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MECHANICAL ENGINEERING AND ENGINEEERING TECHNOLOGY

ENTC 4350 – CAPSTONE PROJECTS
Capstone Project Progress Report

Capstone Project Proposal
Internet of Things (IoT) Enabled Unmanned Traffic Management (UTM) System

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UTM
Unmanned Traffic Management

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EXECUTIVE SUMMARY:
IoT-enabled Unmanned Traffic Management System consists of a developed hybrid system involving unmanned ground vehicles (UGV) and unmanned aerial vehicles (UAV). All vehicles navigate without colliding and accomplish their missions through a testbed environment at the Collaborative Robots and Agents Lab (CORAL). The Swarmie is guided through a wireless mesh network enabled by RF markers that work as “breadcrumbs” to enhance the unmanned vehicle path navigation. The Tello drone is controlled by an IoT cloud platform sending coordinates to the Beaglebone Green that uploads the data to a cloud network. The Swarmie ground robot and Tello drone are used for prototyping. Wireless communications, computer vision, and machine learning were implemented to enable coordination among robots. Knowledge of circuitry and microcontrollers was a must to develop RF navigation markers.

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1. INTRODUCTION

1.1 Project Description

The IoT-enabled Unmanned Traffic Management System consisted of a developed hybrid system involving unmanned ground vehicles (UGV) and unmanned aerial vehicles (UAV). All vehicles navigated without colliding and accomplished their missions through a testbed environment at the Collaborative Robots and Agents Lab (CORAL). The Swarmie was guided through a wireless mesh network enabled by RF markers that worked as “breadcrumbs” to enhance the unmanned vehicle path navigation. The Tello drone was controlled by an IoT cloud platform sending coordinates to the Beaglebone Green that uploaded data to a cloud network. The Swarmie ground robot and Tello drone were used for prototyping. Wireless communications, computer vision, and machine learning were implemented to enable coordination among robots. Knowledge of circuitry and microcontrollers was a must to develop RF navigation markers.

1.2 Purpose and Need

The team had a clear purpose which was to demonstrate a solution to a problem that affects human safety. Specifically, the problem exists where a swarm of swarms cannot be enabled to work alongside each other simultaneously. In our case, UGV and UAV picking up and delivering packages. This is a critical need because it is essential for the safe and efficient operation of autonomous vehicles, which are becoming increasingly more relied upon by humans for transportation of objects alongside other purposes. By demonstrating a solution that enables multiple autonomous vehicles to work together safely and effectively, the team hopes to have showed that this problem can be solved in an IoT enabled manner that results in the improved safety of those who rely on these vehicles.

1.3 Goals and Objectives

We designed and developed a safe testbed environment where UAVs and UGVs can coincide while avoiding obstacles and navigating effectively. An IoT solution was needed to control the drones and record data to send to the cloud as a CSV file.

1.4 Project Scope

Designed and developed a safe testbed environment where autonomous aerial and ground vehicles can coincide.

- Avoid obstacles
- Navigate effectively
- Simulate a mission to pick up and deliver packages
- Use IoT cloud platform to control drones
- Record acceleration/direction data and upload CSV file to the cloud

2. BACKGROUND

2.1 Previous Work

A previous capstone project was done by other students at TAMUCC which built a ground robot (Swarmie) that picked up a package and delivered the package to a separate location. Since this project, the electrical components were stripped and only the chassis was brought into the current phase of the project.

2.2 Journals and Patents

Safety Architecture for Autonomous Vehicles describes an architecture for autonomous vehicles that incorporates autonomy algorithms into a system that upholds safety requirements. For this system, autonomy components are allowed to fail on purpose while safety components uphold safety requirements. The patent then describes a set of stages with each stage having a primary “doer/checker” and an optional second pair just in case the first pair fails. If the doer/checker principle successfully works, then this system can be adopted. However, in the doer/checker system if the doer misbehaves, the checker shuts down the entire function which results in a fail-safe system. This is the problem for autonomous systems since it's required for the system to continue to work even though there was a failure. The solution described here addresses this problem with the use of a multi-channel approach to ensure continued operation even though there has been one or multiple component failures. The first aspect of their idea would be to have a system that is comprised of a stage with primary unit that generates primary data for performing normal system functionality and a secondary unit that generates secondary data for performing alternative system functionality; a primary safety gate that provides the primary data as an output response to determine the validity of the primary data; and a secondary gate coupled to the secondary unit that provides secondary data as an output response to determine the validity of the secondary data. This then has an output selector that is coupled to both gates to determine the validity of both data. In another aspect, their system includes a primary unit that generates path data for moving a device from a location to another and having a planner unit that generates path data for moving the device in presence of one or more adverse conditions during the moving. A gate then receives the data to determine whether the data provided is safe. These parts can then be implemented as a computer program that can be executed on a processing device [1].

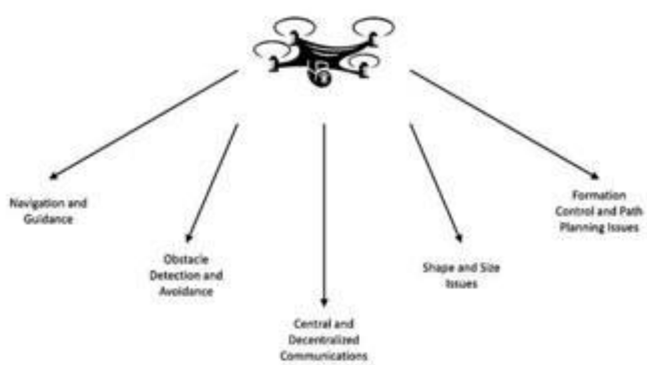


Figure 1: Obstacles for a UAV [1]

The systems work to derive a waypoint using the waypoint computing devices which are connected through traffic corridors. The systems receive initiate and suspend calls from the waypoint computing devices in order to develop a path for the unmanned aerial vehicles. The system is frequently updating the network to include new calls initiated and exclude calls suspended from its path based on the initiate and suspend calls. The updated network sends a request to the systems and methods to form a path for the unmanned aerial vehicle. The flight plan includes multiple traffic corridors along the path connecting the origin point of the vehicle and the requested destination. The systems and methods relay the flight plan to the unmanned aerial vehicle for it to take its flight [2].

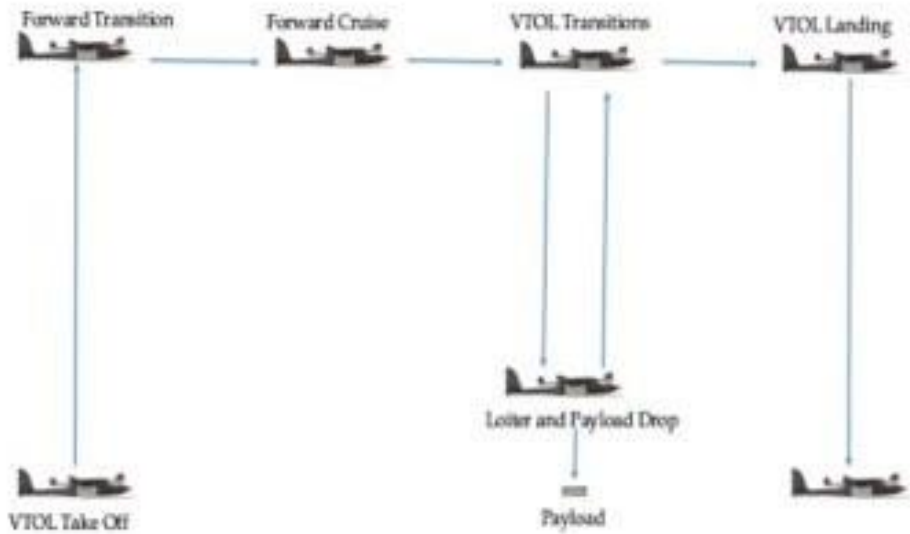


Figure 2: Payload mission profile [2]

Drone technology has advanced to the point that package delivery systems are now in development within major corporations, with the idea of these drones be controlled autonomously or by a ground pilot. A predominant problem with the ability to have autonomous drones' delivery system is the ability to have a viable way to manage the air traffic that the drones would have to endure. With the desire to have little to no human interaction with the drones there is a need for a management system that can minimize the intervals of incidents that are inevitable such as collisions between drones, structure, and animal strikes; all while keeping within FAA regulations [3].

Variables	**Unstandardized Beta**
Concern about leak of personal data	−0.125
Concern about further regulation	−0.005
Civic duty to public safety	0.496 ***
Trust in government	0.402 ***
Federal government as a rule-setter	0.291
Existence of state regulation	−0.079
Knowledge about drone registration requirement	0.446 *
Participation in drone-related training	0.028
Drone use (commercial and recreational)	−0.514 *
Participation in drone-related club activities	−0.174
Education	−0.025
Income	0.067
Gender	0.088
Model Summary	
Number of observations in the model	337
Adjusted R-Square	0.306

Figure 3: Individual drone regulatory compliance [3]

Unmanned Aerial System (UAS) technology is rapidly growing in popularity due to the several applications that it can be used for. Although these applications are expanding daily, there are still several limitations that slow UAS integration into the National Airspace System (NAS). Safety and serviceability become the primary concerns when considering the commerciality of Unmanned Aerial Vehicles (UAV) and Unmanned Ground Vehicle (UGV) systems. The project objective, alongside many others, is to demonstrate how unmanned vehicles can operate safely while providing a service that is applicable and cost effective [4].

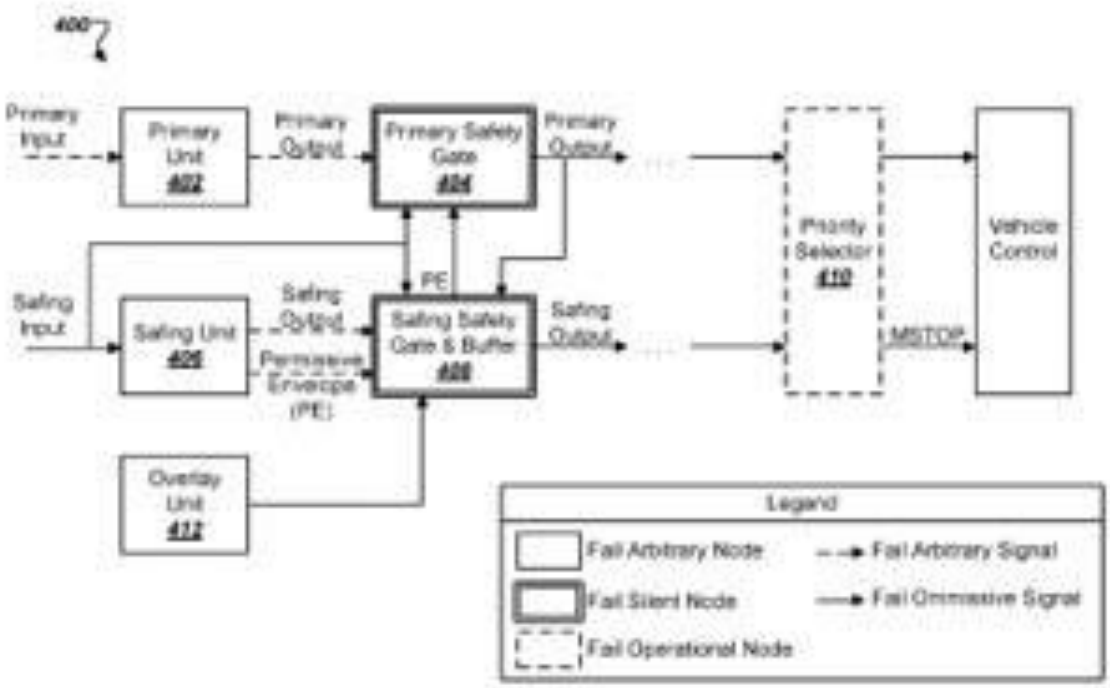


Figure 4: Safety guidelines flow chart [4]

Concerns of developing and implementing drones for daily use poses an issue with the public. The use of drones in local areas is growing as well as the policies that define what is acceptable and what is not. The regulation of drone operation is governed for the safety of the public so that drone operators can use these devices in a capacity that adheres to the policies. The journal focuses on city drone user demographics and how they pertain to regulatory compliance and their compliance behavior, as well as the differences of city versus metropolitan drone users. The capstone project titled IoT enabled Unmanned Traffic Management System (UTM), when used in the real world, would require such policies to be adhered to since the drones and rovers would need to take off, transition, deliver packages, land and have situational awareness to the nearby objects which could potentially interfere with the preprogrammed task all the while following the local guidelines [5].

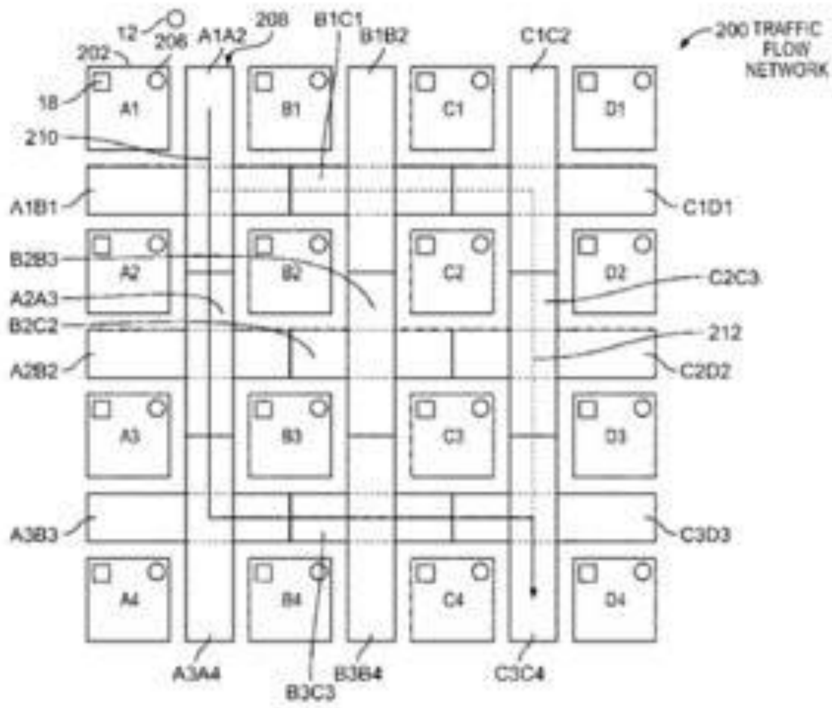


Figure 5: Aerial view of UAV testbed [5]

Unmanned Aerial Vehicles (UAVs) technology is highly sought after in present civilian and military applications. There are several types of challenges to overcome when setting up UAVs to perform certain tasks such as navigation, obstacle detection/avoidance, shape/size, path planning issues, and formation control issues. Developments in UAVs have allowed for the ability to overcome these challenges with present technology. For example, Multi-Rotor UAVs have multiple propellers and motors that allow for the UAV to not require a runway for vertical takeoff. Developments in collision avoidance include concepts such as a perception phase, where the collision avoidance system detects an obstacle while utilizing various active and passive sensors. Another development in collision avoidance includes action phase, using strategies such as a geometric, force-field, optimized, and sense and avoid methods. UAV technology tackles the issue of formation control protocols using three different concepts. The first is the leader-follower strategy, which as the name suggests, designates a single drone to be the master and the other drones in the system mimicking the tasks of the master. The next one is the behavior-based strategy. This approach produces control signals that consider several mission essentials, by adding various vector functions. The final strategy is the virtual structure strategy. This approach considers rigid structure for the desired of the group of UAVs. To achieve the desired shape, there is a need to fly each UAV towards its corresponding virtual node [6].

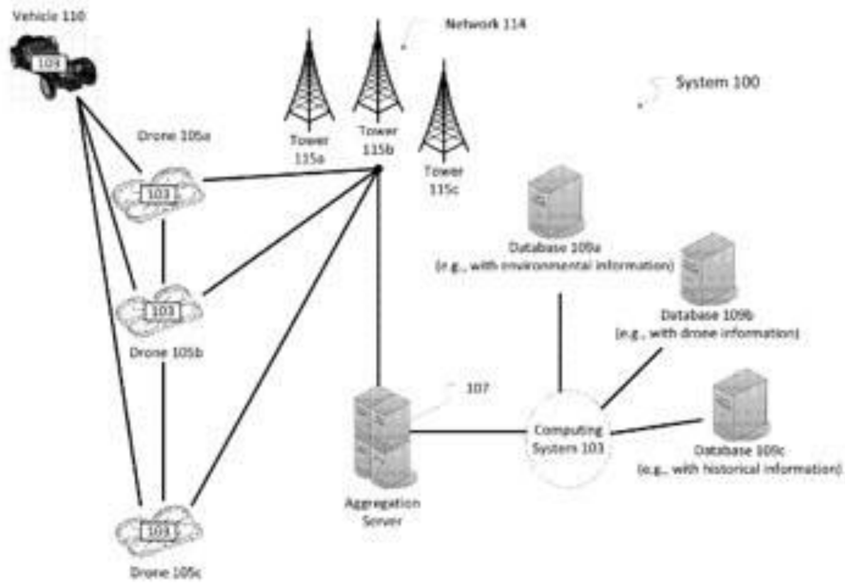


Figure 6: Server communication network [6]

3. UNDERLYING ENGINEERING PRINCIPLES

3.1 Theory

Friis Transmission Equation (Contemporary Formula)

$$\frac{P_r}{P_t} = G_t G_r \left(\frac{\lambda}{4\pi R}\right)^2$$

P_r: Power at the receiving antenna

P_t: Output power of transmitting antenna

G_t , G_r: Gain of the transmitting and receiving antenna, respectively

λ: Wavelength

R: Distance between the antenna

3.2 Engineering Economic Analysis

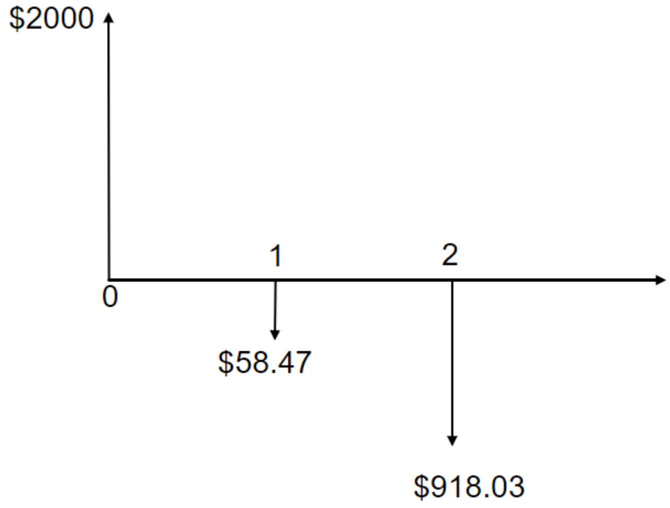


Figure 7: Engineering Economic Analysis Chart

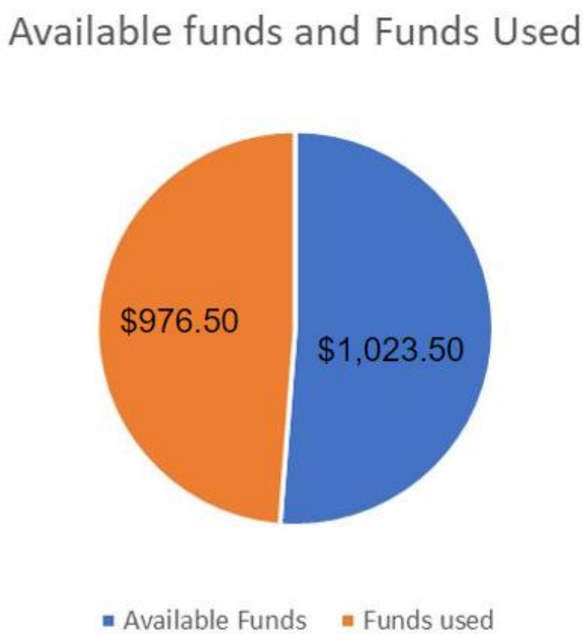


Figure 8: Available Funds Chart

The project began with an initial funding of two thousand dollars with one thousand dollars coming from university funding and the other one thousand dollars coming from the IoT grant. The team spent a total of nine hundred and seventy-five dollars with nine hundred and sixteen dollars being used from the IoT grant and fifty-eight dollars being used from the university funding. After buying the materials needed for the project, the team has been left with a total of one thousand and twenty-four dollars.

4. RISK AND FEASIBILITY ANALYSIS

For this project, the team ensured that the payload that the drone picked up remained less than 30 grams to remain feasible. The buildings were spaced about twice the Swamie's width for it to comfortably travel through the environment. Vents were covered for a more controlled environment. Batteries were kept on the charger between tests to provide fresh batteries when needed. RFID Markers were tested a multitude of times with great results. Drone crashing was at times unavoidable and at times made the process much longer to finish testing but with spare parts the team was able to achieve our final result. See Risk Matrix below in Figure 9.

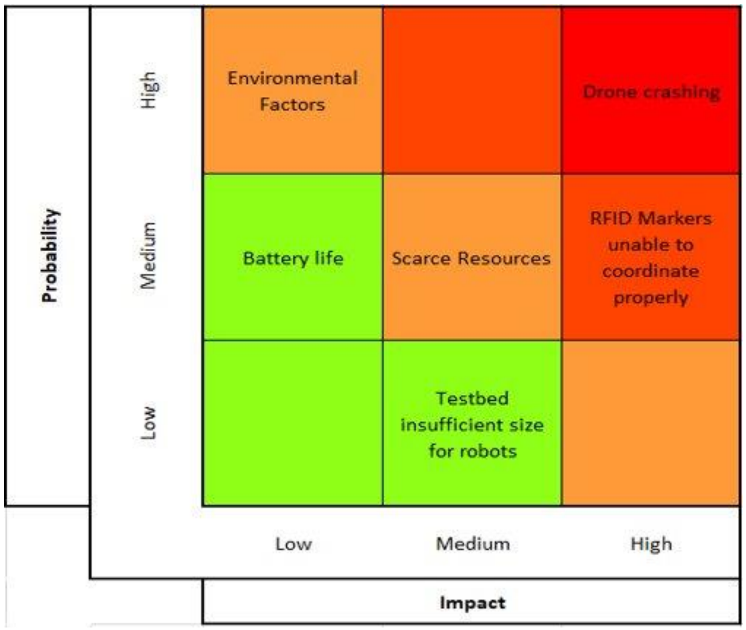


Figure 9: Risk Management Plan – Qualitative Analysis

5. DESIGN

5.1 Design Constraints and Specifications

Requirements: IoT enablement was required in order to control and record data for the drones, while sensor data fusion was required to control and record data for the Swarmie. Both requirements were needed and meet in order to maintain an autonomous ecosystem.

Constraints: The Tello battery not only powered itself but also a servo motor and microcontroller simultaneously, the Tello has a maximum payload of 30-grams, and there may also be RSSI inaccuracies that deal with the Swarmies and XBee communication.

The testbed environment fit within the designated area of the CORAL lab and was made of a stable material.

Specifications: The design of the SkyLift mechanism had dimensions of 32 x 24 x 32 (L x W x H) to be small enough to fit on the underside of the Tello and outside of the Tello down-facing camera's range of view.

The testbed environment had at least 3 ft between the mock buildings in order to allow the Swarmie to pass in between. The mock buildings had a top with the minimum dimensions of 2ft x 2ft.

5.2 Final Design

SkyLift Original Design:

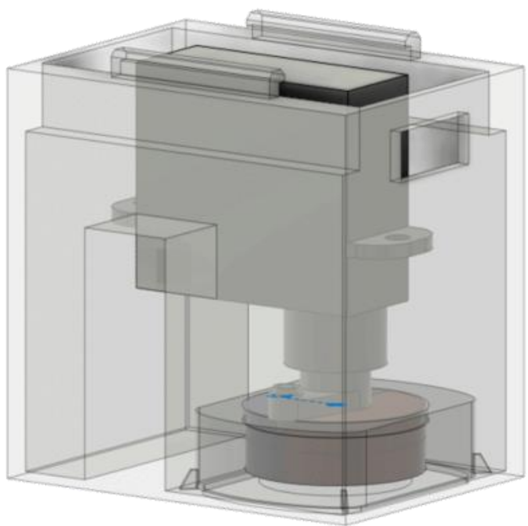


Figure 10: Transparent view of SkyLift design

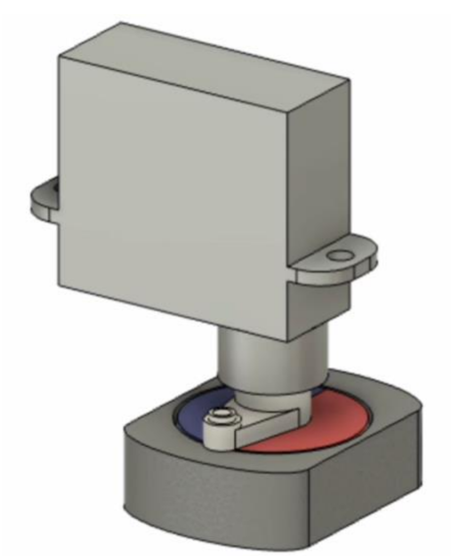


Figure 11: SkyLift design in initial "on" position

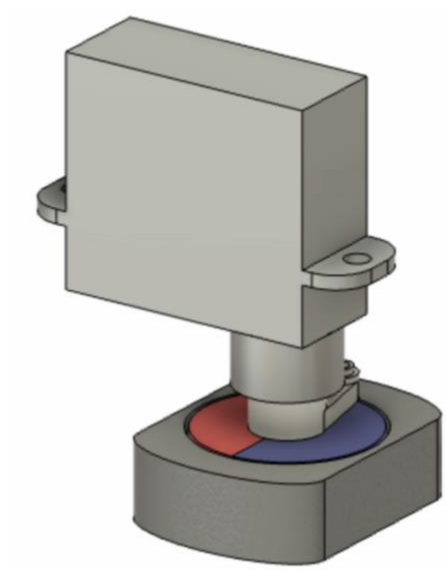


Figure 12: SkyLift design in final "off" position

Figure 10 illustrates the original design of the SkyLift mechanism. This design utilizes the practice of controlled magnetism to pick-up and release metal objects. The magnetic design is made up of 7 components: the SkyLift enclosure, magnetic housing, 2 diametric magnets, a servo horn, a servo pin, and a servo motor. Figure 11 illustrates the magnetic design in its initial position while Figure 12 displays the design in its final position. In its initial position, the magnetic flux emitted from the diametric magnets is maximized. This means that the attraction force between the magnets and any metal objects becomes the greatest. However, after orienting the top magnet 180° so that its magnetic poles face opposite to that of the bottom magnet, the team can contain any electromagnetic field within the space of the magnetic housing. This results in a small attractive force between the magnets and any metal objects. By transitioning between these two positions throughout the course of the drone navigation, the team is able to pick-up, carry, and release different objects and accomplish the set objectives. This design was decided primarily due to its light weight, small size, and ability to pick-up and transfer objects as the team intends.

Servo Claw Proposed Design:

Figure 13: Claw Design (Exploded View)

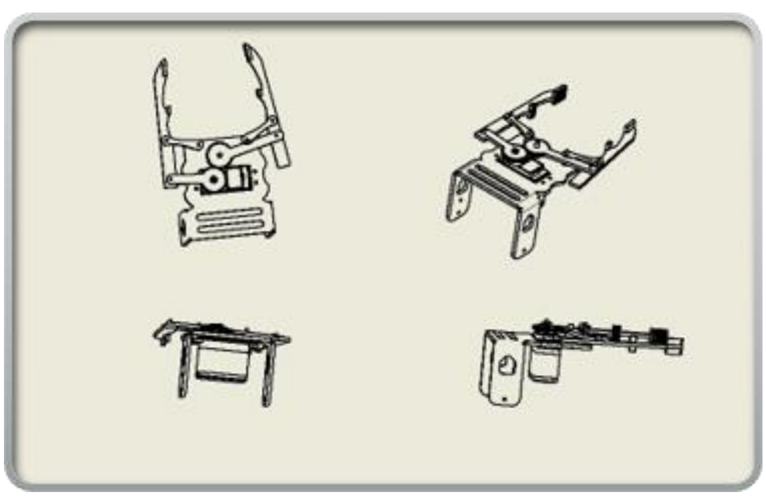


Figure 14: Claw Design (Orthographic View)

Figure 15: Claw Design (Assembled)

Figure 15 shows the servo motor, illustrated in blue, that allows the claw to close and open. The motor is connected to the gear arm which translates the rotation of the motor to the closing of the claw blades. The gear on the arm allows the rotation on the left side to be in sync with the right side by rotating the right gear arm. The claw blades were designed with two notched pads to ensure proper grip on the desired object. Figure 13 illustrates the exploded view of the Claw Design, in which the guiding arm can be seen connecting the claw blade to the body. Figure 14 provides the side, back and top views of the Claw Design.

Swarmie Proposed Design:

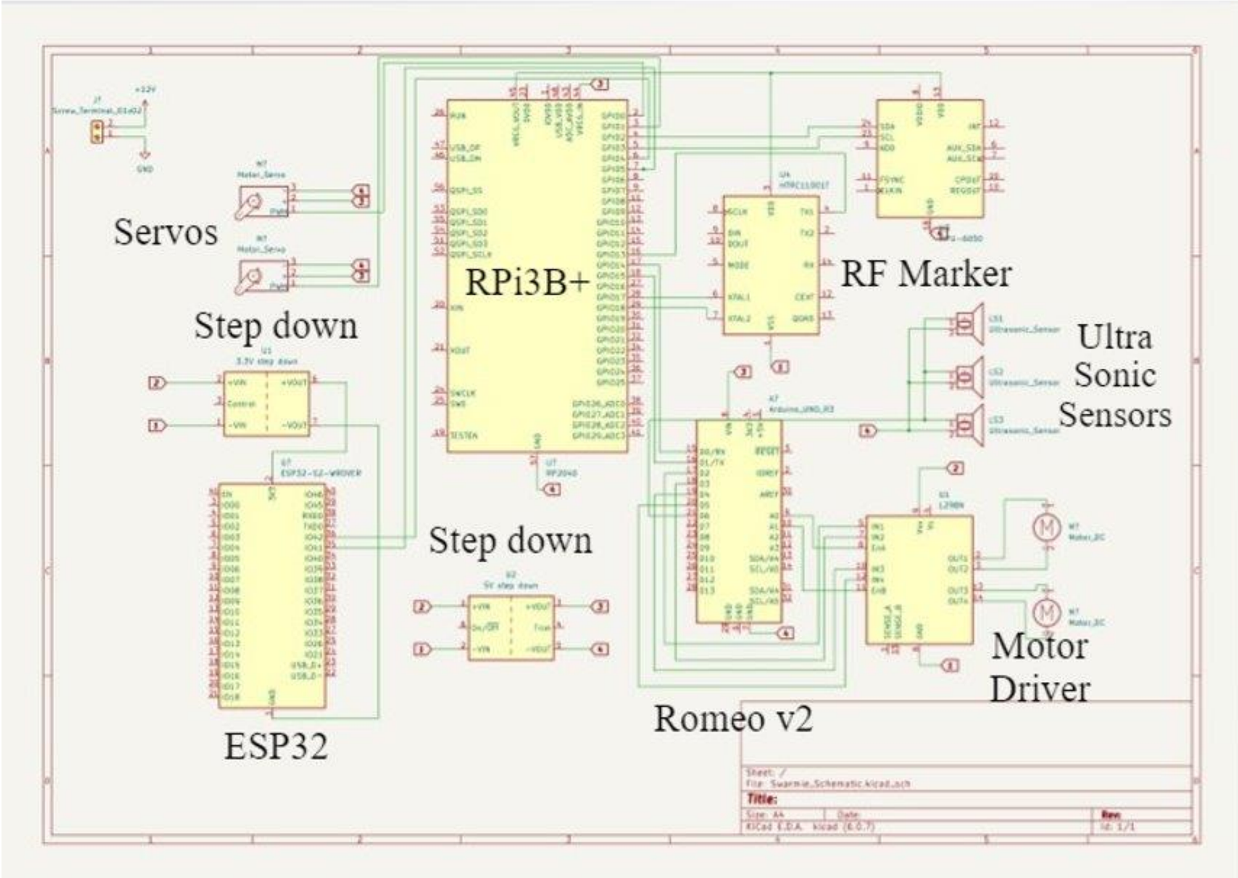


Figure 16: Wiring Schematic for Swarmie

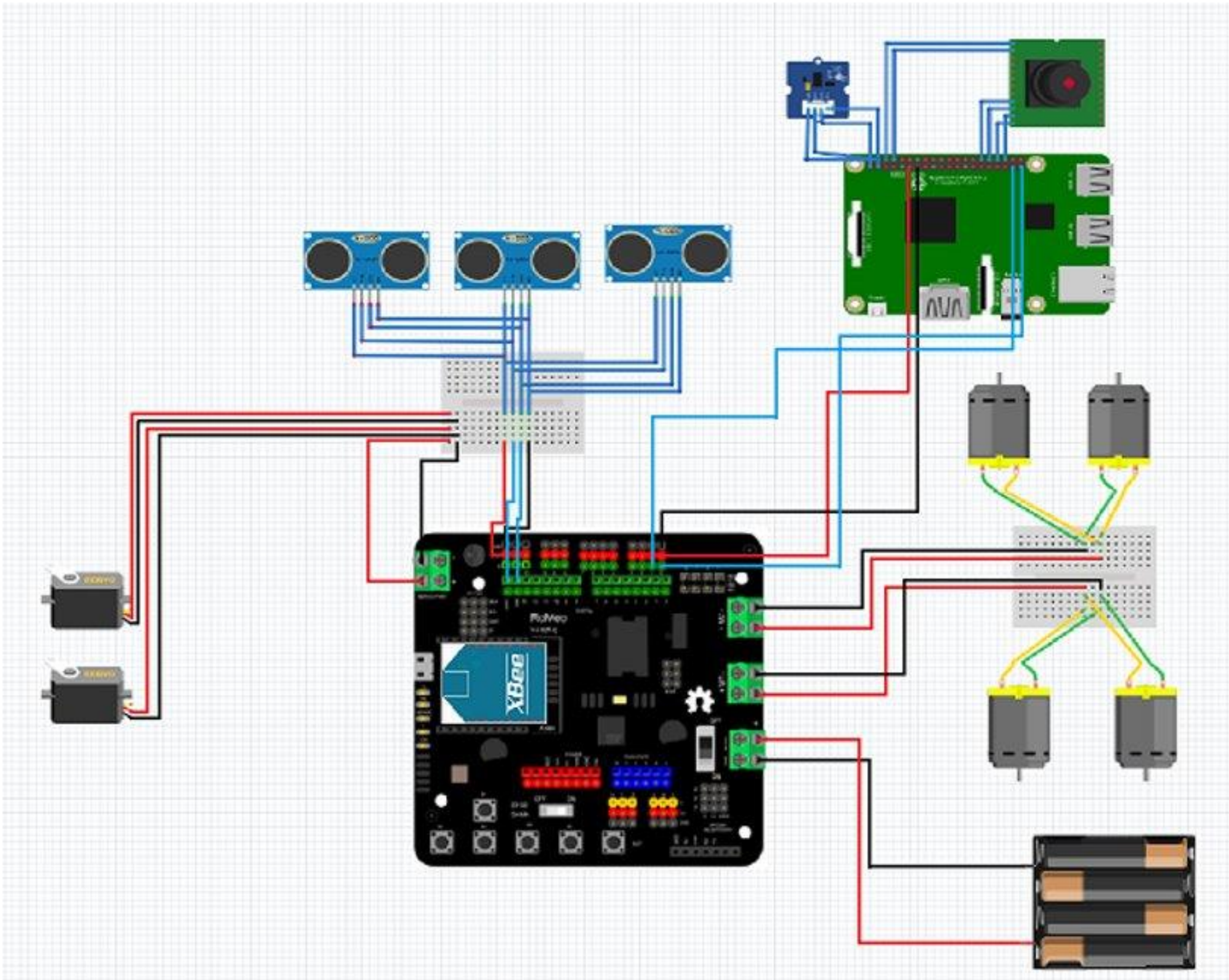


Figure 17: Wiring Diagram for Swarmie

Figure 16 and Figure 17 represent the schematic and diagram of the Swarmie circuitry. The Romeo V2 is the main microcontroller with regulators, H-bridge, and XBee mounts integrated into the system. This microcontroller receives sensor data from the Ultrasonic sensor and controls the motors based on feedback. This simple obstacle avoidance robot is enhanced with a camera, RFID marker, and gyroscope using sensor data fusion to discover the Swarmie location and future path planning. The gyroscope receives translation and rotation in x, y, and z axis, the camera detects the QR code on the package, and the XBee marker checks for the RSSI value on each ID that act as “breadcrumbs” for it to travel through the testbed environment. The servo motors represent the claw that is secured to the front of the Swarmie. This represents the claw that is used to retrieve the package so that the Swarmie can complete its mission.

IoT Implementation Design:

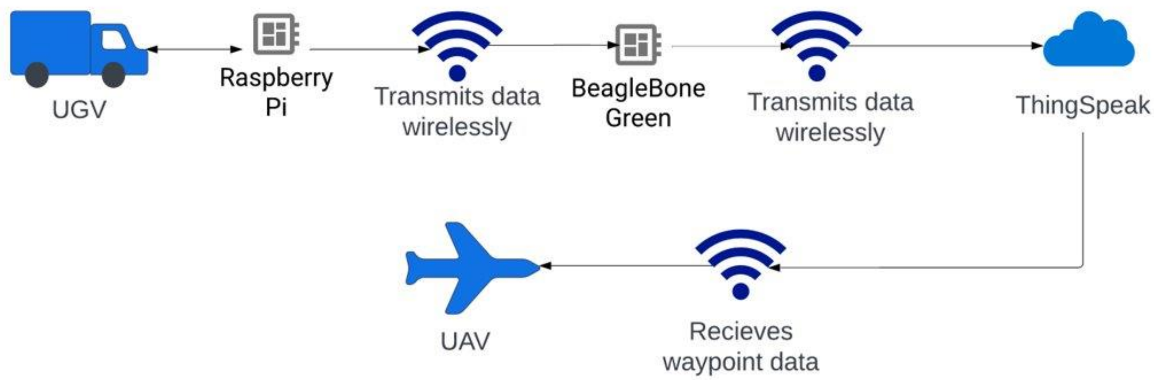


Figure 18: IoT Implementation Design

Figure 18 represents how IoT is implemented into the UTM system. First the UGVs send sensor data to the Raspberry Pi which is integrated into the UGV with an onboard accelerometer and gyroscope. This data is then transmitted to the team's BeagleBone Green which is then transmitted wirelessly to the cloud platform, in our case it's ThingSpeak. On ThingSpeak, the team was able to generate waypoints which our UAV's were able to receive using a microcontroller and Wi-Fi. On ThingSpeak our data can be visualized on graphs or charts; whichever the user sees fit, and all data is plotted in real time.

SkyLift Design:

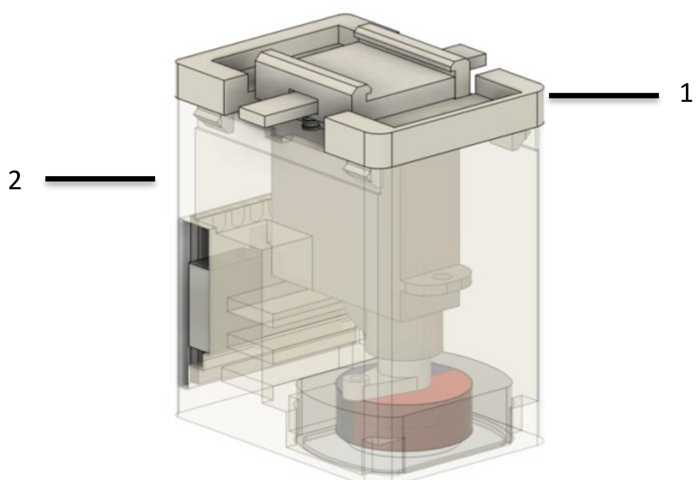


Figure 19: Transparent view of SkyLift design

Figure 19 illustrates the SkyLift design with an adjustable attachment piece labeled 1 and the enclosure (labeled 2) that houses all of the components. The adjustable attachment piece was introduced to enable our SkyLift mechanism to be compatible with drones of varying sizes. Composed of four different pieces, the adjustable attachment is spring loaded and can be removed and connected to the enclosure. The enclosure introduces a compartment that allows connection between an integrated microprocessor and our servo motor. It has been designed to better stabilize the magnetic housing component while remaining light weight due to the additional slots included within its interior. Additionally, an adhesive was introduced to connect the servo horn to the top magnet.

5.3 Standards

ISO/IEC DIS 27402 Cybersecurity – IoT security and privacy – Device baseline requirements
ISO DIS 21384-1 Unmanned aircraft systems
ISO/IEC 10536-1:2000(en) Identification cards – Contactless integrated circuit(s) cards – Close-coupled cards

6. SOLUTION METHODOLOGY

6.1 Methods Used

In order to ensure the safe and successful completion of their missions, UAVs and UGVs must be able to operate autonomously without any incidents. To achieve this goal, a solution methodology needed to be developed.

To begin, problem identification was necessary. The problem at hand was ensuring the safe and successful completion of missions by Tello's and Swarmies while operating autonomously.

Data collection was the next step in the Solution Methodology. This involved the use of an IoT cloud platform that generated coordinates for the Tello's and Swarmies to travel to. Additionally, gyroscope, RFID, ultrasonic, and camera sensors were used to collect data that was critical to ensuring the safety of the mission.

Finally, analysis was conducted on the collected data to determine the location of the UGVs and to plan their future paths based on velocity and time. The collected data was analyzed to generate paths that avoid any obstacles or potential hazards that may be encountered during the mission. While UAVs used IoT provided waypoints and machine vision to generate paths that avoid any obstacles or potential hazards that may be encountered during the mission.

By following this Solution Methodology, the safe and successful completion of autonomous missions by Tello's and Swarmies were ensured.

6.2 Simulations and Simulation Results

Solution Generation: Based on analysis, Calculations were performed to discover proper time taken, or specific sensor readings for unmanned vehicles to reach specific locations.

Solution Implementation and Monitoring: Software was altered so unmanned vehicles could be tested and observed again for them to complete their missions.

SkyLift Simulations:

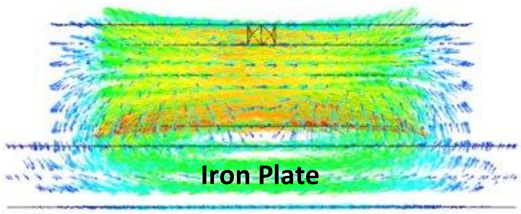


Figure 20: Magnetic flow of SkyLift in “on” position.

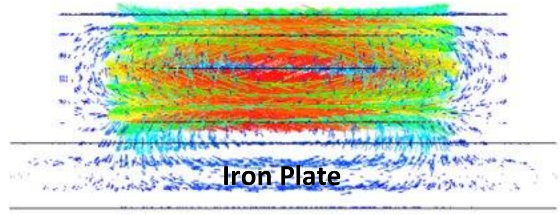


Figure 21: Magnetic flow of SkyLift in ”off” position.

Figures 20 and 21 depict electromagnetic field simulations conducted on the SkyLift mechanism in both the "on" and "off" positions, while touching an iron plate. In the "on" position, both diametric magnets' poles are aligned, and the combined magnetic field strength is approximately 0.0260T as illustrated in figure 21.1. In contrast, in the "off" position, the magnetic field is contained within the housing material surrounding the magnets, and a negligible magnetic field strength of 0.0002T is generated (see figure 21.2).

Figure 21.1: Maximized magnetic field strength.

Figure 21.2: Minimized magnetic field strength.

7. IMPLEMENTATION

7.1 The Process

The implementation process involved five key steps. Firstly, the team needed to gain a deep understanding of IoT and how it would be integrated into a UTM system. Once this knowledge had been acquired, the team began to write programs and design mechanisms that enabled unmanned vehicles to travel and pick up objects autonomously. The next step involved the purchase of electrical and claw components, as well as the printing of CAD designs and the integration of wiring to bring all the design pieces together. With all the components in place, the team then deployed them in a testbed environment for trial-and-error examination, allowing them to identify and address any issues that arise. Finally, a live simulation of the UTM system was conducted and recorded in the CORAL Lab, which served as the platform for the team's final presentation and demonstration of their autonomous unmanned vehicle solution.

7.2 The Prototype (Final Product)

IoT-enabled Unmanned Traffic Management (UTM) System consisted of developing a hybrid system involving UGVs and UAVs. All vehicles navigated without colliding and accomplishing their missions through a testbed environment at the Collaborative Robots and Agents Lab (CORAL). The Swarmie was guided through a wireless mesh network enabled by RF markers that worked as “breadcrumbs” to enhance the unmanned vehicle path navigation. The Tello drone was controlled by an IoT cloud platform sending coordinates to the Beaglebone Green that uploaded the data to a cloud network. The project is a proof of concept that enables future versions to scale up to larger UGVs and UAVs and allow them to carry a much greater payload.

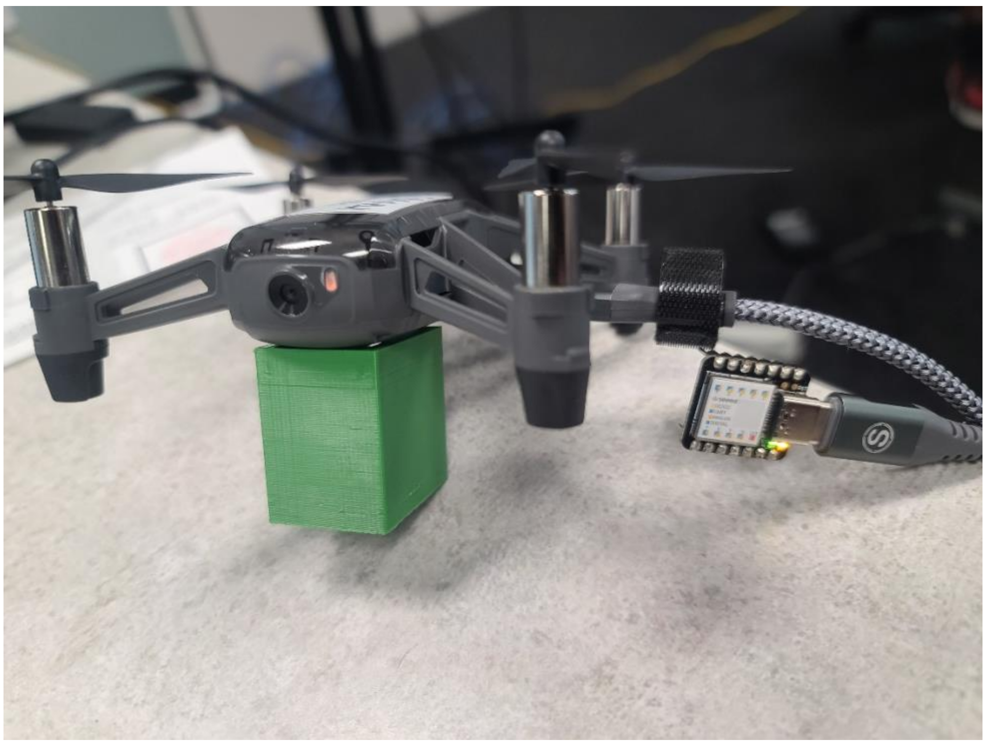


Figure 22: UAV with SkyLift Mechanism Prototype

Figure 23: UGV Anticollision Prototype

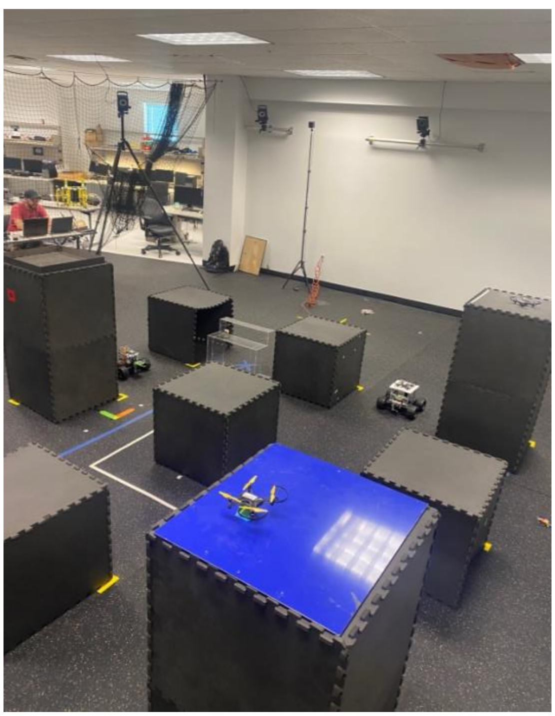


Figure 23.1: Testbed Environment Prototype in Initial Position.

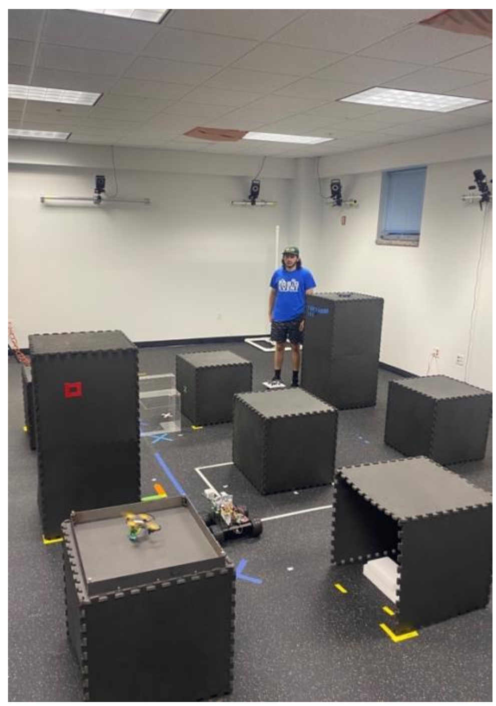


Figure 23.2: Testbed Environment Prototype with Mobile Drones.

8. TESTING

8.1 Experimental Design

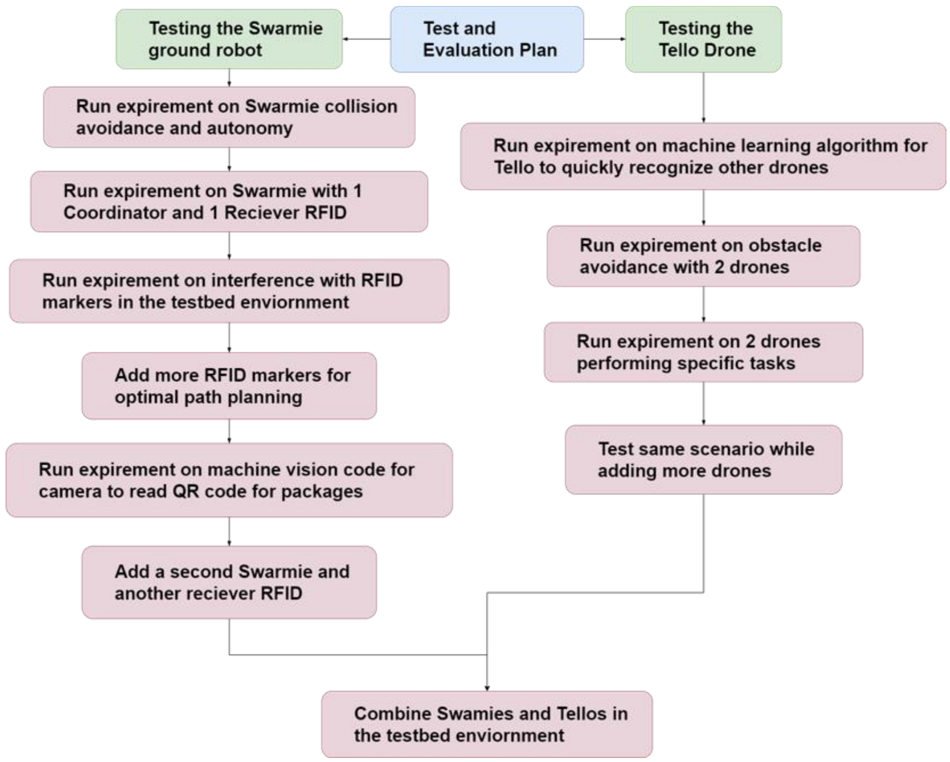


Figure 24: Testing and Evaluation Plan

Figure 24 illustrates the testing and evaluation plan used throughout the project. Throughout the project, we utilized the testing and evaluation plan as a contingency plan or guide to ensure that our project remained on track and met all necessary testing and evaluation requirements.

8.2 Data Collection

```
IoT Coordinates Log - 20230322-151831

CSV to array:  {1: 'A', 2: 'I', 3: 'B', 4: 'D', 5: 'E', 6: 'G'}
Total items in array:  6

Sending message:  command
Sending message:  takeoff

Waypoint:  1 of 5
Move from building A to building I
Sending message:  cw 45
Sending message:  forward 280
Sending message:  land
Flag set to:  1
http://192.168.1.240:80/servo?position=0
<Response [200]>
Servo motor moved to position:  0
Sending message:  takeoff

Waypoint:  2 of 5
Move from building I to building B
Sending message:  ccw 162
Sending message:  forward 221
Sending message:  land
Flag set to:  0
http://192.168.1.240:80/servo?position=180
<Response [200]>
Servo motor moved to position:  180
Sending message:  takeoff

Waypoint:  3 of 5
Move from building B to building D
Sending message:  ccw 73
Sending message:  forward 140
Sending message:  land
Flag set to:  1
http://192.168.1.240:80/servo?position=0
<Response [200]>
Servo motor moved to position:  0
Sending message:  takeoff

Waypoint:  4 of 5
Move from building D to building E
Sending message:  ccw 135
Sending message:  forward 99
Sending message:  land
Flag set to:  0
http://192.168.1.240:80/servo?position=180
<Response [200]>
Servo motor moved to position:  180
Sending message:  takeoff

Waypoint:  5 of 5
Move from building E to building G
Sending message:  cw 135
Sending message:  forward 140
Sending message:  land
Flag set to:  1
http://192.168.1.240:80/servo?position=0
<Response [200]>
Servo motor moved to position:  0
Sending message:  takeoff

No more waypoints found.
Mission completed successfully!

Project Details:
Building connections:  {1: 'AI', 2: 'IB', 3: 'BD', 4: 'DE', 5: 'EG'}
Drone angle command:  {1: ('cw', 45), 2: ('ccw', 162), 3: ('ccw', 73), 4: ('ccw', 135), 5: ('cw', 135)}
Drone move command:  {1: 280, 2: 221, 3: 140, 4: 99, 5: 140}
```

Figure 25: UAV Automated Flight Log with SkyLift Values

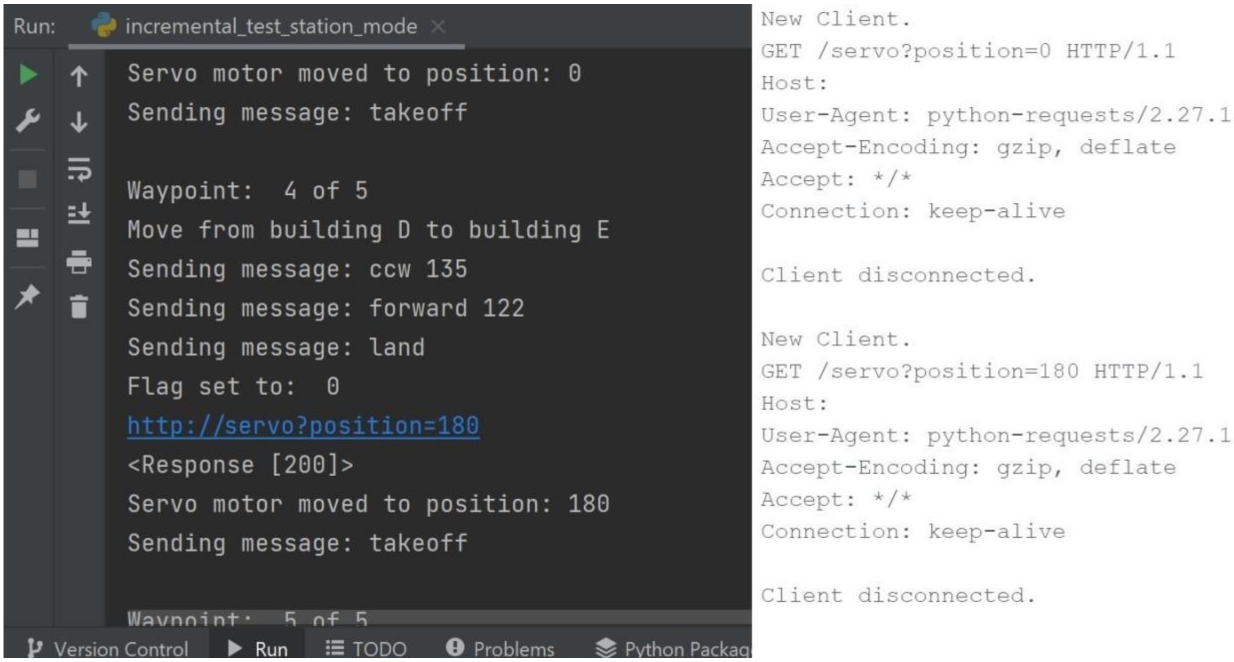


Figure 26: UAV SkyLift Mechanism Output from Python (left) and Arduino (right)

In Figure 25 the Python code saves the information for CSV values from the IoT cloud saved file, tells the commands used, which waypoint and from which building the drone will be traveling from and to, how the drone will rotate in degrees for the next building, how far forward in centimeters will travel to next building, SkyLift response on which position the servo will be in, and so on until all waypoints are complete then gives project details of building connections, angle commands, and forward commands. In Figure 26 output from Python and Arduino shows that when the request from Python is given to rotate servo that the information is received in the Arduino serial monitor to verify that it is working correctly.

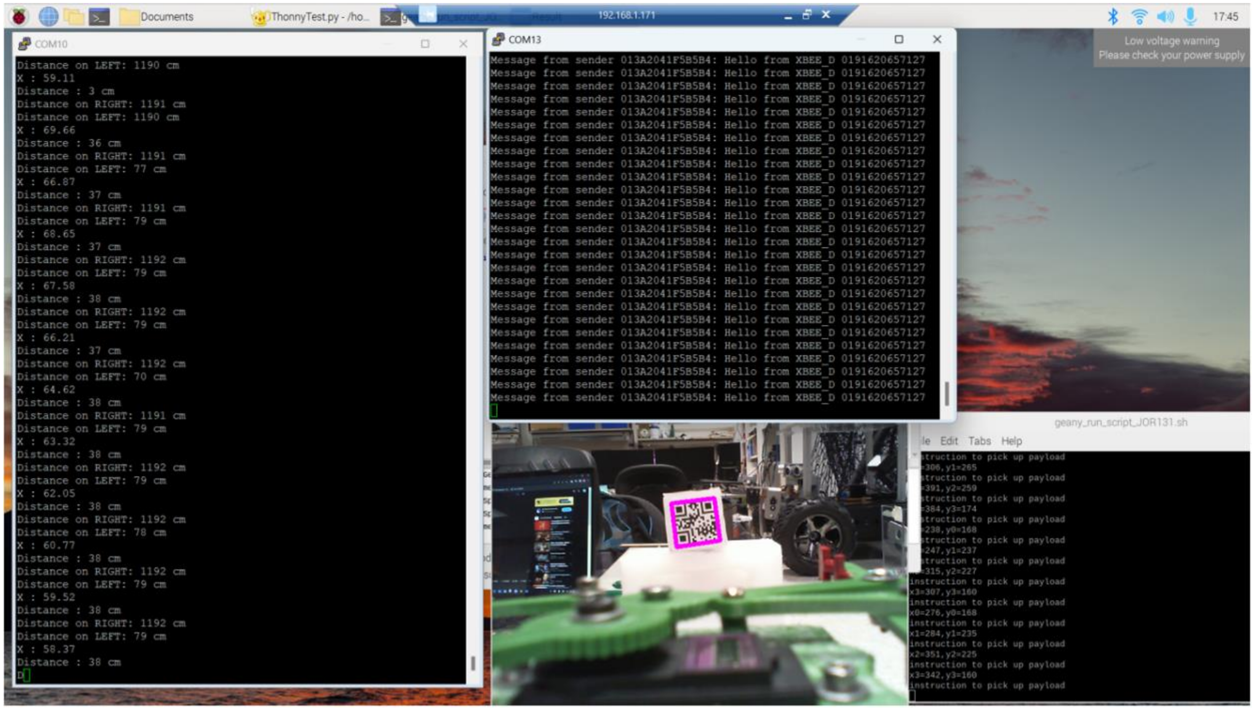


Figure 27: All 4 sensors displayed on Raspberry Pi for Swarmie

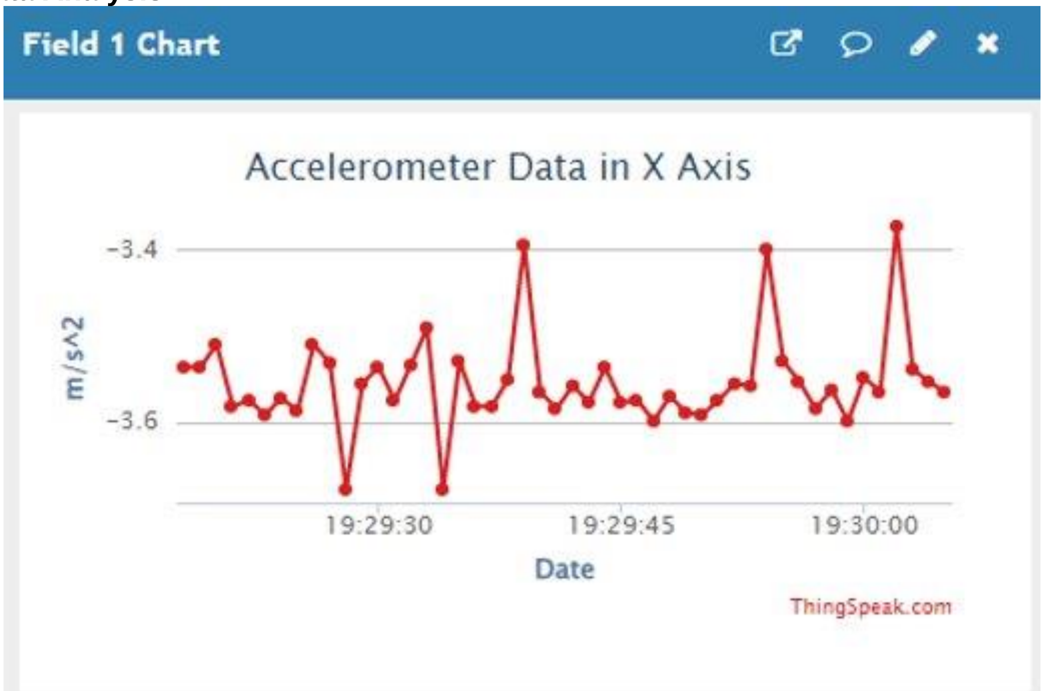
In Figure 27, the angle calculated and three ultrasonic values (left), received XBee signal (top), and camera values (bottom center and right) are all shown to illustrate how the Swarmie is making its calculated decisions based on sensor feedback.

Ax	Ay	Az	Gx	Gy	Gz	x	y
-3.5362	-1.7573	-8.1954	-0.0344	0.0166	-0.1756		
-3.5362	-1.7286	-8.1379	-0.0155	0.0162	-0.4427		
-3.5099	-1.5897	-8.1762	0.0376	0.0132	-2.4275		
-3.5817	-1.7119	-8.1594	-0.0335	0.0144	-0.5954		
-3.5745	-1.7358	-8.1594	-0.0413	0.0145	-0.1221		
-3.5913	-1.7573	-8.1977	-0.0314	0.0153	-0.5038		
-3.5721	-1.7166	-8.1906	-0.0347	0.0151	-0.5725		
-3.5865	-1.731	-8.157	-0.0343	0.0296	-0.6641		
-3.5099	-1.719	-8.1642	-0.0348	0.0163	-0.5267		
-3.5314	-1.7214	-8.1618	-0.0346	0.0156	-0.4809		
-3.6775	-1.7382	-8.1786	-0.0374	0.0153	-0.3664		
-3.5554	-1.7573	-8.1307	-0.0151	0.0135	-0.3206		
-3.5362	-1.7621	-8.1666	-0.0363	0.0006	-0.3511		
-3.5745	-1.7478	-8.1307	-0.0397	0.0151	-0.2443		
-3.5338	-1.7334	-8.1547	-0.0388	0.0161	-0.3206		
-3.4907	-1.7454	-8.1714	-0.0379	0.0296	-0.4275		
-3.6775	-1.743	-8.1882	-0.0364	0.0009	-0.5115		
-3.5291	-1.7238	-7.9918	-0.0324	0.0146	-0.6183		
-3.5817	-1.7885	-8.2025	-0.0365	0.0179	-0.2748		
-3.5817	-1.7286	-7.9871	-0.0436	0.0164	-0.2214		
-3.4931	-1.7095	-8.1714	-0.0338	0.0149	-0.5496		
-3.5482	-1.7095	-8.2097	-0.0446	0.0132	-0.4809		
-3.6009	-1.7119	-8.102	-0.0333	0.0003	-0.5496		
-3.5314	-1.7502	-8.1427	-0.0251	0.0138	-0.4504		
########	########						
Ax	Ay	Az	Gx	Gy	Gz	x	y
						245	283
						364	294
						379	167
						257	158
-3.5027	-1.5993	-8.193	-0.0347	0.0153	-0.4962		
						238	292
						357	305
						373	177
						250	168
-3.6751	-1.6185	-8.1499	-0.0427	0.016	-0.374		
						237	292
						356	303
						371	176
						249	167
-3.5267	-1.6161	-8.181	-0.0418	0.0156	0.0153		
-3.5434	-1.64	-8.2744	-0.0308	0.0145	-0.5038		
						234	291
						353	305

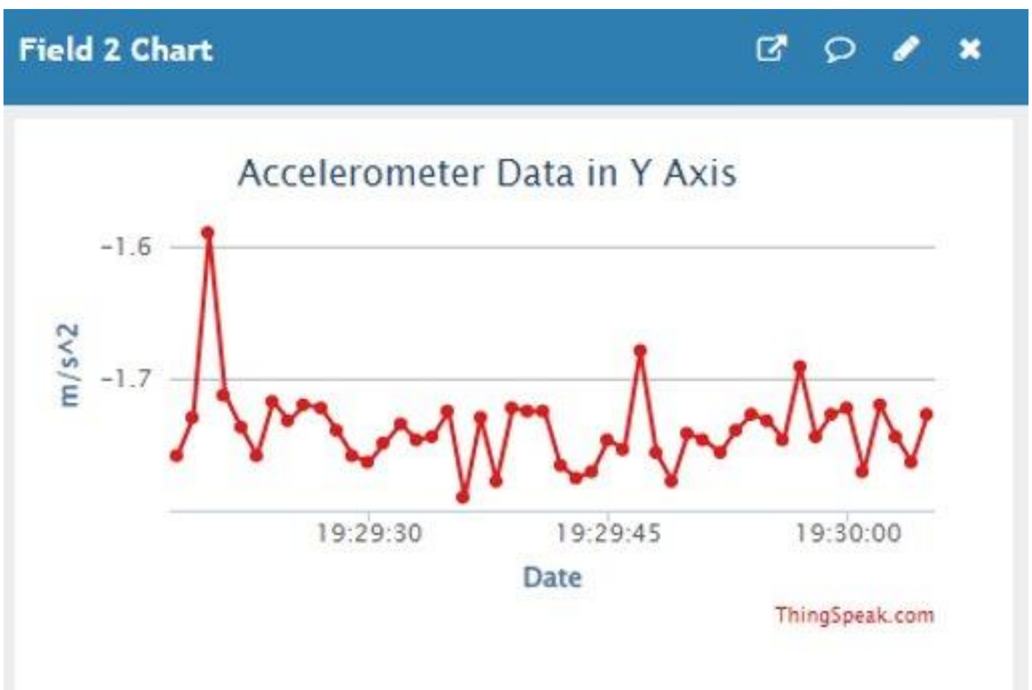
Figure 28: PuTTY Output of Acceleration Data

In this Figure 28, sensors interfaced to the Raspberry Pi 3b+ are saved to a document. Raw gyro values and QR code orientation in reference to the camera are stored on a CSV file.

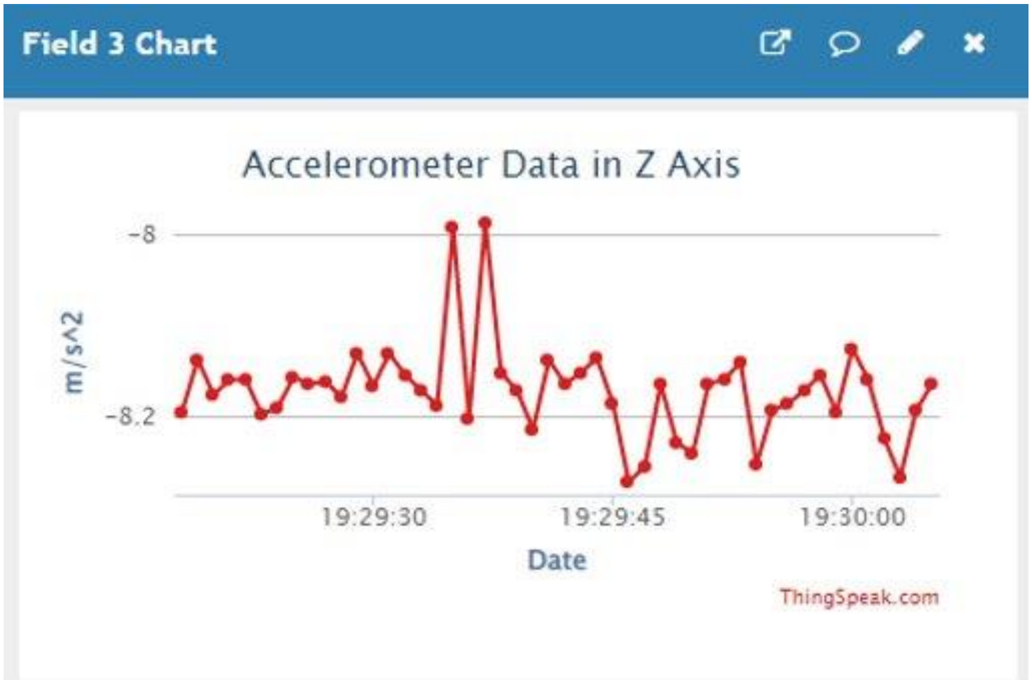
8.3 Data Analysis



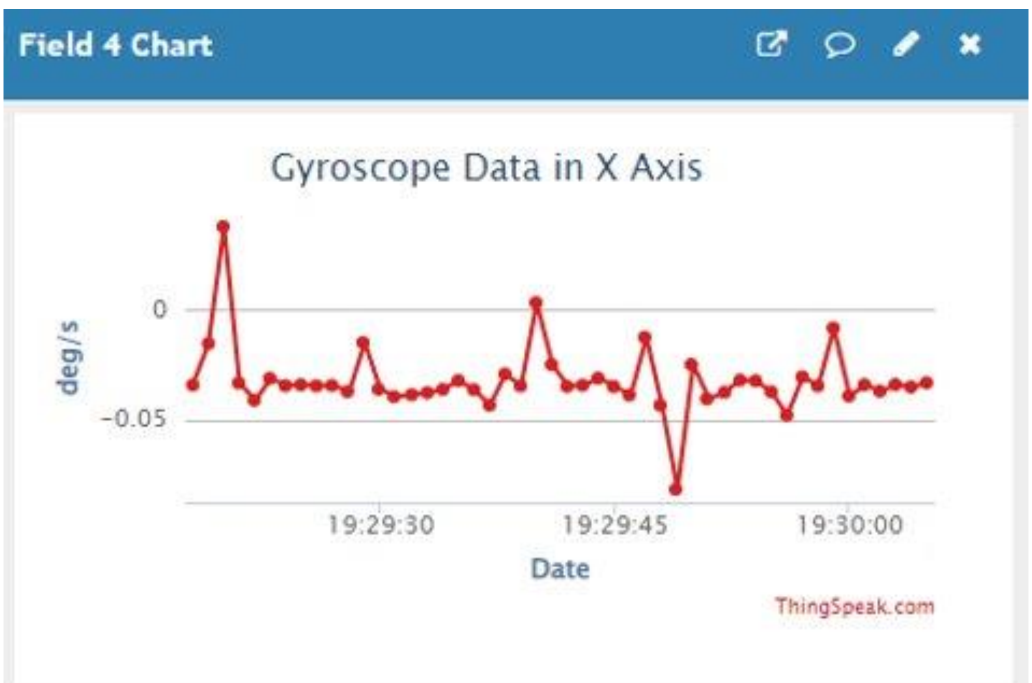
(a)



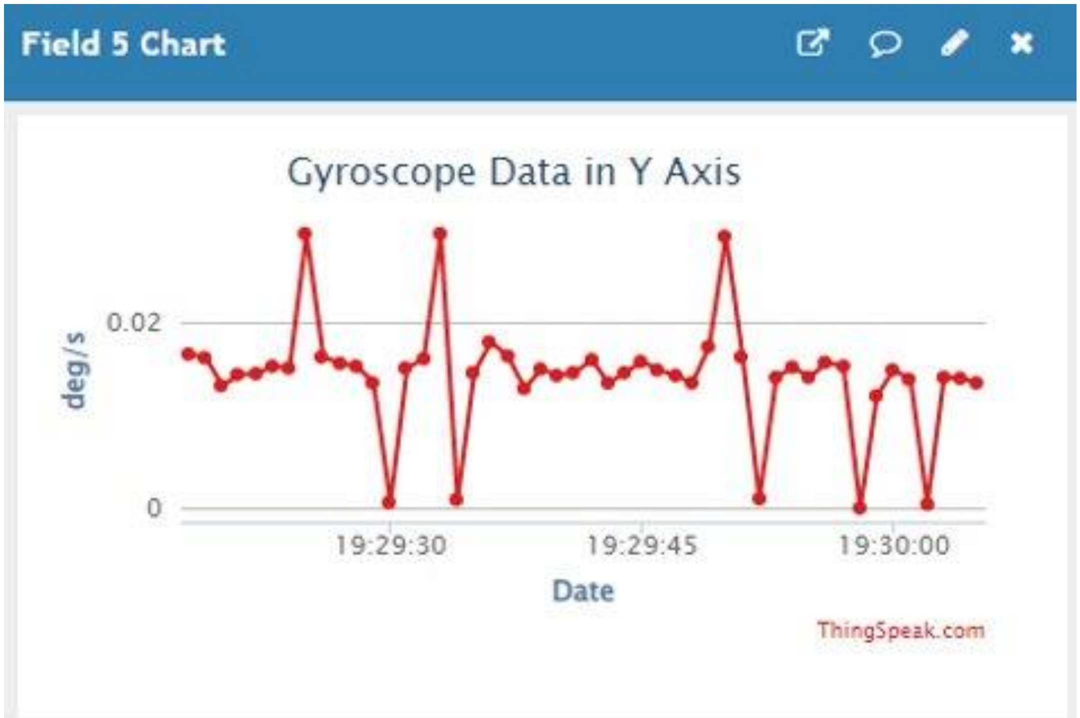
(b)


Field 3 Chart
Accelerometer Data in Z Axis
-8
-8.2
m/s^2
19:29:30
19:29:45
19:30:00
Date
ThingSpeak.com

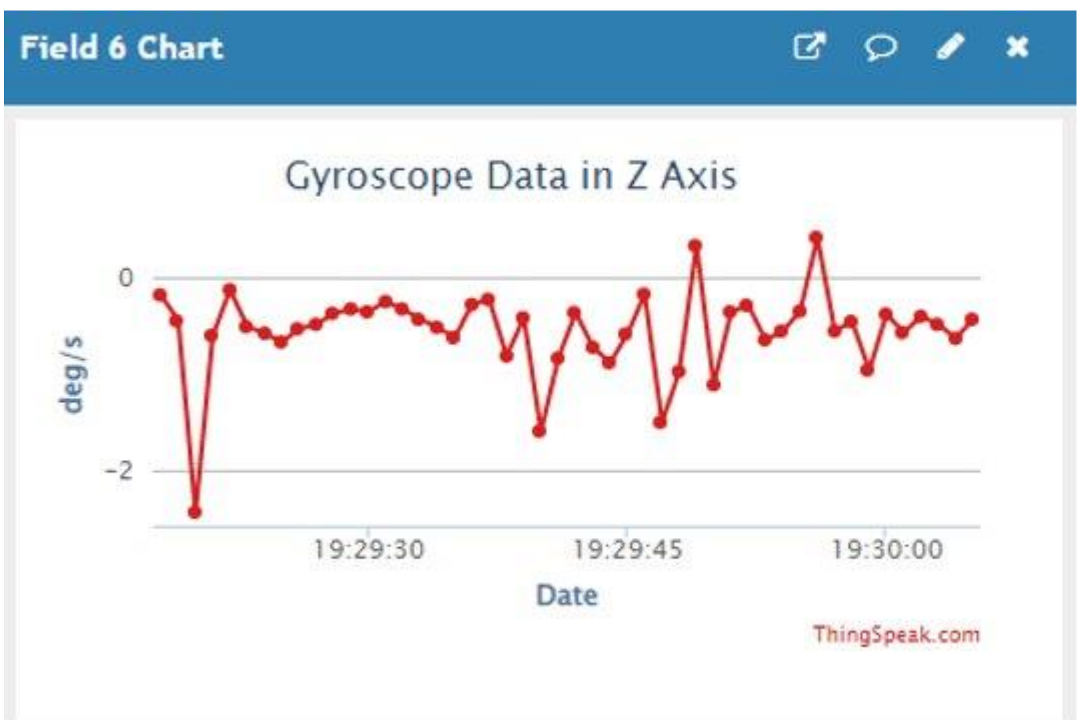
(c)


Field 4 Chart
Gyroscope Data in X Axis
0
-0.05
deg/s
19:29:30
19:29:45
19:30:00
Date
ThingSpeak.com

(d)


Field 5 Chart
Gyroscope Data in Y Axis
0.02
0
deg/s
19:29:30
19:29:45
19:30:00
Date
ThingSpeak.com

(e)


Field 6 Chart
Gyroscope Data in Z Axis
0
-2
deg/s
19:29:30
19:29:45
19:30:00
Date
ThingSpeak.com

(f)

8.4

Figure 29 (a-f): Testing and Evaluation for Accelerometer and Gyroscope

Here, the team was able to send data from the UGV's onboard Raspberry Pi to the BeagleBone Green and then to the IoT cloud platform. This was a success and as seen in Figure 29 (a-f) , the team can see the acceleration and the angular velocity in the X, Y, and Z axis.

8.5 Validation

Drone weight test: The team conducted preliminary testing in the Collaborative Robots and Agents Lab (CORAL) with the drone using 10-gram weights that were able to attach to the bottom of the drone itself. From this point the weight increased by 10-grams until the drone was unable to lift itself from the ground thus concluding the test. The test results allowed us to determine the final weight the SkyLift needed to be and still allow us to have a payload of less than 30 grams.

9. RESULTS: PROTOTYPE EVALUATION

9.1 'Exit test'

To test the final prototype, the team ran both the UAV and UGV to perform their specified tasks in which they picked up and delivered a payload. The UAV used IoT enabled data to have the drone fly autonomously from building to building using the SkyLift mechanism to take advantage of magnetism to accomplish this goal. The UGV used IoT data sensor fusion to navigation safely through the simulated city to accomplish this goal.

9.2 Functionality

The final prototype ran both the UAVs and UGVs to perform their specified tasks of picking up or delivering a package. The first UAV used IoT enabled data to have the drone fly autonomously from building to building using the SkyLift mechanism to take advantage of magnetism to accomplish this goal while a second UAV used anticollision to detect the first UAV and stopped until it had passed. The first UGV used IoT data sensor fusion to navigate safely through the simulated city to accomplish this goal while a second UGV interfered with the first UGVs pathway to show it's anticollision feature. This functionality is similar in that the first UAV and first UGV preferred that tasks as first thought of but differs in that the second UAV and second UGV do not perform in the same way. Also, the first and second UAV would have anticollision features.

10. IMPACT ASSESSMENT

10.1 Impact of the Prototype

The prototype of an unmanned aerial and ground traffic management system was designed to manage and regulate the traffic flow of unmanned aerial vehicles (UAVs) and ground vehicles. The system aimed to ensure safe and efficient operations of both types of vehicles by providing real-time information to operators and autonomous systems. This impact assessment aimed to evaluate the potential benefits and drawbacks of the prototype system.

10.2 Intellectual Property (IP)

Intellectual property (IP) is a vital aspect of developing innovative products, as it protects the unique creations of the mind that form the basis of those products. IP encompasses various forms of creativity, such as inventions, literary and artistic works, symbols, and names, which are safeguarded by law. Although our SkyLift mechanism is not currently patented, we plan to do so in the future to secure our intellectual property rights associated with the SkyLift to prevent competitors from copying the design.

10.3 Benefit to Society

The unmanned aerial and ground traffic management system could have a positive social impact by improving mobility and accessibility. The system could enable faster and more efficient transportation, reducing the time and effort required for travel. The system could also facilitate the delivery of goods and services to remote or hard-to-reach locations, improving access to resources and opportunities.

10.4 Ethical Considerations

Drones have cameras that could record and possibly violate personal privacy. Another possible issue that could happen is that the drones could malfunction in the air, crash, and damage peoples' properties.

10.5 Economic Impact

The unmanned aerial and ground traffic management system could have a positive economic impact by reducing costs associated with transportation. The system could reduce travel time, fuel consumption, and maintenance costs for ground vehicles, resulting in cost savings for businesses and individuals. The system could also enable new applications and use cases for UAVs, such as aerial delivery and inspections, which could generate new revenue streams.

10.6 Health, Safety and Environmental Impacts

The unmanned aerial and ground traffic management system could have a positive effect. Health, safety and environmental impact by helping emergency responders quickly and safely navigate drones to the scene of an emergency which can potentially save lives, reduce risk of collision which can improve the safety of the airspace for both manned and unmanned vehicles, and reduce fuel consumption and carbon emissions, The system is designed to optimize routes, minimize travel time, and reduce congestion, which would result in lower fuel consumption and less pollution. The system could also facilitate the integration of electric and hybrid vehicles, further reducing carbon emissions.

10.7 Political Impact

The implementation of a UTM system could lead to the development of new regulations and policies around the use of drones, governments may need to ensure that the UTM system is effective and safe for all users, including both recreational and commercial users of drones. As drones become more ubiquitous, there may be concerns about privacy and the potential for drones to invade people's personal space. There may be concerns about the use of drones for nefarious purposes, such as spying or terrorism, governments may need to develop new strategies, laws, and regulations to address these concerns.

10.8 Global Impact

Automated package delivery for both drones and ground vehicles are used all around the globe by very well-known companies and use of said vehicles will only continue to grow.

10.9 Standards/Codes

ISO/IEC DIS 27402 Cybersecurity – IoT security and privacy – Device baseline requirements
ISO DIS 21384-1 Unmanned aircraft systems
ISO/IEC 10536-1:2000(en) Identification cards – Contactless integrated circuit(s) cards – Close-coupled cards

11. RESOURCES

11.1 Parts and Equipment List (Bill of Materials)

The parts utilized throughout the project consist of two Raspberry Pi terminal boards, ten Arduino uno's, ten RFID module shields, ten RFID markers, six diametric magnets, one spring, one servo motor, one accelerometer, and one drone propeller set which all came out to a total of $987.71.

Materials	Amount	Unit Price ($)	Total
Raspberry Pi Terminal Board	2	$5.99	$11.98
Arduino Uno	10	$28.50	$285.00
RFID Module Shield	10	$8.99	$89.90
RFID Marker	10	$54.20	$542.00
Servo Motor	1	$19.99	$19.99
Accelerometer	1	$9.99	$9.99
Tello Drone propellers	1	$11.99	$11.99
Magnets	6	$1.13	$6.78
Springs	1	$10.08	$10.08
Total Sum			$987.71

Figure 30: Bill of Materials

11.2 Software Used

Arduino IDE, AutoDesk Fusion 360, AutoDesk Inventor, Emworks, Nvidia Cuda, Packet Sender, Pasco Capstone, PuTTY, PyCharm, Stratasys for 3D Printing, ThingSpeak, Wokwi, X-CTU for XBEE, YOLO

11.3 Sponsors

Aside from the $1,000 University funding and $1,000 IoT Grant, no other sponsors contributed to this project.

11.4 Budget

To develop a budget, the team had to forecast the resources that would be required throughout the project. This budget included the quantity of each resource, when they were needed, and how much they cost. Table 20 illustrates the expected budget for the project based on the resource requirements. As illustrated in the table, each teammate was paid an hourly salary of $50.00, while the project manager was paid $51.00/Hr. Accounting for 10-hour work weeks, the total combined gross pay for all team members was an estimated $3,010 per week or $84,280 for the duration of the project between October and May. The parts utilized throughout the project consist of two Raspberry Pi terminal boards, ten Arduino uno's, ten RFID module shields, ten RFID markers, four diametric magnets, one servo motor, one accelerometer, and one drone propeller set. An expected budget of $987.71 was used to acquire these items. Therefore, the total estimated budget for the development of the project is an approximate $85,267.71.

Materials	Amount	Unit Price ($)	Total	Overall Budget	Hourly Pay Rate	Salary/week
Raspberry Pi Terminal Board	2	$5.99	$11.98	Daniel Armstrong	$50.00	$500
Arduino Uno	10	$28.50	$285.00	Matthew Salas	$50.00	$500
RFID Module Shield	10	$8.99	$89.90	Edward St. John	$50.00	$500
RFID Marker	10	$54.20	$542.00	Scott Tardif	$51.00	$510
Servo Motor	1	$19.99	$19.99	Marcial Torres	$50.00	$500
Accelerometer	1	$9.99	$9.99	Preston Whaley	$50.00	$500
Tello Drone propeller set	1	$11.99	$11.99			
Magnets	6	$1.13	$6.78	Total Sum		$3,010
Springs	1	$10.08	$10.08			
Total Sum			$987.71			

Figure 31: Budget

12. TASKS AND TIMELINE

Task Name	Duration	Start
Project Management Workplan	**185 days?**	**Mon 22-08-22**
Initiation Phase	**33 days**	**Mon 22-08-22**
Requirements Gathering & Analysis	**22 days**	**Mon 22-08-22**
Define process for gathering requirements	1 day	Wed 07-09-22
Document project-stakeholder interviews	1 day	Wed 14-09-22
Analyze requirements	1 day	Thu 15-09-22
Create requirements document	1 day	Tue 20-09-22
Project Charter Development	**12 days**	**Tue 20-09-22**
Business Case	**3 days**	**Tue 20-09-22**
Document summary of business purpose justification	2 days	Tue 20-09-22
Define expected benefits	2 days	Wed 21-09-22
Project Scope Definition (High Level)	**5 days**	**Mon 26-09-22**
Define primary market research objectives	4 days	Mon 26-09-22
Define primary market research deliverables	2 days	Thu 29-09-22
Identify specific exclusions to scope	2 days	Thu 29-09-22
Establish high-level time, cost, and resource estimates	2 days	Mon 03-10-22
Establish list of key stakeholders	2 days	Mon 03-10-22
Document project charter	1 day	Wed 05-10-22
Project Charter Approval	0 days	Wed 05-10-22
Initiation Phase Approval	0 days	Wed 05-10-22
Planning Phase	**33 days?**	**Wed 05-10-22**
Project Plan Development	**32.5 days**	**Wed 05-10-22**
Scope Statement	**4 days**	**Wed 05-10-22**
Create scope description (based on business objectives)	2 days	Wed 05-10-22
Define scope boundaries (both in and out of scope)	2 days	Wed 05-10-22
Define key project deliverables (including user-acceptable criteria)	2 days	Fri 07-10-22
Work Breakdown Structure (WBS)	**4 days**	**Tue 11-10-22**
Create WBS to work-level execution	2 days	Tue 11-10-22
Define task dependencies (including predecessors/successors)	2 days	Thu 13-10-22
Performance Baseline Measurement	**2 days**	**Mon 17-10-22**
Create schedule baseline (with expected resource effort)	1 day	Mon 17-10-22
Define budget baseline (with schedule and cost assumptions)	1 day	Tue 18-10-22
Establish baseline tolerance thresholds (trigger change control)	1 day	Tue 18-10-22
Procurement Planning	**4 days**	**Tue 11-10-22**
Develop procurement management plan	2 days	Tue 11-10-22
Develop statement of work	2 days	Thu 13-10-22

Figure 32: Gantt Chart (Initial and Planning Phases)

Task Name	Duration	Start
Project Schedule Plan	**2.5 days**	**Wed 19-10-22**
Project Milestones (PMs)	**0.5 days**	**Wed 19-10-22**
Define major milestones (alignment with deliverables)	0.5 days	Wed 19-10-22
Project Scheduling Work Plan	**2 days**	**Wed 19-10-22**
Define standard PM and approval gates	0.5 days	Wed 19-10-22
Document WBS, milestones, and deliverables (dates and resourcing)	2 days	Wed 19-10-22
Document schedule baseline	1 day	Wed 19-10-22
Resource Management	**2 days**	**Thu 20-10-22**
Name project team members (with roles and responsibilities)	2 days	Thu 20-10-22
Define all project stakeholders (with roles and project team liaison)	2 days	Thu 20-10-22
Create org chart: project team, sponsor, steering committee, stakeholders	2 days	Thu 20-10-22
Supporting PM Process Plans	**19 days**	**Mon 24-10-22**
Change Management	**4 days**	**Mon 24-10-22**
Document change control procedure for budget and schedule baselines	2 days	Mon 24-10-22
Document change control for approved scope baseline	2 days	Mon 24-10-22
Document change control for systems modifications	2 days	Wed 26-10-22
Risk Management	**4 days**	**Fri 28-10-22**
Document risk process: prioritization, mitigation, and contingency guidelines	2 days	Fri 28-10-22
Document risk assessment for scope, budget, and schedule baselines	2 days	Tue 01-11-22
Issues Management	**2 days**	**Thu 03-11-22**
Document issues process: prioritization, resolution, and tracking guidelines	2 days	Thu 03-11-22
Document formal 3-tiered escalation: project manager, sponsor, and executives	2 days	Thu 03-11-22
Communication Plan	**4 days**	**Mon 07-11-22**
Document guidelines: project updates and stakeholder collaboration	2 days	Mon 07-11-22
Document guidelines for document repository access and controls	2 days	Mon 07-11-22
Document standard project team and executive status report guidelines	2 days	Wed 09-11-22
Quality Assurance and Control Plan	**2 days**	**Fri 11-11-22**
Define criteria for user-acceptance testing (with checklist)	2 days	Fri 11-11-22
Define criteria for cost/benefit analysis	2 days	Fri 11-11-22
Define criteria and process for periodic stakeholder satisfaction survey	2 days	Fri 11-11-22
Define criteria for "Lessons Learned" (during closeout)	2 days	Fri 11-11-22
Create Draft Project Plan	3 days	Tue 15-11-22
Project Plan Approval	0 days	Fri 18-11-22
Planning Phase Approval	0 days	Fri 18-11-22

Figure 33: Gantt Chart (Planning Phase)

Task Name	Duration	Start
Execution Phase	**117 days?**	**Fri 18-11-22**
Prep Work	**3.25 days**	**Fri 18-11-22**
Define objectives	1 day	Fri 18-11-22
Identify brainstorming team	0.5 days	Mon 21-11-22
Identify location	0.25 days	Tue 22-11-22
Develop agenda	1 day	Tue 22-11-22
Schedule facility	0.25 days	Wed 23-11-22
Arrange facilitator	0.25 days	Wed 23-11-22
Idea Development	**17 days**	**Wed 30-11-22**
Analyze market condition	53.25 days	Wed 30-11-22
Identify risks	1 day	Tue 14-02-23
Select primary market research tool	0.5 days	Wed 15-02-23
Gather ideas	1 day	Wed 15-02-23
Analyze ideas	0.5 days	Thu 16-02-23
Design testbed enviornment	17 days	Wed 30-11-22
Develop research brief	1 day	Fri 17-02-23
Present to management	0.5 days	Mon 20-02-23
Research & Development	**71 days?**	**Fri 20-01-23**
Swarmie/Drone Design/Planning	**25 days**	**Fri 20-01-23**
Develop/Purchase Material List	7 days	Fri 20-01-23
Write program for Tello drone collision avoidance	25 days	Fri 20-01-23
Write program for Swarmie drone collision avoidance	15 days	Fri 20-01-23
Write program for RF markers and Swarmie navigation	25 days	Fri 20-01-23
Plan and design blueprint for Swarmie mechanism	14 days	Fri 20-01-23
Plan and design blueprint for Tello mechanism	14 days	Fri 20-01-23
Plan and design components to hold microprocessors for Swarmie and Tello	14 days	Fri 20-01-23
Build	**35 days?**	**Fri 24-02-23**
3D-print necessary components	35 days	Fri 24-02-23
Build mobile app	30 days	Fri 24-02-23
Create model environment	25 days	Thu 09-02-23
Build Swarmie	35 days	Fri 24-02-23
Test	**5 days**	**Fri 14-04-23**
Test Tello/Swarmie collision avoidance	3 days	Fri 14-04-23
Test Swarmie claw mechanism	3 days	Fri 14-04-23
Test Tello/Swarmie navigation	3 days	Fri 14-04-23
Run simulation	2 days	Wed 19-04-23
Finalize	5 days	Fri 21-04-23

Figure 34: Gantt Chart (Execution Phase)

13. Discussion AND Analysis

13.1 Challenges and Recovery

UAVs had several crashes and broken blades but those were easily replaced. Some code required several days and in some cases weeks before the code could be completed. Making the SkyLift work through Wi-Fi posed a huge challenge and at one point an automatic update made the microcontroller unusable which was confirmed from different sources on the internet. Getting familiar with and implementing the IoT kit was a challenge since there isn't very much information on a kit like this; however, with the help of the team and with great use of time, the team was able to solve this challenge. The testbed environment had outside interference coming from the air vents in the ceiling that would blow the UAV off of its course, by covering the vents this issue has been fixed.

13.2 Accuracy and Completeness

The accuracy of the UAV pickup and delivery was off and after further testing and adjustments to the code, without adding GPS or using multiple cameras to detect the UAV and relay information back to it, the code is as good as it could get. All code for the UAV is 99%.

14. CONCLUSIONS

The UTM system was able to fulfill its intended functionality with both UAVs and UGVs. While the scale was different in the testbed, the result of the robots operating cooperatively was similar to the real-world use of this project. The various impacts of implementing IoT into the system was seen in many parts of the project, including the computational components that communicate with the vehicles and the markers that lead the vehicles to their intended destinations.

15. RECOMMENDATIONS

Some recommendations for future phases of this project include using a larger quantity of unmanned vehicles, increasing the scale for the environment and size of the unmanned vehicles and finally adjusting the obstacle avoidance algorithms to include outdoor interferences.

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APPENDICES

Appendix I – Required Skills Set

To achieve the desired goal, the project team must possess both professional and technical skills. During each phase of the project, teamwork and communication skills were important for unity and innovative ideas. For the planning phase, our mechanical engineers had to be proficient in CAD and simulation software to reduce errors, improve design quality, and save fabrication time. On the other hand, for the electrical aspects of the project, wireless communication, computer vision, and machine learning were the skills necessary to enable coordination amongst the robots. As the project progressed to the execution phase, 3D printing skills, circuitry and microcontroller knowledge, and programming proficiency in a language like Python were essential for bringing the CAD designs to life, developing RF markers for drone navigation, and programming the UAVs to fly and UGVs to drive autonomously while avoiding collisions.

Appendix II – Weekly Advisor Meetings

RW
1/30/2023

ENTC 4450 Capstone Projects
Team-Advisor Meeting Summary – Spring 2023
(To be submitted to the course instructor WEEKLY)

Project Title (in Full): **IoT Enabled Unmanned Traffic Management (UTM) System**

(**Please TYPE.** No handwriting. All pages except the signature page must be initialed by all. Do not copy and paste signatures. Signatures must be original on all reports. **In place of signatures, e-mail messages from mentor and team members stating they approve the summary will be accepted.**)

1. **Meeting Summary (5-10 sentences - include technical details):**
   (The summary should focus on **technical aspects** of the discussion, and **not** necessarily **logistic efforts.)**
   Drone capabilities in performing tasks needed for project, such as payload and battery limitations.
   Discuss different software to use to create an app to use for IOT.
   - **Blynk, Particle IOT, AWS IOT, Fogwing IOT**

   Discuss how the obstacle avoiding Swarmie will be enhanced to follow a specific path using RFID markers.

2. **Action items (technical) resolved from previous week (5-10 sentences - include technical details):**
   Drone code modified and tested to allow video using onboard camera as opposed to computer camera.
   Drone carrying system modified to adjust for size and weight limitations.
   Get 2 XBee RFID markers on the same network and communicating with each other.
   Design claw to integrate into Swarmie grasping system.

3. **Challenges/Problems that might cause delays and need attention (if applicable):**
   Using small drone to pick up item may require the use of a bigger drone and would delay next step due to learning and tweaking code to work with different drone.
   Difficulty getting app to communicate with project
   Limited information about Romeo v2 microcontroller online, such as XBee mount pins.

4. **Action Items (technical) for the following week (5-10 sentences):**
   Work in testbed environment for anticollision code adjustment.
   Begin integrating app with project
   Begin EMF simulation to identify magnetic field depth.
   Create a project using Arduino and XBee RFID markers to learn RSSI values before applying to Swarmie. Begin working on code for camera to recognize QR code and researching IoT kit donated by Dr. Ruby.

ES MT PR

DA PW MS

Rw
1/30/2023

ENTC 4450 Capstone Projects
Team-Advisor Meeting Summary – Spring 2023
(To be submitted to the course instructor WEEKLY)

	Signature	Date
Daniel Armstrong Team Member Name	[illegible] Signature	1/30/23 Date
Matthew Salas Team Member Name	[illegible] Signature	1/30/23 Date
Ed St. John Team Member Name	[illegible] Signature	1/30/23 Date
Scott Tardif Team Member Name	excused (Rw) Signature	excused (Rw) Date
Marcial Torres Team Member Name	[illegible] Signature	1/30/2023 Date
Preston Whaley Team Member Name	Preston Whaley Signature	1/30/2023 Date
Dr. Pablo Rangel Advisor Name	[illegible] Signature	1/30/2023 Date

Rww
2/5/2023

ENTC 4450 Capstone Projects
Team-Advisor Meeting Summary – Spring 2018
(To be submitted to the course instructor WEEKLY)

Project Title (in Full): IoT Enabled Unmanned Traffic Management (UTM) System

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1. **Meeting Summary (5-10 sentences - include technical details):**
   (The summary should focus on **technical aspects** of the discussion, and **not** necessarily **logistic** efforts.)

Discussed methods to be used to integrate a project done to learn how to use the RFID markers into the software for capstone, such as creating conditional statements based on received signal strength indication values. Verify drone in testbed environment for anticollision. Begin process of generating a new model for anticollision. Discussed what materials would be optimal for environment (plastic$$$, drywall, foam).

2. **Action items (technical) resolved from previous week (5-10 sentences - include technical details):**

Conducted successful range test with RFID markers.
Finished taking pictures to create a model for the Tello drone to better recognize another drone
Started magnetic simulation.
Finished Cad Model.
Gained information on the Arduino MKR 1010 to create an app using Blynk.
Found local prices for materials to build environment.

3. **Challenges/Problems that might cause delays and need attention (if applicable):**

More than expected knowledge required for sending data packets containing RSSI values within the wireless mesh network for series 2 XBees.
Transitioning knowledge gained from getting familiar with the Arduino and Blynk to the Beaglebone.
New anticollision model may work worse than previous model.

4. **Action Items (technical) for the following week (5-10 sentences):**

Connect IoT kit with XBee markers and interface them with the current network. Run a Test with the Raspberry Pi and camera to detect QR code.
Begin 3D printing.
Spend a week creating the app using the Arduino and then transition this knowledge with the Beaglebone.
Possibly begin creating the app using the Beaglebone.
Label images and run algorithm to generate anticollision model.
Purchase materials for environment.

ESS PR MT

DA

ENTC 4450 Capstone Projects
Team-Advisor Meeting Summary – Spring 2018
(To be submitted to the course instructor WEEKLY)

Rum
2/5

Name	Signature	Date
Daniel Armstrong Team Member Name	Signature	2/6/23 Date
Matthew Salas Team Member Name	Signature	2/6/23 Date
Ed St. John Team Member Name	Signature	2/6/23 Date
Scott Tardif Team Member Name	Signature	2/6/2023 Date
Marcial Torres Team Member Name	Signature	2/6/2023 Date
Preston Whaley Team Member Name	Signature	2/6/2023 Date
Dr. Pablo Rangel Advisor Name	Signature	2/6/2023 Date

RW 2/20/2023

ENTC 4450 Capstone Projects
Team-Advisor Meeting Summary – Spring 2023
(To be submitted to the course instructor WEEKLY)

Project Title (in Full): IoT Enabled Unmanned Traffic Management (UTM) System

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Week of 2/13

1. **Meeting Summary (5-10 sentences - include technical details):**
   (The summary should focus on **technical aspects** of the discussion, and **not** necessarily **logistic efforts.**)
   For this week, the team focused on the Capstone presentation and report.

2. **Action items (technical) resolved from previous week (5-10 sentences - include technical details):**
   The team finished the capstone presentation and report.

3. **Challenges/Problems that might cause delays and need attention (if applicable):**
   Challenges included finishing the capstone presentation.

4. **Action Items (technical) for the following week (5-10 sentences):**
   Research further into the coordination of RFID markers with Beaglebone and Swarmie. Research further into the coordination of Tello drone with the mobile app and Beaglebone. Test power from Tello battery for microprocessor. Research further into testbed environment building materials. Verify specifications for SkyLift mechanism to work properly and update enclosure design as required. Finalize SkyLift simulations and begin ordering necessary components.

Name	Signature	Date
Daniel Armstrong (Team Member Name)	[signature]	2/20/23
Matthew Salas (Team Member Name)	[signature]	2/20/2023
Ed St. John (Team Member Name)	[signature]	2/20/23
Scott Tardif (Team Member Name)	[signature]	2/20/2023
Marcial Torres (Team Member Name)	[signature]	2/20/2023
Preston Whaley (Team Member Name)	[signature]	2/20/23
Dr. Pablo Rangel (Advisor Name)	[signature]	2/20/2023

RW
2/20/2023

ENTC 4450 Capstone Projects
Team-Advisor Meeting Summary – Spring 2023
(To be submitted to the course instructor WEEKLY)

Project Title (in Full): IoT Enabled Unmanned Traffic Management (UTM) System

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week of 2/20/2023

1. **Meeting Summary (5-10 sentences - include technical details):**
   (The summary should focus on **technical aspects** of the discussion, and **not** necessarily **logistic efforts.**)
   Discuss how the coordination of RFID markers with Beaglebone and Swarmie will work. Discuss how the coordination of Tello drone with the mobile app and Beaglebone will work. Discuss components needed to test power from Tello battery for microprocessor. Discuss testbed environment building materials. Discuss specifications for SkyLift mechanism to work properly for updating enclosure design if required. Discuss components needed to order for SkyLift.

2. **Action items (technical) resolved from previous week (5-10 sentences - include technical details):**
   Code refined for Tello drone to navigate primarily. Code refined for RFID to communicate with one another. Skylift evaluation. Successfully completed mesh network experiment. Successfully completed QR code recognition experiment with the camera that will be attached to the Swarmie.

3. **Challenges/Problems that might cause delays and need attention (if applicable):**
   Ordering parts that are sold out and finding components that are comparable. RFID markers delivered had specifications different from the ones ordered and must be re-ordered.

4. **Action Items (technical) for the following week (5-10 sentences):**
   Research further into the coordination of RFID markers with Beaglebone and Swarmie. Research further into the coordination of Tello drone with the mobile app and Beaglebone. Test power from Tello battery for microprocessor. Research further into testbed environment building materials. Verify specifications for SkyLift mechanism to work properly and update enclosure design as required. Finalize SkyLift simulations and begin ordering necessary components. Complete final experiment with RFID markers so Swarmie can be built and begin testbed environment testing.

Team Member Name	Signature	Date
Daniel Armstrong	[signature]	2/20/23
Matthew Salas	[signature]	2/20/2023
Ed St. John	[signature]	2/20/23

DA ES PR MT MS

Rw 2/20/23

ENTC 4450 Capstone Projects
Team-Advisor Meeting Summary – Spring 2023
(To be submitted to the course instructor WEEKLY)

Team Member Name	Signature	Date
Scott Tardif		2/20/2023

Team Member Name	Signature	Date
Marcial Torres		2/20/2023

Team Member Name	Signature	Date
Preston Whaley		2/20/23

Team Member Name	Signature	Date
Dr. Pablo Rangel		2/20/2023
Advisor Name		

Ruw 2/27/2023

ENTC 4450 Capstone Projects
Team-Advisor Meeting Summary – Spring 2023
(To be submitted to the course instructor WEEKLY)

Project Title (in Full): IoT Enabled Unmanned Traffic Management (UTM) System

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1. **Meeting Summary (5-10 sentences - include technical details):**
   (The summary should focus on **technical aspects** of the discussion, and **not** necessarily **logistic** efforts.)
   Make sure order for markers is placed so compatibility and integration into the environment can be attained. Discuss methods of how the Swarmie will turn and move towards each RFID marker. Gain further knowledge of Seeeduino Xiao for controlling microservo on SkyLift. Discuss if the team wants to incorporate swarmies into the app

2. **Action items (technical) resolved from previous week (5-10 sentences - include technical details):**
   Code for Xiao corrected and tested, servo code needs adjustment.
   Redesigned Skylift enclosure for microprocessor integration.
   XBEE marker treasure experiment tested.

3. **Challenges/Problems that might cause delays and need attention (if applicable):**
   Controlling drone and Xiao from a router may not work.
   How swarmies would be able to be controlled from the app

4. **Action Items (technical) for the following week (5-10 sentences):**
   Final code adjustments before building Swarmie prototype. Further code for microcontroller, drone coordination, and anticollision.
   Focus on manufacturing magnetic housing for Skylift.
   Focus on creating app for drone implentation

Team Member Name	Signature	Date
Daniel Armstrong		
Matthew Salas	[signature]	2/27/23
Ed St. John	[signature]	2/27/23
Scott Tardif	[signature]	2/27/2023
Marcial Torres	[signature]	2/27/2023

GS

MR

RW 2/27/2023

ENTC 4450 Capstone Projects
Team-Advisor Meeting Summary – Spring 2023
(To be submitted to the course instructor WEEKLY)

Preston Whaley	Preston Whaley	2/27/2023
Team Member Name	Signature	Date
Dr. Pablo Rangel	Pablo Rangel	2/27/2023
Advisor Name	Signature	Date

Week
3/6/2023

ENTC 4450 Capstone Projects
Team-Advisor Meeting Summary – Spring 2023
(To be submitted to the course instructor WEEKLY)

RW
3/6/2023

Project Title (in Full): IoT Enabled Unmanned Traffic Management (UTM) System

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1. **Meeting Summary (5-10 sentences - include technical details):**
   (The summary should focus on **technical aspects** of the discussion, and **not** necessarily **logistic** efforts.)
   Ideas given to begin test and evaluation with Swarmie within testbed environment. Put together app for integration of sensor data. Microprocessor and servo motor for SkyLift tested.

2. **Action items (technical) resolved from previous week (5-10 sentences - include technical details):**
   Outlined the conditions within the code for how the Swarmie will work with the XBees. XBees that were ordered were able to connect. Code created and tested for microprocessor for SkyLift.

3. **Challenges/Problems that might cause delays and need attention (if applicable):**
   Code for microprocessor for SkyLift worked early last week but had issues later in the week, upon researching, there is an issue with an update that caused these types of microprocessors to not work.

4. **Action Items (technical) for the following week (5-10 sentences):**
   Putting together Swarmie (3/6/23) and start testing. This process will continue throughout the month. Further investigation on microprocessor issue. Print SkyLift Enclosure.

Team Member Name	Signature	Date
Daniel Armstrong	Daniel Armstrong	3/6/23
Matthew Salas	Matt S	3/6/23
Ed St. John	[illegible]	3/6/23
Scott Tardif	[illegible]	3/6/23
Marcial Torres	[illegible]	3/6/23
Preston Whaley	Preston Whaley	3/6/23

DA

PR

(Rw)

ENTC 4450 Capstone Projects
Team-Advisor Meeting Summary – Spring 2023
(To be submitted to the course instructor WEEKLY)

Dr. Pablo Rangel	Pablo Rangel	3/6/2023
Advisor Name	Signature	Date

PRESTON IS OUT OF TOWN.

RW 3/20/2023

ENTC 4450 Capstone Projects
Team-Advisor Meeting Summary – Spring 2023
(To be submitted to the course instructor WEEKLY)

Project Title (in Full): IoT Enabled Unmanned Traffic Management (UTM) System

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1. **Meeting Summary (5-10 sentences - include technical details):**
   (The summary should focus on **technical aspects** of the discussion, and **not** necessarily **logistic** efforts.)
   Daniel:

   Matthew:

   Ed: Discussed calculation of a yaw angle with Kalman filter as the sensor itself only calculates offset with roll and pitch. Discussed ways to communicate with mesh network as a fallback on the assumption that function for RSSI has further challenges such as (size of payload etc.)

   Scott: Coding a Waypoint code to use packets for commands through router. Adding angles to Waypoint code to rotate in the most efficient way then move forward. Working to get Xiao ESP32C3 to work without wifi to get servo to operate using Arduino IDE. Adding data and log files to write to CSV and LOG files, respectively.

   Marcial: Get sensor data onto either app/Thingsspeak

   Preston:

2. **Action items (technical) resolved from previous week (5-10 sentences - include technical details):**
   Daniel:

   Matthew:

   Ed: Interfaced the accelerometer to the motor control to make 90 degree turns based on input from acceleration and rotation about the z axis. Coded the Raspberry pi to register the package in the middle of the camera based on the tracking of each corner around the perimeter of the QR code.

   Scott: Debugged code for Waypoints. Servo code updated for wifi communication.

   Marcial: Sensor data displayed on IoT Kit

   Preston:

3. **Challenges/Problems that might cause delays and need attention (if applicable):**

PR MT MS DA ES SJ March 20, 2023

ENTC 4450 Capstone Projects
Team-Advisor Meeting Summary – Spring 2023
(To be submitted to the course instructor WEEKLY)

RW 3/20/2023

Daniel:

Matthew:

Ed: Finishing other tasks before returning to challenges with getting the mesh network to register RSSI

Scott: Xiao ESP32C3 transmits data over wifi but does not have pin to servo working (may possibly be header file issue).

Marcial: Getting code to work for Thingspeak

Preston:

4. **Action Items (technical) for the following week (5-10 sentences):**
   Daniel:

   Matthew:

   Ed: Perfect accelerometer code (alter angle variables) to minimize possible turn errors. Communicate to motor control when package is registered and engage command to retrive package and return to the street before further instruction.

   Scott: Connect drone to router for wireless communication of commands. Research Xiao ESP32C3 issue further.

   Marcial: Get sensor data onto either app/Thingsspeak

   Preston:

Team Member Name	Signature	Date
Daniel Armstrong	[signature]	3/20/23
Matthew Salas	[signature]	3/20/23
Ed St. John	[signature]	3/20/2023
Scott Tardif	[signature]	3/20/2023
Marcial Torres	[signature]	3/20/2023

MT MS ES DA

March 20, 2023

Rw 3/25/2023

ENTC 4450 Capstone Projects
Team-Advisor Meeting Summary – Spring 2023
(To be submitted to the course instructor WEEKLY)

Preston Whaley		
Team Member Name	Signature	Date
Dr. Pablo Rangel	Pablo Rangel	3/20/2023
Advisor Name	Signature	Date

DA

March 20, 2023

ES

Rw
4/3/2023

ENTC 4450 Capstone Projects
Team-Advisor Meeting Summary – Spring 2023
(To be submitted to the course instructor WEEKLY)

Project Title (in Full): IoT Enabled Unmanned Traffic Management (UTM) System

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1. **Meeting Summary (5-10 sentences - include technical details):**
   (The summary should focus on **technical aspects** of the discussion, and **not** necessarily **logistic efforts.)**
   Daniel:

   Matthew:

   Ed: Discuss best method for structuring code to account for as many contingencies as possible. Information about Mealy and Moore machines given.

   Scott: Issues with drone moving from it's location to another discussed.

   Marcial: Continue working with IoT implementations and how to get our data onto cloud

   Preston:

2. **Action items (technical) resolved from previous week (5-10 sentences - include technical details):**
   Daniel:

   Matthew:

   Ed: All Swarmie tasks aside from XBee path planning and communication between camera and motors completed.

   Scott: Tested drone angle and movement commands using Station Mode.

   Marcial: Sensor data uploaded and can be visualized on cloud

   Preston:

3. **Challenges/Problems that might cause delays and need attention (if applicable):**
   Daniel:

   Matthew:

   Ed: Place XBee markers in testbed environment and test path planning. When claw is completed servo values will be found and the package will be included in the test runs.

DA MT PR ES

April 3, 2023

ENTC 4450 Capstone Projects
Team-Advisor Meeting Summary – Spring 2023
(To be submitted to the course instructor WEEKLY)

4/3/2023

Scott: Servo header file not working properly, will need to research and will cause some delays.

Marcial: !

Preston:

4. Action Items (technical) for the following week (5-10 sentences):
Daniel:

Matthew:

Ed:

Scott: Research servo header file and correct movements based on environmental issues.

Marcial: Continue working with IoT implementations and how to get our data onto cloud

Preston: Evaluate alternative magnet solutions and begin developing new design.

Team Member Name	Signature	Date
Daniel Armstrong		4/3/2023
Matthew Salas		4/3/2023
Ed St. John		4/3/2023
Scott Tardif		4/3/2023
Marcial Torres		4/3/23
Preston Whaley	Preston Whaley	4/3/23

Advisor Name	Signature	Date
Dr. Pablo Rangel		4/3/2023

April 3, 2023

4-10-23

Rwu 4/10/2023

Project Title (in Full): IoT Enabled Unmanned Traffic Management (UTM) System

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1. **Meeting Summary (5-10 sentences - include technical details):**
   (The summary should focus on **technical aspects** of the discussion, and **not** necessarily **logistic efforts.)**
   Daniel:

   Matthew:

   Ed: Discussed finalizing code and process of recording video.

   Scott: Arduino and Python code updated to allow Skylift mechanism to work autonomously.

   Marcial:

   Preston: Get values for enclosure redesign and 3D print prototype.

2. **Action items (technical) resolved from previous week (5-10 sentences - include technical details):**
   Daniel:

   Matthew:

   Ed: Voltage response from camera when condition is met.

   Scott: Arduino and Python code updated to allow Skylift mechanism to work autonomously.

   Marcial: yes

   Preston: Enclosure redesigned.

3. **Challenges/Problems that might cause delays and need attention (if applicable):**
   Daniel:

   Matthew:

   Ed: Code works but sometimes gets caught in a loop.

   Scott: Navigation of Tello is based on hard coded values that may not process correctly as the Tello does not always run the process through completely before another one starts.

ES PR MT DA

4-10-23

RM
4/10/2023

Marcial:

Preston: Magnetism may interfere with Tello.

4. Action Items (technical) for the following week (5-10 sentences):
   Daniel:

   Matthew:

   Ed: Work on Swarmie navigation

   Scott: Work on Tello navigation.

   Marcial: Get sensor data on cloud

   Preston: Test SkyLift mechanism.

Name	Signature	Date
Daniel Armstrong Team Member Name	Signature	4/10/23 Date
Matthew Salas Team Member Name	Signature	4/10/23 Date
Ed St. John Team Member Name	Signature	4/10/23 Date
Scott Tardif Team Member Name	Signature	4/10/23 Date
Marcial Torres Team Member Name	Signature	4/10/23 Date
Preston Whaley Team Member Name	Preston Whaley Signature	4/10/23 Date
Dr. Pablo Rangel Advisor Name	Signature	4/10/2023 Date

RW
4/17/2023

ENTC 4450 Capstone Projects
Team-Advisor Meeting Summary – Spring 2023
Week of 4/10/2023 (To be submitted to the course instructor WEEKLY)

Project Title (in Full): IoT Enabled Unmanned Traffic Management (UTM) System

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1. **Meeting Summary (5-10 sentences - include technical details):**
   (The summary should focus on **technical aspects** of the discussion, and **not** necessarily **logistic** efforts.)
   Daniel:

   Matthew: ?

   Ed: Met to discuss progress on XBee code (Getting the receiver to take all incoming messages and break them apart by the ID).

   Scott: Discussed working with IoT to get waypoints, angle and moving up logic issues, wifi controlled microcontroller issues, and forward logic issues for Tello drone.

   Marcial: Discuss what other sensor data can/should be sent to IoT platform

   Preston:

2. **Action items (technical) resolved from previous week (5-10 sentences - include technical details):**
   Daniel: Met with Jack and printed the parts to the Swarmie claw. Claw has been assembled.

   Matthew: ? HELPED PRESTON TEST MAGNETIC HOUSING WITH MAGNETS

   Ed: Resolved situation to let slow camera framerate catch up so a decision could be made based off the camera and not other sensors.

   Scott: IoT waypoints received, angle and moving up logic issues resolved, and wifi controlled microcontroller issues resolved for Tello drone.

   Marcial: Accelerometer and Gyroscope data can be seen on ThingSpeak. Waypoints can be recognized with drones

   Preston: SkyLift magnets and housing components assembled and tested.

3. **Challenges/Problems that might cause delays and need attention (if applicable):**
   Daniel: There were not enough screws to fit the claw and the screws cannot be purchased in stores.

MCT DA MR ES

April 17, 2023

ENTC 4450 Capstone Projects
Team-Advisor Meeting Summary – Spring 2023
(To be submitted to the course instructor WEEKLY)

Rver 4/17/2023

Matthew: ? Ceiling Vents Keep Breaking, Need to Remove One Side

Ed: Ultrasonic and gyroscope values appear to be altered by initializing the servo motors on the claw.

Scott: Tello drone tends to get caught in command, may need extra delay time.

Marcial: ?

Preston:

4. Action Items (technical) for the following week (5-10 sentences):

Daniel: The right side of the claw has been redesigned to fit a larger more available screw size. Updated designs need to be approved and printed.

Matthew:

Ed: Choose decisions that the Swarmie will make based off the XBEE marker signals and locations.

Scott: Work on forward logic and delay time issues for Tello drone.

Marcial: Work on what other sensor data can/should be sent to IoT cloud

Preston: Print out final enclosure design, assemble parts, retest design.

Team Member Name	Signature	Date
Daniel Armstrong	[signature]	04/17/23
Matthew Salas	[signature]	4/17/23
Ed St. John	[signature]	4/17/23
Scott Tardif	[signature]	4/17/2023
Marcial Torres	[signature]	4/17/23
Preston Whaley	[signature]	4/17/23

April 17, 2023

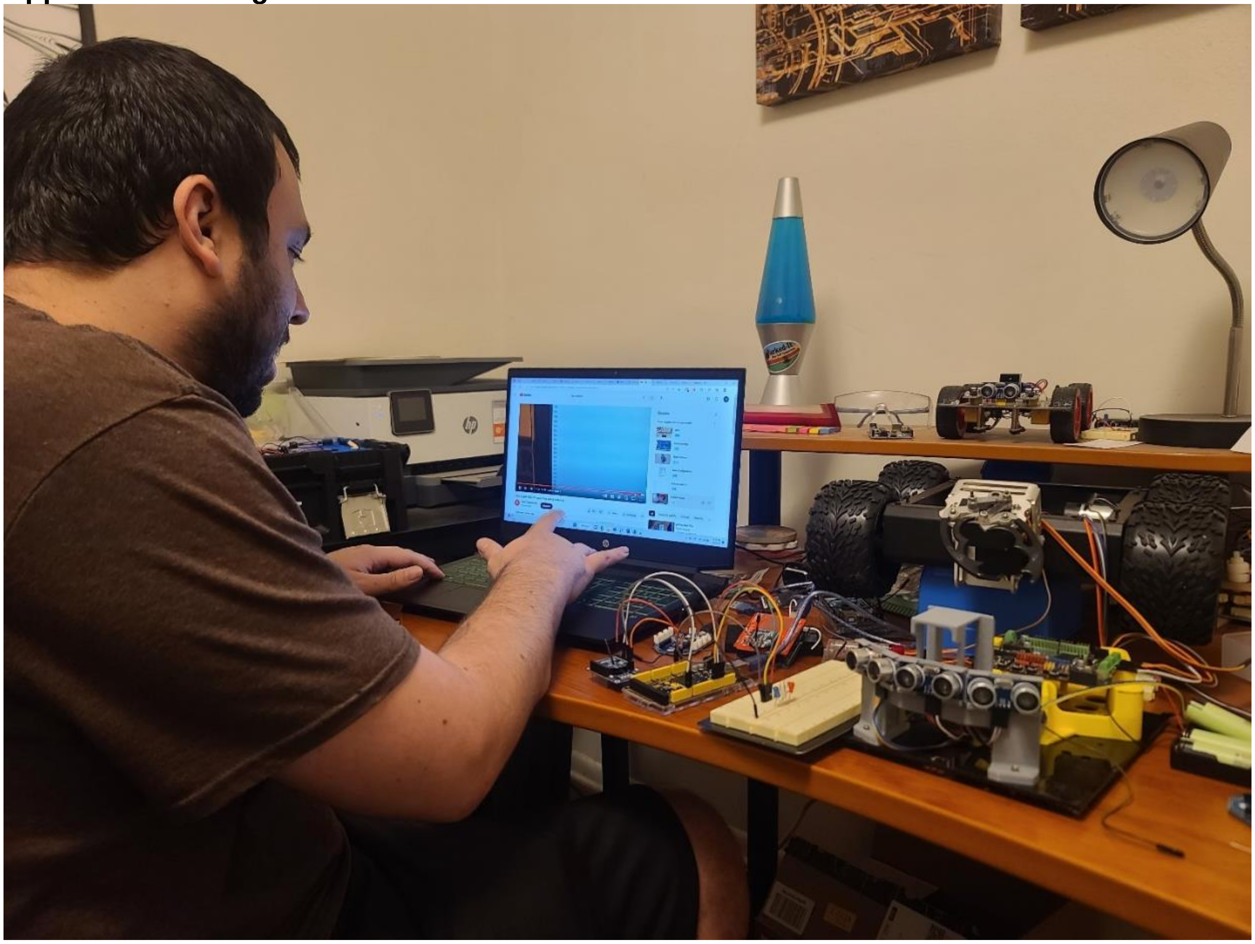
4/17/2023

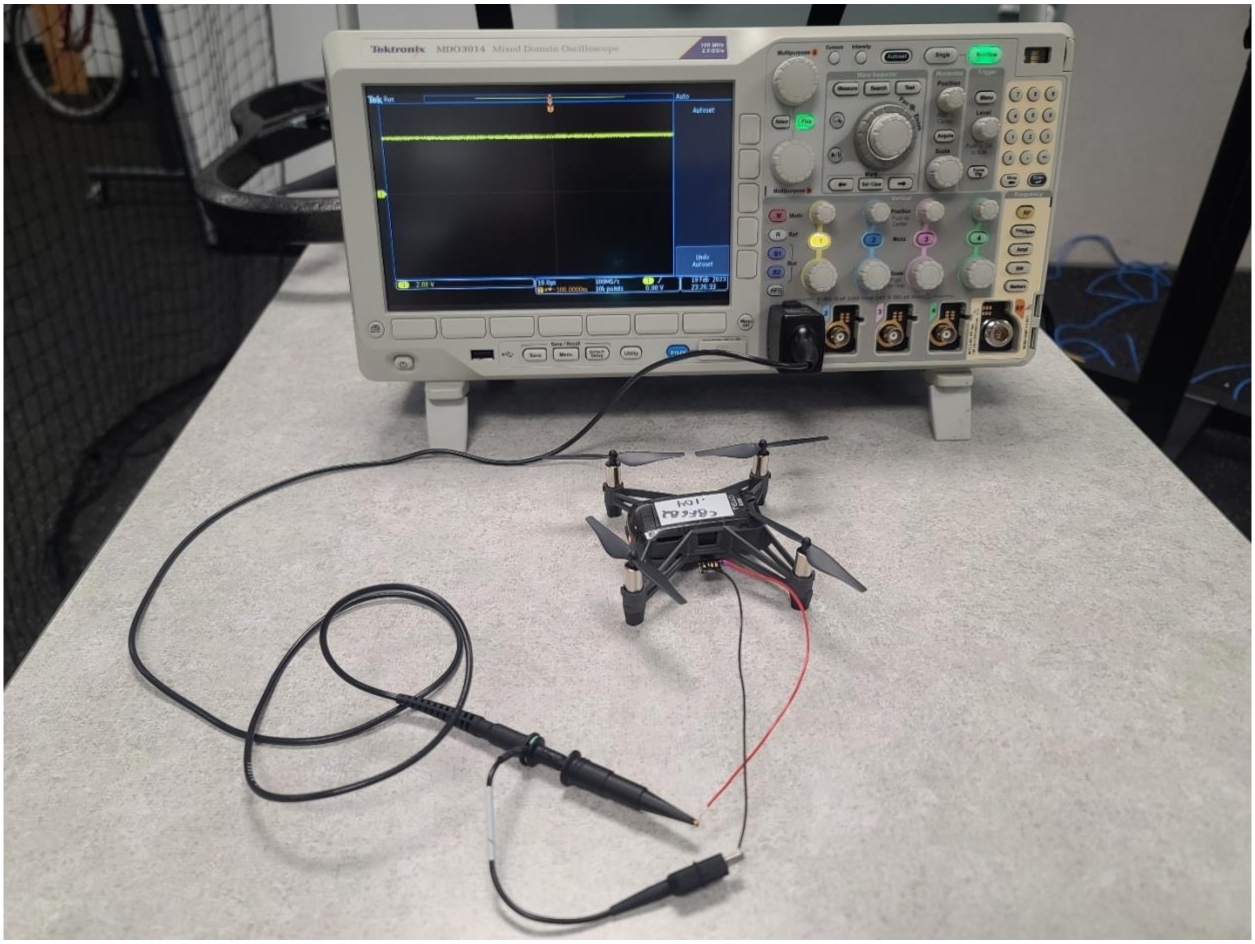
ENTC 4450 Capstone Projects
Team-Advisor Meeting Summary – Spring 2023
(To be submitted to the course instructor WEEKLY)

Dr. Pablo Rangel		4/17
Advisor Name	Signature	Date

April 17, 2023

Appendix III – Progression in Pictures




Tektronix MDO3014 Mixed Domain Oscilloscope


CORAL
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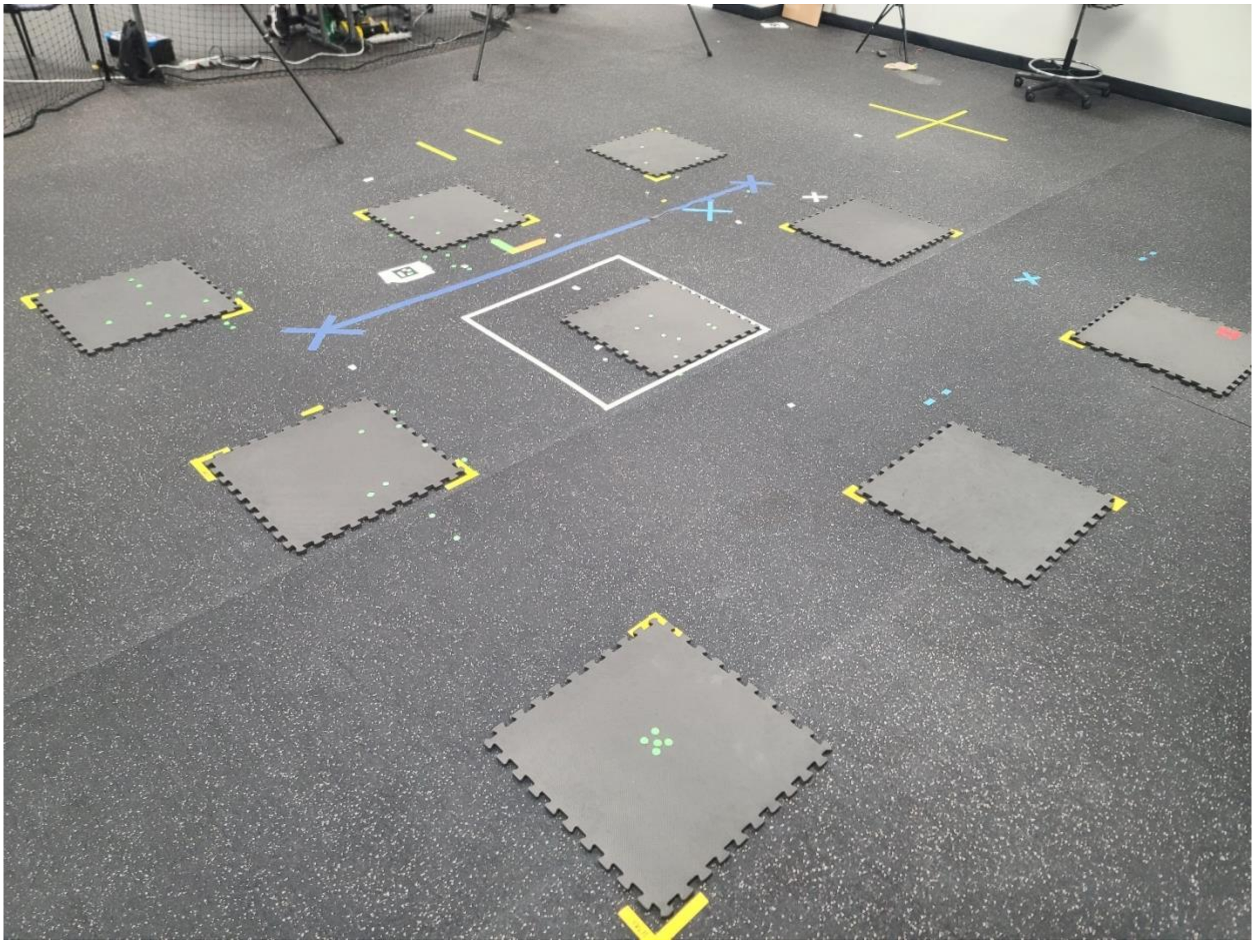

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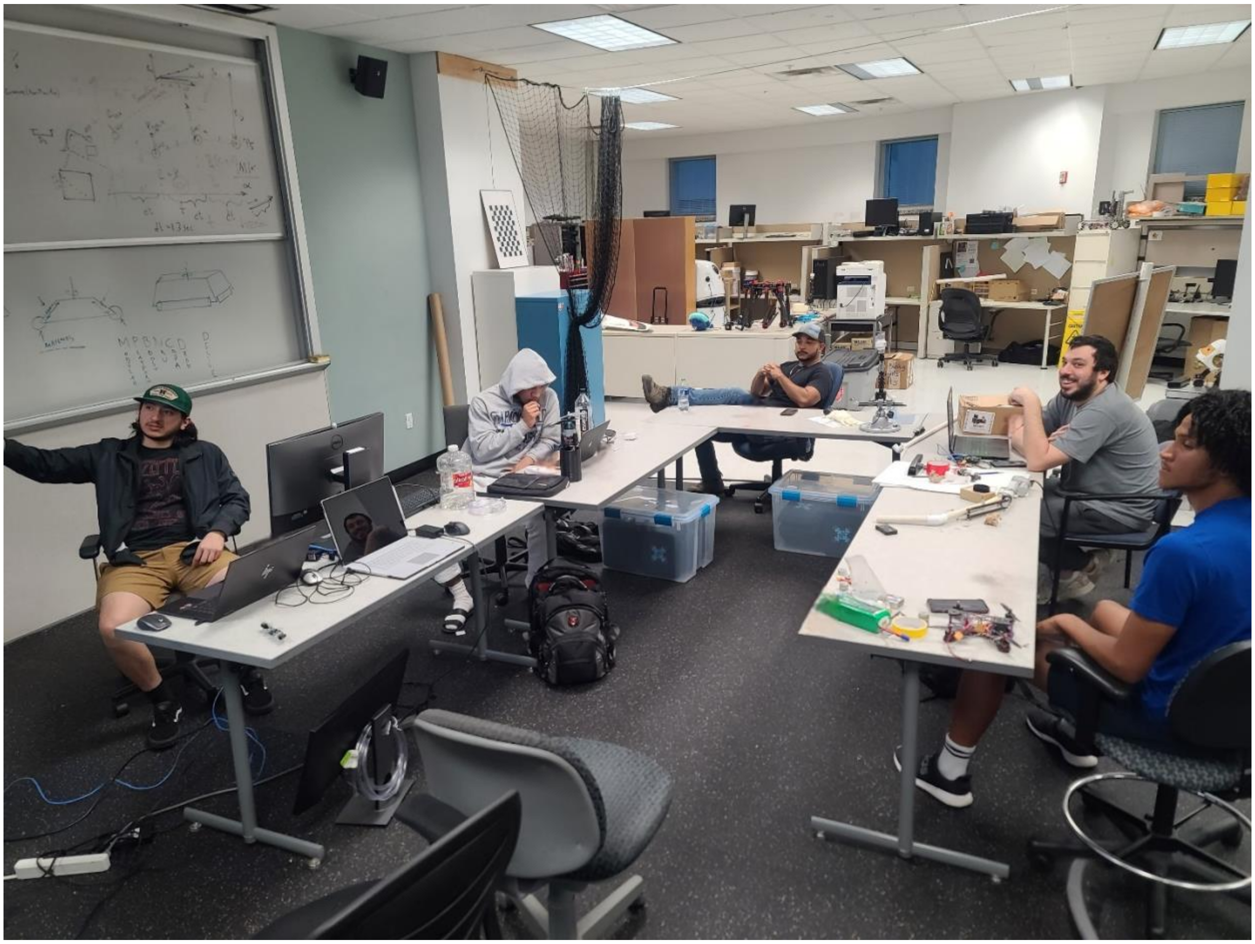
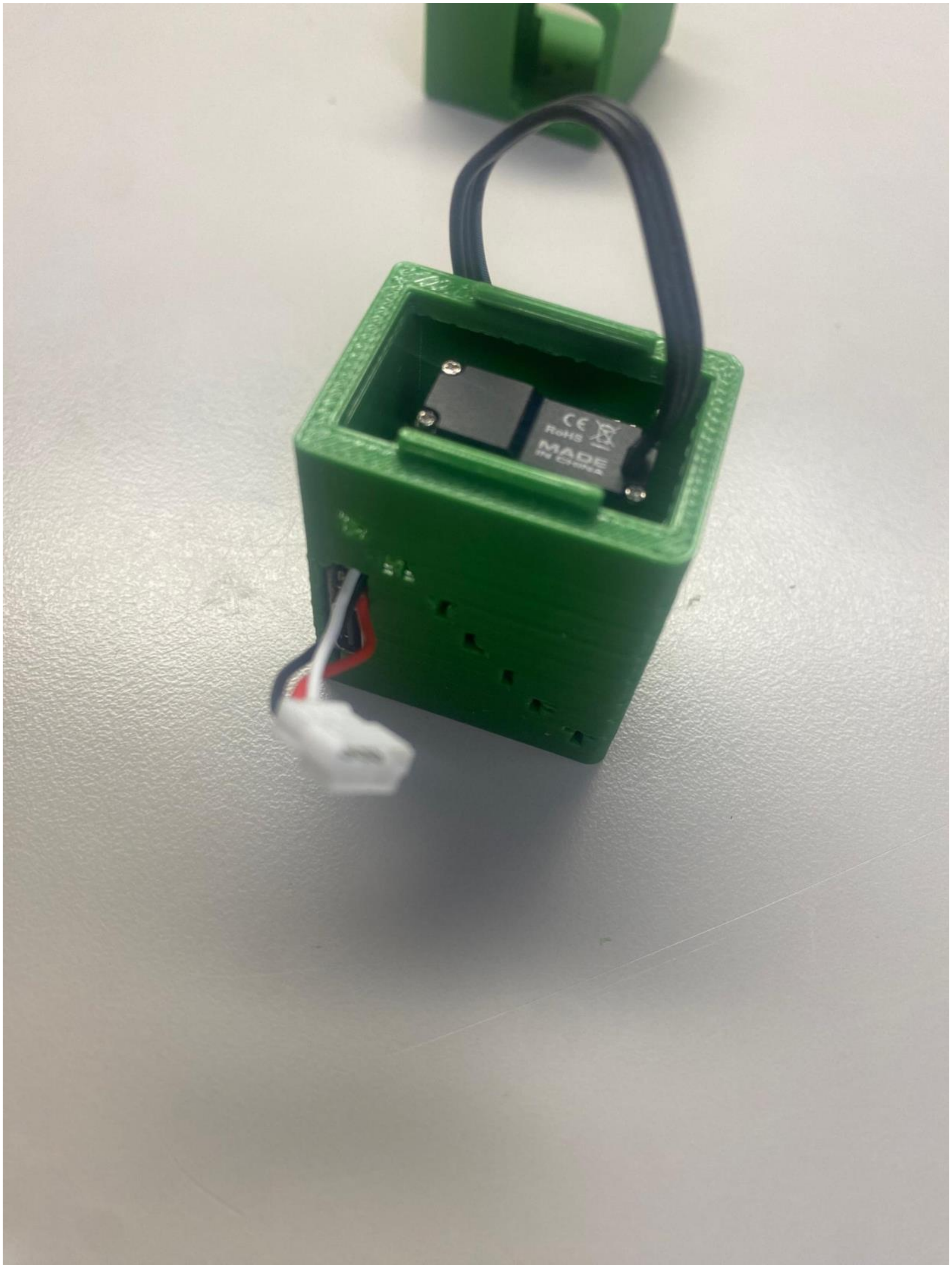



DRONE 59% - STOP!



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