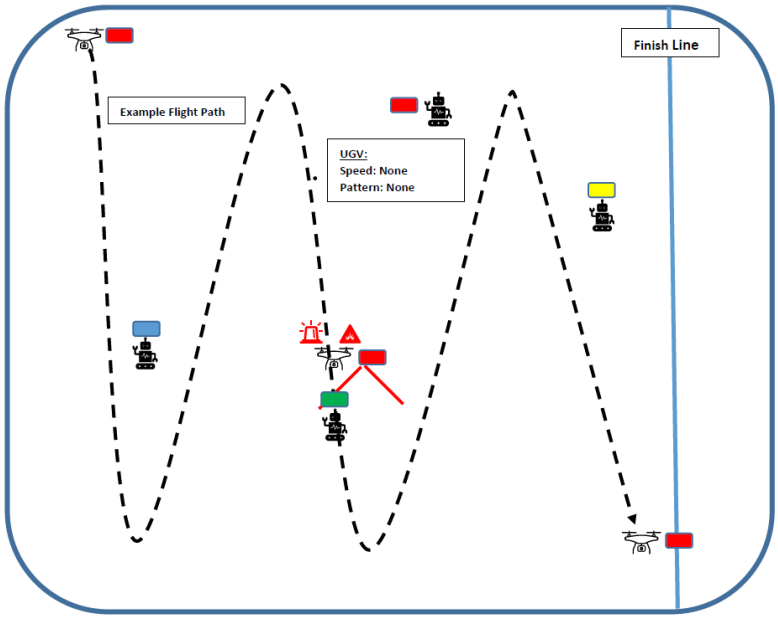
Submission Date: 4/23/2024

Abstract

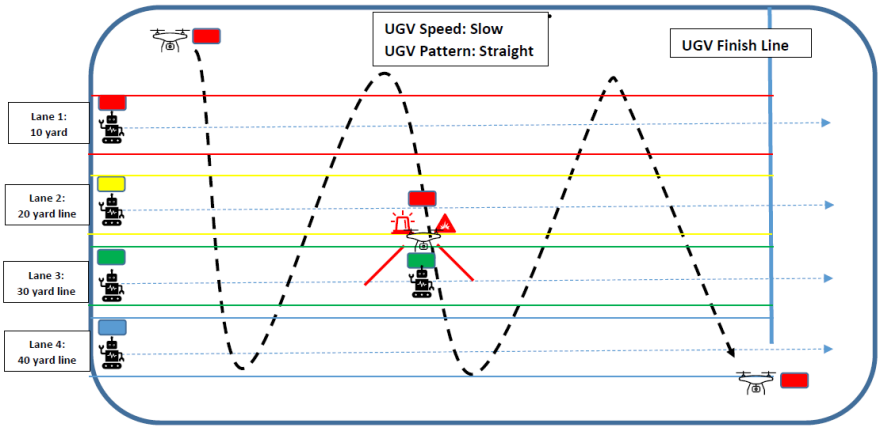
The development of drones first commenced when the Royal Air Force of the United Kingdom required target practice for training their pilots. The previous method of towing gliders behind the aircraft proved too ineffective in emulating the realistic situation pilots needed. In response to this, the De Havilland DH.828 Queen Bee aircraft, which was a radio-controlled drone, was developed for a more pragmatic aerial target practice. From its early uses in warfare, the modern drone has now expanded in its uses such as videography, weather monitoring, personal use, and more.

The purpose of this report is to design and develop a drone that conforms to the guidelines of the RTX Drone Challenge. For the RTX Challenge, there is a total of four challenges in addition to a bonus challenge which in total comes out to be five challenges.

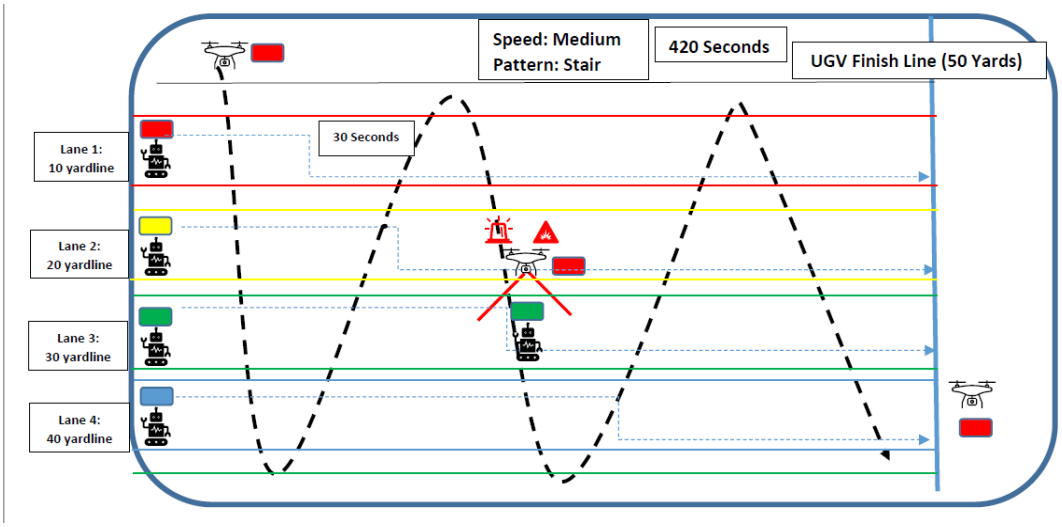
The first challenge requires the UAV to deliver water to opposing UGVs while stagnant within 10 minutes.



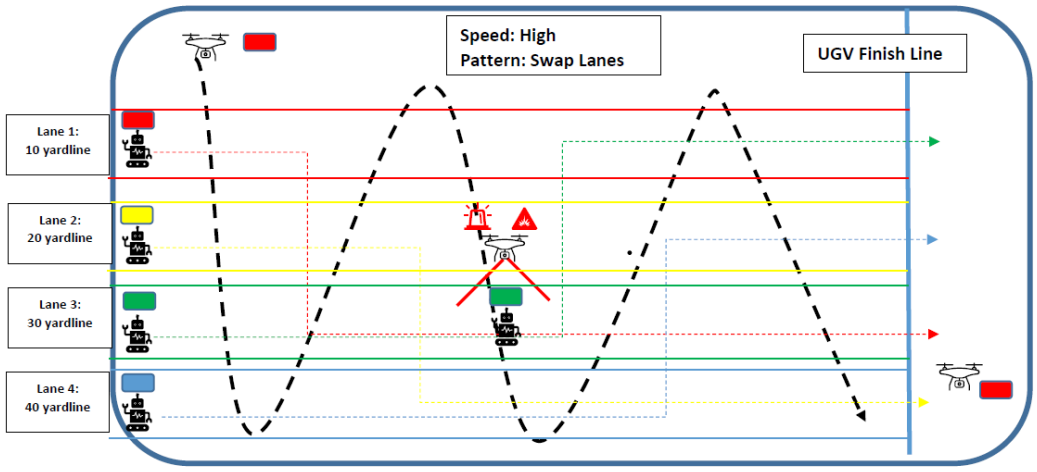
The second challenge requires the UAVs to search for the opposing UGVs while moving 12 seconds per yard to deliver a water blast and after doing so will land in its designated landing zone within 10 minutes.



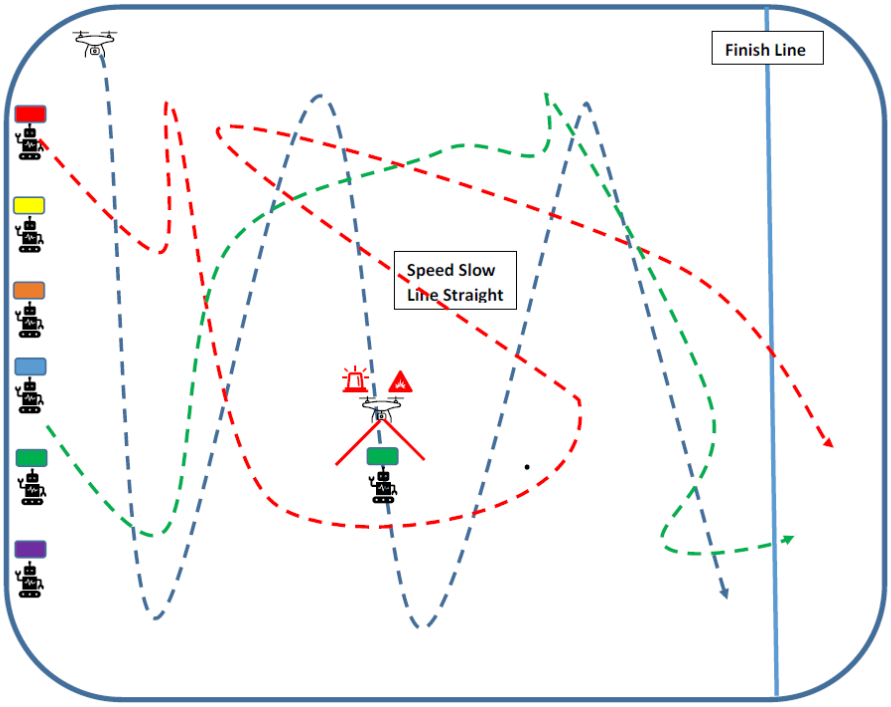
The third challenge requires the UAV to autonomously search and tag the UGVs delivering water blasts onto opposing UGVs while the UGV makes 90 degrees to left and right, and then returns to the designated landing zone within 7 minutes.



The fourth challenge requires the UAV to identify the opposing UGVs delivering water blasts while the UGVs are swapping routes within 5 minutes.



The Bonus challenge requires the UAVs to identify all opposing UGVs and deliver water blasts while the UGVs are moving randomly. The UAV will be autonomous in all challenges and this will be achieved by using Python and possibly Arduino.



From these requirements, we can determine what is required of our UAV which will particularly require a camera and water jet to identify and deliver water to the correct UGVs. As a team, we are looking forward to the outcome of our drone and its performance in this challenge.

Problem Statement

People need to access moving ground objects using an autonomous flying drone. We have come to a few conclusive ideas that would allow the drone to make autonomous decisions in determining who is an ally or an enemy on the ground level. Customers will use drones to perform tasks in dangerous environments for military use in targeting enemies from afar. Our project will allow people to access environments that could pose threats to them, allowing them to avoid injuries/harm.

Design Requirements

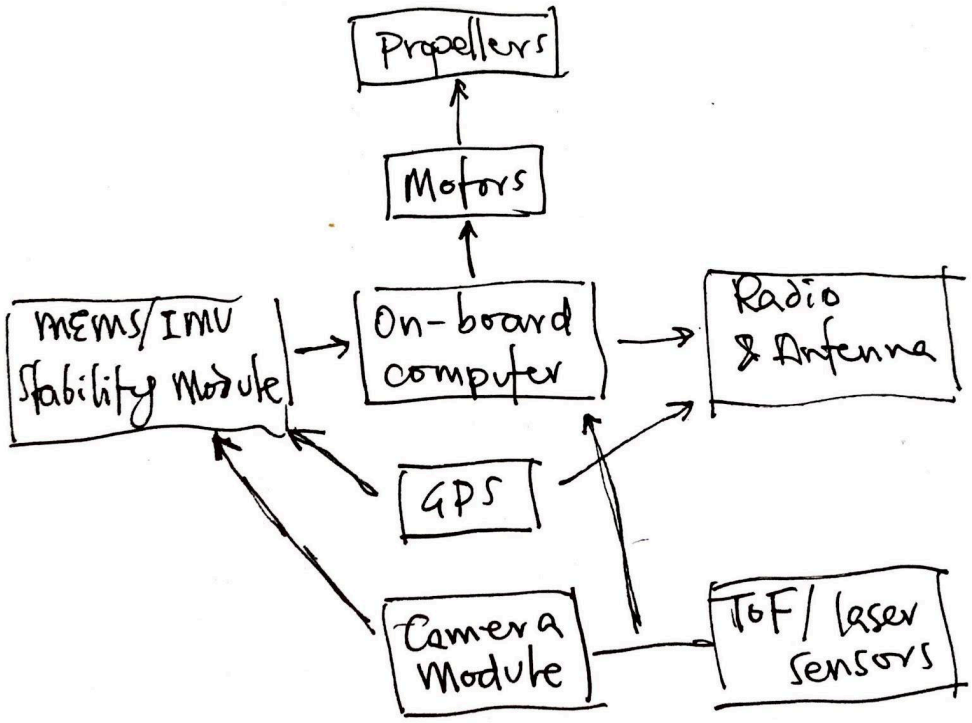
Requirements	Items	Quantity
1. Product Specification	Propellers	4-6
	Battery(input and output charger)	1-2
	Flight LED	1
	Remote Control Board	1
	Camera	1
	Landing apparatus	1
	On-board computer (PCB?)	1
	Ultrasonic ToF(time of flight) sensor Barometric pressure sensor	1 each
	GPS	1
	Motors	4-6

2. Constraints	**Environmental Constraints**	Battery limitation Wildlife and ecosystem disruptions
	Socio-Cultural Constraints	The geographic location must not be tampered with. Noise liability Weight limitations Privacy disrespect
	Compliance (Rules, Regulations, and Standards)	The drone cannot fly over the stadium Altitude limitations(specifically plane altitudes)

Design and Alternative Design

Description of Solution Design 1

The drone in the image above will have a flight LED/laser and a camera. The propellers will help our drone fly up from the landing apparatus when in motion. From the air, the camera will help detect which ground object is an ally or an enemy and will use the laser to single out the enemy target. The battery and the Ultrasonic ToF, the Barometric sensor, and GPS will hidden away underneath the drone to avoid unwanted outside elements. The Ultrasonic sensor will help the drone detect other objects/ drones in the sky, the barometric sensor will help the drone determine the altitude when in the air, and the GPS will help us track where the drone will be at all times. A remote control will be used if the drone ever goes off-course or is unable to direct itself back to the landing apparatus.



Description of Solution Design 2

The modern drone is a marvel of advanced technology and combines several essential components to achieve exceptional flight capabilities. Central to its design are four propellers powered by electric motors, allowing agile flight. The battery powers the drone and charges it efficiently. The Flight LED is equipped with a laser that harmlessly targets and tracks enemy Unmanned Ground Vehicles (UGVs) as identified by the camera. The high-resolution camera captures photos and videos and is crucial for detecting and tracking UGVs. The drone is equipped with a stable landing gear for safe landing and protection. The onboard computer (PCB) processes the data and coordinates the flight. Ultrasonic ToF and barometric pressure sensors ensure precise altitude control. The GPS technology enables precise location tracking, while powerful electric motors drive the propellers to generate thrust.

Sub	Pros	Cons
Sub- 1	● Lightweight ● Easy use ● Protected camera and laser ● Protected barrier for other parts	● Weak stability in the wind ● No ease of movement for the camera or laser
Sub 2	● Stable flight ● Accurate navigation ● Precise targeting	● Complexity ● Weight increase

Decision Matrix

	Wt	**Design 1**	**Score**	**Agg Score**	**Design 2**	**Score**	**Agg Score**
Functionality	5	Remote control	2	10	- GPS - ToF - Propellers Process	5	25
Connectivity	3	Bluetooth	2	6	Radio	4	12

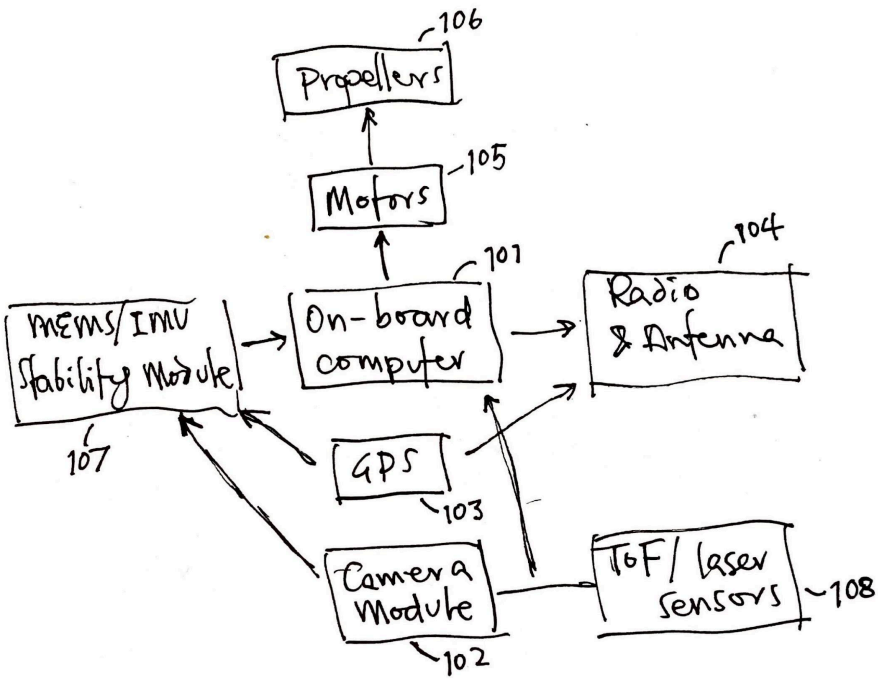
Weight	2	Approx 4.2 lbs	5	10	Approx. 6 lbs	2	4
Power	4	Few devices to power	5	20	More Power needed	2	8
Convenience	1	- Landing apparatus - protective frame	3	3	OIS, MEMS, Landing	5	5
Total				49			54

Top Chosen

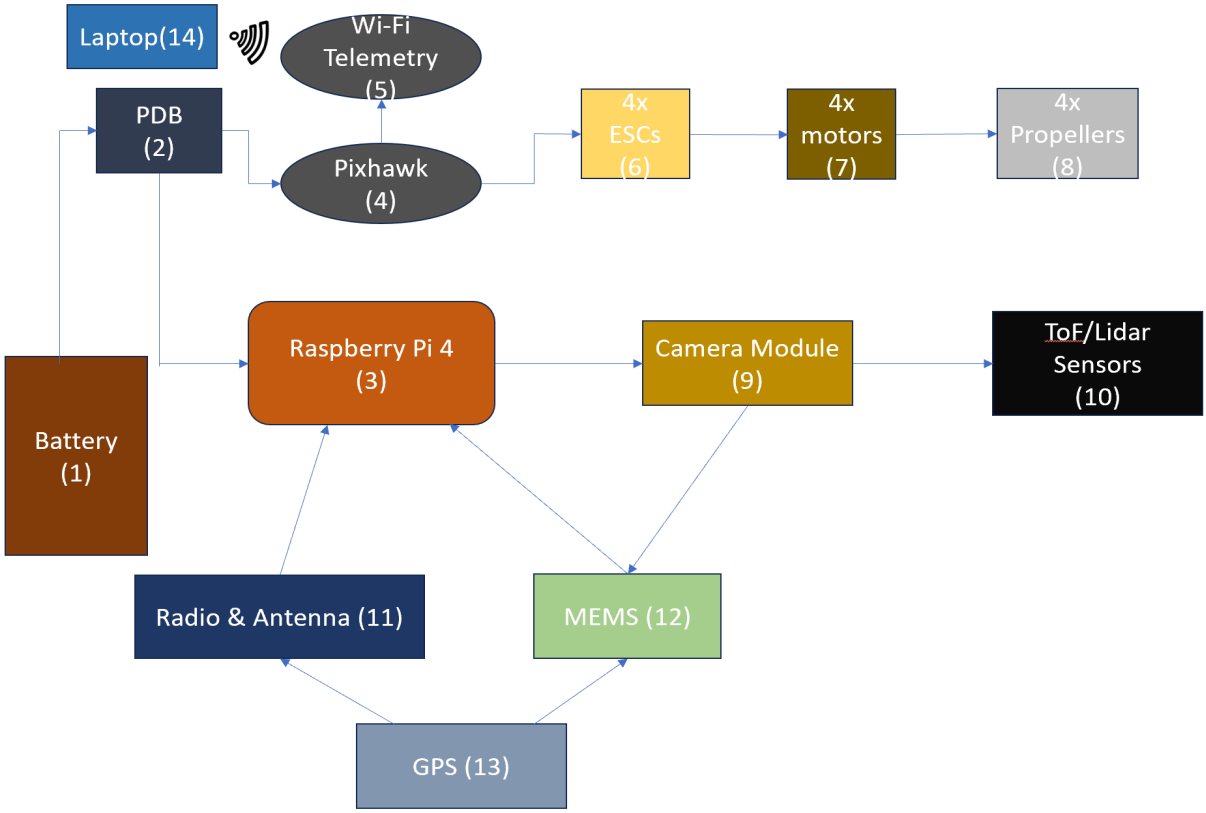
According to the design matrix, our team decided to follow design 2 as it is much more articulate and has more materials that can be helpful for our drone competition.

Top Solution Description

The modern drone is a marvel of advanced technology and combines several essential components to achieve exceptional flight capabilities. Central to its design are four propellers **(106)** powered by electric motors **(105)**, allowing agile flight. The battery powers the drone and charges it efficiently. The Flight LED is equipped with a laser **(108)** that harmlessly targets and tracks enemy Unmanned Ground Vehicles (UGVs) as identified by the camera **(102)**. The high-resolution camera **(102)** captures photos and videos and is crucial for detecting and tracking UGVs. The drone is equipped with stable landing gear **(107)** for safe landing and protection. The onboard computer [PCB] **(101)** processes the data and coordinates the flight. Ultrasonic ToF **(108)** and barometric pressure sensors ensure precise altitude control. The GPS **(103)** technology enables precise location tracking, while powerful electric motors **(105)** drive the propellers **(106)** to generate thrust.



Component-Level Blueprint



Howard University's: UAV Team

Lauren Dewberry
Adebola Babatunde-Lawal
Emmanuel Igban
Philips Akinbami

Detailed Expense Report

Fall 2023

Educational Institution
Howard University

School
College of Engineering and Architecture

Department
Electrical Engineering and Computer Science

Project Advisor
Kim Charles/Danda Rawat

Purpose
Product Specifications

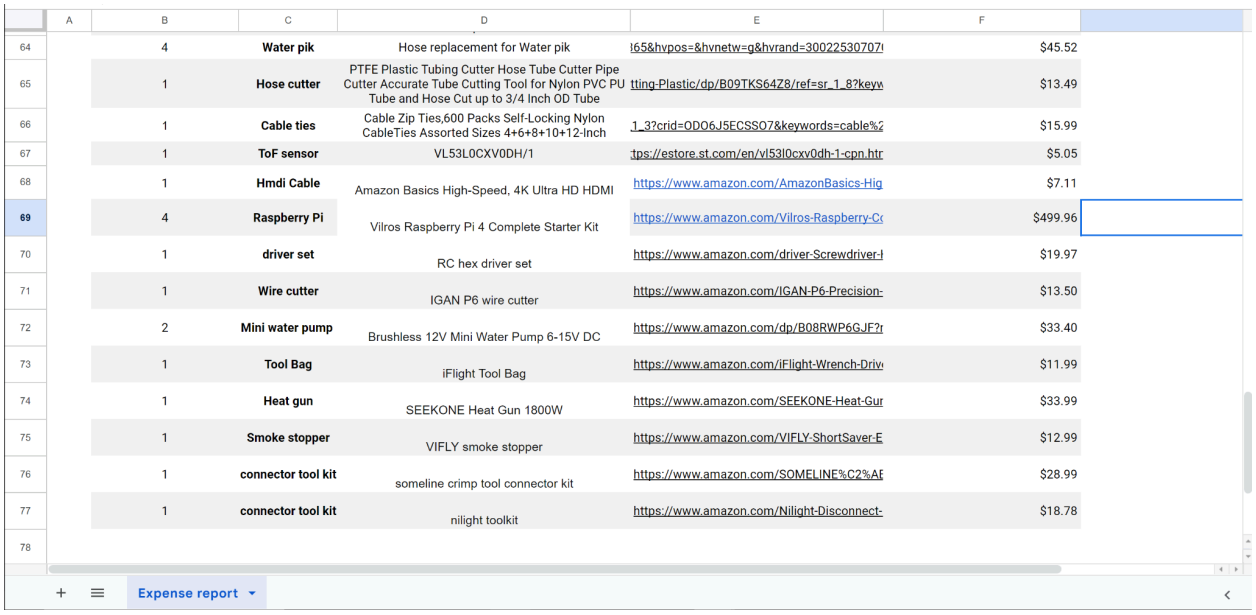
Quantity	Category	Product	Website Links	Cost Range
2	**Battery**	OVONIC 6S Lipo Battery 100C 1300mAh 22.2V Lipo Battery with XT60 Connector for RC FPV Racing Drone Quadcopter	'058745944&hvpone=&hvptwo=&hvqmt=&hvde	$55.78
1	**Batter Straps**	QWORK Safety Lashing Kit, 4 Pack Battery Box Retaining Strap Kit Large Retaining Strap for	T37PBBX3JHGO&keywords=Battery%2BStraps	$9.97
3	**Propeller(2 pairs)**	YoungRC A2212 1000KV Brushless Motor + 30A ESC Electric Speed Controller + 1045 Propeller	id=Y8G66R01M06H&keywords=Propeller+104	$62.97
1	**Extra propellers(10 pairs)**	QWinOut 3k Carbon Fiber Propeller Cw CCW 1045, 10 pairs	T/ref=sr_1_7?crid=K3VVDJOSV5JF&keywords=	$27.88
1	**Camera Module**	LEEKWI for Raspberry Pi Camera Module, IMX219 Camera Module V2-8 Megapixel, 1080P@30fps RPI CAM	&keywords=raspberry+pi+camera+module+v2	$14.99
2	**PINS**	Pastall Raspberry Pi camera cable 15 pin	rid=3NEKNIG8KQ5PC&keywords=15+pin+to+2	$15.98
1	**Electrical cables**	Silicon wire--> 10awg	omotive/dp/B089CPT19P/ref=sr_1_5?keyword	$39.99
1	**Electrical cables**	Silicon wire--> 12awg	omotive/dp/B089CJ65SC/ref=sr_1_5?keyword	$17.99
1	**Electrical cables**	Silicon wire--> 14awg	omotive/dp/B089CNJPRD/ref=sr_1_5?keyword	$24.99
1	**Electrical cables**	Silicon wire--> 16awg	omotive/dp/B089CPH72F/ref=sr_1_5?keyword	$11.99
1	**Electrical cables**	Silicon wire--> 18 awg	omotive/dp/B089CRCXRK/ref=sr_1_5?keyword	$11.99
1	**Electrical cables**	Silicon wire--> 22 awg	omotive/dp/B089CQ2N69/ref=sr_1_5?keyword	$9.49
1	**Electrical cables**	Silicon wire--> 26awg	omotive/dp/B089CQJHQC/ref=sr_1_5?keyword	$15.99
1	**Electrical cables**	Silicon wire--> 30 awg	omotive/dp/B089D2B6T6/ref=sr_1_5?keyword	$8.99
1	**soldering iron**	UY CHAN originalsoldering iron	ammable-Pocket-size-Acceleration/dp/B01MD	$79.99

	A	B	C	D	E	F
35		1	**soldering iron**	UY CHAN originalsoldering iron	ammable-Pocket-size-Acceleration/dp/B01MD	$79.99
36		1	**Raspberry Pi**	Raspberry Pi 4 Model B 2019 Quad Core 64 Bit WiFi Bluetooth (4GB)	)Z&keywords=Raspberry+Pi&qid=1699810273	$65.98
37		5	**SD cards**	SanDisk 512GB Ultra SDXC UHS-I Memory Card	XyH5IAvH3I6rWHwwaPyG_gX1v68TKtPu0hl84	$234.75
38		5	**Additional SD cards**	Gigastone 128GB 5-Pack SD Card UHS-I U1 Class 10 SDXC Memory Card	rWHwwaPyG_gX1v68TKtPu0hl841zKxUyEGNk	$79.98
39		1	**MEMS**	HiLetgo 3pcs GY-521 MPU-6050 MPU6050 3 Axis Accelerometer Gyroscope Module	m/dp/B00LP25V1A/ref=twister_B078SS8NQV	$9.99
40		1	**Antenna**	Radiolink AT10II 12 Channels RC Transmitter and Receiver R12DS 2.4GHz Radio Remote, Voltage Telemetry for RC Airplane, FPV Racing Drone, Quad, Helicopter, Car and Boat (Mode 2 Left-Hand Throttle)	and+Receiver&qid=1699811135&sprefix=rc+tra	$168.99
41		1	**Pixhawk**	Pixhawk PX4 PIX 2.4.8 Flight Controller	746dde5-5539-43d2-b75f-28935d70f100&pf_r	$279.00
42		1	**GPS**	FPVDrone M8N GPS Module	1SPAEJA&keywords=GPS+and+Compass+Mo	$34.99
43		2	**PDB**	Matek X Class 12S PDB	7MHKTF7F/ref=sr_1_1?crid=3J58R9NXGHVB	$77.58
44		1	**ESC**	Flycolor 60A ESC 3-6S Electric Speed Controller	?crid=290W0NCEBHS8Z&keywords=motor+fla	$33.85
45		4	**Extra Motors**	Motor 2216-880KV-CCW (1PC)	ctions/s500/products/spare-parts-s500-v2-kit?	$79.96
46		4	**Extra Motors**	Motor 2216-920KV-CCW (1PC)	https://holybro.com/collections/s500/produ	$79.96
47		4	**Extra ESC**	S500 V2-BLHeli S 20A ESC(1PC)	ctions/s500/products/spare-parts-s500-v2-kit?	$55.96
48		1	**Carbon Fiber Frame**	S500 Quadcopter Frame Stretch X FPV Drone Frame Kit PCB Version with Carbon Fiber Landing Gear	6dde5-5539-43d2-b75f-28935d70f100&pf_rd_r	$47.89
49		2	**Wifi Telemetry Module**	PONPED Pixhawk APM Wireless WiFi Radio Telemetry Module with Antenna for New MAVLink2 Compatible with Flight Controller FPV Drone Smartphone Table (Color : for Pixhawk)	_4?crid=2HT7714ARAFSK&keywords=Wifi%2B	$61.94
50		2	**Double sided tape**	3M Double Sided Tape, Heavy Duty Waterproof Foam Tape	l&keywords=double-sided+tape+%283M&qid=1	$25.98
				Benewake TF-Luna LiDAR Module Range Finder		

G69 | fx

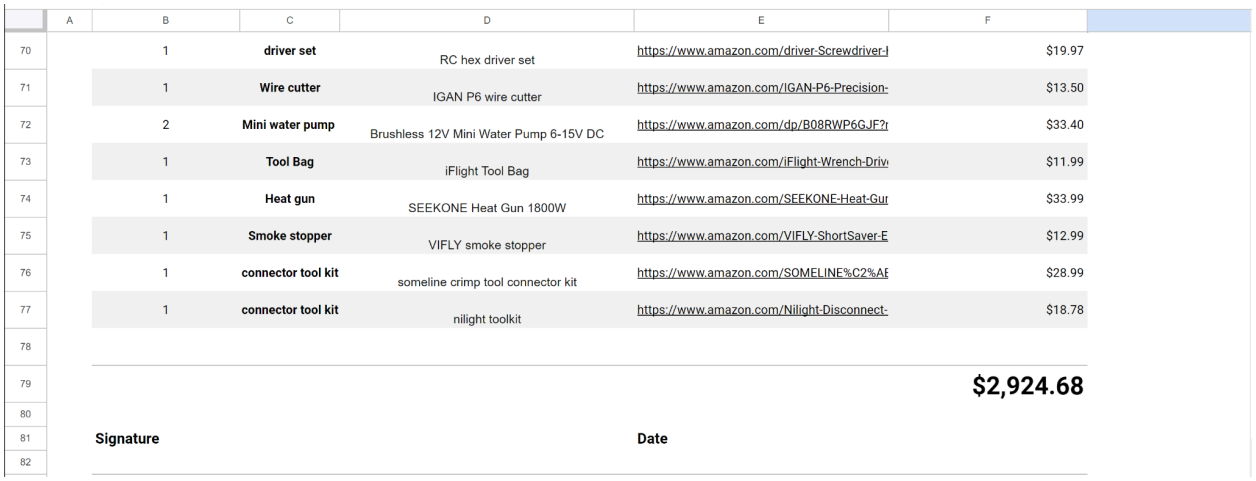
	A	B	C	D	E	F
				Smartphone Table (Color : for Pixhawk)		
50		2	**Double sided tape**	3M Double Sided Tape, Heavy Duty Waterproof Foam Tape	l&keywords=double-sided+tape+%283M&qid=1	$25.98
51		2	**LiDAR**	Benewake TF-Luna LiDAR Module Range Finder Sensor Single-Point Micro Ranging Module for Arduino Pixhawk 5V UART IIC Interface	n/Benewake-TF-Luna-Single-Point-Ranging-Int	$53.18
52		1	**Soldering kit**	YIHUA 926 III 60W Digital Display Soldering Iron Station Kit	007761&hvnetw=g&hvqmt=e&hvrand=108542	$59.99
53		1	**Water Container**	SUPANT Collapsible Emergency Water Jug 5L 4 packs	rd_p=a53ea610-e450-44d1-897e-68c0c718bf5	$12.88
54		1	**Sprinkling system w/ pump**	Mornajina Outdoor Misting Cooling System with Pump Kit	SB7T9H&keywords=misting%2Bsystem%2Bpu	$66.89
55		2	**Sprinkler**	Hourleey 360 Degree Metal Spot Sprinkler, 2 Pack Circle Pattern Sprinkler with Gentle Water Flow for Small Area Yard Lawn Garden Watering, Coverage Up to 30FT (Blue)	lW1M2/ref=sr_1_36?crid=3IWE7E7JDZQ2F&ke	$23.98
56		1	**Waterproof Glue**	Plimida Waterproof Insulating Glue	8BVSt2s9Izjd6EyHjCswITShebtIQcpPEkUo_gvk	$8.59
57		1	**Mechaical claw**	Drone remote control intelligent mechanical cla	7Q&keywords=mechanical+claw&qid=1702494	$98.18
58		1	**Airpseed Sensor**	System Digital Airspeed Sensor	3DI7XE&keywords=drone+Time-of-Flight+%281	$64.26
59		3	**Water balloons**	Water Balloons Quick Fill 777 Pack Self	lable-Swimming/dp/B0CC452L3D/ref=sr_1_16	$89.97
60		1	**Water misting system**	LANDGARDEN Outdoor Misting Fan Kit for a Cool Patio Breeze,Water Mister Spray for Cooling Outdoor	9-36FT-Nozzles/dp/B08DXSS216/ref=zg_bs_g	$16.99
61		1	**Misting system**	Mornajina Outdoor Misting Cooling System with Pump Kit	SB7T9H&keywords=misting%2Bsystem%2Bpu	$66.89
62		1	**Addional misting system**	Standing Misters for Outside Patio, 26.5 FT Portable Misting System	graded-Backyard/dp/B0BWQ1MGYZ/ref=zg_bs	$19.99
63		1	**Addition hose**	Hourleey 50 Feet Blank Distribution Tubing Irrigation Drip Hose	lTPT&keywords=water%2Bpipes%2Bfor%2Bde	$9.99
64		4	**Water pik**	Hose replacement for Water pik	65&hvpos=&hvnetw=g&hvrand=300225307071	$45.52
				PTFE Plastic Tubing Cutter Hose Tube Cutter Pipe		

Expense report



	A	B	C	D	E	F
64		4	**Water pik**	Hose replacement for Water pik	!65&hvpos=&hvnetw=g&hvrand=30022530707(	$45.52
65		1	**Hose cutter**	PTFE Plastic Tubing Cutter Hose Tube Cutter Pipe Cutter Accurate Tube Cutting Tool for Nylon PVC PU Tube and Hose Cut up to 3/4 Inch OD Tube	tting-Plastic/dp/B09TKS64Z8/ref=sr_1_8?keyw	$13.49
66		1	**Cable ties**	Cable Zip Ties,600 Packs Self-Locking Nylon CableTies Assorted Sizes 4+6+8+10+12-Inch	1_3?crid=0DO6J5ECSSO7&keywords=cable%2	$15.99
67		1	**ToF sensor**	VL53L0CXV0DH/1	tps://estore.st.com/en/vl53l0cxv0dh-1-cpn.htr	$5.05
68		1	**Hmdi Cable**	Amazon Basics High-Speed, 4K Ultra HD HDMI	https://www.amazon.com/AmazonBasics-Hig	$7.11
69		4	**Raspberry Pi**	Vilros Raspberry Pi 4 Complete Starter Kit	https://www.amazon.com/Vilros-Raspberry-C(	$499.96
70		1	**driver set**	RC hex driver set	https://www.amazon.com/driver-Screwdriver-I	$19.97
71		1	**Wire cutter**	IGAN P6 wire cutter	https://www.amazon.com/IGAN-P6-Precision-	$13.50
72		2	**Mini water pump**	Brushless 12V Mini Water Pump 6-15V DC	https://www.amazon.com/dp/B08RWP6GJF?r	$33.40
73		1	**Tool Bag**	iFlight Tool Bag	https://www.amazon.com/iFlight-Wrench-Driv	$11.99
74		1	**Heat gun**	SEEKONE Heat Gun 1800W	https://www.amazon.com/SEEKONE-Heat-Gur	$33.99
75		1	**Smoke stopper**	VIFLY smoke stopper	https://www.amazon.com/VIFLY-ShortSaver-E	$12.99
76		1	**connector tool kit**	someline crimp tool connector kit	https://www.amazon.com/SOMELINE%C2%AE	$28.99
77		1	**connector tool kit**	nilight toolkit	https://www.amazon.com/Nilight-Disconnect-	$18.78
78						

Expense report



	A	B	C	D	E	F
70		1	**driver set**	RC hex driver set	https://www.amazon.com/driver-Screwdriver-I	$19.97
71		1	**Wire cutter**	IGAN P6 wire cutter	https://www.amazon.com/IGAN-P6-Precision-	$13.50
72		2	**Mini water pump**	Brushless 12V Mini Water Pump 6-15V DC	https://www.amazon.com/dp/B08RWP6GJF?r	$33.40
73		1	**Tool Bag**	iFlight Tool Bag	https://www.amazon.com/iFlight-Wrench-Driv	$11.99
74		1	**Heat gun**	SEEKONE Heat Gun 1800W	https://www.amazon.com/SEEKONE-Heat-Gur	$33.99
75		1	**Smoke stopper**	VIFLY smoke stopper	https://www.amazon.com/VIFLY-ShortSaver-E	$12.99
76		1	**connector tool kit**	someline crimp tool connector kit	https://www.amazon.com/SOMELINE%C2%AE	$28.99
77		1	**connector tool kit**	nilight toolkit	https://www.amazon.com/Nilight-Disconnect-	$18.78
78						
79						**$2,924.68**
80						
81		**Signature**			**Date**	
82						

Provided Link to expense report

https://docs.google.com/spreadsheets/d/1iypLpu4U_Y-u0FJ-ekXIWA-rFStiEybE3t1-MWIk4bA/edit#gid=1483315145

Agile Workflow

EECE404 Senior Design II
404 Agile Weekly Project Implementation Plan

Team Name	UAV TEAM
Final Solution Product	AUTOMATED DRONE

Starting Date of Week (M)	Sprint #	Increment (or intermediate working component)	Weekly development tasks
1/30/2024	1	Working stationary Drone/UAV	Acquiring the necessary UAV components listed on BOM
2/5/2024			Assemblying the UAV following close online instructions
2/12/2024			Testing UAV components and their compatibilities
2/19/2024	2	UAV autonomously flying and recognizing UGV Markers	Implementing the code recieved from Vigrina Tech
2/26/2024			Obtaining the FAA liscense by taking the required exam
3/4/2024			Testing Pixhawk and sensors to complete tasks and recognize markers
3/11/2024			Debugging for any possible errors
3/18/2024	3	UAV delivering water payload on the UGV Markers	Testing different alternatives for delivering water payload over markers before coming to a conclusion
3/25/2024			Recognizing Howard's marker and opponents markers to differentiate where to deliver water payload.
4/1/2024			Completed all possible fixes and tests the UAV require

The UAV team had the original timeline split into three sprints, where in the first sprint we would acquire the required materials. In the second sprint, we would be testing said materials and implementing the necessary code. In the final sprint, we would implement the water payload system and test it on UGV markers.
However due to some unforeseen circumstances, we were unable to get the materials, therefore we turned our focus from hardware to software. Therefore, in the first sprint, we started with implementations whereby we worked on Raspberry Pi, Ardupilot, and Ubuntu implementation – meaning we poured our focus on understanding each application. In the second sprint, we worked on the Mission Planner which would allow us to deliver commands to our UAV. It was during the second shift when we realized our focus needed to shift so we turned to simulations. Our previous efforts were helpful in the simulation process. On Oracle VM, we were able to simulate our UAV traveling on a field which we presented to all on EECS day.

Project Implementation Process:

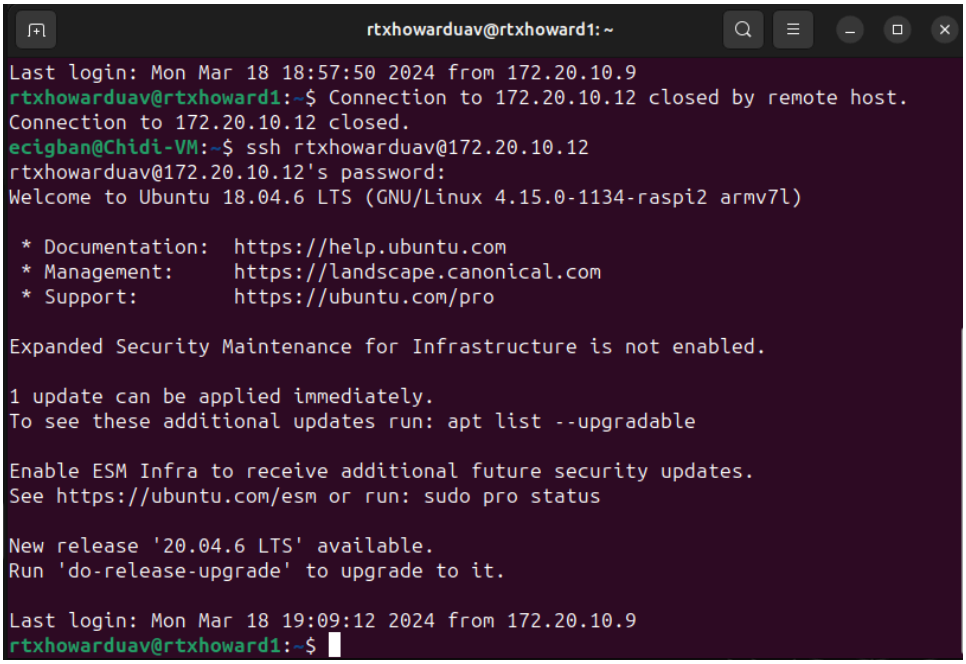
In preparation for the receipt of the necessary hardware, we began working on the software functionality of our UAV, starting with the ArUco marker detection. The publicly available CV2 python library was a crucial tool for detecting, decoding, and extracting several sizes and marker configurations from camera data, similar to a barcode reader. Given that the UAV is intended to scan its surroundings as it advances through the course and would need to execute the detection code in real-time, we used an algorithm that captures photos from the live camera feed at regular intervals and attempts to extract marker data.

```python
# import the necessary packages
from imutils.video import VideoStream # webcam access
import argparse # command-line parse
import imutils # resize image
import time # camera delay
import cv2 # open cv library
import sys # system command (exit script)

# construct the argument parser and parse the arguments
ap = argparse.ArgumentParser()
ap.add_argument("-t", "--type", type=str,
        default="DICT_ARUCO_ORIGINAL",
        help="type of ArUCo tag to detect")
args = vars(ap.parse_args())

# define names of each possible ArUco tag OpenCV supports
ARUCO_DICT = {
        "DICT_4X4_50": cv2.aruco.DICT_4X4_50,
        "DICT_4X4_100": cv2.aruco.DICT_4X4_100,
        "DICT_4X4_250": cv2.aruco.DICT_4X4_250,
        "DICT_4X4_1000": cv2.aruco.DICT_4X4_1000,
        "DICT_5X5_50": cv2.aruco.DICT_5X5_50,
        "DICT_5X5_100": cv2.aruco.DICT_5X5_100,
        "DICT_5X5_250": cv2.aruco.DICT_5X5_250,
        "DICT_5X5_1000": cv2.aruco.DICT_5X5_1000,
        "DICT_6X6_50": cv2.aruco.DICT_6X6_50,
        "DICT_6X6_100": cv2.aruco.DICT_6X6_100,
        "DICT_6X6_250": cv2.aruco.DICT_6X6_250,
        "DICT_6X6_1000": cv2.aruco.DICT_6X6_1000,
        "DICT_7X7_50": cv2.aruco.DICT_7X7_50,
        "DICT_7X7_100": cv2.aruco.DICT_7X7_100,
        "DICT_7X7_250": cv2.aruco.DICT_7X7_250,
        "DICT_7X7_1000": cv2.aruco.DICT_7X7_1000,
        "DICT_ARUCO_ORIGINAL": cv2.aruco.DICT_ARUCO_ORIGINAL,
        "DICT_APRILTAG_16h5": cv2.aruco.DICT_APRILTAG_16h5,
        "DICT_APRILTAG_25h9": cv2.aruco.DICT_APRILTAG_25h9,
        "DICT_APRILTAG_36h10": cv2.aruco.DICT_APRILTAG_36h10,
        "DICT_APRILTAG_36h11": cv2.aruco.DICT_APRILTAG_36h11
}
```

```
# verify that the supplied ArUCo tag exists and is supported by
# OpenCV
if ARUCO_DICT.get(args["type"], None) is None:
        print("[INFO] ArUCo tag of '{}' is not supported".format(
                args["type"]))
        sys.exit(0)
# load the ArUCo dictionary and grab the ArUCo parameters
print("[INFO] detecting '{}' tags...".format(args["type"]))
arucoDict = cv2.aruco.Dictionary_get(ARUCO_DICT[args["type"]])
arucoParams = cv2.aruco.DetectorParameters_create()
# initialize the video stream and allow the camera sensor to warm up
print("[INFO] starting video stream...")
vs = VideoStream(src=0).start()
time.sleep(2.0)

# loop over the frames from the video stream
while True:
        # grab the frame from the threaded video stream and resize it
        # to have a maximum width of 1000 pixels
        frame = vs.read()
        frame = imutils.resize(frame, width=1000)
        # detect ArUco markers in the input frame
        (corners, ids, rejected) = cv2.aruco.detectMarkers(frame,
                arucoDict, parameters=arucoParams)

        # verify *at least* one ArUco marker was detected
        if len(corners) > 0:
                # flatten the ArUco IDs list
                ids = ids.flatten()

                # loop over the detected ArUCo corners
                for (markerCorner, markerID) in zip(corners, ids):
                        # extract the marker corners (which are always returned
                        # in top-left, top-right, bottom-right, and bottom-left
                        # order)
                        corners = markerCorner.reshape((4, 2))
                        (topLeft, topRight, bottomRight, bottomLeft) = corners

                        # convert each of the (x, y)-coordinate pairs to integer
                        topRight = (int(topRight[0]), int(topRight[1]))
```

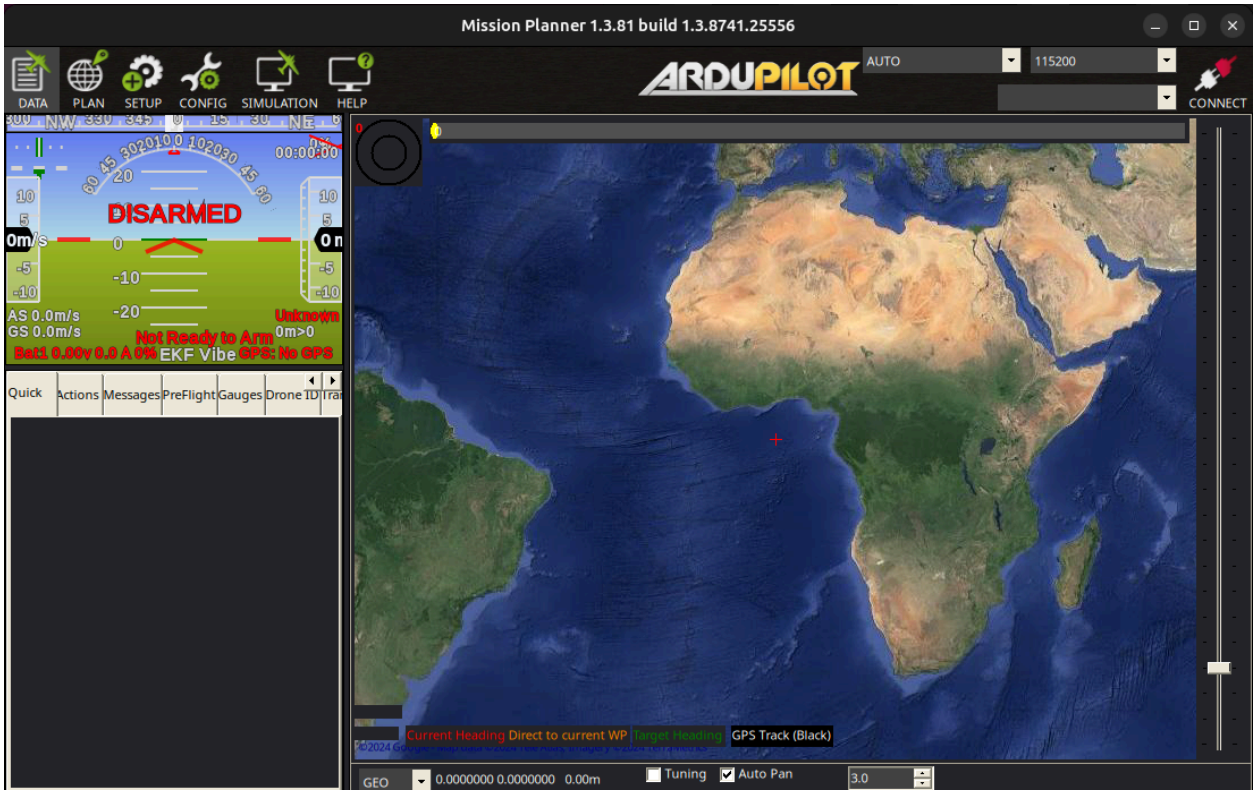
Code snippets for ArUco marker detection

Next, we began setting up the ground computer for remote communication and control of the UAV. The ground computer selected is the Ubuntu 18.04 mounted on a virtual machine. We found this version of Ubuntu to be the most flexible operating system to work with and the most compatible with the ArduPilot Mission Planner, a widely-used software tool for simulating, controlling, and monitoring the operation of various kinds of electronic vehicles. The Mission Planner also works well with the Pixhawk flight controller we intended to use, making it an easy choice. On the Raspberry Pi 3B serving as our onboard computer, we installed a light version of Ubuntu (Ubuntu MATE) and set up a remote SSH connection to the ground computer, allowing us to issue commands directly from the ground computer, even during operation of the drone and even mid-flight.

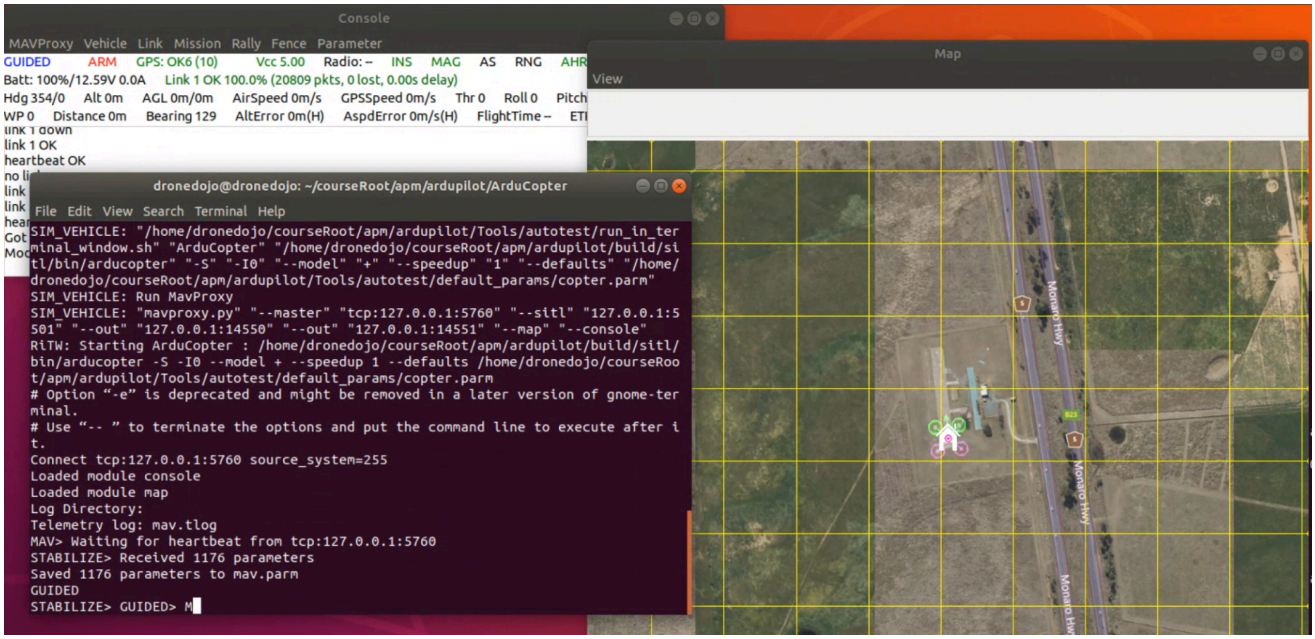


Remote connection success

As introduced earlier, the ArduPilot Mission Planner was integral to the simulation aspect of our project. We can manually input commands to control our virtual UAV in GUIDED mode or in AUTO mode with precoded instructions. For illustrative purposes, we manually set waypoints for the vehicle to follow.



Mission Planner Graphical Interface



Controlling the UAV in GUIDED mode from the Terminal

Manual control of the UAV:
We can set the destination waypoints, control takeoff and landing, and have access to many more instructions from the terminal using simple commands. We also have access to a console for monitoring the status of the UAV and important operational parameters.

1. Arming the propellers: The drone cannot take off if its components have not been initialized. To arm, we input the instructions:
   arm throttle
   When successfully ARMED, the red "ARM" signal on the console should turn green.
2. Prepare for flight: To allow direct control of the vehicle through instructions, we set the mode to GUIDED:
   mode GUIDED
3. Ready for takeoff: Input the command to lift the drone off the ground and set the desired altitude:
   takeoff 10
   The vehicle will rise to the altitude of 10 meters and maintain it until the next instruction.
4. Fly to waypoint: On the map, right-click on the desired location and select "Fly to" and then input the desired altitude.
5. Landing: There are two options for landing the UAV. Landing at the current waypoint we input:
   mode LAND
   RTL (Return to Launch) returns the drone to its point of launch (home symbol):
   mode RTL
   Either method causes the drone to slowly land and then disarm automatically.

Conclusion

This report has discussed the development of an Unmanned Aerial Vehicle (UAV) which originally would have had the capabilities of following a defined path, detecting friendly and enemy vehicles, and executing an action. The main objective of this project was to design and develop a UAV with image detection, autonomous movement capabilities, and targeting and projectile systems. Rather than that, we had undergone slight changes and were able to produce a working simulation of our UAV. Throughout this entire phase, we encountered a few challenges in acquiring materials, understanding software applications, and redirecting our original concept to procure a tangible end product. Albeit the difficulties, we are grateful for the mentorship from Raytheon and the experience gained from this entire project.