Unmanned Aerial Vehicle (UAV) for Urban Remote Sensing

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Abstract— **Unmanned aerial vehicles (UAVs) such as an octocopter are a mature technology applied in various fields including geography, biology, archaeology, forestry, agriculture, and photography. UAVs, for example, afford photographers an added dimension in their art. UAVs may be suitable platforms that meet cost-effective solutions for urban planning, however, applications of UAV in urban mapping and remote sensing are in their infancy. UAV platforms can be flown on demand, easy-to-operate, cost-effective, and can deliver high resolution images. An automated flight system on a 32-bit single-board computer is employed to minimize errors in flight control, although the craft can be manually controlled. The UAV is equipped with navigational sensors including GPS for position, altimeter for altitude, magnetometer for heading, and accelerometer for tilt and motion. Since the payload of the craft is variable, the craft has adequate lifting capacity of about 3 kilograms. Weight of the craft is reduced by using carbon fiber frame tubes and propellers. For the craft to capture a large field of view, it has to travel a large area to capture mosaic images with a flight time between 10 to 12 min with an imaging system such as a digital camera. To sustain these flight times, a high-capacity 4S lithium polymer battery pack (10,000 to 20,000 mAh) is used, which powers only the motor and the flight control system. Radio telemetry (433 MHz) is used to send and receive data to the flight computer to monitor the aircraft's systems. A proportional, integral and differential (PID) controller is coded into the flight computer to control flight dynamics. The control system is automatically tuned for trim, roll, pitch, and yaw controls as well as auto pilot. The craft can be flown on fully automatic mode by uploading a flight plan but can be overridden manually and has fail-safe systems in case the craft veers from its flight envelope. The theoretical noise produced by the craft at 120m is about 55.22dB which is acceptable as daytime outdoor noise for urban environments.**

Keywords — autopilot, waypoints, control, unmanned aerial vehicle, octocopter, urban remote sensing, multicopters

I. Introduction

As one of the 35 highly urbanized city, Cebu City has an emerging and increasing population. With regard to this alarming condition, slum and squatter areas are becoming overcrowded [0] that resulted to these problems that mainly include accidents, unsanitary conditions, crimes and vulnerability to disasters. The transformation of these urban communities is so rapid that it requires immediate response [1]. As a result, urban planning and monitoring should be incorporated with technology that is cost-effective and can deliver immediate results [2][3]. With the current state of our economy, sensing technologies such as LiDAR and satellites are expensive to maintain, operate and impractical for use in surveying small but overcrowded community areas [4][5]. Also, they will not be able to produce high-detailed images of landscapes because of their high elevation from the earth compared to images captured at lower altitudes.

The aim of this paper is to design and develop a UAV that will be applicable for urban remote sensing. The UAV is expected to be able to lift up to 9 kilograms of net payload. It is expected to reach an ideal altitude of more than 120 meters. It is expected to be able to navigate to given waypoints through an autopilot system. It is expected to produce an acceptable noise level of 31.1 to 57.8 decibels to minimize noise pollution. It must have a manual override at any time while on autopilot flight as a failsafe in case of emergency. It must be able to achieve a flight time of at least 30 minutes at full power with payload. A program that will calculate flight time and can perform telemetry between the UAV and the ground control station is expected to be implemented on this study.

This paper describes the methodology used in building the UAV and the processes conducted in performing the different tests proposed to validate the objectives. Section 4 shows the analysis of the data gathered from the tests.

II. Methodology

The research will involve the design and development of a prototype UAV. It will be tested on its flight dynamics, control, power management, range, altitude and noise. The UAV design considerations are its lifting capacity, altitude (Civil Aviation Authority of the Philippines, or CAAP, requires pilot license for flying at and beyond 120 meters altitude), noise and flight time.

A. System Block Diagram

The UAV is an octocopter which has 8 motors. Each motor is controlled by an electronic speed controller (ESC), therefore, there are eight ESC's in total. The ESC's are connected to the servo rail of Navio+. The Navio+ has built-in sensors for global positioning system (GPS), altimeter, accelerometer and magnetometer and the data from these sensors are sent wirelessly through a telemetry radio kit [6]. These components are powered by a Lithium Polymer (LiPo) battery pack and connected via the power module. A universal battery eliminator circuit (UBEC) regulates the high voltage from the battery pack to the necessary value of 5 volts for the receiver and servo rail on the Navio+.

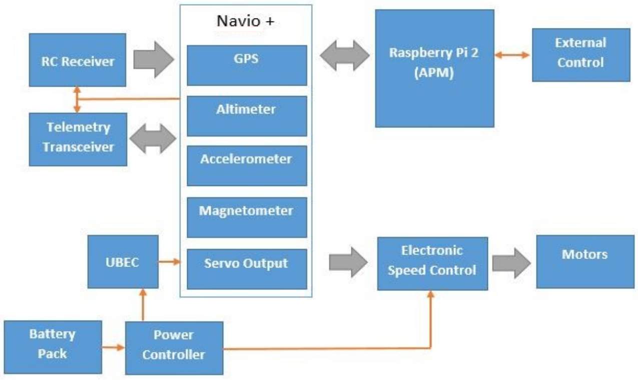

Figure 1. Overview of the system block diagram

B. Component Specification

The chosen configuration of the UAV is an octocopter because it has eight motors that give more power for lifting heavier payload. Losing one or two motors will still allow the octocopter to fly depending on the payload. The table below shows the components used in building the octocopter.

Table 1. Off-the-shelves components of the UAV

Chassis	SkyKnight X8-1100 22mm Carbo Octocopter Frame + Multi-Axis Carbon Fiber Landing Gear
Motors	T-Motor U3 700KV High Efficiency 4S Brushless Motor
Propellers	T-Motor Professional Carbon Fiber Prop (14"x4.8")
Controllers	Raspberry Pi 2/Raspberry Pi B+
Sensor Package	Navio+ Autopilot Kit for Raspberry Pi A+/B+ (accelerometer, gyroscope, altimeter, magnetometer, GPS)
Remote Control	FrSky X9D Plus 2.4GHz Radio Remote Control
RC Receiver	FrSky D8R-XP 8-Channel w/ Telemetry (optional), RSSI and CPPM
Telemetry	3D Robotics 433MHz Radio Set
Battery Pack	Turnigy Multistar 4S 10000mAh 10-20C LiPo
ESC	T-Motor Air Series 40A 2-6S 600Hz (No BEC)
UBEC	Henge 4A BEC

C. Assembled UAV (Parts)

All the components except for the motors and propellers are placed on the center of the chassis to balance the weight of the UAV. The GPS antenna is elevated due to its sensitivity towards metals and vibrations.

D. Layout (Octocopter)

The layout adopted is the octocopter plus (+) layout [7][8][9][10]. This layout uses motors 1 and 2 as the fulcrum for when rolling to the left or right and motors 7 and 8 as the fulcrum for when pitching up and down. Roll refers to the movement of the UAV forward and backward. Pitch refers to the movement up and down along the vertical axis from the front to the back of the UAV. Yaw refers to the clockwise and counterclockwise movement of the UAV. The speed of motors 1 & 2 remains the same when the UAV rolls to the left or right unless the throttle input changes. The same can also be said for motors 7 & 8 when the UAV pitches up and down [7][9][10][11][12].

Legend: [1]GPS Antenna [2]Raspberry + Navio+ [3]RC Receiver [4]Telemetry Radio Receiver [5]UBEC [6]Battery Pack [7]Power Module [8]Landing Gear V2

Figure 2. Assembled UAV with its complete parts

Motor Orientation: *Pitch* – Motors 5, 7 and 6 vs Motor 3, 8 and 4
Roll – Motors 5, 1 and 3 vs Motor 6, 2 and 4
Yaw – Clockwise (CW) vs Counter-clockwise (CCW)

Figure 3. Octocopter + layout for the motors

Motor 1 is designated as the UAV heading and is to be pointing to the magnetic north in autopilot missions. This layout does not utilize all motors for pitch and roll actions but is simpler and easier to configure.

E. Controller and Control Software

The flight controller is a hybrid design controller for the basic functions such as pitch, roll and yaw. A master controller, the autopilot feedback control system depicted in figure 4, controls the navigation of the UAV by controlling the heading, altitude and position. It can perform autopilot functions as well as allow manual control from the pilot. For this UAV, the open source ArduPilot Mega (APM) Multiplatform Autopilot system will be used. The software package includes PID control system, mission planning, telemetry, failsafe programming and data logging [8][10][11][12]. It also has multiple command modes including manual control of the UAV through the remote control.

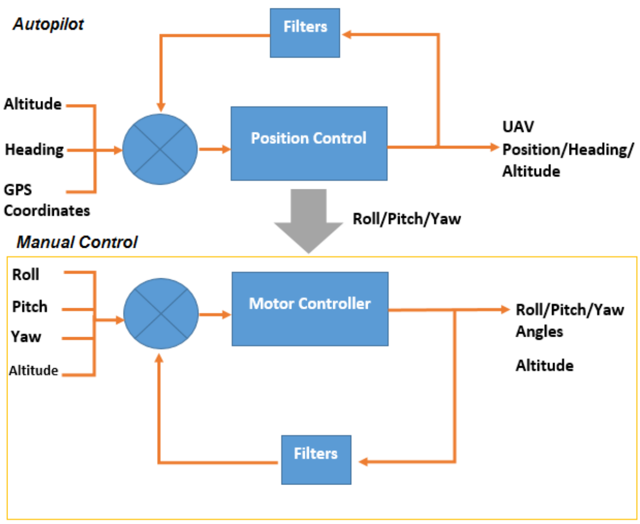

Figure 4. Control system of the UAV

The software was customized for this octocopter including the system model. In order to configure the UAV and monitor its sensors, Mission Planner is used. Mission Planner is an open-source software used in ground control stations [8]. The parameters of the APM control system are configured through this program. This program also loads the flight plan into the UAV.

F. Control Tuning

To compensate the drifting, the PID controller is tuned automatically by performing Auto-trim. It is done by flying the UAV as stable as possible for at least 25 seconds. The controller saves the new PID values and the UAV is tested again.[7] The UAV drifts upon taking off the ground even without roll and pitch input before auto-trim was performed. The drift was minimized and a stable flight without roll or pitch input is achieved (wind tends to drift the UAV) after auto-trim was performed.

G. Evaluation

The assembled UAV underwent different tests to evaluate whether the objectives are met or not. The tests are as follows:

a) Roll-Pitch-Yaw

The roll-pitch-yaw testing was done in Stabilize or manual flight mode. Stabilize flight mode is when the UAV is being manually controlled by the pilot through the remote controller. The flight angles are designated with their respective control sticks. Channels 2, 3 and 4 are for roll, pitch and yaw angles, respectively. This test was conducted first because every flight mode of the UAV depends on getting this test correctly.

b) Loiter

Loiter mode of the UAV depends on the GPS to function properly. The test is carried out by switching the switch on the remote controller which is configured through the Mission Planner before the flight. This test determines if Loiter mode is able to maintain the UAV's current position and altitude if the UAV does not receive any command to change its throttle, pitch or roll.

c) RTL

Return-To-Launch (RTL) depends on the GPS to function properly. This test is carried out by switching the switch on the remote controller which is done before the flight. This flight mode commands the UAV to return to the location where it is armed. The UAV will ascend if its current altitude is below the set altitude or descend if it is above the set altitude.

d) Autopilot

This flight mode incorporates the altitude control and position control of the Loiter. The UAV will follow a flight plan which is made up of navigation commands. This test was done by switching a switch in the remote controller which was set as one of the flight modes. The UAV will follow the set waypoints and go to RTL mode after the last waypoint.

e) Altitude

This test is conducted in order to determine if the UAV is able to reach 120 meters. The UAV is flown to the target altitude via autopilot. The 120 meter target is set by setting a waypoint at 120 meters through the Mission Planner.

f) Lifting

This test is made in order to determine the payload capacity the UAV can carry. Different plates with the weights of 1.134 kilograms and 2.268 kilograms will be loaded onto the UAV. The plates weighed in pounds and converted to kilograms. The payload will start from 1.134 kilograms and will be incremented by 1.134 kilograms until the UAV is unable to lift the payload.

g) Flight Time

Flight test is done to determine how much time will one single 10000 milli-amps battery pack last. The UAV will fly in autopilot mode and traverse to the waypoints repeatedly until failsafe regarding current output of the battery, has been invoked by the system.

h) Noise

The noise test is done to determine how much noise the UAV will produce. This test also aims to determine the altitude from which the noise produced by the UAV is within acceptable level, which is within 31.1 to 57.8 decibels.

i) Photographic Mission

This test is done to determine if the UAV is able to execute its intended task, which is to capture images of areas from high altitude. A point and shoot camera is mounted underneath the UAV. The test is carried out in a football stadium.

III. Results and Discussions

This section includes the data gathered and interpretation from the different performance evaluation performed.

A. Autopilot Test

This test is divided into two parts: Stabilize-Loiter-RTL and Programmed Waypoints.

a) Stabilize-Loiter-RTL

This test requires the UAV to be manually flown (Stabilize Mode) then switched to Loiter Mode then finally switched to Return to Launch (RTL) Mode. This test verifies the ability of the control system to hold the UAV in position (Loiter Mode) as well as to navigate to the home position and land automatically.

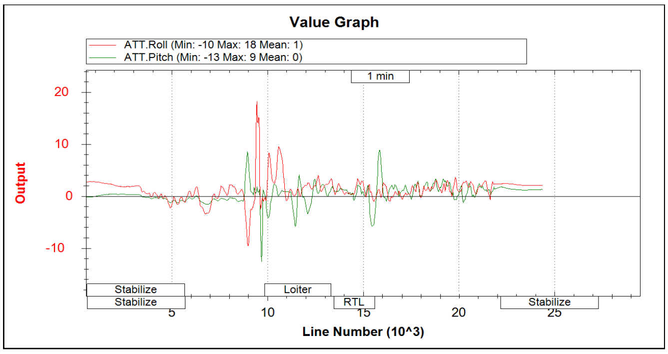

Figure 5. Performed roll vs performed pitch in Loiter mode

Without the aid of the autopilot system, the UAV needs to be compensated manually to maintain position as seen on the first part (Stabilize mode) of the graph. When Loiter Mode is switched on, the roll and pitch compensates automatically and reduces overcompensation in manual flight as seen on the middle part of the graph. It is also true in RTL Mode where the autopilot is in full control of the UAV.

b) Programmed Waypoints

The autopilot functionality of the UAV is tested to verify the accuracy of its positioning with respect to the desired position. There are two (2) waypoints for this test. Real-time GPS coordinates are logged and the error (waypoints) is calculated.

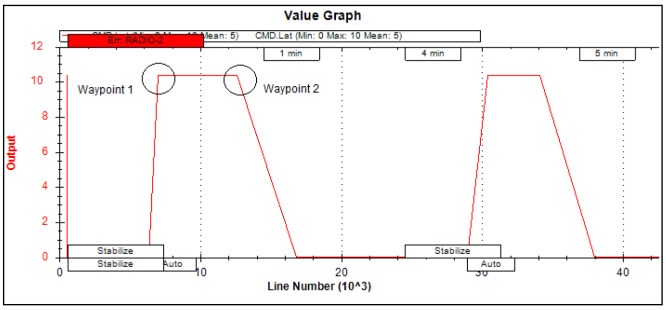

Figure 6. Input latitude

The latitudes for waypoint 1 and waypoint 2 are 10.356801 and 10.356785 respectively. Figures 6 & 7 show the autopilot command and the actual GPS data respectively.

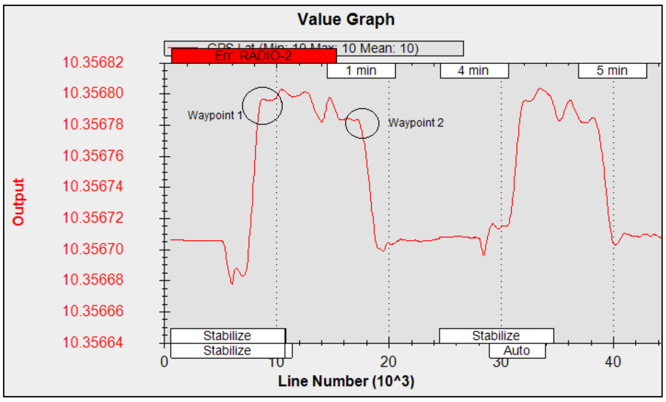

Figure 7. Actual latitude

The longitudes for waypoints 1 and 2 is set to 123.909862 and 123.909988 respectively. Figures 8 and 9 show the autopilot command and the real-time GPS data respectively.

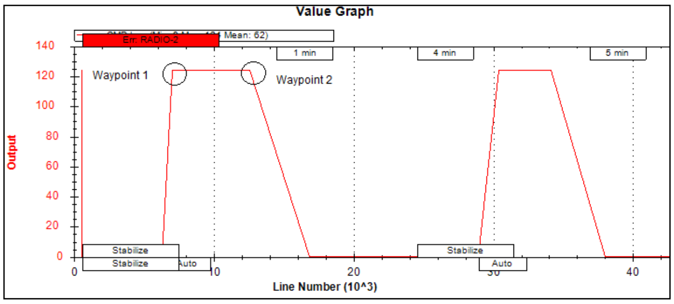

Figure 8. Input longitude

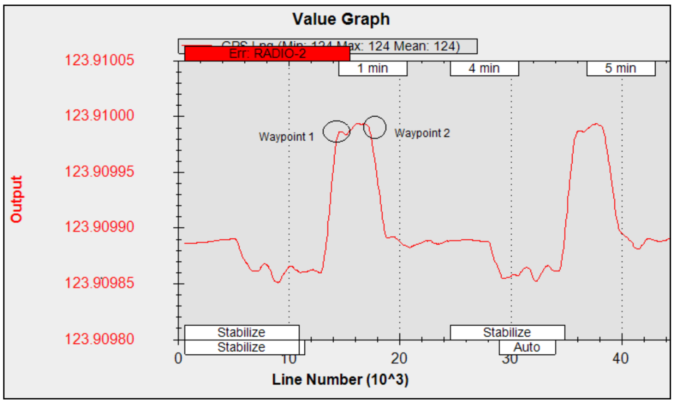

Figure 9. Actual longitude

Based on figures 6, 7, 8 and 9, it is found that the UAV responds to the command (desired latitude and longitude on both waypoints). The error in the real-time GPS data is caused by the UAV drifting as it navigated to the each waypoint. It is noted that the UAV compensated accordingly to reach the waypoint.

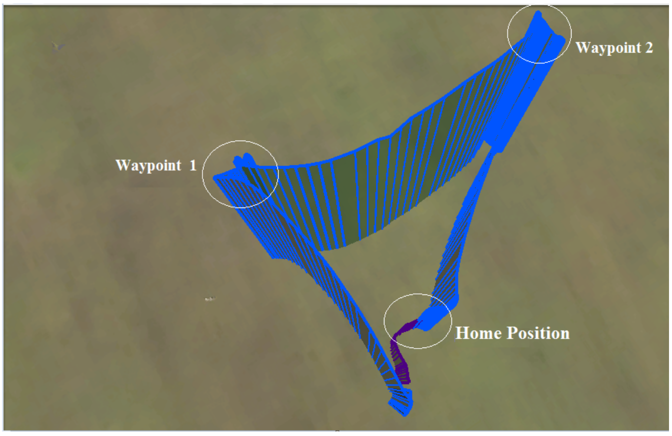

Figure 10. Flight path of the UAV in one mission (ascent, level and descent)

The violet line represents the flight path of the UAV in stabilize mode while the blue line represents the flight path in autopilot mode. Therefore, the UAV can navigate into its predefined waypoints.

B. Altitude Test

The average error at 30 meters, 60 meters, 90 meters and 120 meters were 0.24 meter, 0.33 meter, 0.14 meter and 0.20 meter respectively. It is noticed that at 60 meters, the average error of the actual altitude is higher than at other altitude levels. The team could not determine the cause of the error although an investigation had been done. The average battery level consumed by the UAV was 3 percent when flying from 0 to 30 meters and from 90 to 120 meters. The average battery level consumed by the UAV was 2 percent when flying from 30 to 60 meters and from 60 to 90 meters. The ascent to 30 meters was 3 percent on average because the UAV had to generate more power when lifting off the ground. The ascent to 60 meters and 90 meters both consumed 2 percent on average because wind gusts are minimal. The ascent to 120 meters from 90 meters was 3 percent on average because the UAV kept on compensating itself to stay on course due to gusty winds blowing it off-course. The telemetry disconnected in one trial though the UAV was able to return to the ground on its own. It is found out that the UAV can reach 120 meters. The Civil Aviation Authority of the Philippines (CAAP) limits the altitude to 120 meters for non-licensed pilots [13].

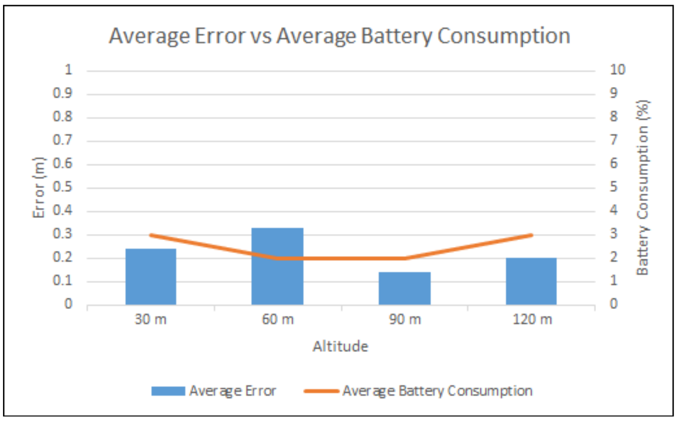

Figure 11. Average error vs average battery consumption

The data in Figure 12 shows the UAV is capable of reaching the maximum allowable altitude. The sudden spike was caused by the switching of flight mode into autopilot. The graph on Figure 12 depicts the steady climb and descent of the UAV as seen on the middle part of the graph.

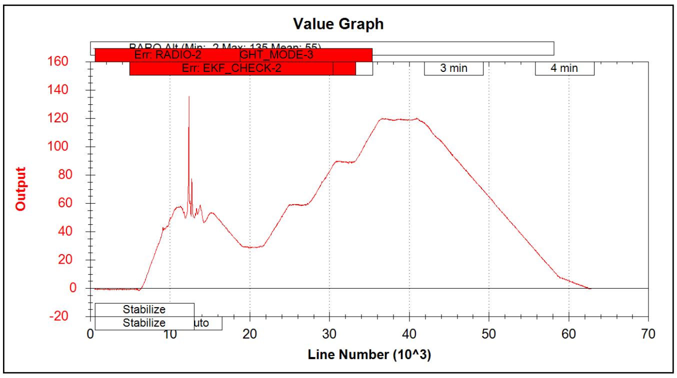

Figure 12. Ascent and descent of the UAV. It shows the graph of the altitude reached by the UAV as it ascended into 30, 60, 90 and 120 meters and its descent back to its starting position.

C. Lifting Evaluation

The lift test was conducted by mounting a metal disc on the UAV. The total weight of the UAV is 3.6 kilograms which includes the battery and landing gear. Added weight to the UAV means that the motors shall produce more torque.

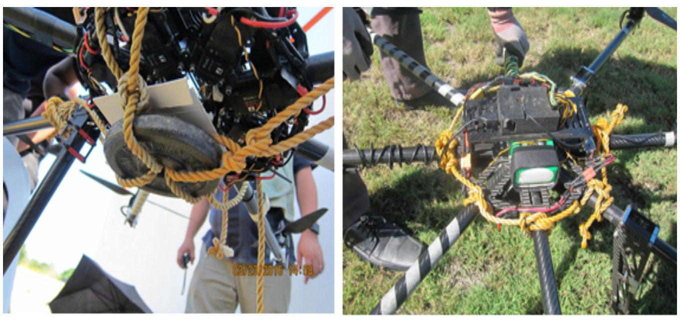

Figure 13. A metal disc was mounted before conducting the lift test.

This also requires more current draw in which was monitored as to not exceed the 60 amps limitation of the current power module used.

The test is done by enabling the autopilot mid-flight. The auto-pilot system will maintain the altitude and position. In this test, the altitude is set to 120 meters (operational altitude). The average current draw during autopilot is 45 amps. The average current draw during ascent, level flight and descent is 45, 44 and 38 amps respectively. The average current draw during descent is still high because the UAV is controlling its descent speed. The battery level was at 97 percent before the test began and was at 78 percent when the UAV returned to the ground. The lifting test consumed 19 percent of the battery. The flight time of the test, recorded with a stopwatch, is 174 seconds. Monitoring the current draw is crucial since the power module of the flight controller is rated only to a maximum current draw of 60 amps. Exceeding the rated current will result in overheating of the connectors and the power module which could cut the power to the flight controller and servo rail. The average current draw as found out does not exceed 60 amps. Based on the 1.134 kilograms load, increasing the load will result in a higher current draw. With the current hardware, the UAV will exceed 60 amps in current draw when flying at 120 meters altitude if another 1.134 kilogram metal disc is added.

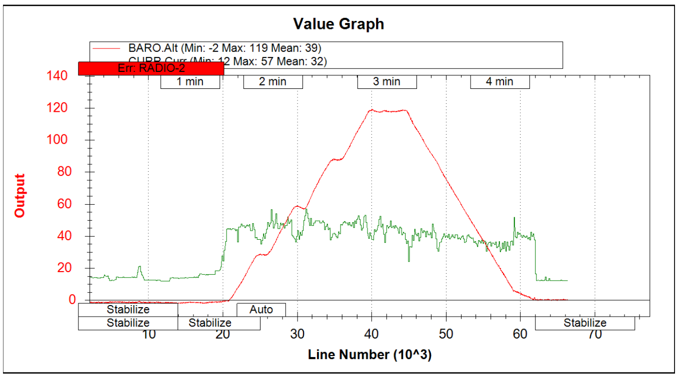

Figure 14. Altitude vs. current

However, there is always a danger of current draw surging to beyond 60 amps and therefore the current is to be monitored carefully during flight with heavier loads. To remedy this, the power module can be replaced with another power module with a 90 or 180 amps capacity.

D. Flight Time

The flight time test is conducted to determine how long the UAV can operate on a single battery which is a 4-cell 10000 milli-amps per hour 10C LiPo battery pack. Based on the battery consumption recorded in the Lifting Test, the theoretical battery consumption of the flight with payload in an ascent, level flight and descent mission would be 19 percent with a gross payload of 1.134 kilograms. The flight time of the lift test (mission time) was 174 seconds.

$$Gross\ Flight\ Time = \left(\frac{Max\ Battery\ Power*}{Power\ Consumption}\right) \times Mission\ Time \qquad (1)$$

$$Gross\ Flight\ Time = \left(\frac{80\%}{19\%}\right) \times 174\ seconds$$

$$Gross\ Flight\ Time = 732.63\ seconds\ or\ 12.21\ minutes$$

*To allow a power buffer, the maximum battery power for the flight is only 80%. The 20% buffer is a safeguard from complete power drain during flight.

The flight time calculation was based on the ascent, level flight, and descent mission. Therefore, in sustained level flight, the flight time would be higher as the ascent and descent consume more battery power as seen on Figure 14.

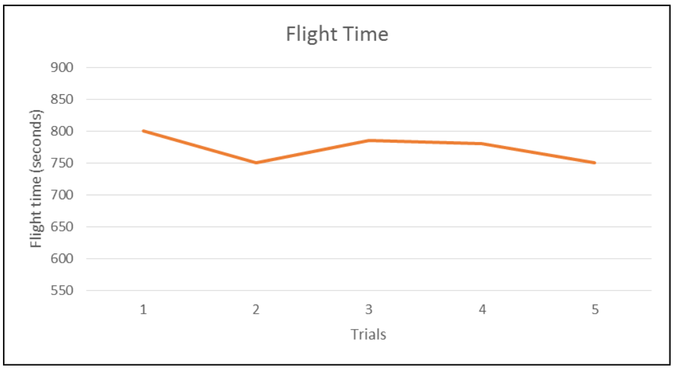

Figure 15. Flight time of every trial

Based on the calculation, the flight time with one 10000 milliamps-hour battery is not enough to reach the desired flight time of 30 minutes. A simulation of a 20000 milliamps-hour battery was performed. Two 10000 milliamps-hour batteries were loaded on to the UAV but only one was connected to power it. This set-up simulates a half-charged 20000 milliamps-hour battery. Six trials were performed in total but one was not included in the data because the telemetry between the UAV and ground control station disconnected and it was decided to return the UAV to the ground for safety reasons. The battery was not fully consumed, therefore, the recorded flight time of that particular trial was invalid. The flight times recorded from each trial are found in Table 3 in the Appendix. The average flight time of the simulated half-charged 20000 milliamps-hour battery was 773.8 seconds or 12 minutes and 53.8 seconds. The estimated flight time of a fully charged 20000 milliamps-hour battery would be 1547.6 seconds or 25 minutes and 47.6 seconds by doubling the average flight time obtained from the five trials.

E. Noise Test

The noise test for the UAV was conducted in a sound-proof room using the SPLnFFT Noise Meter software application. The application was calibrated to an acceptable decibel level of 35 decibels and below before the test began. The UAV was tethered to the ground with an initial throttle input of 0 where it is set to 1000 as a value by the flight controller on the graph. The recording device with the installed application was positioned 1 meter away from the north arm of the UAV. The throttle was gradually increased to 100 percent and was immediately set back to its initial position at 0. Throughout the test using the recording device, the maximum intensity the graph below. By classification, this measurement is considered "very loud" as it is similar to discotheques and loud rock concerts [14].

The inverse square law was used to calculate the sound level of the UAV at an increasing distance. It ideally assumes exactly equal sound propagation in all directions. Since the UAV is moving vertically from the ground, reflected sounds are no longer significant.

$$\Delta \text{L} = L_2 - L_1 \qquad (2)$$

$$\Delta \text{L} = \left|10 \text{ x} \log \frac{{d_2}^2}{{d_1}^2}\right| \qquad (3)$$

$$\Delta \text{L} = \left|20 \text{ x} \log \frac{d_2}{d_1}\right|$$

$$L_2 = L_1 - \left|10 \text{ x} \log \frac{{d_1}^2}{{d_2}^2}\right|$$

where:

L_1 = sound pressure level at location 1 (decibel)

L_2 = sound pressure level at location 2 (decibel)

d_1 = distance from source to location 1 (meter)

d_2 = distance from source to location 2 (meter)

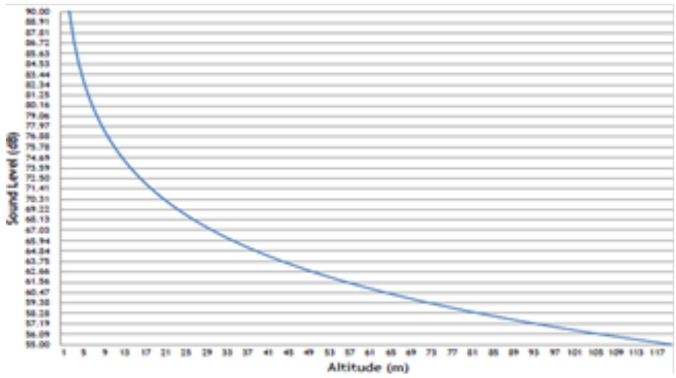

Figure 16. Sound pressure level vs. altitude

Since the sound intensity level is difficult to measure, sound pressure measured in decibels is commonly used instead. Doubling the sound pressure raises the sound pressure level (SPL) by 6 decibels. Doubling the sound intensity raises the sound intensity level by 3 decibels. At a distance of 120 meters, the inverse square law predicts a sound level of about 55.22 decibels. In real world, this would be lower since the sound source will move vertically away from the ground with minimum reflection.

To prove this projected data, an actual test was done. The test was in autopilot mode with two waypoints at different altitudes which were at 60 and 70 meters. The UAV traversed to the waypoints 10 times at 60 meter altitude and 26 times at 70 meter altitude providing that each time the UAV moved to the waypoint was equal to one trial.

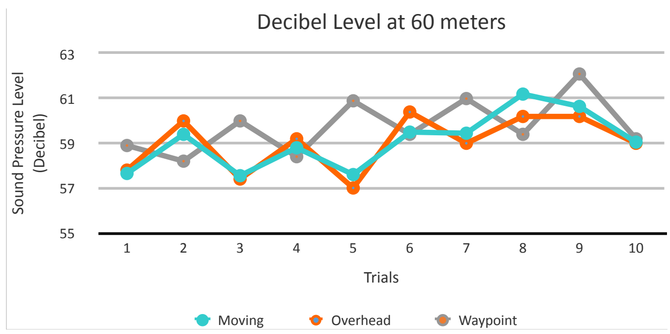

Figure 17. Sound pressure level (Decibel) at 60 meters

It is found that the actual decibel values are lower compared to the decibel level computed from the theory of inverse square law. The decibel level when the UAV hovers at a certain waypoint has a noticeable increase compared when it is moving as seen in Figure 18. The average decibel level is

59.3. Therefore, at 60 meters altitude, the decibel level exceeds the noise level proposed which is at 57.8 decibel.

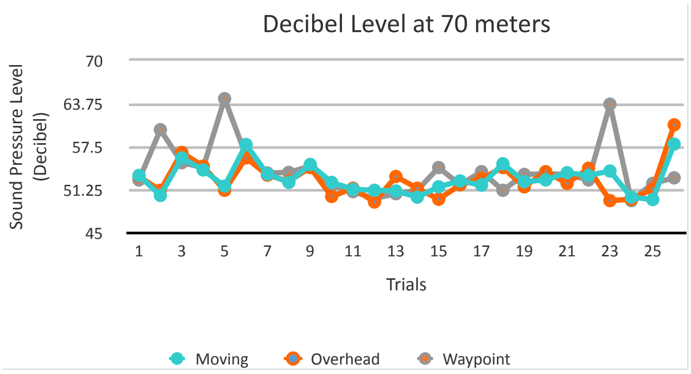

Figure 18. Sound pressure level (Decibel) at 70 meters

To achieve a noise level of 57.8 decibels or lower, the altitude was raised to 70 meters. The test was repeated for 26 times to observe the consistency of the noise levels. The sudden spikes in the graph shows the different conditions affecting the ambient decibel level. These conditions include the test environment being windy and mechanical disturbances. The average decibel level is 53.2. It is found out that the average decibel level from all the trials on the 70 meter altitude does not exceed to 57.8 decibel which is the maximum decibel level of this study.

F.Photographic Mission Test

This test is conducted for the actual application of the UAV, which is taking images of areas. A point and shoot camera is mounted underneath the frame of the UAV. The camera is a Canon S90 digital camera. The focal length of the camera was set to 22.5 mm and the capturing mode was set to "shutter speed priority". The shutter speed was set to 1/1600 in order to reduce the image blur.

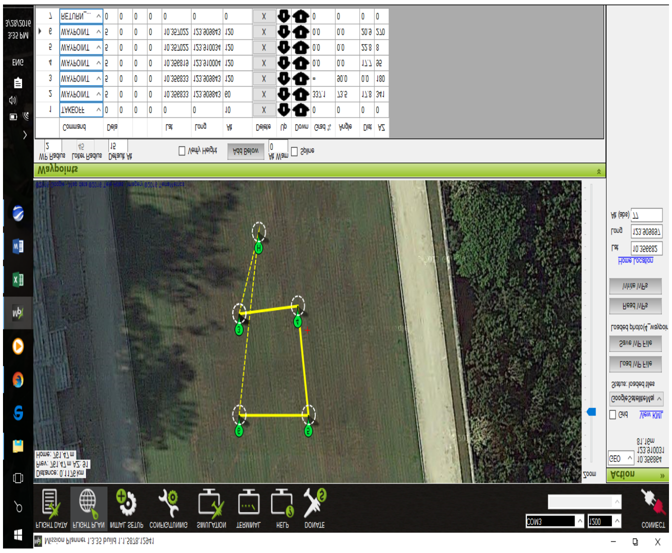

Figure 19. Flight plan of the UAV with its predefined waypoints. It depicts the flight plan of the UAV. An image is captured at each waypoint, except at the home or starting position.

The firmware of the camera was modified with a script so that it can be remotely triggered through a USB port. The signal to capture images is received from the servo rail on the flight controller.

In Figure 20, the point and shoot camera is mounted underneath the frame of the UAV. The camera is connected to the servo rail of the flight controller through a cable. Figure 21 depicts the yaw angle or heading of the UAV as it navigated to the four waypoints. It can be observed that the UAV's autopilot corrects the errors of the yaw angle caused by the wind at 120 meters. Figure 22 shows the images captured by camera on each waypoint. The entirety of the USC Stadium was not captured by the camera despite being at 120 meters from the ground.

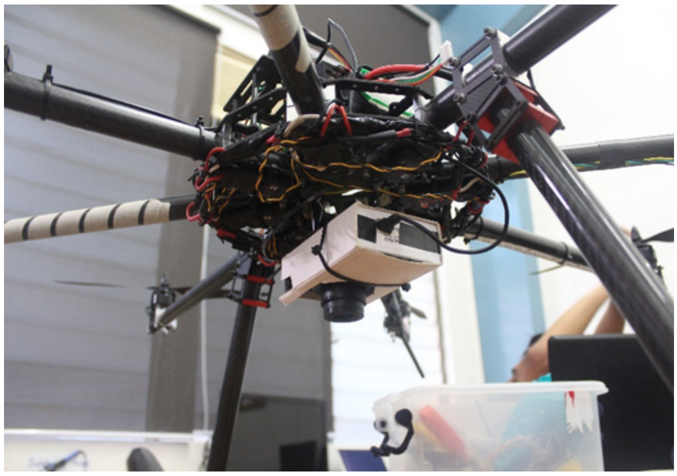

Figure 20. Point and shoot camera mounted underneath the UAV

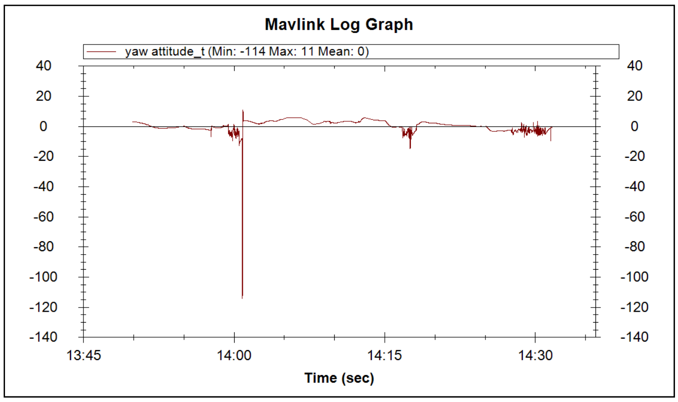

Figure 21. Heading values during the test

The orientation of the first image (top-left) is noticeably different from the others. The most likely cause of this is the camera may have been triggered before the autopilot was able to correct the heading of the UAV. The fourth image (bottom-right) is also noticeably different from the others, having a much closer image of the stadium than the others. The most possible causes of this is either the signal to trigger the camera must have been delayed, arriving when the UAV has begun its descent or the camera took too long to capture the image. Figure 23 depicts the graph of the signal that triggers the camera. The signal increases to its max value when triggering the camera. The camera is triggered four times in each waypoint as seen in the figure.

Figure 22. Images captured at 120 meters

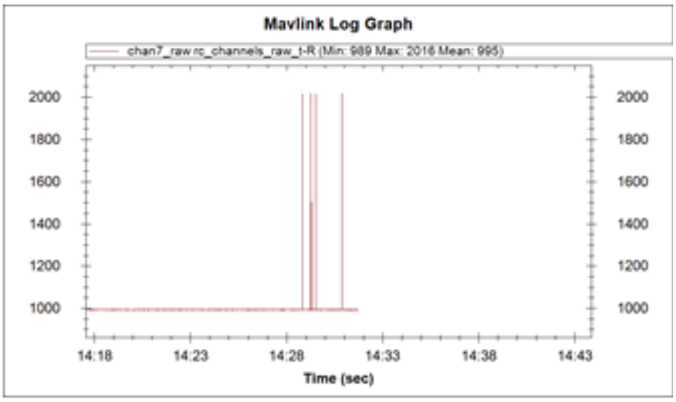

Figure 23. Signal that triggers the camera

G. Manual Override

During autopilot missions, there are times where uncontrolled factors arise like flyaways caused by a faulty compass, GPS glitches and low batteries. Manual override test is to ensure that the UAV can be switched to Stabilize mode during emergencies.

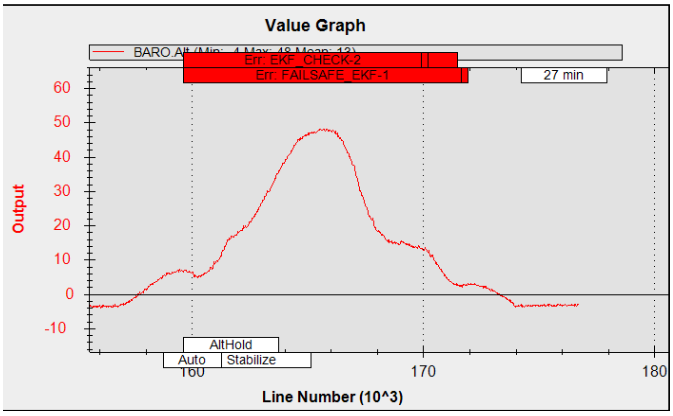

Figure 24. Error during the flight

The figure above shows an error caused by a high interference on the external compass while the UAV is in autopilot mode. It ascended in a circular path and drifted from its specified waypoint. The failsafe mechanism for the error kicked in by switching the flight mode to Altitude Hold and waited for manual override by the pilot. Stabilize mode was used to bring the UAV to the ground.

H. Failsafe Systems

Failsafe test is conducted to check if the failsafe mechanism of the UAV works during low battery current. The failsafe relies on RTL mode to return to its arming point or home position. During these circumstances, the pilot can always retake manual control if needed.

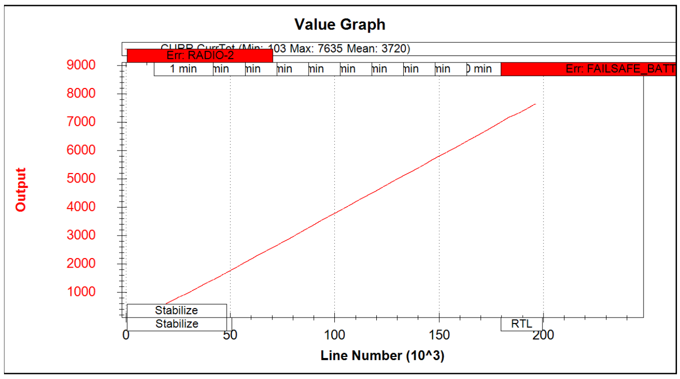

Figure 25. Remaining current capacity (Failsafe activated)

Battery failsafe is set to 3000 milliamps-hour. When the UAV reaches the said failsafe current at any flight mode, it will invoked RTL to return to its home position as seen on the graph above.

I. Pre-flight Calculation Application

The pre-flight calculation application calculates the total mission time based on the velocity of the UAV and the total distance it will travel. The application determines the waypoints automatically and calculates the distance between the waypoints.

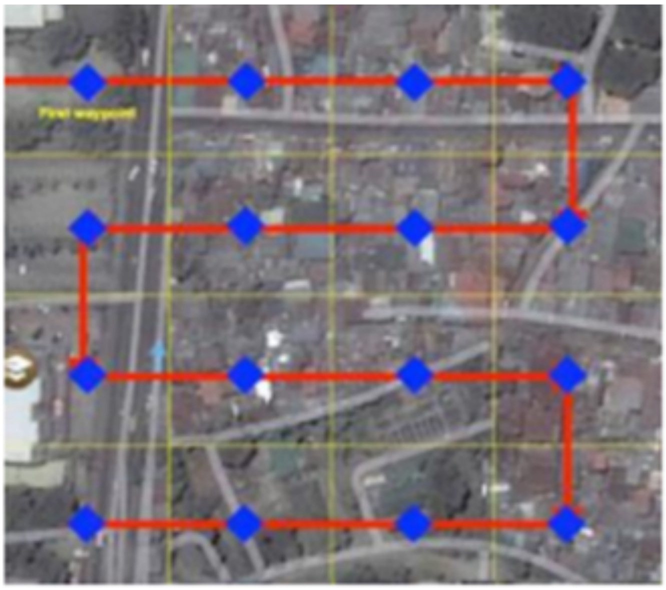

Figure 26. Flight path concept

The total distance the UAV will travel is based on its flight path concept. Figure 27 depicts a sample flight plan of the UAV. To approximate the distance from the take-off position to the first waypoint and from the last waypoint to the take-off position, it is assumed that the take-off position is at the center of all waypoints.

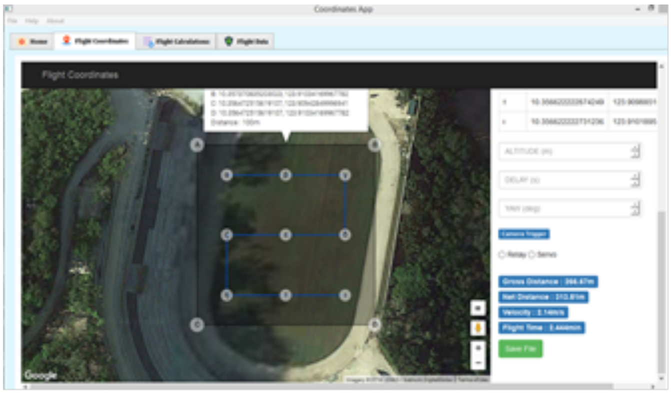

Figure 27. Pre-flight calculation application screenshot

IV. CONCLUSION

The proposed UAV was designed and developed. It performed its intended functions and capabilities albeit some limitations. Some performance parameter such as lifting capacity and flight time of the craft is limited but can be augmented by the proper hardware such as a higher capacity power controllers and higher capacity batteries. Acquiring those components presents logistical problems especially the shipping of high capacity battery packs in excess of 10,000 milliampere-hours. The developed UAV can be used in various applications in urban remote sensing and other applications such as mapping and monitoring. The noise and safety concern operating in urban environments are already addressed.

V. RECOMMENDATION

Replacing the power module with another with a higher current draw, at least 90 amps, would improve the lifting capability of the UAV because heavy payload requires the motors to need more current to generate lift. Replacing the battery with one with a higher capacity will increase flight time. There are cases of telemetry between the UAV and the ground control station disconnecting when there is great distance between them. Replacing the telemetry module with a better one will allow the ground control station to monitor the UAV over greater distances. Mounting a parachute would be a good improvement for safety purposes in case of critical failure. Also, pilot's license shall be obtained to allow the UAV to fly at higher altitudes.

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