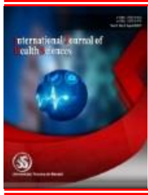

International Journal of Health Sciences

Available online at www.sciencescholar.us
Vol. 6 No. 3, December 2022, pages: 1565-1578
e-ISSN: 2550-696X, p-ISSN: 2550-6978
https://doi.org/10.53730/ijhs.v6n3.13265

DJI Phantom Frame Quadcopter for Aerial Monitoring of Objects (A Preliminary Study of Quadcopter Design for Natural Disaster Detection)

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Manuscript submitted: 15 April 2022, Manuscript revised: 09 June 2022, Accepted for publication: 08 September 2022

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Keywords

DJI phantom frame;
quadcopter;
disaster detection;
technology;

Abstract

Quadcopter is an unmanned aircraft driven by four motors and can be controlled remotely, making it usable for detecting an object. Current adaptation of the technology is incredibly effectively used for the public interests, especially for monitoring the safety of victims during natural disasters. The purpose of the present study was to design a quadcopter using the DJI Phantom Frame as an initial test for detecting objects at several heights. The present study used the experimental method, in which the quadcopter was designed first and subsequently several tests were performed. In terms of specifications, the designed quadcopter had an X configuration with 2 rotors at the front and 2 rotors at the rear. It used 2-blade propellers of 9 inch in diameter, Inav FC, Dji Phantom Frame, Esc Blheli_s 30a, DJI 920-kv motor, Phantom 4s battery, DJI gimbal, DJI Phantom camera, DJI Phantom remote control, Ublox m8n GPS, 9-inch propellers, Inav software and DJI GO. The quadcopter was subjected to the following tests: the Li-po (lithium polymer) battery power tests; quadcopter remote control test, Global Position System (GPS) test, and radio telemetry test. The result of the present study is a prototype of DJI Phantom Frame quadcopter using a DJI Phantom camera capable of detecting objects at heights of 10 meters to 130 meters. In the test at a distance of 10 meters the quadcopter could still communicate with the remote control. In the test at a distance of 100 meters in a place of high intervention the quadcopter could still connect to the remote control, but the video signal transmission was not connected. It indicated that the telemetry system remained active, and only the video signal was not connected to the remote control.

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Contents

1 Introduction

Indonesia is among countries prone to natural disasters. This is due to the fact that, geographically, Indonesia is an archipelagic country and located on the confluence of 4 tectonic plates. With Indonesia's numerous volcanoes, there is also a great potential for natural disasters, such as volcanic eruptions, earthquakes, tsunamis, floods and landslides. The many natural disasters in Indonesia require serious handling, especially in the aftermath of a disaster (Pi et al., 2020; Xu et al., 2018). The impacts of disasters were very detrimental to the surrounding communities. In addition to material losses, the evacuation process or the search for victims also took a long time due to the difficult-to-access disaster location (Khan et al., 2020; Anbarasan et al., 2020). To prevent losses, such efforts are needed as prevention, mitigation, preparedness and early warning. However, during a disaster, emergency response disaster management, such as victim evacuation, must be done immediately. In the process, evacuation and monitoring of disaster locations can be made by land and air (Xu et al., 2020; Ullah et al., 2022). In the former, heavy equipment and volunteers' help are usually used. However, the risks are quite a lot, including difficult-to-access routes and possible increase in casualties from the evacuation team. Meanwhile, in the latter, helicopters are usually used to monitor the disaster location. However, helicopters require a special runway for the landing site and cannot monitor optimally due to their relatively large size and vulnerability (Arnanto *et al*., 2019; Swamardika et al., 2014; Pawełczyk & Wojtyra, 2020).

The BASARNAS team and the medical team have a serious challenge to monitor the disaster location and find disaster victims, both alive and dead. Meanwhile, to find victims, both alive and dead, they remain using volunteers with the help of heavy equipment (Paz et al., 2020; Allison et al., 2020). These methods are very difficult for the volunteer teams and the medical teams and require a long time in handling victims of natural disasters (Selwyn, 2003; Thostensonet al., 2001). Thus, there is a need for a monitoring equipment with a helicopter-like capability but capable of lower flying in order to perform more efficient evacuation. A quadcopter is among the monitoring equipment that can be used (Faradila et al., 2016; Rafiq *et al*., 2020).

Quadcopter is an unmanned flying robot driven by four motors and can be controlled remotely so that it can be used to detect an object. Current adaptations of the technology are very effective in automatically detecting and identifying objects at a distance that are used for the public interest, especially for monitoring the victim safety during natural disasters (Arnanto *et al*., 2019; Menggala, 2018).

The purpose of the present study was to design a DJI Phantom Frame quadcopter as an initial test for detecting victims of natural disasters at several heights.

2 Materials and Methods

The present study used the experimental method, in which the quadcopter was designed first. In terms of specifications, the designed quadcopter had an X configuration with 2 rotors at the front and 2 rotors at the rear. It used 2-blade propellers of 9 inch in diameter, Inav 5.0 FC, DJI Phantom Frame, Esc Blheli_s 30a, DJI 920-kv motor, Phantom 4s battery, 3-axis bgc gimbal, DJI Phantom camera, DJI Phantom remote control, 9-inch propellers, Inav software, DJI Goand DJI Assistant, and Ublox m8n GPS. The quadcopter had landing gear to assist in landing. The quadcopter was subjected to the following tests: the Li-po (lithium polymer) battery power tests; quadcopter remote control test, Global Position System (GPS) test, and radio telemetry test to detect objects.

A. How to assemble the Quadcopter:

1. Assemble the frame and install the PDB
   Assemble the frame by installing the body and landing skid components of the frame used
2. Install the brushless motor on the frame arm
3. Install the flight controller
4. Install the ESCs on the quadcopter frame
5. Solder the motor wires to each ESC
6. Solder the ESC signal cable to the fight controller
7. Install and connect GPS
8. Install the TX receiver transmitter on the flight controller
9. Solder the power cable for the li-po battery
10. Install and connect the camera gimbal to the flight controller
11. Cover the body and ensure all components are assembled correctly
12. Set the flight configuration using the flight controller software

B. Quadcopter Design

The designed quadcopter had an X configuration with 2 rotors at the front and 2 rotors at the rear. It used 2-blade propellers of 9 inch in diameter, Inav 5.0 FC, DJI Phantom Frame, Esc Blheli_s 30a, DJI 920-kv motor, Phantom 4s battery, 3-axis bgc gimbal, DJI Phantom camera, DJI Phantom remote control, 9-inch propellers, Inav software, DJI GO and DJI Assistant, and Ublox m8n GPS.

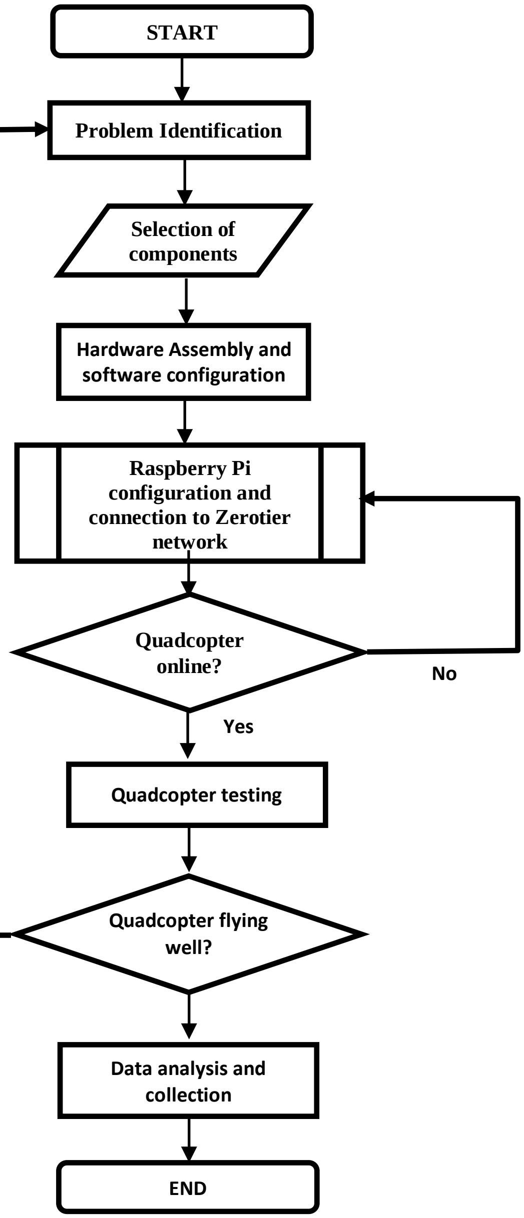

Figure 1. Design flowchart

C. Quadcopter Working Principle

In the aviation sector, types of aircraft are divided based on the lifting mechanisms, including rotor planes, such as quadcopters. Drone is a general term used for all unmanned aerial vehicles, despite the fact that quadcopters can also fly in an unmanned fashion by incorporating drone traits into them.

The first quadcopter was designed in 1907 and the first manufacturer was named "Louis Charles Bréguet". A quadcopter uses four rotors, with two rotors rotating clockwise (CW) and two rotors counterclockwise (CCW). This is used as the basis for a system to control aircraft movements (Arnanto *et al.*, 2019; Kushayati, 2014). Drones work by the lift from the rotation of the propeller driven by electric rotors or motors. The lift is related to the fixed-wing airfoil model, but it can also be generated by propellers.

The Bernoulli's principle theory explains the lift. It states that air flow is a constant energy. When air flows in a section that has low air pressure, the air will flow faster (Andika *et al*., 2018; Swamardika et al., 2014).

A conclusion can be drawn from the Bernoulli's principle that the air pressure at the top moves faster, so the pressure is lower than that at the bottom, which makes the air flow slower. The difference in air pressure produces aerodynamic forces (Komilova et al., 2021).

The concept of propellers on a drone with four rotors is called quadcopter. The direction of propeller rotation is divided into two different directions, clockwise (CW) and counterclockwise (CCW). The clockwise-rotating motors are motors C and B, while the counterclockwise-rotating motors are motors A and D. The difference in rotation of each motor aims to prevent a turning moment on the quadopter body (Arnanto *et al*., 2019; Pawełczyk & Wojtyra, 2020).

D. Hardware Design and Selection

The quadcopter hardware selected in the present study was the DJI Phantom Frame quadcopter using 2-blade propellers of 9 inch in diameter, Inav 5.0 FC, DJI Phantom frame, Esc Blheli_s 30a, DJI 920-kv motor, Phantom 4s battery, 3-axis bgc gimbal, DJI Phantom camera, DJI Phantom remote control, 9-inch propeller, Inav software, DJI GO and DJI assistant, and Ublox m8n GPS. Figure 2 shows the quadcopter hardware design which has an X configuration with 2 rotors at the front and 2 rotors at the rear. There were 4 supporting legs at the center of the quadcopter that ware used to support the quadcopter when it landed. A 4-cell Li-po Phantom 4s battery was placed on the body of the Quadcopter frame. The Ublox m8n GPS was placed at the bottom. The DJI Phantom Frame quadcopter was also equipped with a camera at the bottom that was connected to the Inav software, DJI GO and DJI assistant. DJI 920-kv motors were placed at the end of the four gimbals. In addition, the DJI Phantom Frame quadcopter had four 9-inch propellers at the end of the gimbal (Harista & Nuryadi, 2018; Rafiq *et al*., 2020).

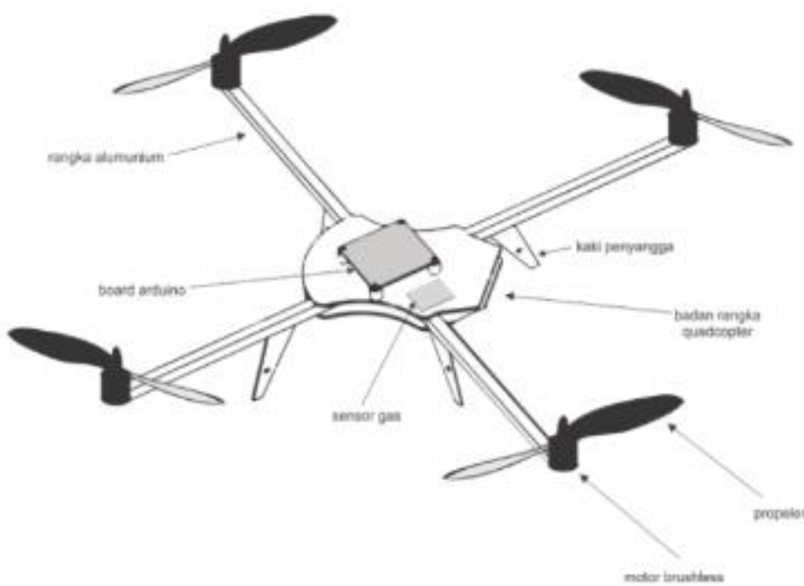

Figure 2. Quadcopter mechanical design (Swamardika et al., 2014)

Figure 3. The finished DJI Phantom Frame quadcopter

E. Software design and selection

The software design for the DJI Phantom Frame quadcopter was a program that was entered into the microcontroller. The Arduino language was used for programming in the Arduino IDE (Integrated Development Environment) version 1.01. Arduino itself is a C++ derivative language so that C++ and C functions can run on Arduino. The Arduino language was selected to mark the mathematical calculations of the DJI Phantom Frame quadcopter and is open-sourced (Al-Emadi *et al*., 2021; Faradila & , Sutopo Purwo Nugroho, 2016).

3 Results and Discussions

Quadcopter testing
Quadcopter tests include:

1. Li-po (lithium polymer) battery power test
   The Li-po (lithium polymer) battery power test was undertaken to determine the output voltage, battery charging time, and drone flight duration using this type of battery. The quadcopter used the Phantom Intelligent battery with a capacity of 4480mAh and arranged in 4x series, producing an output voltage of 15.2V (volt).

2. Remote control test of quadcopter
   Tests were performed to determine what percentage of the throttle that would be able to lift the quadcopter. The assembled quadcopter had an auto take-off feature or an automatic flight feature by placing the throttle stick in the middle. Pressing the auto take-off button in the application will lift the quadcopter.

Figure 7. Auto Take-Off feature

3. Global Position System (GPS) test
   This test was performed to determine the quadcopter position at a certain location point. The GPS test was performed at a point. The following are the results of the GPS test.

Figure 9. Quadcopter location

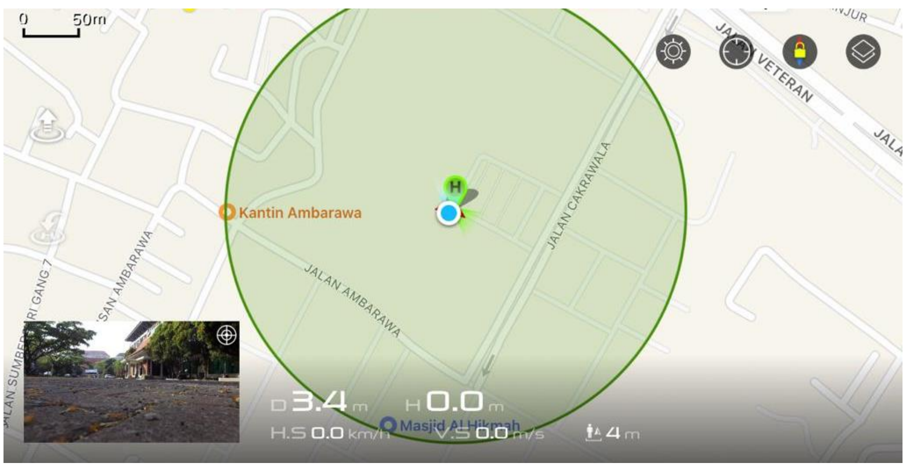

Figure 10. Quadcopter location on the DJI GO app

Figure 5 shows the position of the quadcopter in a location around Jalan Ambarawa and Figure 6 shows the location of the drone on the DJI GO software, showing that the quadcopter is on Jalan Ambarawa area.

4. Radio telemetry test
   This test was done to determine what obstacles telemetry can pass. This telemetry test was performed in the building area with many interventions.

Table 1
Test of the distance reached by telemetry

Distance	Results Reached
10 m	100% reached
40 m	90% reached

80 m	80% reached
130 m	60% reached

The following figure shows the verification of the data table above.

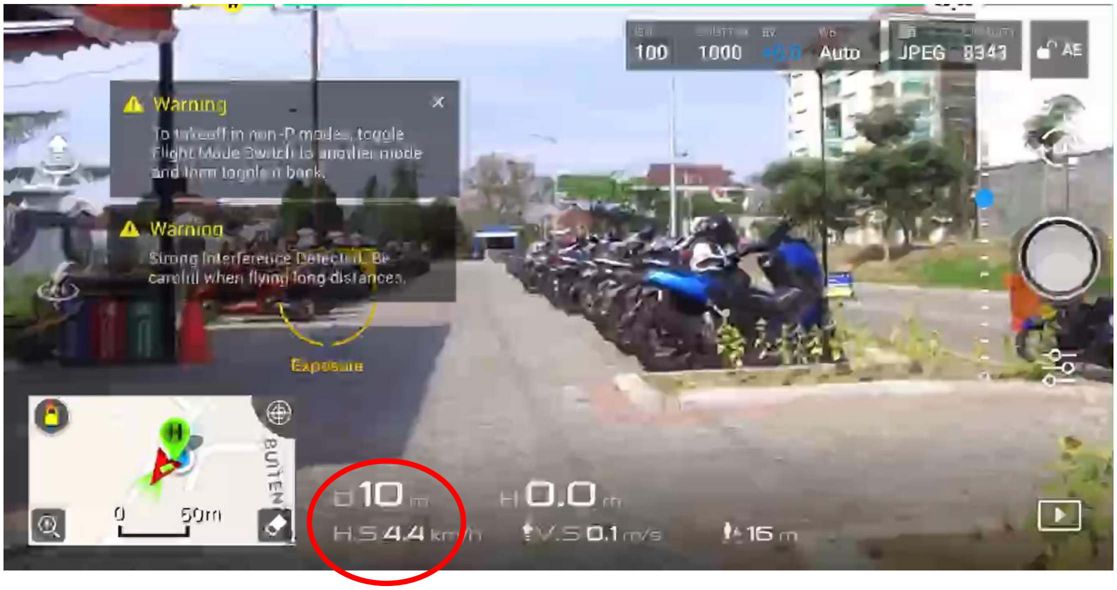

Figure 11. The signal from the quadcopter at the height of 10 meter remains connected to the remote control at H.S4.4 km/h

In this test, the quadcopter was tested at a distance of 10 m. It turned out that at such a distance the quadcopter could still communicate with the remote control.

Furthermore, the quadcopter was tested at a distance of 100 m from the remote control. It turned out that at a distance of 100 meters in a place with a high intervention the quadcopter was still connected to the remote control but the video signal transmission was not connected. This indicates that the telemetry system remains active and only the video signal was not sent to the remote control.

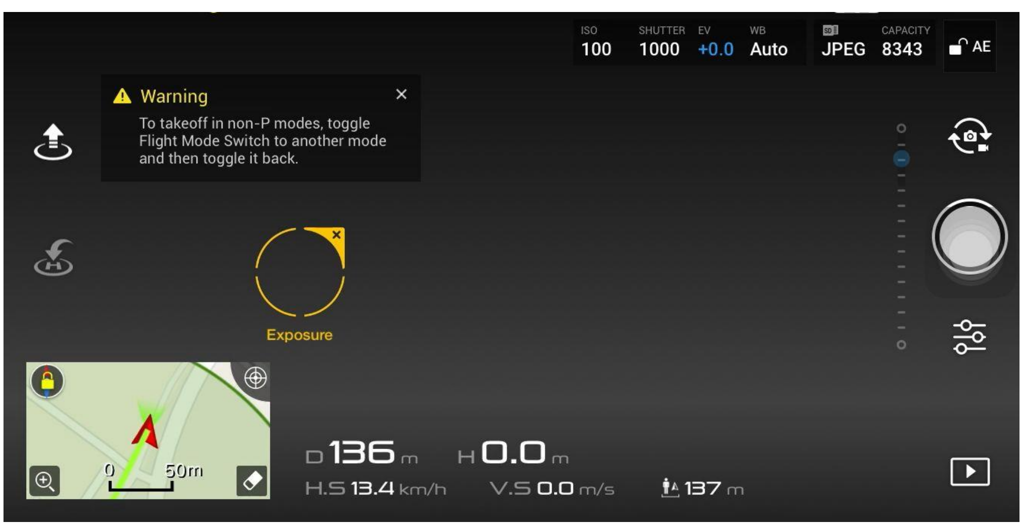

Figure 12. The signal from the quadcopter at a height of 100 meters remains connected to the remote control at H.S 13.4 km.

5. Test of Disaster Victim Detection
   Object detection was tested using the DJI Phantom camera on the DJI Phantom Frame quadcopter, which was strongly influenced by distance, light intensity and frames per second (FPS). This test was performed at several heights and the telemetry signal was looked at for strength.

Table 2
Quadcopter Tests for Object Detection (Disaster Victims)

Tests	GPS Satellite	Telemetry Signal	Heights (m)	Object Detection
1	3	99%	2	Detected
2	3	98%	3	Detected
3	3	99%	2	Detected

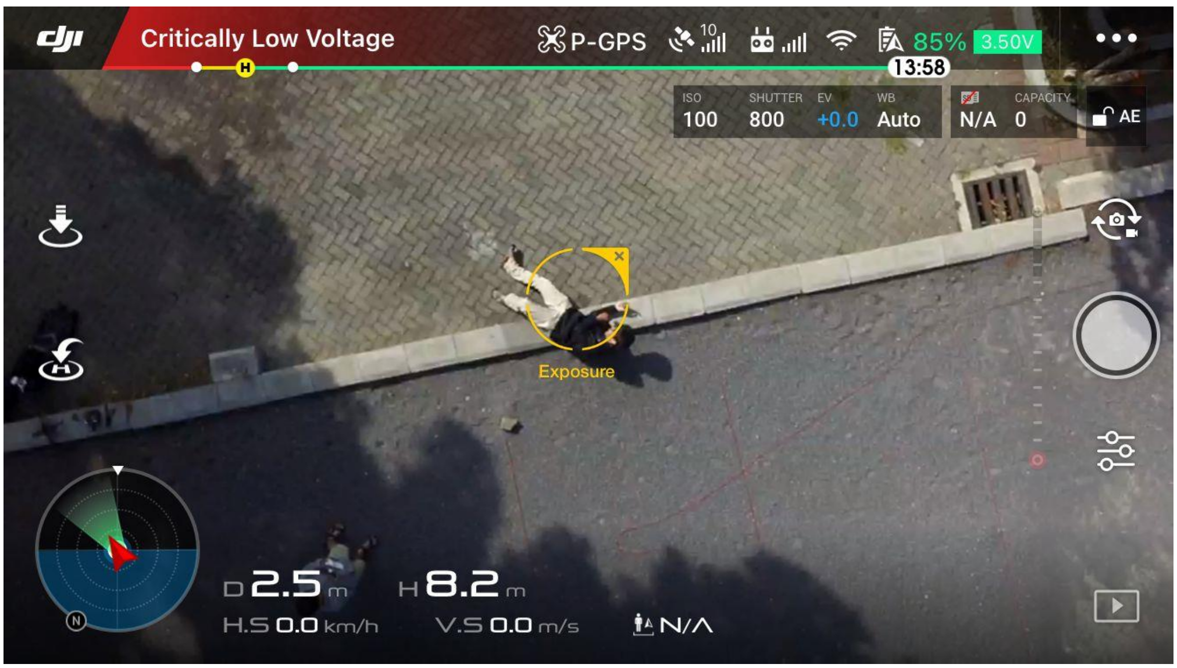

Figure 13. Quadcopter test to detect objects (disaster victims) at a height of 2 meters, GPS 3, at 99% telemetry signal

Figure 13 shows the results of the object detection test using the DJI Phantom camera on the DJI Phantom Frame quadcopter at a height of 2 meters, GPS 3, and at 99% telemetry signal. The quadcopter was able to detect objects (disaster victims) clearly. However, in order to determine further whether the victim is still alive or dead, a check by the use of a heart rate sensor is necessary. The heart rate sensor has been designed in the present study which would later be brought by the triage team upon knowing the victim location which has been detected by the quadcopter.

The present study subjected the DJI Phantom Frame quadcopter design into several tests, including:

1. Li-Po (lithium polymer) battery power test
   The use of Li-po (lithium polymer) Phantom Intelligent battery with a capacity of 4480mAh arranged in 4x (4 cell) series for the DJI Phantom 3 Frame quadcopter design has an advantage of voltage output of up to

15.2V (volts). At the voltage of 15.2V, the quadcopter or drone is able to fly for around 18-20 minutes. Within 18-20 minutes, the position of the natural disaster victims is expected to be found immediately. The authors selected the Li-Po (lithium polymer) battery due to the advantage of large current, making the quadcopter capable of carrying heavy drone loads. The short charging time would also save the time it takes to assemble drone devices to be used (Wang *et al*., 2020).

Previous studies used batteries specifically designed for aeromodeling or robotic purposes since the current should be strong and the battery should be able to store large enough amount of power. The larger the size, the stronger and longer the flight hours are. The battery sensor is among the important device used to display several indicators, such as health & remaining battery power, notification alarms, and to provide power information to the controller (Rafiq *et al*., 2020).

2. Remote Control Test of Quadcopter

The assembled DJI Phantom Frame quadcopter had an auto take-off feature or an automatic flight feature by placing the throttle stick in the middle. Pressing the auto take-off button in the application will lift the quadcopter.

The ability of remote control (RC) to control the DJI Phantom Frame quadcopter was tested using the mechanism as shown in the block diagram below.

Figure 14. Block diagram of RC range test

Based on the test results above, RC capabilities can be improved by using a battery with a large power, since it will affect the range of the RC. The DJI Phantom Frame quadcopter uses a Li-po (lithium polymer) battery of Phantom Intelligent type which has an advantage of large current, making it capable of carrying heavy drone loads (Coluccia *et al*., 2021).

3. Global Position System (GPS) Test

The test was aimed at determining the ability of the GPS module to capture satellite signals and lock location. The test was performed outdoors since the DJI Phantom Frame quadcopter was designed to detect disaster victims in the open. The test was conducted to determine the position of the quadcopter at a certain location point. The GPS was tested at a point. Figure 9 shows the position of the quadcopter in a location around Jalan Ambarawa and Figure 10 shows the location of the drone in the DJI GO software, indicating that the quadcopter was in the Jalan Ambarawa area.

A conclusion can be drawn from the results of GPS test that GPS can capture satellite signals better, at a value of 3.4. The GPS should reach a value of 3, a minimum requirement for locking GPS. The GPS status can be seen on the HUD display in the mission planner application with the following explanation: Gpsstatus indicates the value of the satellite signal captured by GPS. GPS: (description) shows the GPS status, where “3D Fix” indicates that the GPS is locked and “Not Fix” indicates that the GPS is not locked (Pawełczyk & Wojtyra, 2020).

4. Radio Telemetry Test

The quadcopter uses telemetry to provide information to the user. The test was performed by connecting the telemetry on the quadcopter to that on the laptop (user). Results of the telemetry test on the DJI Phantom Frame quadcopter in the building area with many interventions showed the test maximum distance of 130 meters and the test minimum distance of 10 meters. The telemetry test at a distance of 10 meters showed a 100% signal strength, 90% at a distance of 40 meters, 80% at a distance of 80 meters, and only 60% at a distance of 130 meters.

A conclusion can be drawn from the results of telemetry test that the telemetry on the quadcopter is well connected to that on the laptop as a GCS with a maximum distance of 130 meters; the connection will be lost when it is more than that. The distance between telemetries greatly affects the signal strength (Al-Emadi *et al*., 2021).

5. Object Detection Test
The DJI Phantom 3 Frame quadcopter, designed with specifications of 4 rotors – 2 rotors on the front and 2 rotors on the back, had the ability to fly at a range of 10 meters to 100 meters in the radio telemetry test. At a height of 10 meters, the DJI Phantom 3 Frame quadcopter could still communicate with the remote control properly. This would make it easier to monitor the victims of natural disasters at a distance of 10 meters to the remote control. Communication with the remote control is highly required to operate a quadcopter.
The overall system run well as designed and planned. Overall testing can also be used to determine the problems with the quadcopter (Pawełczyk & Wojtyra, 2020). The detection test of objects (disaster victims) was conducted at several heights of the quadcopter, including at a height of 2 to 3 meters. Figure 13 shows a screen displaying a clearly detected object, where a moving object can indicate that the victim is alive, and vice versa. Objects are clearly detected at heights of 2-3 meters, GPS 3 and 99% telemetry signal.

4 Conclusion

Prototype of DJI Phantom Frame quadcopter using a DJI Phantom camera capable of detecting objects at heights of 10 meters to 130 meters. In the test at a distance of 10 meters the quadcopter could still communicate with the remote control. In the test at a distance of 100 meters in a place of high intervention the quadcopter could still connect to the remote control, but the video signal transmission was not connected. It indicated that the telemetry system remained active, and only the video signal was not connected to the remote control.

Acknowledgments
This work was supported by the Research Fund provided by Kemendikbudristekdikti skim National Competitive Funding .

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