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DISSERTATION

Solar power assisted Quadcopter

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Contents

Introduction 2
Literature review 3
Solar panel drones 3
Business Insider 5
Drone zone 8
Quadcopter cloud 9
Methodology 10
The construction of the drone 12
Thrust test 15
Lift to weight ratio 16
To calculate the power of the drone 17
Design 20
Analysis &result 26
Thrust test results 26
Results of the power of the drone 27
Flight test 28
Calculation of predicted time the drone will be power for with the solar panel 30
Discussion 30
Conclusion 31
References 32

Figure 1 CH-T4 (Jeffrey Lin, 2017) 3
Figure 2 Atlantik Solar AS-3 (atlantiksolar, 2016) 4
Figure 3 Live-streamed thermal camera images with annotation (atlantiksolar, 2016) 4
Figure 4 Estimated Investment In drone hardware Bar graph source (Joshi, 2017) 6
Figure 5 Top industries Using drone pie chart source: (Joshi, 2017) 7
Figure 6 solar panel housing 11
Figure 7 complete construction of the drone 12
Figure 8 power distribution board configuration 13
Figure 9 The circuit of the drone 14
Figure 10 Racestar DC brushless motor 15
Figure 11 2400KVDC brushless motor 15
Figure 12 Set up for the thrust test 16
Figure 13 transmitter calibration 18
Figure 14 Motor calibration 18
Figure 15 the attitude of the drone 19
Figure 16 3D CAD model of the drone's frame 20
Figure 17 Exploded view of the frame 20
Figure 18 Top frame of the drone 21

Figure 19 Bottom frame of the drone....21
Figure 20 The arm of the drone....22
Figure 21 Half of the solar housing with rods....22
Figure 22 solar housing component with the hole slots....23
Figure 23 exploded view of Solar housing....23
Figure 24 first version of solar housing....24
Figure 25 view of solar housing from the bottom....24
Figure 27 The drone with connected to the solar panel and solar charge controller....25
Figure 28 the solar panel under lamp light....25
Figure 26 solar housing attached to the frame....25

Introduction

For my dissertation which is titled "new aircraft and development including aircraft structures and materials including develop futuristic aircraft for a particular function". For this I have decided to create and design Drone (UAV) with solar power that has a thermal imaging camera with the purpose of being more efficient and locating hotspot in areas that have affected by natural disasters.

My project is designing and creating a concept UAV with a thermal imaging camera, which will be a quadcopter drone. Quadcopter flight control would be easier for surveying since it can hover which would be useful ability. If my design works, the drone will only be one the ground for a short time during operations. Having solar panels would be ideal for with places where electrical is limited which would be used to power the battery.

Literature review

Solar panel drones

Figure 1 CH-T4 (Jeffrey Lin, 2017)

The Caihong-T4 (CH-T4) is a drone built by the Chinese Academy of Aerospace Aerodynamics (CAAA). The Cailhong-T4 has a wing span of 40 meters, a double-bodied fuselage, cranked wing and twin tail, but even with its enormous size it only weighs between 880 to 1100 pounds, this lightness is due to its carbon fibre and plastic components. It has 8 motors. The Caihong-T4 can fly 12 miles up into the atmosphere.

CH-T4 can fly up to 65,000 feet meaning that it flies above almost the clouds so the solar panels that are attached on the wing will receive almost unlimited sunlight during flight, at night it draws power from the onboard batteries to power the motors. This drone has the potential to be used for many different applications for example, the military could be use a drone like this to execute surveillance missions. The drone could also be a replace or back up for satellite communications, maintain coverage between distant aircraft and ships.

Figure 2 Atlantik Solar AS-3 (atlantiksolar, 2016)

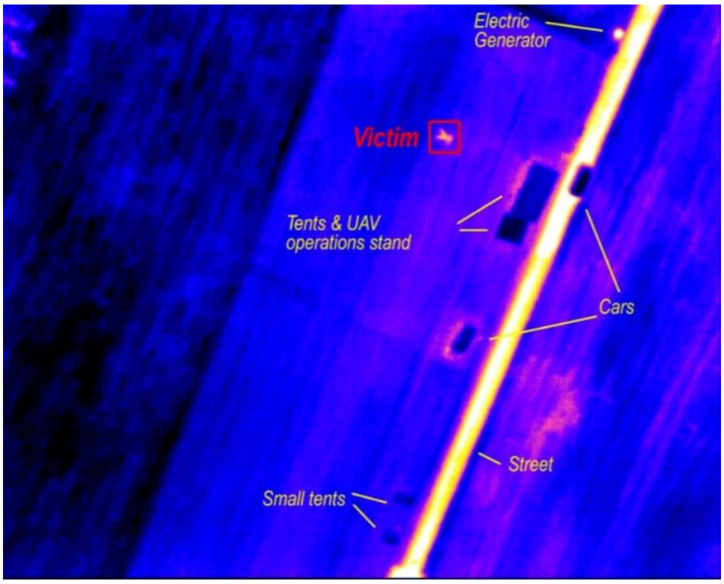

Figure 3 Live-streamed thermal camera images with annotation (atlantiksolar, 2016)

Altantik solar built a solar power drone that has a flight time of 26 hours for search and rescue operations, the aircraft carried 300g payload, the payload was one colour camera, one thermal camera and ODROID onboard computer with WLAN. The 26-hour flight was started on July 19th at 18:02 local time in Hinwil, CH with full batteries. The launch was performed fully autonomously, after all system checks were complete, the aircraft was tossed in the air via a hand-launch and then continued automatically and without pilot interaction towards its first loitering waypoint. The respective flight control technology is based on an ETHZ/3DR Pixhawk autopilot with a custom flight controller designed at the Autonomous Systems Lab. Equipped with a colour camera, thermal camera, an onboard computer and wireless LAN, the aircraft began live-streaming the respective images. (atlantiksolar, 2016)

The actual testing of the Search-and-Rescue capabilities were started shortly before 23 o'clock as shown in figure 3 with the aircraft now flying in total darkness, the infrared camera served as the only source of aerial imaging information. As visible in the video, the payload system clearly manages to find the victim lying in low grass (and surrounding houses, tents, cars, the streets and especially the warm electric generator) at 23:05 o'clock. The victim detection was performed manually by the ground station operator based on the live-streamed images this time. (atlantiksolar, 2016)

Altantik solar have demonstrated the capabilities that drones how they can be used to help people, proving that drone can be integrated into work that helps people for example a drone like the Atlantik Solar AS-3 could be used by the coast guard, first aider that need to find missing people during a natural disaster.

Business Insider

The top issues that drone usage can offer industries worldwide are that it can increase work efficiency and productivity, decreasing workload, better accuracy, improving service and customer relations and resolving security issues. Drone technology across industries have become a something that wasn't used that often to becoming quite common plus more businesses are realising the potential of integrating drones into their operations.

Drones have the ability to reach remote area with minimal manpower and requires the least amount of effort, time and energy, with different methods of controlling these drones via smartphone apps and remote control. These are the reasons why globally drones are being used particularly in the Military, commercial, personal and future technology sectors.

Military Drone Technology

In today's world the military have been using drones as target decoys, for combat missions, research and development and for supervision. Report from Goldman Sachs, predicted that global militaries will spend 70 billion dollars on drones by 2020, with this match money being spend it shows that drones will play a crucial part when resolving future conflicts. Example of military spending, a single US predator drone cost approximately 4 million dollars and another 2.4 billion dollars for the program. With these numbers UAVs will be applied in various military operations since they are highly convenient to perform high profile and time sensitive missions.

Commercial Drone technology

Commercial drone usage is on a steady increase since many industries are working with drones to be integrated into their daily business operations. "The market for commercial and civilian drones will grow at a compound annual growth rate of 19% between 2015 and 2020, compared with 5% growth on the military side, according to BI Intelligence, Business Insider's premium research service" (Joshi, 2017). The commercial drone is still in its infant stage, but the drone industry has seen some partnerships and major investment from industrial conglomerates, chip companies, IT consulting firms and major defences contractors.

As it becomes cheaper to customize commercial drones, this open a gateway that allows drones to have new functionality in wide array of different sectors, so you could see drones doing a range of everyday task such as fertilising crop fields on an automated basis, monitoring traffic incidents, surveying hard to reach places and even delivering pizza. "The impact of commercial drones could be $82 billion and a 100,000 jobs boost to the U.S. economy by 2025, according to AUVSI" (Darryl Jenkins, Dr. Bijan Vasigh , 2013).

Personal Drone Technology

Sales in civilian drone have risen, and with this rise the safety concerns surrounding drones among regulators and law enforcements agencies also tends to increase, since drones have collided with airplanes and crashed into crowded stadiums. "A Lobbying group, Consumer Technology Association expects 2.8 million consumer drones will be sold in the United States in 2016/17 and revenue will reach $953 million" (Joshi, 2017).

Business insider Intelligence predicts the sales of drone to suppress $12 billion by 2021, however consumers will spend $17 billion on drones over the next few years. UAVs come in all sorts shapes and sizes, varying from small cheap single motor, to huge expensive $1000 quadcopter, with different attachments such as GPS, cameras and first-person control. These drones are mainly targeted at hobbyist, plus these types of drones are widely accessible and the market is growing.

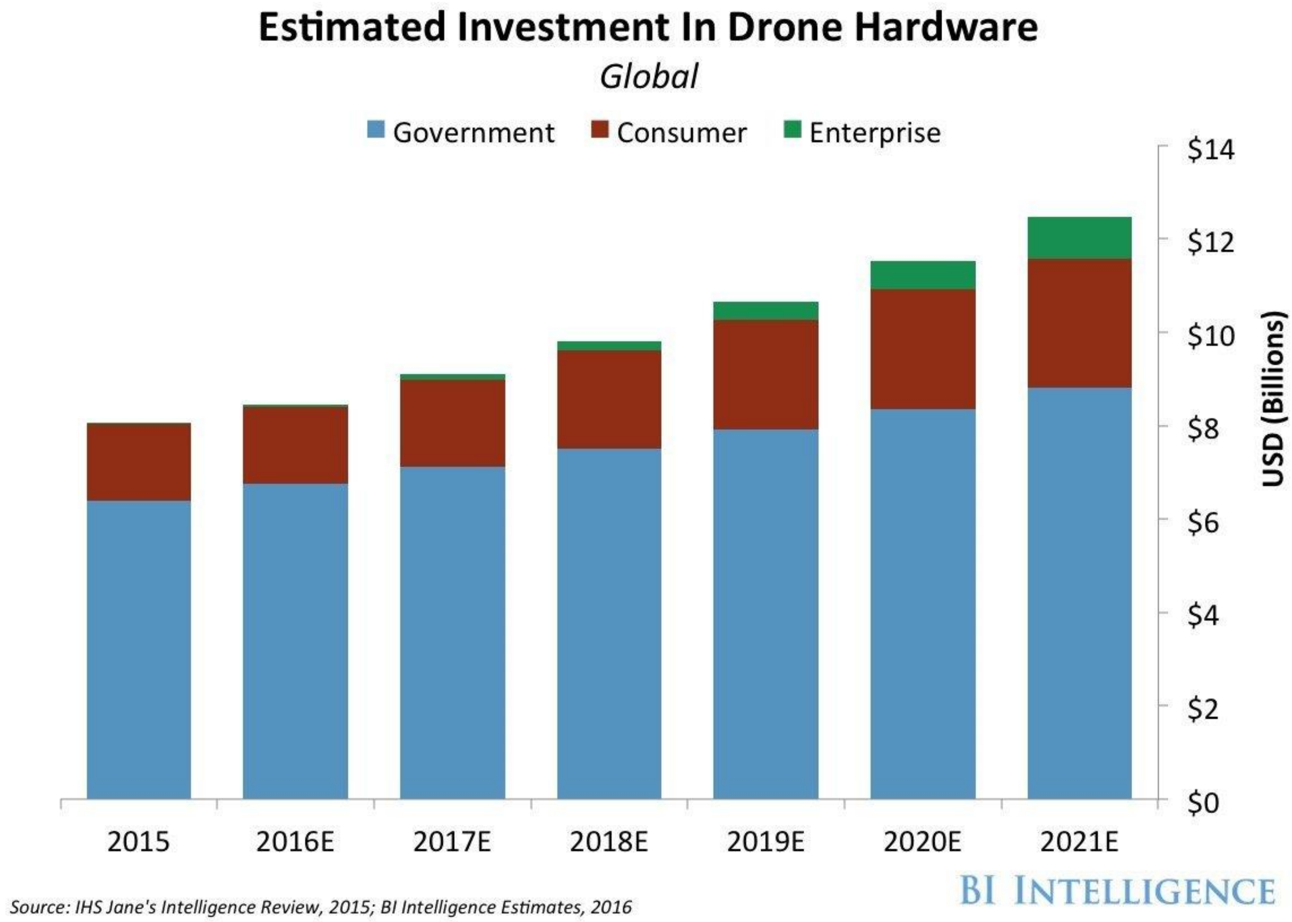

Figure 4 Estimated Investment In drone hardware Bar graph source (Joshi, 2017)

The bar graph on figure 4 shows the prediction by the business insider of the growth of investment of drone by governments, consumers and enterprises and by looking at the graph it shows that the investment increases annually, the one that are and will invest the most are the governments. In later years enterprise investing more money in 2021 compared with the money they invested in 2015.

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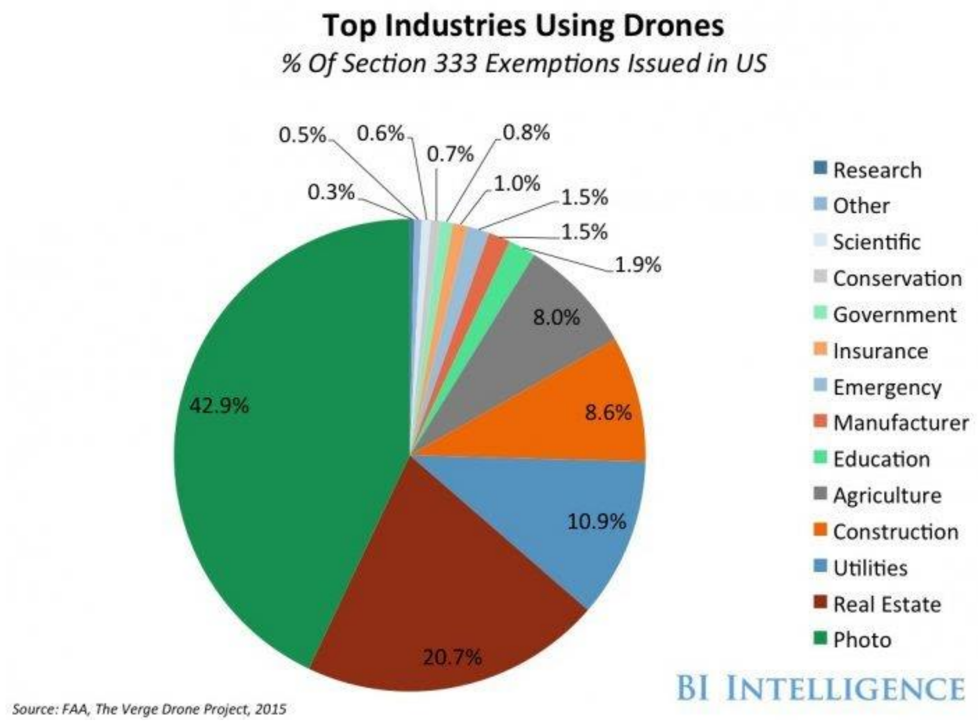

Figure 5 Top industries Using drone pie chart source: (Joshi, 2017)

The pie chart on figure 5 shows the different industries that drones can be used for where the highest industry is the photo industry at 42.9 percent. But as show on the graph drones have a range of industries they can be used in. The graph is an indication that drones are going to integrate in many industries and already have.

Drone zone

Unmanned aerial vehicle technology covers a range of different areas from aerodynamics of drone, material in manufacturing of the physical UAV, to circuit boards, chipset and software which are brains of the drone. Most UAV are manufactured from light composite material because it reduces the weight and increases manoeuvrability. Drones come in numerous sizes from large ones such as the MQ-1 predator and smaller ones like the Nano Hummingbird UAV which is a mere 19 grams.

Main components that make up a drone: standard Propellers, pusher proper, brushless motors, motor mount, landing gears, main drone body part, electronic speed controllers, flight controller, GPS module, receiver, antenna and battery.

UAV industry is growing fast, they are so countless uses for drones now and in the coming years. The usage of drones in some sectors were originally used by helicopter and planes, but since it cheaper to use drone and helicopters and plane are not always readily available, plus using these vehicles is very time consuming as they have to fly in from another location and then do their work.

A couple years ago drone would only be equipped with ordinary camera but now with improved technology like thermal, Multispectral, vision, ToF camera sensors that are being mounted on the drones generating new uses for drones. other sensor for example such as methane sensor which researcher are looking to develop drones to fly over landfills dumps to monitor the levels of gas being released into the atmosphere, with the data collected they can come up with ways to make the area a cleaner environment.

There are plenty of sectors that are benefiting from drones in the commercial, conservation or environment sector. In other sectors such as mining, they would save time and resources, plus it be a much safer method of surveying the structures and building, by drones going in these areas it avoids the need to put workers into hazardous and dangerous areas.

There are many uses today for drones for example professional film making, construction/building site surveying, parcel delivery service, counting stockpiles and agriculture. The drone that going to be build and designed for this project will be used for search and rescue in disaster regions which will give first aiders an overall picture of the damage that has occurred after an earthquake, floods and hurricanes and find people.

Investment in drone technology is growing considerably year by year since massive technology firms and wealthy individuals are investing in the drone market. “Consumer drone sales in 2015 reached $1.5 billion. By 2020, this is set to increase to $4 billion. That’s just the consumer market.” (Corrigan, 2015). According to Fintan Corrigan drone start-ups reached $172 million in equity financing which is the raising capital through the sale of shares in 2015 which was more than the previous three years put together. Examples of investment that have taken place in the drone market, intel invested $60 million in drone maker Yunee plus Richard Branson investing in 3DR on 16th September 2014 where this is want he said, “*They can do a lot of good in the world, and I hope this affordable technology will give many more people the chance to see our beautiful planet from such a powerful perspective*.”.

Quadcopter cloud

In the 21st century people have seen a siege of unmanned aircraft that are taking over the air space, with this growth it now common that are see drones being used by the military, meteorologist, companies, and hobbyists. The use of these UAV would be used to launch attacks on enemy territories, delivering goods to customer houses and used as a toy for hobbyist. The downfall with the rise of drones is that there have been public outcries in some countries because drones have been used to spy on people thus violating people's right to privacy.

Reasons why drones have become so popular, one of them is that they are small and portable. Drones have the ability to capture important information from various angles, for example of filming and capturing live feed. The fall in cost in technology has also contributed to the rise of drones, since you can purchase a done from a little as 30 pounds to 30000 pounds depending on what you need the drone to do, so if it needs a long battery life and what accessories are attached to the drone such as camera, (find attachment to drone such as GPS and auto pilot software).

The increasing popularity of drones have raised concerned from the public since there a percentage of people the use drones for bad intentions, therefore forcing aviation authorities to impose regulations on drone usage, with these regulations people will be more inclined not to misuse drones.

Methodology

For this dissertation to design a solar assisted UAV the first thing that is needed is the frame. When choosing what frame, the main things to considered is the material and it physical properties such as the density, tensile strength, stiffness and melting point. This is important because you want the drone to be tough enough to be able to absorb high energy impact due from crashes. The reason that the drone has to be lightweight is to maximise the lift to weight ratio and when the payload from the battery, receiver and motors is put into consideration it is ideal that the frame is as lightweight as possible. The rigidity is an important factor to take into account due to that the UAV would be a quadcopter, so you would want the arm of the quadcopter not to bend from the load of the motor. Due to that the arm will experience bending moments caused by the motors.

The size of the frame has to be thought out too. The factors that need to be considered when deciding the size of the frame is the application of the drone, example for a delivery drone you would not want to have a small frame that would not be able to handle the payload or a frame that is too large which will result in excess weight which will compromise the weight to lift ratio. The role for this drone is for surveillance so why designing the frame you wouldn't want a frame that is too big but since this drone has a solar panel attached to it, the drone needs to have a component large enough to accommodate for the solar panels and the solar charge controller that regulates the solar panel.

When looking at frames for all sort of drones such as tri-copter, quadcopter and hex-copter the majority of them are made from carbon fibre and some are made from high density plastic. Carbon fibre is widely used and will be the material for the drone because it has a high strength to weight ratio meaning the drone can be relatively lightweight and still strong. Carbon fibre is also rigid, has a high tensile strength, brittle and has low coefficient of thermal expansion.

The properties listed are characteristics that are wanted for the frame since with high stiffness constant while the motors are and producing thrust the arms of the motor will not start to bend. High tensile strength is a good characteristic since it means the frame can handle a lot of pressure before it starts to deform plasticly. Carbon fibre having a low coefficient of thermal expansion is a useful property because the dc brushless motor heats up while they are on, so the arms are not going to deform when expose to the heat from the motor and the sun. The frame for this drone will be made from carbon fibre.

The ZMR 250 frame is frame that going to be used for the drone which will be drawn on solidwork which is made from carbon fibre. The frame cost £16.43 which was purchased from online retailer banggood.com. The frame is drawn on solidworks gives a computerized visual representation of the drone.

The solar panels and solar charge controller need to be placed on the drone, to do this a housing needs to be created that will be attach to the top frame. The requirements for the housing are that there is space for the solar panel and the solar charge controller, the housing has to be symmetrical so not to disturb the centre of gravity of the drone and the drone doesn't start to lean on one side causing unequal lift and a constant Yaw to the heavier side. The material of the housing must be rigid and lightweight.

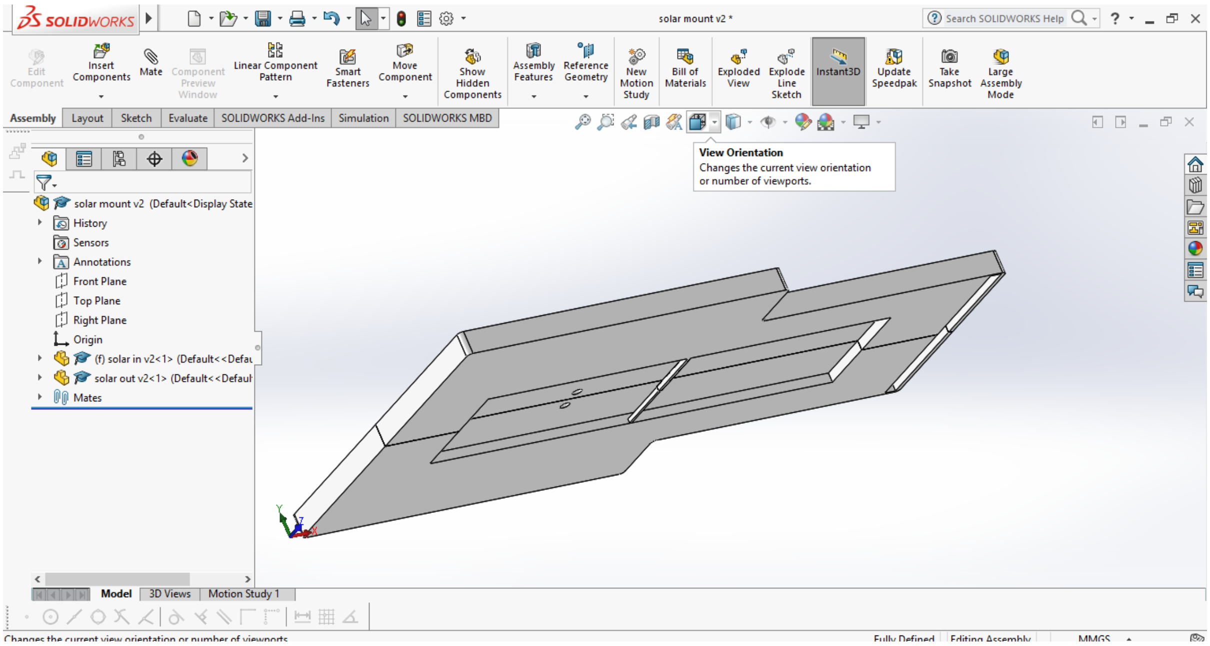

Figure 6 solar panel housing

the housing for the solar panel and solar charge controller was made from Acrylonitrile Butadiene Styrene (ABS) because it is rigid, tough and is a strong material and lightweight which are the desired property for a component of the drone to have. With the use of a 3D printer the housing is easily machinable. The things needed to be figured out are the length and width and depth, the material and how to connect it to the solar panel.

The solar panel housing put together by two part which attach to form one component, the reason for this is when adding and removing the solar housing from the drone is not a difficult process. The Solar housing will be designed using solidworks.

The solar housing as lightweight as possible and symmetrical so it does not disrupt the yaw of the drone causing one set of DC brushless motors on one side to do more work to maintain steady flight, by removing all sharp edges to make it more streamline, this is important as that the drag needs to be small as possible.

Price of all the component

- Carbon fibre frame – £16.37
- DC brushless Motors - £3.55
- Propellers - £0.70
- Electronic speed controller – £3.03
- Flight controller - £11.47
- Power distribution board - £2.15
- Receiver - £12.91
- Transmitter - £27.26
- Battery - £15.90
- Solar panels – £3.98
- Male and female bullet Connectors - £4.71
- Solar charge controller – £9.99
- 16 AWG metre red and black Wires – £1.98

The construction of the drone

To construct the drone the frame must be build first. The bottom frame has holes where ten millimetres M3 button socket head screw which is used to attach to arms to the bottom frame. There's a second bottom frame where the six millimetres M3 button socket head screw goes that is to use to attach the 37 aluminium rods. The second bottom frame is placed on the arm aligned with the holes on the arm where the ten millimetres M3 button socket head screw goes through which is then locked in by nuts.

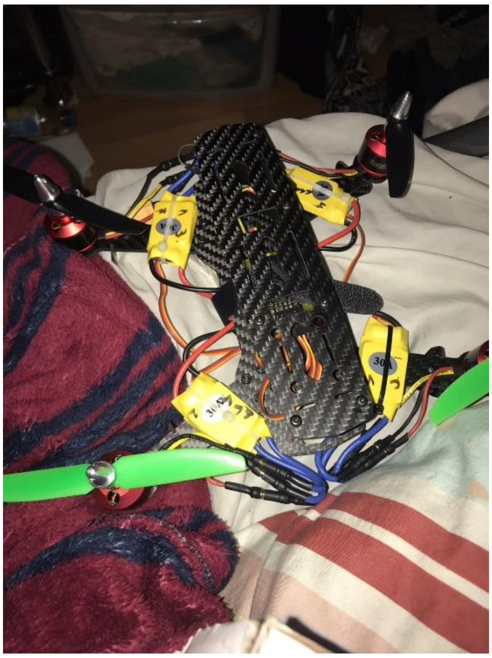

Figure 7 complete construction of the drone

The frame has three layers where the bottom two layers and used to keep the arms in the correct position with the use of nuts and bolts to secure its shape. Afterwards six aluminium rods will be screwed to the bottom layer of the second bottom frame acting as a spacer between the top and bottom layer, where the flight controller and receiver can be placed inside the drone. The tools that will be required for this is only a screwdriver.

To connect the motor to the electronic speed controller (ESC), male gold connectors are soldered to the DC brushless motor and the female gold connectors is soldered to the 30 amps ECS, this is done 4 times for each motor. The male and female connector allows the ECS to connect to the motor. The connectors are made from gold because gold is unreactive to chemicals and has a high melting point so will not melt during soldering process and gold is a good electrical conductor. The equipment needed for this process is a soldering iron, solder, solder station and a sponge.

Before the second frame is placed the power distribution board has to be set up so all the dc brushless motors can be powered by the battery simultaneously. The configuration for the power distribution board is shown in figure 8, then cover in electrical tape to prevent short circuits. The arms are afterwards attached to the bottom frame then the second button frame is place on top sandwiching the four arms and the power distribution and fasten by nuts

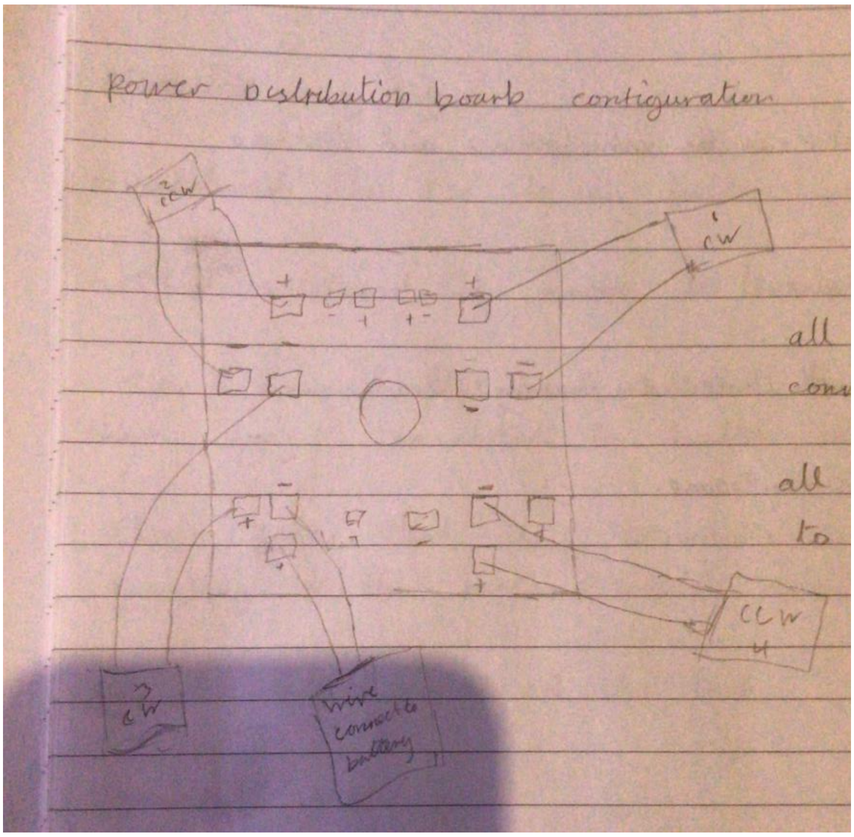

Figure 8 power distribution board configuration

The motors are then attached to by screwing it through the holes that are located at the end of the of the arms. The aluminium spacers are placed on the allocated spots and fixed to the top and second frame by a 6 millimetres screws.

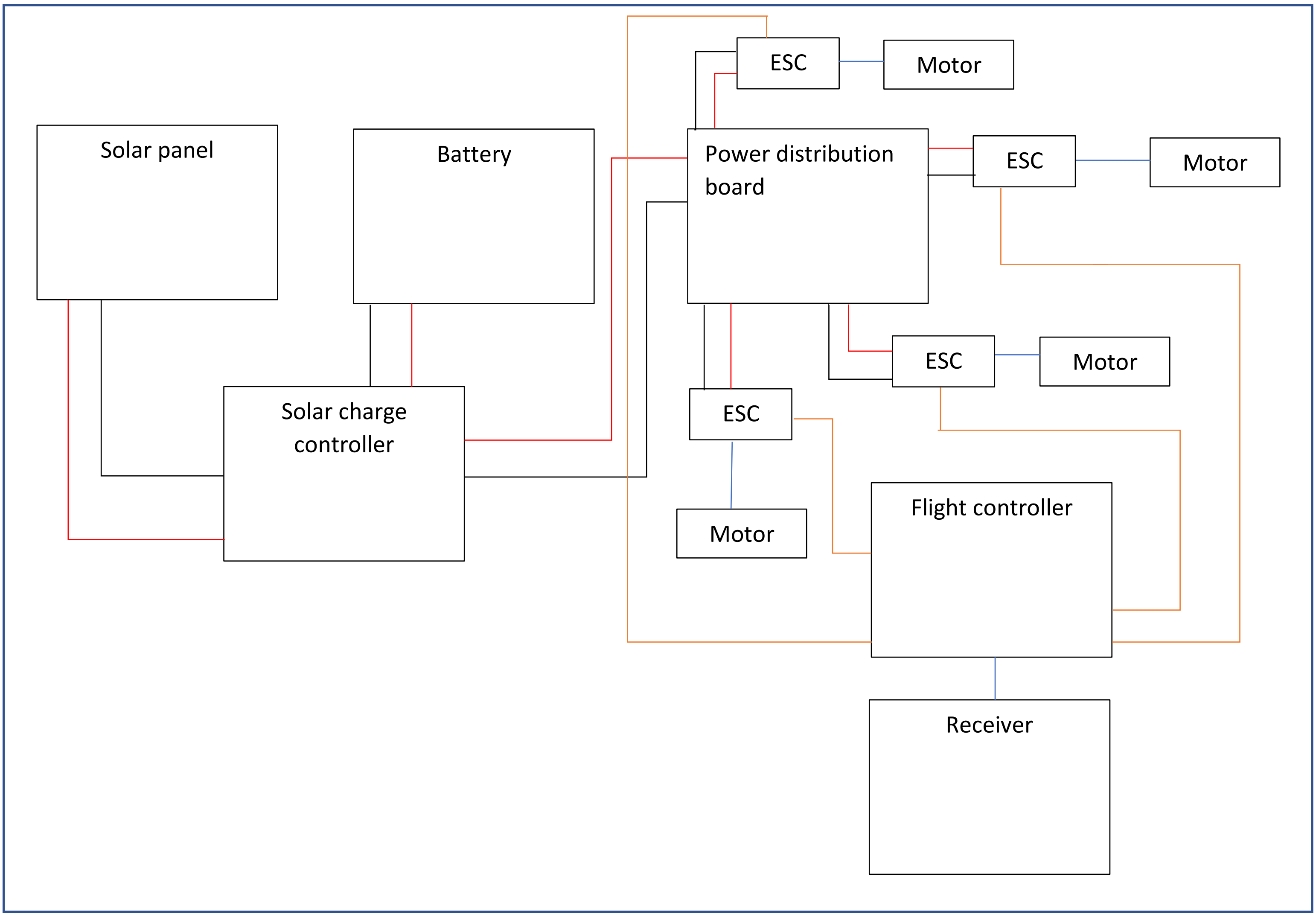

Figure 9 The circuit of the drone

To connect the solar panel there needs to be a device that can regulate the power from the solar panel. the device that could do this job was a solar charger controller. Solar charge controller prevents the batteries from overcharging which is a safety concern. “Most "12 volt" panels put out about 16 to 20 volts, so if there is no regulation the batteries will be damaged from overcharging. Most batteries need around 14 to 14.5 volts to get fully charged.” (Sun, 2018).

For the solar charge controller, it is required that the voltage of that of the charge controller and the solar panel were the same. The physical requirements charge controller had to meet were that it was small and compacted meaning it doesn’t take up much space and has a small mass.

The solar Charge Controller, LESHP Solar Panel 20A 12V 24V Battery Regulator Safe Protection was chosen because if fit the requirements needed. When weighed it had a mass of 112 grams. The solar charge controller was brought from amazon.co.uk at the price of £9.99. The width of the charge controller is 95 millimetre and length of 103 millimetres. These dimensions are not too big and can be placed on a solar housing, without a great compromise to space.

Thrust test

The thrust for the drone comes from the DC brushless motors. The thrust produced has to be more than the weight and the payload for the drone to take off and fly and perform the role it is intended to do.

Figure 10 Racestar DC brushless motor

Figure 11 2400KVDC brushless motor

The thrust produced using 5030 propellers on the motors in figure 10 and figure 11 was not given in the data sheet. In order to get the thrust produced when the motors are attached to 5030 propellers, where 5030 means that end to end the width of the propellers are 5 inches so has a diameter of 5 inches and have a pitch of 3 inches. To deduce the thrust for each motor a thrust test will be conducted. The equipment needed for the this is: scales, battery, transmitter, receiver, Propeller and DC brushless motor.

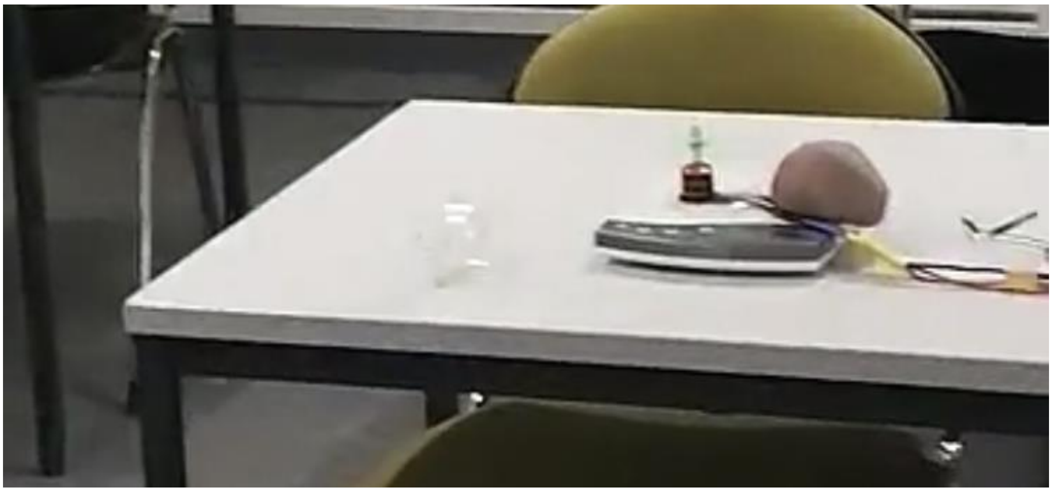

Figure 12 Set up for the thrust test

To set up the thrust test the motor that being tested had to be attached to the arm by screwing the motor to the arms of the frame. Then secure the arm to the scale with the motor placed in the middle of the scales to do this you need to tape the arm to the scale. This is done to hold the motor in place because once the motor is power it would want to move and vibrate. Once that is done you connect the propellers upside down to the DC brushless motor. The rotation of the motor has to be checked, to connect the appropriate propeller so if the motor spins counter clockwise then you attach the counter clockwise propellers and vice versa. Link the ESC wire to the motor and the receiver. To power the motor, connect the ECS to the battery with the black and red wire that are attached to the ESC, the black one is the negative lead and the red one is the positive lead. The red gets placed in the positive port and the black to the negative ports of the battery. The motor will start beeping to signal that its armed, and the receiver will also start flashing a red light to indicate that it is on. Zero the scales, then by using the transmitter put the motor gradually in full throttle and reading will start appearing on the scales then take note of the reading. The last step is repeated 5 times.

Lift to weight ratio

To calculate the lift to weight ratio of the solar powered assisted drone all the components of the drone was measured using scales, by doing this the total weight of the drone will be obtained. The total thrust will be acquired once the thrust test is performed.

Mass of the component on the drone

- Carbon fibre frame – 139 grams
- DC brushless Motors – 54 grams
- Propellers - 2 grams
- Electronic speed controller – 24 grams
- Flight controller – 15 grams
- Power distribution board – 5 grams
- Receiver – 16 grams
- Battery – 121 grams
- Solar panels – 89 grams
- Low voltage Buzzer alarm – 9 grams
- Solar charge controller – 112 grams
- Solar housing – 154 grams

Total mass of the drone is 980 grams

The formula to calculate the lift to weight ratio is $lift\ to\ weight\ ratio = \frac{lift\ (g)}{wieght\ (g)}$.

Since it a ratio the lift to weight ratio doesn't have any units which the formula explains due to the units cancelling each other out.

To calculate the power of the drone

The power of the drone will be calculated to deduce how much power in watts the drone consumes. To do this the drone will be powered with all four DC brushless motor running at full throttle, the reason for full throttle is because that when the motor draws the most current so according to the formula $P = IV$. I is current and V is voltage. Since the voltage is sourced from a DC power supply the voltage will remain constant. At the point where the most current is drawn is where the most power is being used.

The battery that will be used has a 14.4Wh rating and 1300 mah rating, meaning that is the load runs at 14.4 watts then it will last for an hour. Wh is the formula $E = PT$ where E is the energy which has units of joules, P is the power which is in watts and T is the time in seconds. Using the formula and the information of the battery the number of joules will be calculated.

The data collected from the drone will be the time it taken for the motor to stop spinning at full throttle. Using the time collected to find the average time the DC brushless motors last, by using the formula $E = PT$ and rearranging it to $P = \frac{E}{T}$.

The flight controller which is connected to the drone, translates input from the receiver that come from the transmitter, Inertial measurement unit (IMU) and other onboard sensors. It will be used to control the speed of the DC brushless motor with the aid of the electronic speed controller in order to steer the drone in the desired direction from the input the pilot has put in using the transmitter.

To configure and link the flight controller to the drone. Librepilot which is a computer software will be downloaded and installed on a computer. The flight controller will be sited on the top bottom frame using double sided tape. When the program has installed, the flight controller gets connected to the PC using a USB A to mini-B5 pin cable. Using Libre Pilot, the calibration of the gyroscope inside the flight controller will be conducted, Librepilot software will check the electronic speed controllers are functioning and will be used to find the neutral rate of each motor. Neutral rate is the slowest speed the motor will start and run consistently which is critical which shown in figure 13.

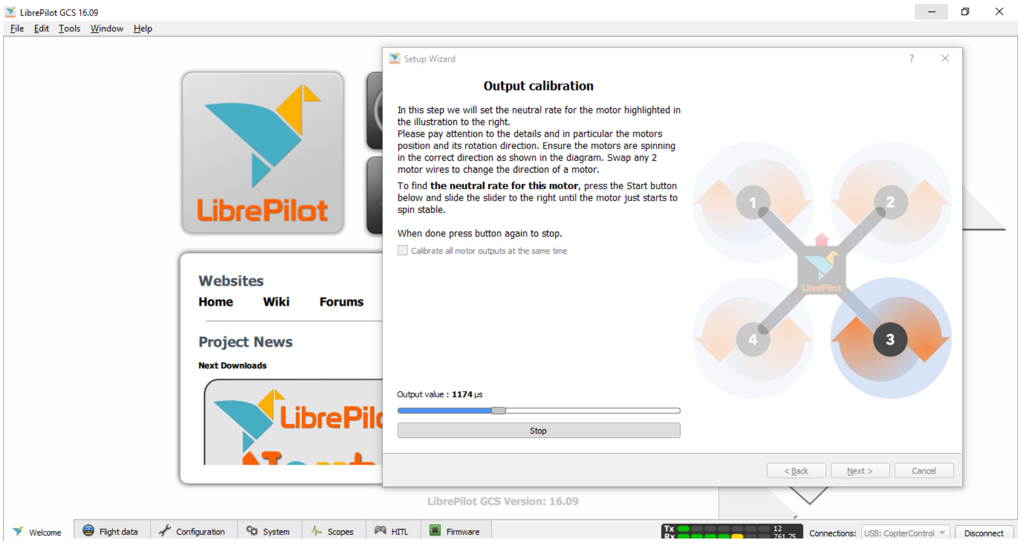

Figure 14 Motor calibration

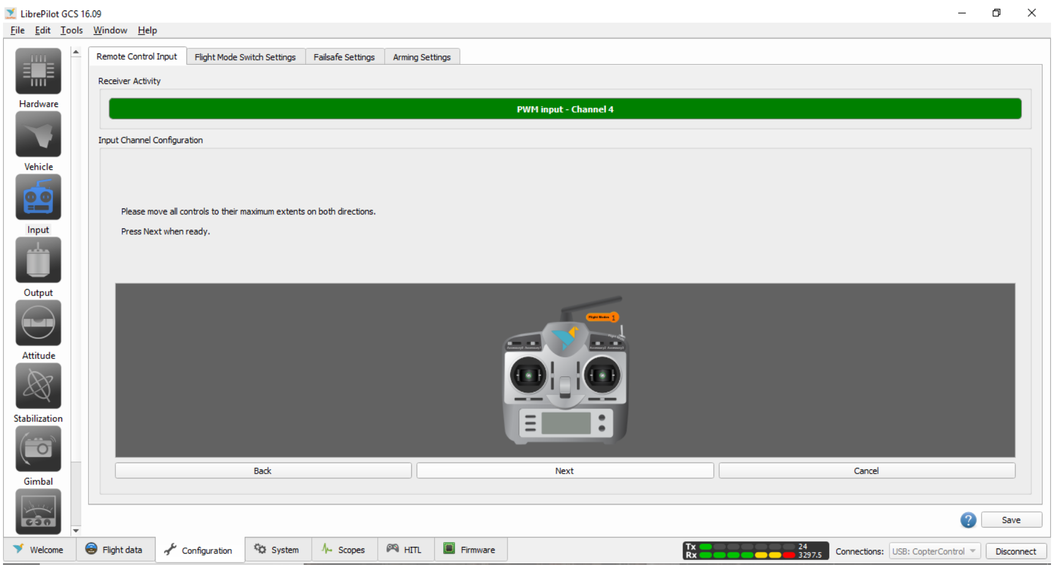

Figure 13 transmitter calibration

The transmitter inputs are calibrated using libre pilot as displayed in figure 14. The input controls for the Yaw, throttle, pitch and roll are linked to drone through the flight controller which will change the rotation of the motor in accordance with the input controls the pilot gives the drone through the transmitter.

The gyroscope on the flight controller is calibrated so the drone can know when it is at steady flight. to calibrate the drone the drone had to be placed on a level surface while the software calibrates the attitude of the drone. Figure 15 shows the attitude of the drone after the calibration was completed.

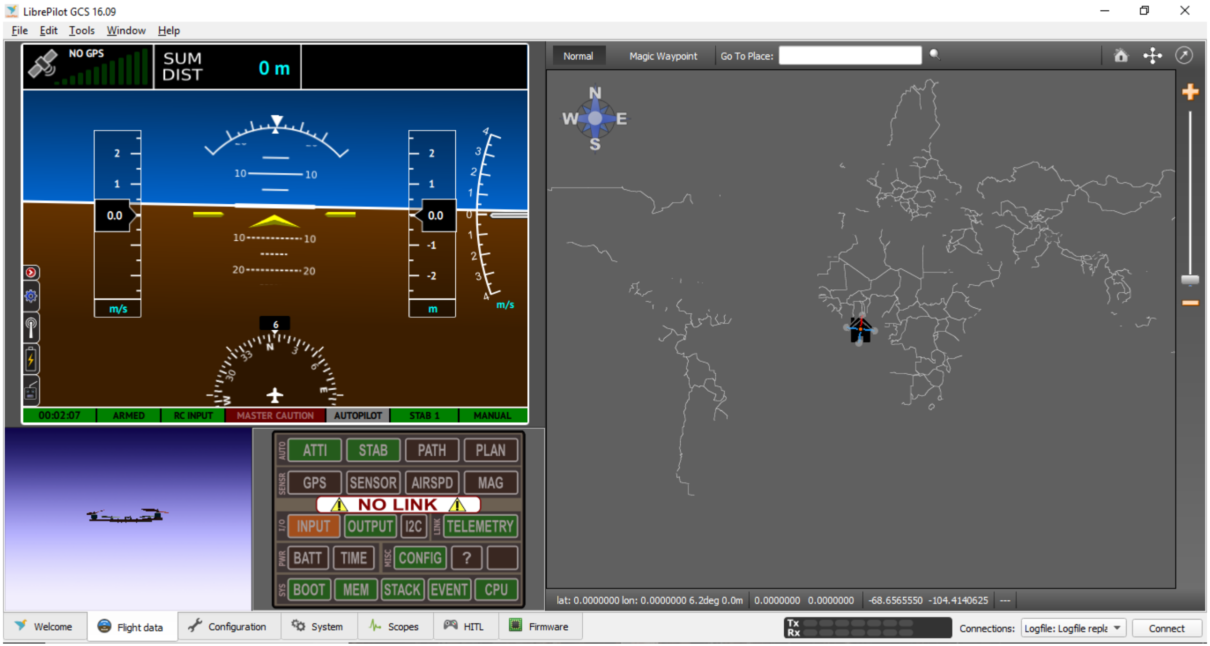

Figure 15 the attitude of the drone

Design

Figure 16 is the drone frame fully assembled, with figure 17 an exploded view on how it comes together. The figure 18 is the top frame, figure 19 is the bottom frame and figure 20 is the arm.

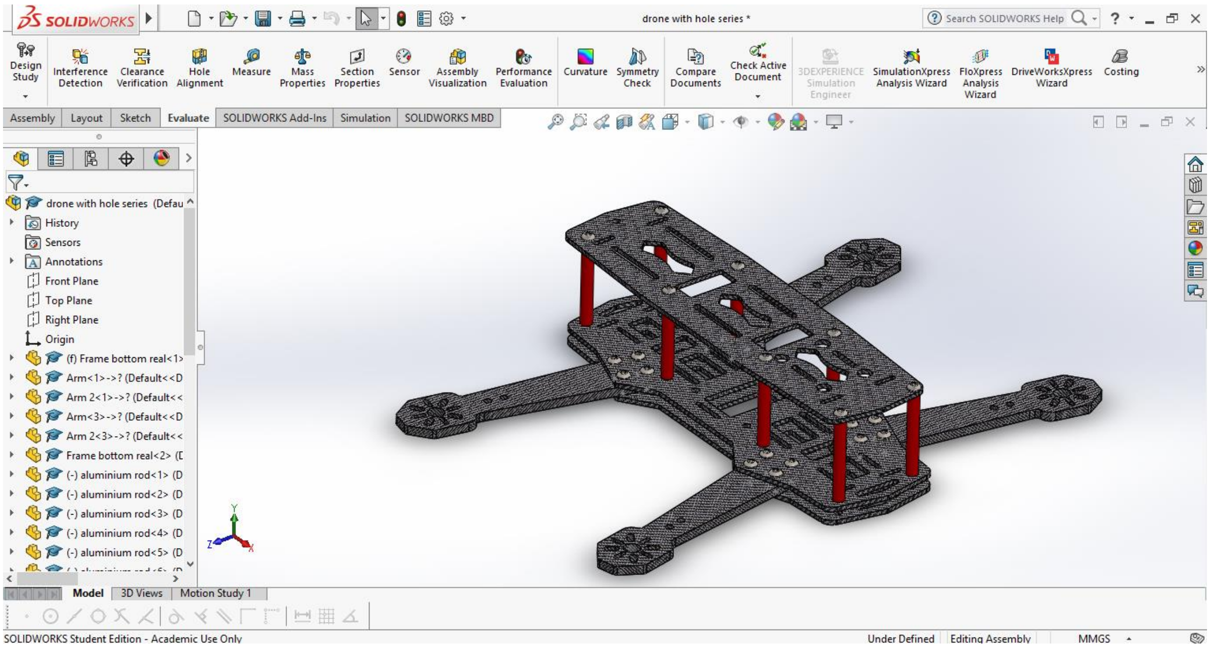

Figure 16 3D CAD model of the drone's frame

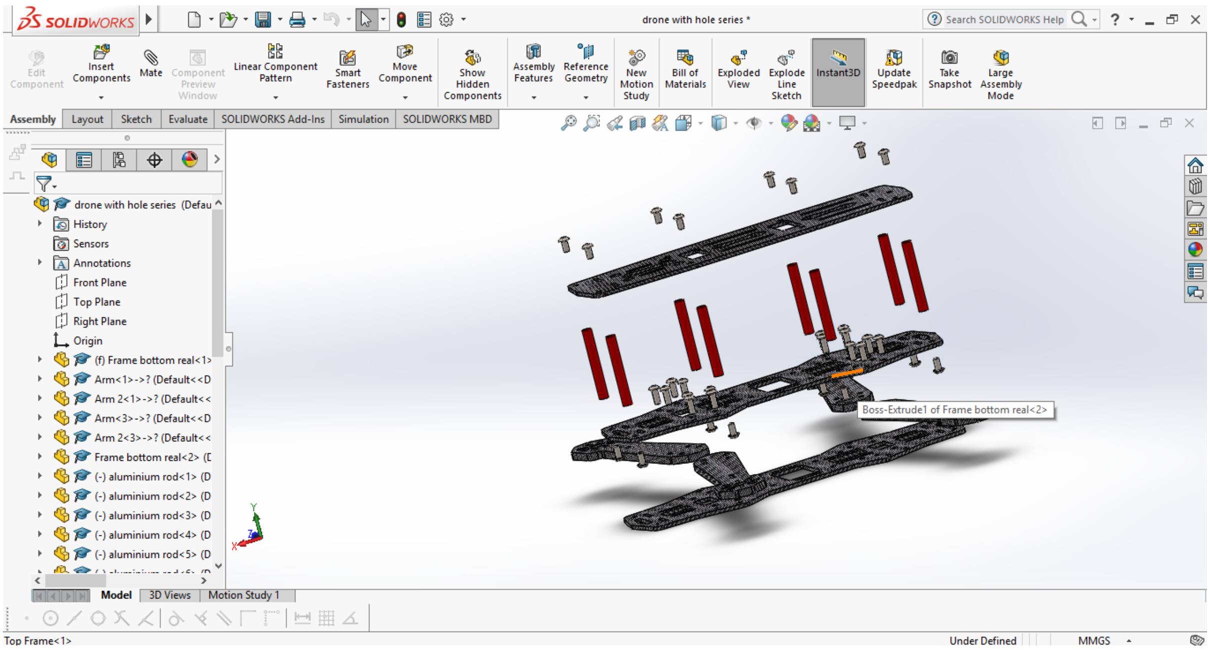

Figure 17 Exploded view of the frame

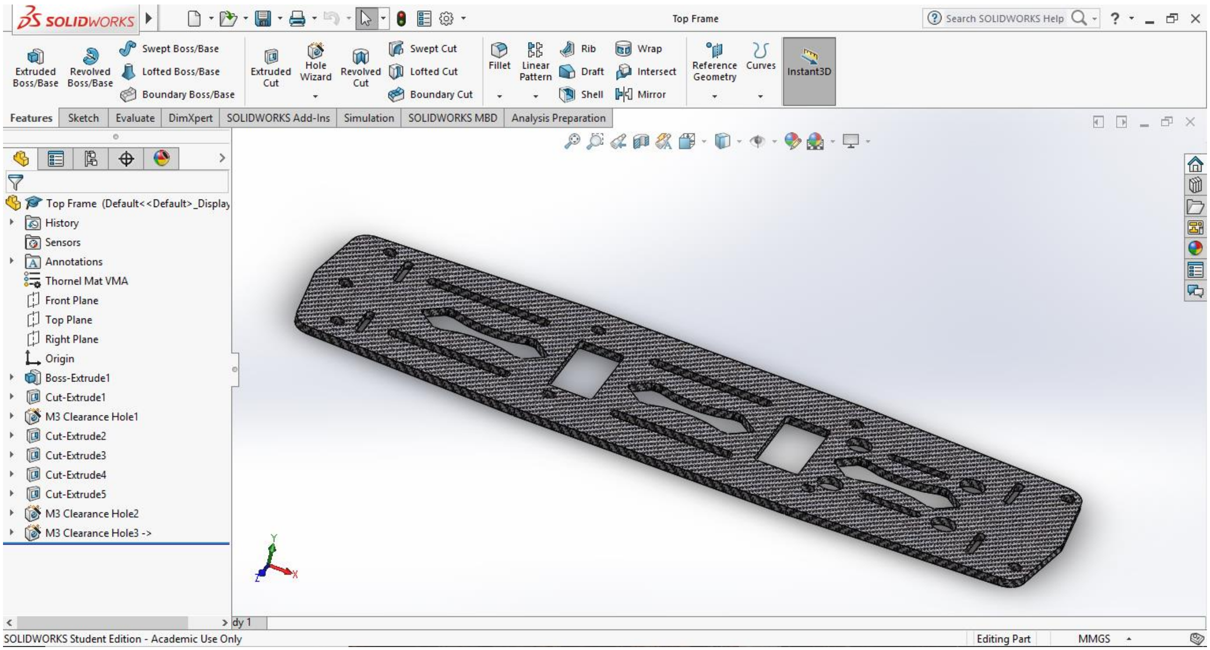

Figure 18 Top frame of the drone

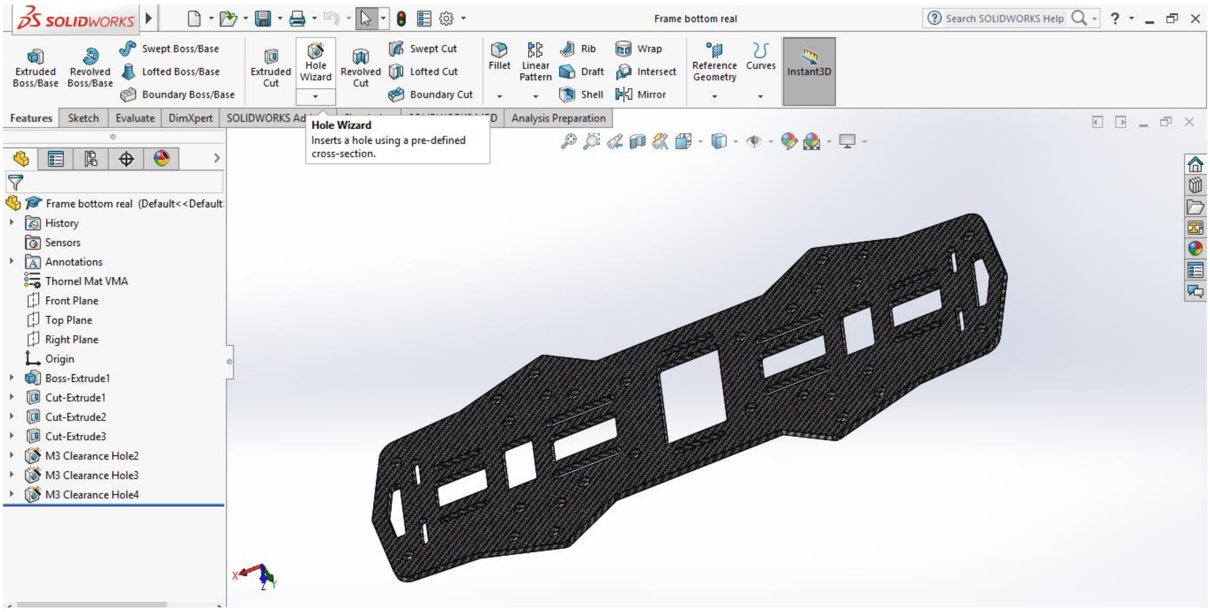

Figure 19 Bottom frame of the drone

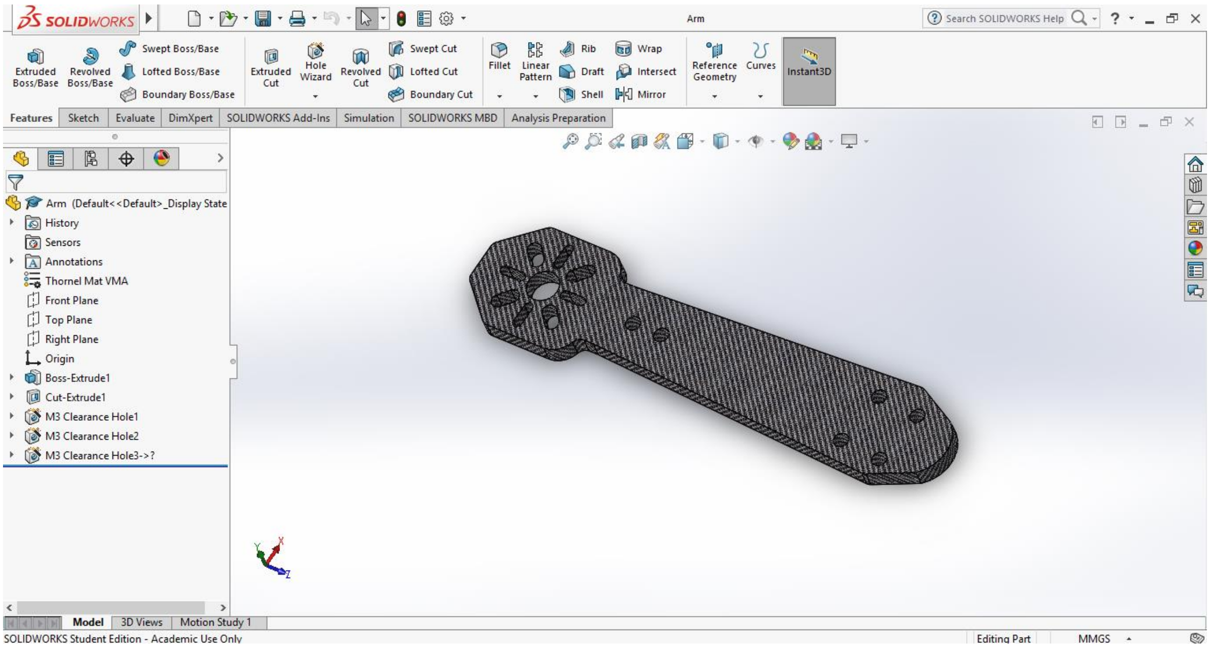

Figure 20 The arm of the drone

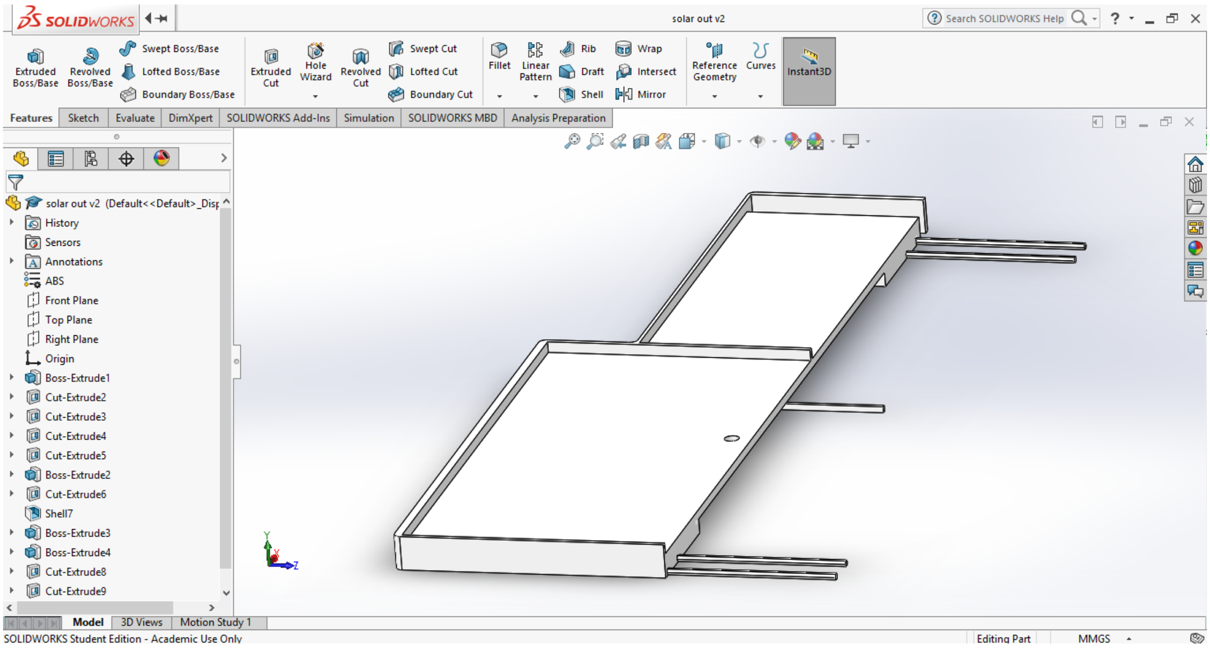

Figure 21 Half of the solar housing with rods

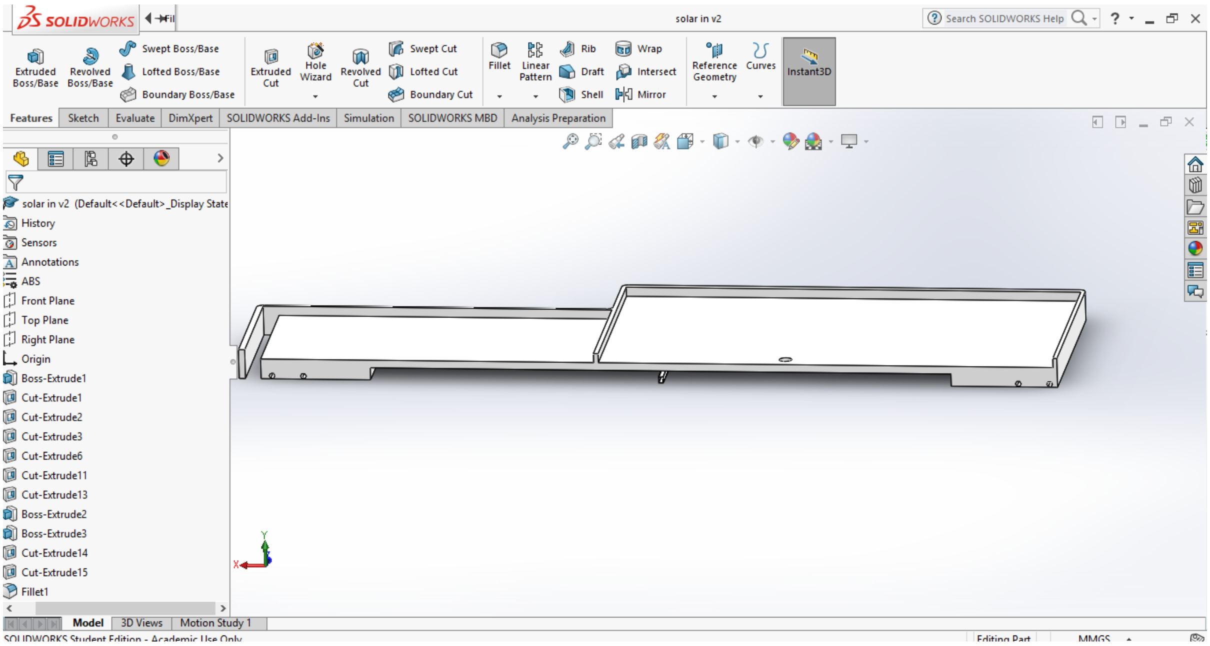

Figure 22 solar housing component with the hole slots

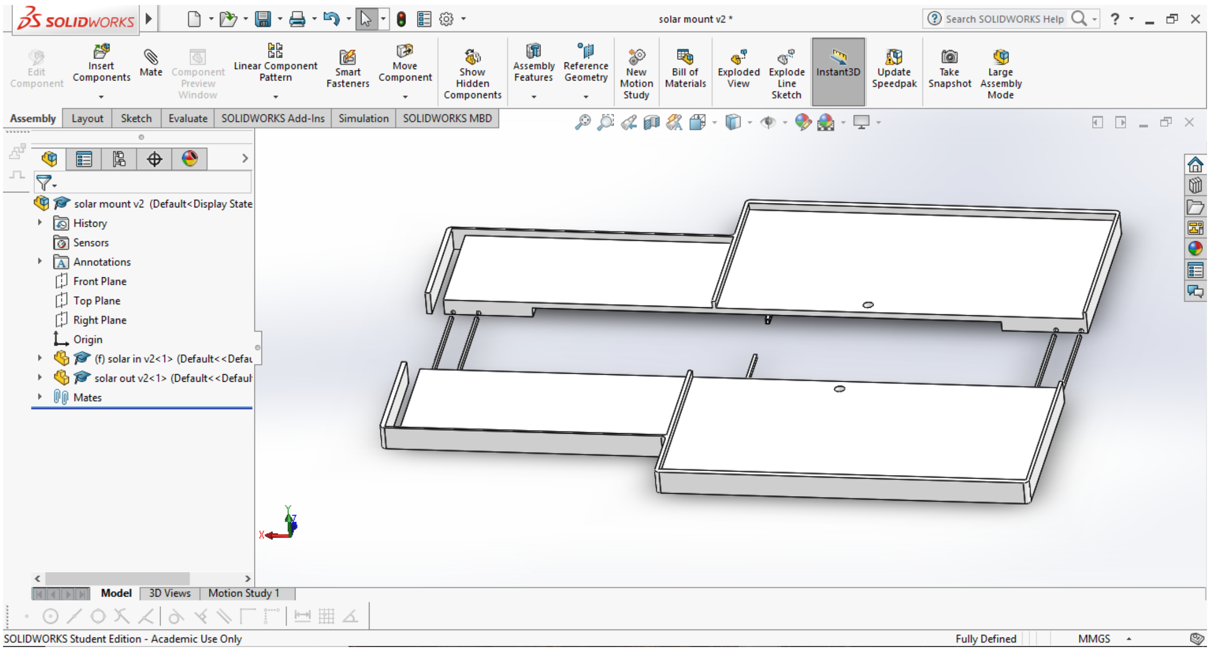

Figure 23 exploded view of Solar housing

When making the solar panel housing the dimensions of the solar panel and the solar charge controller had to be considered. The dimension of the solar panel is 145 millimetres length, 145 millimetres width and 2.5 millimetres height. To make the solar housing easily attachable it was designed in two parts which is shown in figure 23. To determine the thickness of the solar housing the thickness of the top frame and solar panel was observed. The top frame had a thickness of 2 millimetres and the solar panel had 2.5 millimetres thickness giving a total thickness of 4.5 millimetres however there needed to be an allowance of space between the bottom of the solar housing and solar panel since the solar panel is placed on the top of the solar housing in its delegated area.

The solar housing sits on the top frame which is the reason there's a slot at the bottom of the solar housing shown figure 25. But to secure the top frame to the solar housing during flight there's a beam which is shown on figure 25, that sits below the top frame. Figure 23 displays that the beam comes together by a slot in the beam shown in figure 22 where figure 21 has the other piece of the beam which slotted in the hole as display on figure 23. The Beam has a tolerance of 0.1 millimetres which gives the complete beam when come together a tight fit. Figure 21 has two sets of pentagon rods placed near the ends of the solar housing which has an allocated slot shown on figure 22 where the rod slides in with a tolerance of 0.1 millimetres.

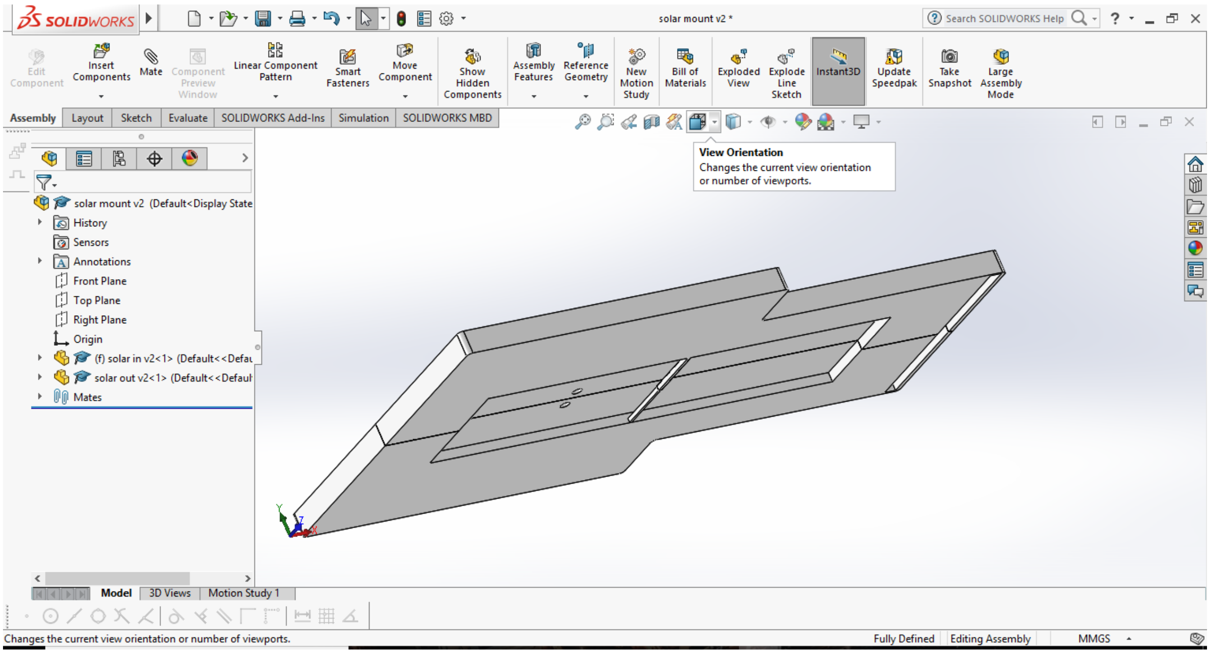

Figure 25 view of solar housing from the bottom

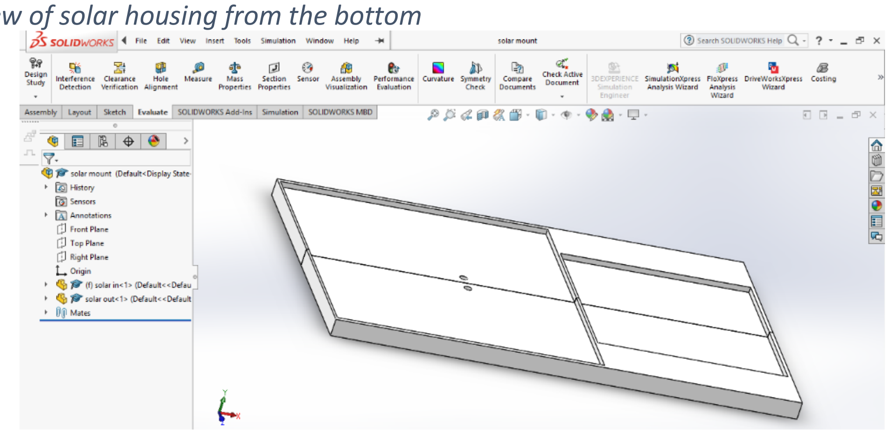

Figure 24 first version of solar housing

The first version of the solar housing originally which is display in figure 25 weighed 206.31 grams, to make it lighter, non-essential material was removed making the mass of the new version 179.64 grams making it 12 percent lighter. Figure 25 displays a further improvement was made to reduce the mass, the improvement was to make figure 21 hollow inside giving a new mass of 154.12 grams creating a 25 percent reduction of mass from the first version. The attachment of the solar panel housing (Figure 24) to the drone makes the total mass of the drone 980.12 grams, the connection between the house and the frame is shown on figure 26.

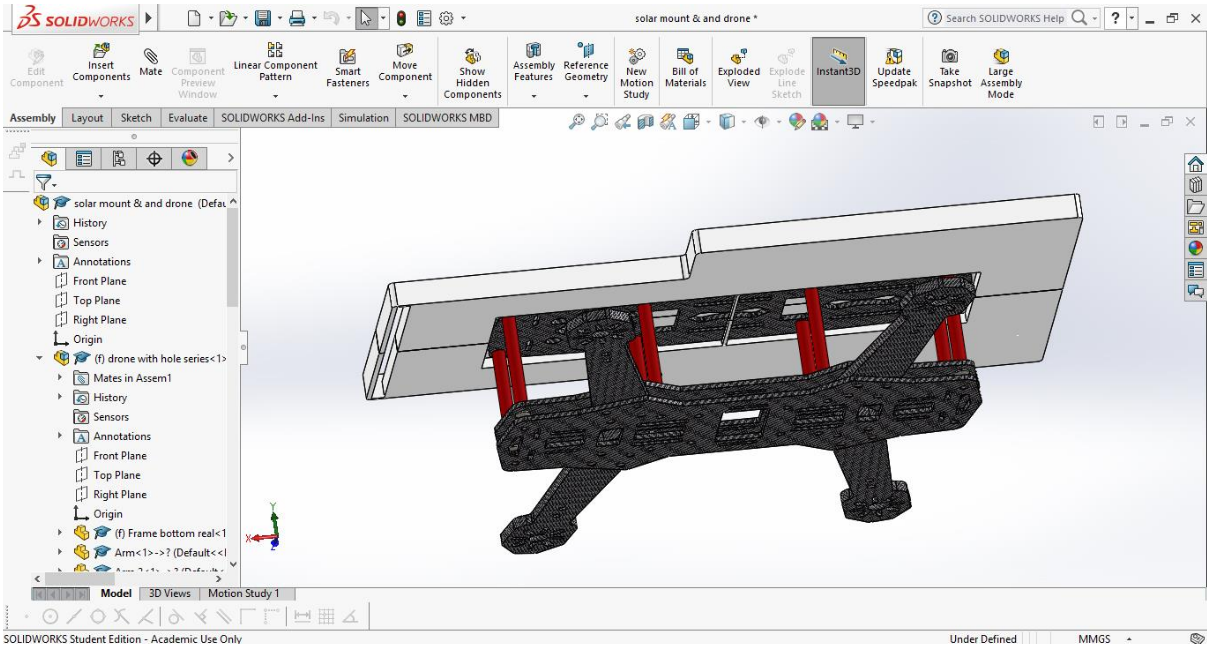

Figure 28 solar housing attached to the frame

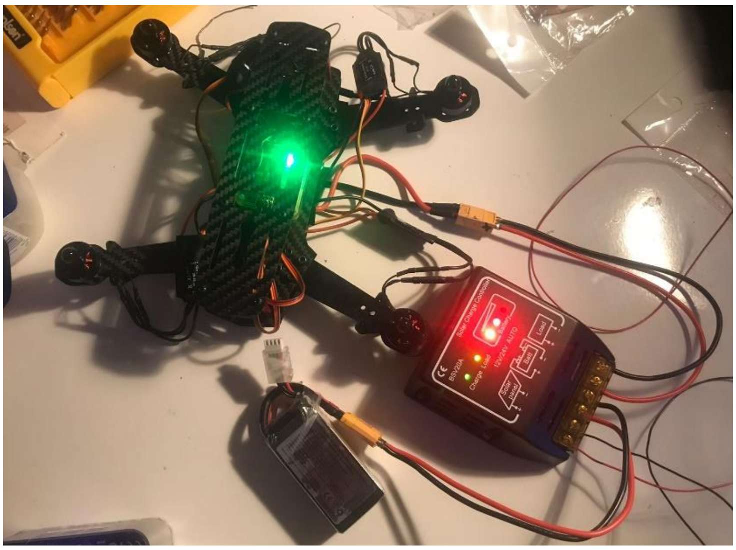

Figure 26 The drone with connected to the solar panel and solar charge controller

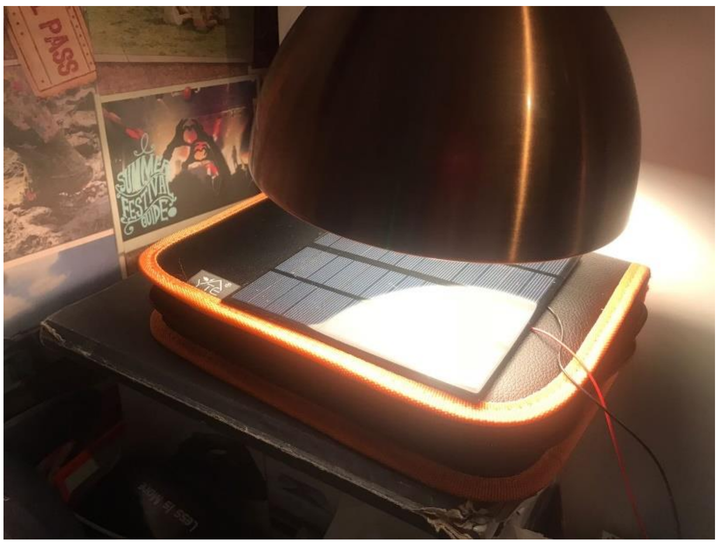

Figure 27 the solar panel under lamp light

Analysis &result

Thrust test results

2400 KV motor	Thrust (g)
1	213
2	219
3	226
4	227
5	223

Table 1 result of 2400kV thrust

2450 KV Racestar Motor	Thrust (g)
1	398
2	397
3	395
4	387
5	364

Table 2 Result of the thrust from 2450KV racestar Motor

Calculations

$$2450\ KV\ motor\ Average\ Thust = \frac{398 + 397 + 395 + 387 + 364}{5} = 388.2\ grams$$

$$2400\ KV\ motor\ Average\ Thust = \frac{213 + 219 + 226 + 227 + 223}{5} = 221.6\ grams$$

The Racestar 2450 KV DC brushless motor produces more thrust then the 2400 KV DC brushless motor. The average thrust of the 2450 KV has an average thrust of 388.2 grams compared with the 2400 KV motor that has an average thrust of 221.6 grams. The 2450 KV motor produces 166.6 more grams of thrust than the 2400 KV motor, this shows that the 2450 KV produces 75 percent more thrust then the 2400 KV motor.

The 2450 KV Racestar DC brushless motor will be used on the drone because it produces more thrust so when you have 4 of them a total thrust of 1555.2 grams of thrust when compared to the 2400 KV motor which will have a total of 886.4 grams of thrust. With a total weight of the drone being 1005.64 grams.

The scales measure the air that being pushed down onto the scales by the propeller being placed upside down. To improve this experiment, the equipment could be placed in a close container so the air that gets pushed down can be contained and doesn’t get displaced into the atmosphere forcing the air to stay on the scales.

Results of the power of the drone

Attempts	Wh (energy rating)	Time (minutes and seconds)	Hours	Watts (Power)
1	14.4	52:24	0.873	16.49
2	14.4	52:51	0.880	16.36
3	14.4	52:46	0.879	16.38

Table 3 results of the power usage of the drone

<u>Calculations</u>

1st attempts:

$$52 \times 60 = 3120$$

$$3120 + 24 = 3144$$

$$3600 \div 3144 = 0.873\ hours$$

$$P = \frac{E}{T}$$

$$14.4\ \div 0.873 = 16.49\ watts$$

2nd attempts:

$$52 \times 60 = 3120$$

$$3120\ + 51 = 3171$$

$$3600 \div 3171 = 0.880\ hours$$

$$P = \frac{E}{T}$$

$$14.4\ \div 0.88 = 16.36\ watts$$

3rd attempts:

$$52 \times 60 = 3120$$

$$3120 + 46 = 3166$$

$$3600 \div 3166 = 0.879\ hours$$

$$P = \frac{E}{T}$$

$$14.4\ \div 0.879 = 16.38\ watts$$

Average time:

$$\frac{52:24+52:51+52:46}{3}=52\ mintues\ and\ 40\ seconds$$

Average power:

$$\frac{16.49+16.36+16.38}{3}=16.41\ watts$$

So, the drone operates at 16 watts.

Flight test

A flight test was conducted without the solar housing attached to the drone in an open field. During the flight test the drone rapidly lifted into the air at levels of 40 percent to 50 percent full throttle. The drone soar approximately 7.05 metres into the air, this height comes from the fact the drone was roughly the same level of 3 story houses that were nearby. It soared this distance in less than 3 seconds.

The rapid acceleration was due to the high lift to weight ratio, which comes from the motors being too powerful for the drone without the solar housing, solar panel and solar charge controller attached to the drone. If the components stated in the previous sentence was attached the lift to weight ratio would be less due to the weight increasing. With the lower lift to weight ratio there will be a decrease in acceleration allowing the pilot to have greater control of the climb of the drone.

Calculation of the lift to weight ratio without solar housing, solar panel and solar charge controller attached:

Formula Lift to weight ratio;

$$lift\ to\ weight\ ratio=\frac{lift\ (g)}{wieght\ (g)}$$

$$lift\ to\ weight\ ratio=\frac{1550}{625}=2.48$$

the lift to weight ratio with solar housing, solar panel and solar charge controller attached

$$lift\ to\ weight\ ratio=\frac{1550}{980}=1.58$$

The calculation of the percentage difference between the two lift to weight ratios;

$$\frac{2.48 - 1.58}{2.48} \times 100 = 36\, percent$$

By adding the solar housing, solar panel and solar charge controller to the drone the lift to weight ratio decreases by 36 percent so the lift to weight ratio with the solar attachment. The climb of the drone will not be as quick, like the climb experienced during the flight test.

The acceleration can be calculated using Newton second law of motion $F = ma$ the thrust before using the newtons second law the grams will have to be converted into kilograms which is the standard base unit for newtons second law. Then the mass will have to be converted to newtons, and in order to do this the mass and thrust will be multiplied by the gravity of the earth, which is 9.8 metres per second squared (m/s^2). Then the resultant force which is F will be divided by the mass (m) in kilograms so the equation gets rearranged to make the acceleration (m/s^2) the subject of the formula $a = \frac{F}{m}$.

The acceleration of the drone without the solar housing, solar panel and solar charge controller;

$$1.55\, kg \times 9.8 = 15.19\, N$$

$$0.65\, kg \times 9.8 = 6.37\, N$$

$$Resultant\, force = 15.19 - 6.37 = 8.82\, N$$

$$F = ma$$

$$a = \frac{F}{m}$$

$$Acceleration = 8.82 \div 0.65 = 13.57\, m/s^2$$

The acceleration of the drone without the solar housing, solar panel and solar charge controller;

$$1.55\, kg \times 9.8 = 15.19\, N$$

$$0.980\, kg \times 9.8 = 9.6\, N$$

$$Resultant\, force = 15.19 - 9.6 = 5.59\, N$$

$$F = ma$$

$$a = \frac{F}{m}$$

$$Acceleration = 5.59 \div 0.98 = 5.7\, m/s^2$$

Adding weight to the drone decreases the acceleration with this decreased acceleration the drone does not rapidly fly upwards into the sky and giving the pilot more time to control the drone, with this acceleration there will be no call for concern of the drone flying out of range.

During the flight control a crash occurred because the pilot panicked due to the drone travelling faster than inspected and swiftly going into the distance, therefore in mid-air the pilot stopped the DC brushless motors and the drone just crashed to the ground. The damage to the drone was that 2 of its propellers broke, on the plus side the frame was undamaged, so the carbon fibre frame could handle the impact from the crash meaning the frame is tough and can absorb the energy from the impact.

Calculation of predicted time the drone will be power for with the solar panel

The solar panel has a power rating of 3 watts

The assumptions that the solar panels will supply the drone with constant power was made. The drone using 16 watts with 3 watts being supplied to the drone the power that the battery will have to supply the drone will be the difference in between the solar panel and the drone power usage.

$$16\ watts - 3\ watts = 13\ watts$$

Where the battery has a power rating of 14.4Wh, the new predicted time of how long the drone will be able to fly for can now be calculated. Using the formula $E = PT$.

$$14.4 \div 13 = 1.108\ hours$$

$$1.108 \times 60 = 66.48\ minutes$$

The addition of solar panel allows the drone to fly for 66 minutes so the drone gains an additional 14 minutes with the average time without the solar panel being 52 minutes, so the operational time of the drone has increased by 21 percent.

Discussion

The drone with the solar panel attached only lasted 49 minutes and 6 seconds which is less that then how long the drone was running without the solar panel attached. With the solar panels and solar charge controller integrated into the drone circuit seem to use more power than the drone without the solar panel integrated circuit. The reason for this could be due to the solar panel not contributing any amount of power since the light source was came from a lamp therefore the battery had to deal with an extra load.

Some charge controller have a load output, which the LESHP Solar Panel 20A 12V 24V Battery Regulator has. This output load can be utilised for smaller loads, for example small appliances and lights. (The assumption that the motors were low often was made) The load terminal have a low voltage disconnect meaning that the charge controller will switch off whatever is connected to the load terminals and prevent the battery running down. There was evidence of this on the drone, when the battery was powered to the drone without the solar charge controller and solar panels, the drone continued running for a period of approximately 3 minutes before the battery died.

The extra 3 minutes the drone was running for took the total of the operating time to 52 minutes and 36 seconds which is similar to the how long the drone would last for before the battery died showing that the only effect that the charge controller had was not letting the voltage of the battery drop to a low state.

The drone getting an additional 14 minutes which still needs to be proven by putting the solar panels under natural sunlight or a machine that simulates sunlight. The DC brushless motors that were used when calculating the power were the 2400 KV motors which produces less thrust. The reason for this is that during initial testing to figure out the power of the drone the electronic speed controller caught fire and was severely damaged and ordering a replacement electronic speed controller would not arrive before the submission date.

The drone could possibly last longer but not produce often enough thrust for it to lift off, so the overall goal to build a solar powered assisted quadcopter was not achieved. If another individual wanted to build solar power assisted quadcopter they could use this report to continue where this report left off and by following the methodology to improve my design and ultimately construct a solar powered assisted drone.

Conclusion

To conclude with the motor, have a low power usage the solar panel power the drone with the aid of battery but couldn’t power the drone only using the solar panel hence the reason for the solar charge controller being needed. With investment from various companies and organisation on drone hardware increasing in the coming years solar technology could be integrated into drone technology.

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