Eastern Mediterranean University

Department of Mechanical Engineering

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EVALUATION

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Abstract

Primarily, this report will be giving an insight into micro aircraft specifically UAV in general. The conceptual design, the manufacturing iterations and development of small solar aircrafts developed as a project for capstone project of Eastern Mediterranean University. The design of the UAV is a variable concept, different UAVs are designed to solve different problems encountered. The primary aim of the report is to give readers background information of the solar unmanned aircraft, the design parameters taken into consideration during the design processes of UAVs. This report is divided into three main sections. Introduction which gives brief information about the problem and describes the objective of the report. Chapter 2 comprises of the literature review, different time line of various UAVs and compares of different design parameters, and chapter 3 comprises of the design methodology and application of the design of a small solar UAV

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Chapter 1

1) Introduction

1.1 Motivation

To help promote global environmental sustainability has had engineers of various disciplines bound to study, experiment and discover ways for solving this phenomenon. The last 50 years have seen an unprecedented increase in global warming, over-exploitation of natural resources, ozone depletion, and other global environmental issues. The ever-high fuel consumption of the aviation industry contributes greenhouse gas emissions across societies that see air travel a necessity in a globalized world. One means for reducing the environmental impact of aviation is to replace the current jet fuel with environmentally friendly alternatives, such as the zero-emission hydrogen fuel. Many airline industries have researched the production and use of biofuels over fossil fuels; however, scarcity of such resources remains as a problem over the long haul. In order to protect the environment, next generation aircraft is expected to use zero-fuel airplanes. Therefore, solar-powered aircrafts continue to take momentum. In accord with the above-mentioned issues

1.2 Objective

This study revolves around the primary objective of designing and building an Unmanned Aerial Vehicle (UAV), which is solar-powered, has the capability of being hand-launched and weighs no more than 2.5 kg. The second objective includes search and selection of a solar-powered UAV. This indeed will be conducted by comparing and contrasting similar alternatives, in order to reach a choice with optimal configurations. This section is followed by an analysis of the propulsion system, preliminary selection, as well as its incorporation into our model of aircraft. In addition, an overall configuration, a wing configuration and an empennage configuration is embodied into the study drawn from the latest findings in solar-powered UAV design. A thorough discussion of the initial configuration is followed by another initial step in our design, which is a weight estimate for this solar-power UAV. We will then look into the equations of the power of our device, since solar energy, as a new form of conversion and accumulation of power is an important factor concerning solar-powered UAVs. Furthermore, the impact of changing the variables of these equations are evaluated. The size of the empennage as the root cause of stabilization is also analyzed and resolved for this design. Finally, three differing methods for evaluating the relationship between lift and drag, also known as drag polar, are compared, contrasted, and followed by an analysis on why our choice of method bears the highest accuracy relative to others.

This report gives insights into unmanned aerial vehicle, comparative similar study of UAVs, History and literature review in the second chapter. The third chapter comprises of applied knowledge of mechanical principles, Measurement drawing, bill of materials, assembling procedure and manufacturing process would be given. The undertaking would be accomplished by the hypothetical information and experience has made with participating of some students and their instructive studies in the field of mechanical designing.

Chapter 2

2.1 Other Studies of UAV

Sun Sailor was an ungraduated student team's attempt at building a UAV, hailing from Israel that broke the world record of flying a 139 km distance in 2006. Months later, the aircraft was sent into a dive in August, the same year, and the damages were away from repair. The team still strives to break the world records up to this day. In 2007, NASA categorized HALE UAVs into heavier-than-air and lighter-than-air concept models to make possible for a hurricane and communications relay capabilities over disaster areas. All heavier-than-air models failed both missions, contrary to lighter-than-air successes to complete both. However, low life cycle and increase in size and mass remain to be drawbacks of this model. One of the notable outcomes of this study was NASA's analysis of propulsion in various configurations of both models, which lays an invaluable comparison of each concept.

Another study, conducted by Tegeder at Brigham Young University produced a solar-powered UAV with more efficiency by implementing an onboard solar tracker, has developed for changing the angle of the airframe, for an aircraft to absorb optimal sunlight at all times. Quantitative measurements demonstrated a 34.5% increase in absorbing solar energy and producing power over conventional unmanned aircraft vehicles.

Lastly, Baldock at Brunel University, United Kingdom, conducted research on high altitude UAVs that resulted in the development of an important concept. The findings as shown us the HALE can't resist more than one year round level flight up to latitudes of 10 degrees north, and not anywhere around the world

2.2 History of Solar-Powered Flight

In order to get the logic of progression in the history of solar-powered flight, one must first understand the history of solar cells (Photovoltaic Cells). The first time human beings started to harness sun's radiation was in the form of making fire using magnifying glasses, and goes back to as early as the 7th century BCE. No more major subsequent advance in solar technology were made until Horace de Saussure created the first solar collector in 1767, which was first put into practical use by producing heat and making solar cooking available. Edmund Becquerel was next in making history as his experiments with exposing electrolytic cells to sunlight led to producing electricity in 1839. His encounter can be marked as the discovery of the first-ever photovoltaic cell, which also happens to be the bedrock of solar cell technology. Electrolytic cells were used in steam engines as well as in water heaters for the next 50 year, for the purpose of powering up these devices only, as no other usage was devised during this period of times. Selenium, when exposed to the sun, also happened to be a candidate to conduct electricity.

The next event finally marks the birth of solar cell technology: photovoltaic technology is born by Bell Labs in the United States in 1954 by creating and developing practical silicon solar cells starting with an initial 6% efficiency. Daryl Chapin, Calvin Fuller, and Gerald Pearson at Bell Labs were the first to create photovoltaic cells (PV cells) capable of using sun radiation to power "everyday electrical equipment"

The first aircraft to fly on solar power was designed by Astro Flight Inc., and flew for the first time on November 4, 194, at Camp Irwin, California. This aircraft, named Sunrise I, flew at an altitude of 100 meters for more than 20 minutes. The upgraded Sunrise I later flew for over three hours before it was damaged in a sandstorm beyond repair. Therefore, the company worked on a new prototype, named Sunrise II, which weighed less and produced more output power than its predecessor produce. Sunrise flights aspired many individuals and companies to pursue solar-powered technology and implement such machinery in their own aircrafts. For example, Dave Beck from Wisconsin built his version of model solar-powered aircraft named Solar Solitude. This model aircraft broke the records both distance flown in a straight line (38.84 km) and altitude (1283 m).

Parallel to this invention, another model aircraft enthusiast, Wolfgang Schaeper from Germany built the Solar Excel. This model aircraft held all world records from 1990 to 1999, including distance in a straight line, distance in a closed circuit, duration, speed, speed in a closed circuit, and gain in altitude. Solar Excel held for more than another decade afterwards all FAI F5-SOL model aircraft records.In terms of long durance, SoLong UAV designed by AC Propulsion is a notable example. This aircraft, although it has a wingspan of less than 5 m, is capable of flying steadily using solar and thermal energy only. On April 22, 2005, the aircraft flew a 24 hours 11 minutes straight without any stop, two months prior to its records breaking flight of 48 hours. Thus, new hopes for reaching zero-fuel flights was once again revived.

The British company QinetiQ tested an aircraft in New Mexico in December 2005 to assess the possibilities of high-altitude long endurance (HALE) of such aircrafts. Zephyr flew a successful six hours and reached a maximum altitude of 7,925 meters. Zephyr achieved an even higher accomplishment as it flew a non-stop 54 hours on September 10, 2007. The new world record unmanned flight reached a maximum altitude of 17,786 meters. The next mission for QinetiQ is to upgrade Zephyr to reach several months record at an altitude of 15,240 meters. Finally, the advent of solar-powered manned flights by Bertrand Piccard in 2003. Piccard, at Solar Impulse, paved the way for developing a revolutionary solar-powered manned aerial vehicle that will soon traverse the globe non-stop on solar power only, By December 2009, the first prototype was built, and by July 2010, Solar Impulse I flew a 26-hour flight, including nearly nine hours of night flying. Solar Impulse 2 departed from Abu Dhabi in 2015, traversed Asia up to Hawaii, almost finishing a complete circumnavigation of the globe before it experienced a thermal damage to its batteries.

2.3 Comparism of Different Models

2.3.1) Comparative Study of Similar Airplanes

In this part the aircraft that will be disscussed are the Helios Prototype and Pathfinder , Venus exploration Solar Solitude, Solar Excel, SoLong, Zephyr, and the Sky-Sailor

For solar UAV, the mission Capabilities and configuration are selected for studying the aircrafts, they are shown in Tables 1 and 2. The vast majority of the capacities of these flying machine are insignificant and utilized principally to think about the capability of sun powered controlled long-perseverance flight.

Table 1: Mission Capabilities for SoLong, Solar Excel and Solar Challenger

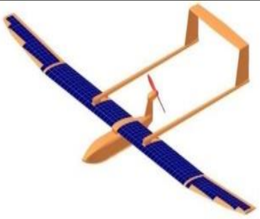
	SoLong	Solar Excel	Solar Challenger
Capabilities	48 hours continously flying is the main aim of this type of UAVs by using solar cells and electronic motors	Minimal capabilities. Holds all records in FAI F5-SOL category	solar-powered aircraft strong enough to handle both long and high flights when encountering normal turbulence
Configuration	Single propeller ordinary design with v-tail.	Single propeller conventional configuration with v-tail.	Single propeller conventional configuration with T-tail.
Solar Cell Configuration	120 Sanyo 1865 Li-Ion cells, 77 Sunpower A300 solar cells, nominal power = 224 W, battery mass = 5.40 kg.	Unknown	16,138 solar cells.
Photo			

Table 2mission capabilities and configurations of solar uav

	Helios Prototype	SKY-SAILOR	Zephyr
Capabilities	Phenomenal levels of execution and security. The Helios Prototype improvement is in accordance with the objective of creating effective electric impetus with cutting edge power device innovation and exceedingly coordinated airframe and drive plans to empower calm, low-emanation flying machine.	huge advancement has been made as of late in the basic fields for such a task, to the point that are: Efficiency, weight and adaptability of sunlight based cells, energy to weight proportion of batteries, scaling down of MEMS and CMOS sensors, execution of single board PCs, and so forth.	Military use it for surveillance and interchanges stages. Nonmilitary personnel projects will utilize it for ground perception
Configuration	14 brushless direct-current electric motors mounted across the wing's entire span. The motors are rated at 2 hp. (1.5 kW)	In light of the required force on the propeller shaft, a few cycles have been made keeping in mind the end goal to choose the best engine for our application. Both the DC and DC Brushless (BLDC) innovations were considered. At last, a MAXON DC, REMAX 29 (161g) was chosen.	2 propeller traditional design with t-tail.
Solar Cell Configuration	More than 61,000 sun oriented cells were introduced on the whole upper surface of the wing amid 2001	A sum of 216 sun powered cells will be introduced on the demonstrator plane. They will be partitioned in 3 modules associated in parallel, each of them made out of 2 arrangement of 35 cells.	Batteries are Lithium Sulfur batteries from Sion.
Photo			

2.3.2) Comparison of Important Design Parameters

Table 3 important design parameters are shown

	Helios Prototype	SKY-SAILOR	Zephyr
Weight (kg)	650	2.8	50
Endurance	55,000 to 72,000 ft.	Continuous long-term , mainly depends on battery life cycle and dust deposition	335 hours, 21:01 minutes (Terminated 14 days)
Wingspan (in m)	80.4	4.5	32
Aspect Ratio	30.9 to 1		11.6

Table 4Technical parameters of our UAV with reference to other UAVS

	SOLAR UAV	SOLAR EXCEL	SUN SAILOR 1/2	THE SOLARINE
Range (km)	33.5	48.5	140	11
Aspect ratio	14	13	13.45	5
Wing area m^2	1.5	0.35	1.65	0.145
Altitude m	1200	2065	200	450
Endurance minute	30	690	-	60
Weight (kg)	0.45	0.72	3.6	0.75

2.4) solar energy

Solar power can be defined as the energy gotten from the sun through solar Radiation, as the law of thermodynamics state that energy can neither be created nor Destroyed but can only be converted from one for to another, solar energy can be Converted into heat, electrical and other forms of energy, there are various technology Existing to help harness the energy from the sun. The application of solar energy is broad, it is used domestically to heat up water, buildings collect and store the solar Energy during the day for use at night, and two major application of solar energy is for Heating and generation of electricity. Photo voltaic cells can convert solar energy into Useful electrical energy, by the chemical reactions taking places in the cells to Generate electricity .the use of external mechanical devices to convert the solar Energy into other forms is called active solar system, while the conversion of solar Energy into other forms without any external work added is called passive.

2.4.1) Solar Photovoltaic Cell

The name of the device used to convert solar energy into electrical current is called a photovoltaic cell, it uses an application of semiconductors that possesses photovoltaic effect. The operating system of a photovoltaic cell uses solar panels which comprises of a number of solar cells which supply useful and usable power. Photovoltaic cell process involves both physical and chemical process occur which involves the crystallized atoms that are ionized in an array of cells that come in contact with sunrays. Most of the photons are reflected as the cells are immersed into the solar cells. In the process of crystallizing, when adequate amounts of photon gets absorbed into the negative layer of the cells, electrons are then released from the negative semiconductor. Due to the process of the manufacturing procedure of the positive layer, the electrons which are released move to the positive layer which generates a voltage difference. The two layers connected in series the power output are increased.

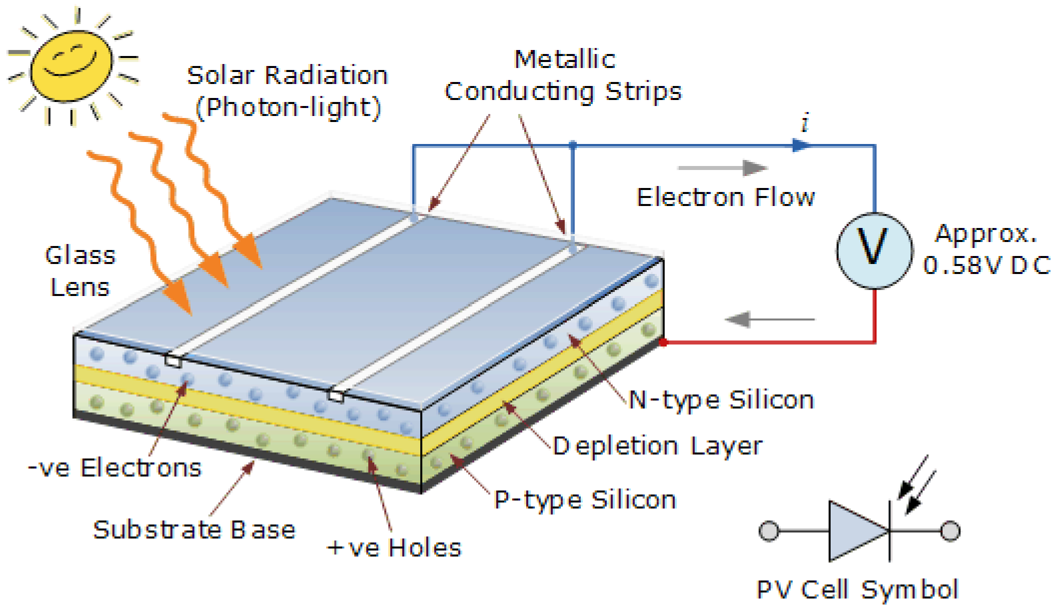


Figure 1Photovoltaic Cell solar panel

2.5) UAV

The shortened form UAV is the short type of unmanned airborne vehicle. This is a flying machine which is flown or controlled without a pilot on load up it is generally controlled from an outer controller, and in some uncommon cases it is prearranged to adjust a specific flight way. The historical backdrop of UAV goes back to the 1900s, the ova as adjusted by the military to perform certain incognito and high hazard missions, and high accuracy missions, around then there were some specialized imperfections in the application and vital execution because of the absence of cutting edge and complex innovation around then.

The present day ova are best in class and created because of the innovation accessible in this advanced age. The progressed ova has been broadly adjusted by the military for doing operations, by regular people for recreational exercises, media outlet for ongoing reconnaissance. With the fast increment in the utilization and interest of ova, ova's would have a noteworthy part later on

2.5.1) Time line of UAV

Table 5 UAV time line adapted

Time line	Description	Inventions
1911s	The main UAV took flight in the U.S. The achievement of UAVs in experimental runs was enormous. Truce landed before the model UAVs could be conveyed decisively.	Sperry Aerial Torpedo (USA). Kettering Aerial Torpedo (USA).
1931s	For over 10 years after the end of World War I, improvement of pilotless air ship in the U.S. what's more, abroad declined strongly. By the mid-to-late 1930s, new UAVs developed as a critical battle preparing instrument.	DH.82B Queen Bee (UK). Radio Planes (USA).
1941s	Amid World War II, Nazi Germany's creative V-1 exhibited the impressive danger a UAV could posture in battle. America's endeavors to kill the V-1 laid the preparation for post-war UAV programs in the U.S.	V-1 (Germany). PB4Y-1 and BQ-7 (USA).
1961s	From their initial use as target automatons and remotely steered battle vehicles, UAVs tackled another part amid the Vietnam War: stealth observation.	AQM-34 Ryan Firebee (USA) D-21 (USA)
1971s	The accomplishment of the Firebee proceeded through the end of the Vietnam War. In the 1970s, while different nations started to build up their own progressed UAV frameworks, the U.S. set its sights on different sorts of UAVs.	Ryan SPA 147 (USA)
1981s	Amid the late 1970s and all through the 1980s, the Israeli Air Force, a forceful UAV designer, spearheaded a few critical new UAVs, variants of which were coordinated into the UAV armadas of numerous different nations, including the U.S.	Scout (ISRAEL) Pioneer(ISRAEL)
1991s to Present day	Amid the late 1970s and all through the 1980s, the Israeli Air Force, a forceful UAV designer, spearheaded a few critical new UAVs, variants of which were coordinated into the UAV armadas of numerous different nations, including the U.S.	Darkstar (USA). Pathfinder (USA). Helios (USA). Etc.

2.6) Classifications of UAV

There is no one standard when it comes to the classification of UAS. (In this course, the terms UAS and UAV will be used interchangeably.) Defense agencies have their own standard, and civilians have their ever-evolving loose categories for UAS. People classify them by size, range and endurance, and use a tier system that is employed by the military. For classification according to size, one can come up with the following sub-classes. The European Association of Unmanned Vehicles System (EUROUVS) gives a grouping of UAV framework taking into account distinctive parameter, for example, most extreme departure weight (MTOW), flying elevations, continuance, speed, size and so forth.

Table 6 Classifications of UAV according to size

	Category	Max. take-off weight (kg)	Max. flight altitude (m)	Endurance (hours)	Example	
					Mission	Systems
Micro/Mini UAVs	Micro	0.11	251	1:01	Scouting, surveillance inside buildings	Black widow, Homet
	Mini	<31	150-3001	<1:59	Agriculture, pollution measurements	Tracker, Raven, Skorpio
Tactical UAVs	Close range	151	3001	2 - 4	Search & rescue, mine detection	Observer l, Phantom
	Short range	201	3001	3 – 5	RSTA, EW, BDA	Luna, Silver fox
	Medium range	151-501	3001-5001	6 – 10	NBC sampling, mine detection	Aerostar, Falco, Sniper
	Long range	-	5001	6:01 – 12	Communication relay, BDA, RSTA	Hunter, Vigilante 502

Table 7 UAVs Classification according to the US Department of Defense (DOD)

Category	Size	Maximum Gross Tal Weight (MGTW) (lb	Normal Operating Altitude (ft.)	Airspeed (knots)
Group 1	Small	0-20	<1,200 AGL*	<100
Group 2	Medium	21-55	<3,500	<250
Group 3	Large	<1320	<18,000 MSL**	<250
Group 4	Larger	>1320	<18,000 MSL	Any airspeed
Group 5	Largest	>1320	>18,000	Any airspeed

*AGL = Above Ground Level
**MSL = Mean Sea Level
Note: If the UAS has even one characteristic of the next level, it is classified in that level.

Chapter 3

3.1) Aerodynamic forces of the wings

3.1.1) Lift

Lift can be defined as the face that acts on the wing of an airplane which counterbalances the weight and enable the aircraft to fly. There are arguably two distinct explanation for the production of lift by an aircraft wings, Bernoulli's and newton's 3rd law. Newton's third law has practical limitations. By Bernoulli, the pressure and fluid flow are inversely related. The flow of wind towards the wing is splatted in to two , the upper part has a positive camber hereby the wind has to travel faster and the pressure drops, while the lower part remains constant and the pressure is higher, the region of higher pressure pushes the wing up generating lift .

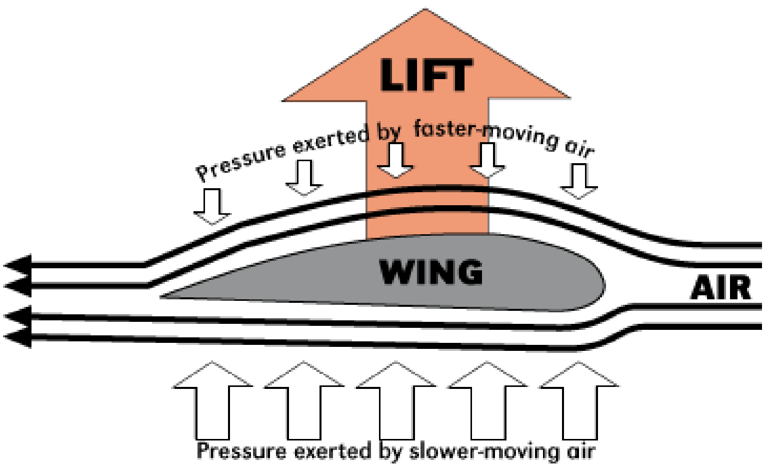


Figure 2weight on the wings of an aircraft

The magnitude of the lift is a function of the coefficient of the lift, surface area, angle of attack a relative wind speed and density of air at that speed and height

3.1.2) Drag Forces

Drag this is the resistance to the flow of the wind, the drag opposes the motion of the plane, it's a form of air friction experienced by the aircraft in flight, the drag is a function of the coefficient of the drag, surface area, angle of attack a relative wind speed and density of air at that speed and height, a well streamed line wing and fuselage assembly can help reduce the drag experienced by the aircraft

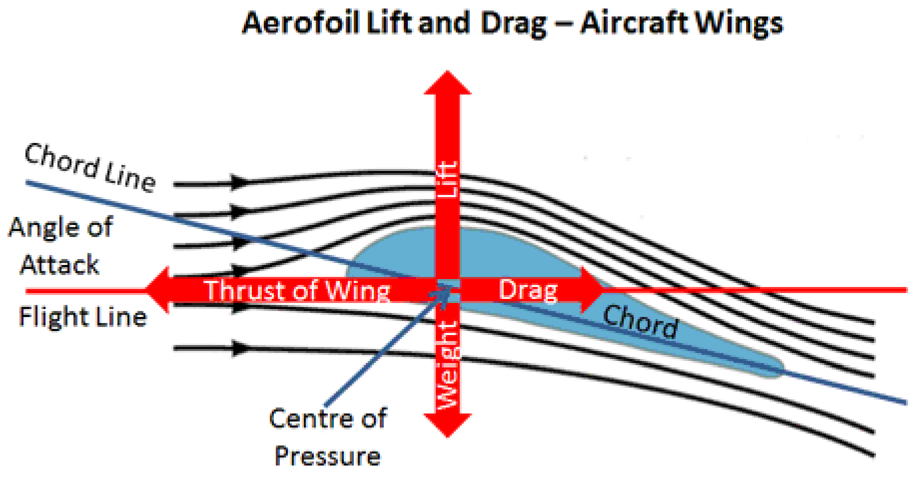


Figure 3airlift and drag

3.1.3) Gravity Force

Gravity this a force that acts on every mass on earth and masses close to the surface of the earth, gravity pulls object towards the earth at a speed of 9.8m/s . The aircraft experiences a downward force pulling it towards the earth at every time. The gravitational force is countered by the lift generated by the wings which enable the aircraft to stay aloft in the air.

3.1.4) Thrust Force

Thrust is a force produced by the propulsion system of the aircraft, the thrust produces a force which propels the aircraft forward, this works in accordance with newton's third law of motion , for every action there is an equal and opposite amount of reaction , and the object moves in the direction of the applied force . The propellers of our aircraft would be used to generate thrust.

3.2 Performance Constraints and Analysis

3.2.1 Constraints

Our analysis of weight has yielded estimates for a wingspan, wing are, and aspect ratio. A performance constraint analysis is required in order to update these estimates to usable values. The following

Table 8 shows the parameters necessary to meeting the mission requirements.

Aspect Ratio	15
Maximum Cruise Velocity	13.4 m/s (37 mph)
Weight	98.1 N (22 lbs)
Cruise Altitude	2,500 m
Rate of climb	2.5 ft./s (0.3 m/s)

3.2.2 Sizing to Cruise Speed Requirements

According to Ruska, a Power Index formula is required to calculate the cruise speed

Equation 3.1: Lift coefficient

$$I_p = \left[\frac{\left(\frac{W}{S}\right)}{\sigma\left(\frac{W}{P}\right)}\right]^{1/3}$$

The correlation between the aircraft spend and the Power Index are further provided in Ruska's studies, which can be seen in Figure 8.1. A maximum cruise speed of 31 mph, demonstrated in the same figure, is shown to result in a power index of 0.1713. We can determine the relationship between the wing loading (W/S) and power loading (W/P) by inserting the power index into our equation (Equation 3.1). In this case, by defining our air density ratio at 2,001, the result will be 0.82167.

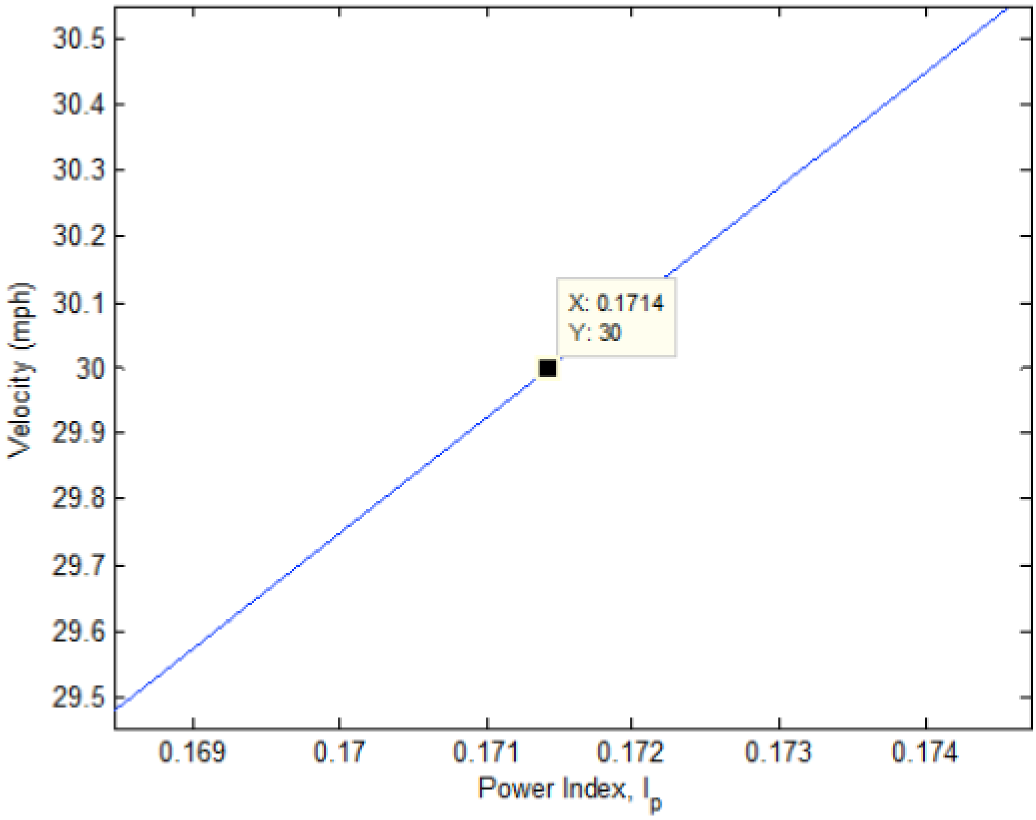


Figure 4Correlation between Aircraft Speed and Power Index

3.2.3 Sizing to far 23 Rate of Climb Requirements

In Table 8, the rate of climb requirement was set at 0.3 m/s, which is an ambitious number for a solar-powered aircraft, but remains to be much lower than a conventional aircraft's climb requirement. The rate of climb as noted by Ruska is define in Equation 3.2.

Equation 3.2: Rate of climb

$$RC = \frac{dh}{dt} = 33{,}000(RCP)$$

Ruska in Figure 4 also defines the rate of climb parameter.

Equation 3.3: Rate of climb parameter

$$RCP = \frac{\eta_{plr}}{\frac{W}{P}} - \frac{\left(\frac{W}{S}\right)^{1/2}}{19\left(\frac{{C_L}^{3/2}}{C_D}\right)\sigma^{1/2}}$$

Here we will assume a propeller effectiveness of half, an air thickness proportion at 2,000 m of 0.82167, a lift coefficient of 1.5, and a drag coefficient of 0.0968. The drag coefficient can, in this manner, be determined utilizing the accompanying equation (see equation 8.4):

Equation 3.4: Drag coefficient

$$C_D = C_{D_{afl}} + C_{D_{par}} + C_{D_0} = C_{D_{afl}} + C_{D_{par}} + \frac{{C_L}^2}{\pi e AR}$$

The total drag coefficient is calculated using the parameters initially used in Notch's model (see Appendix C), by assuming an Oswald efficiency factor of 0.9. It is possible now to determine a relationship between the wing loading and power loading of our aircraft in order to meet our climb requirements.

3.2.4 Performance Sizing Graph

Figure 4 shows the wing stacking versus power stacking associations with information drawn from the two connections characterized. The three bends in Figure 5 speak to the different necessities: journey speed, rate of ascension, and departure speed. Ruska utilizes an estimation of 71% of the voyage speed prerequisite. The ideal outline point is the crossing point between the bends and will decide the force required and wing zone required for the mission.

Since the chart has two crossing point focuses, our purpose of interest is the point that uses the departure and the rate of ascension prerequisites is picked in light of the fact that in the event that the departure necessity is met, then the journey necessity will likewise be met. The directions of this point are (W/S, W/P) = (0.9714, 0.2203).

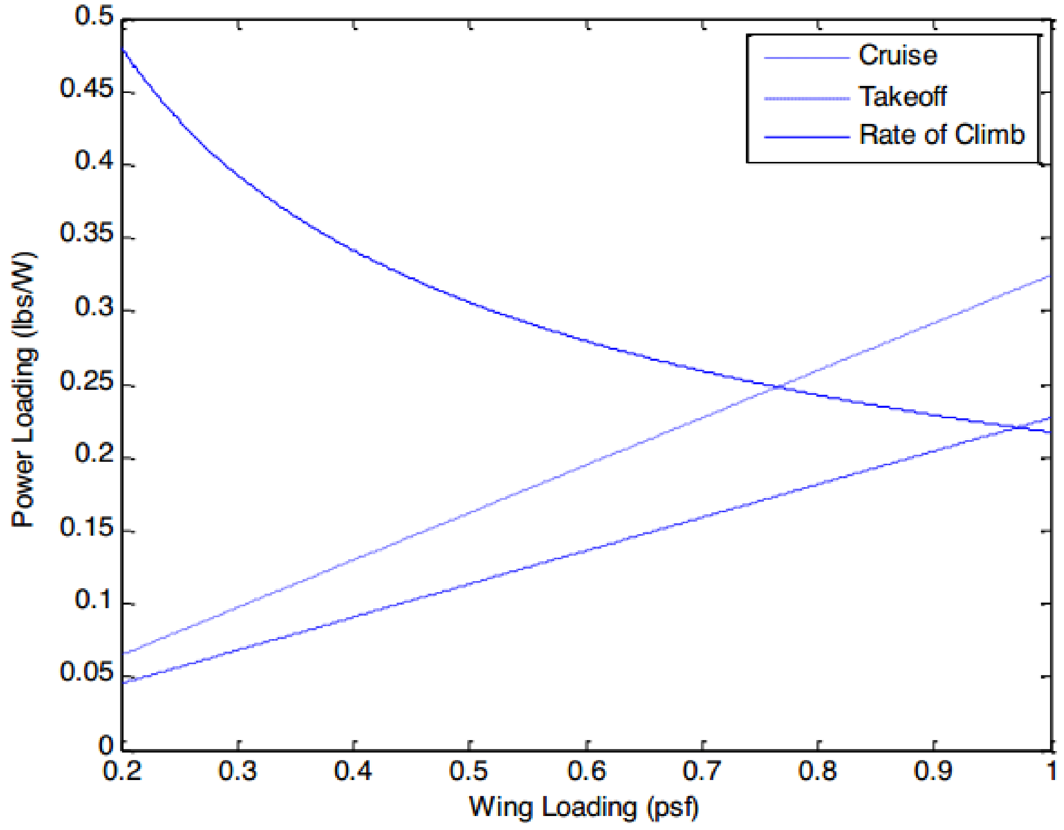


Figure 5Performance sizing graph

The force required and the wing zone for the flying machine can be resolved utilizing the wing stacking and control stacking values, as takes after:

$$\frac{W}{P} = 0.2204 \rightarrow P = \frac{W}{0.2204} = \frac{(10kg)(9.81\, m/s^2)(0.2248\, lb/N)}{0.2204} = 100.06W$$

$$\frac{W}{S} = 0.9715 \rightarrow S = \frac{W}{0.9715} = \frac{(10kg)(9.81\, m/s^2)(0.2248\, lb/N)}{0.9715} = 22.7ft^2 = 2.11m^2$$

Using the given aspect ratio of 12, the new wingspan can be solved as follows:

$$AR = \frac{b^2}{S} \rightarrow b = \sqrt{(AR)(S)} = \sqrt{(13)(2.11m^2)} = 5.24m$$

The new wing chord length can now be calculated as follows:

$$S = bc \rightarrow c = \frac{S}{b} = \frac{2.11m^2}{5.24m} = 0.403m$$

3.2.5 POWER ANALYSIS

The power available calculated using Figure 5 was approximately 100 W. This number excludes the efficiencies of the propeller or the motor to be used. Our initial estimate for the propeller efficiency and motor efficiency is 50% and 85% respectively. Therefore, the total amount of power necessary is solved in the following equation:

$$P = \frac{100.06W}{(0.5)(0.85)} = 235.4W$$

Since the force yielded by the sun based boards should be ascertained, along these lines, sun powered cell sort must be known in advance. The Auspice's S 32 sun based cell is our decision of this flying machine, on account of its low weight and high productivity. North made the counts fundamental on a design of 37 sunlight based cells associated twice in arrangement, and the subsequent aggregate force yield was roughly 31 W. Utilizing the same setup, the force yield per sun powered cell is approximately 0.41 watts for each sun powered cell. By putting the measurements of the sun powered cell to be 31.8 mm by 73 mm into thought, the most extreme number of sun oriented cells conceivable to mount onto the wing can is computed as takes after:

$$c = 0.403m \rightarrow y = \frac{0.403m}{0.0319m} = 12$$

$$b = 5.24m \rightarrow x = \frac{5.24m}{0.074m} = 70$$

The total number of solar cells possible to mount on the wing is 840. The output power of solar cells can be calculated at this moment, as the following:

$$P = (840sc)(0.42W/sc) = 350W$$

Consequently, our calculations show that the number of solar cells to fully power our aircraft is sufficient. However, this number does not put into consideration neither the camber of the airfoil nor weather conditions. It is also unreasonable to assume that the entire wing can be covered with solar cells, as control surfaces on the trailing edge of the wing are necessary, which will take the space, and not let solar panels mounted on.

3.2.6 Stall Speed

The following stall speed equation is provided by Ruska to evaluate steady level flight:

Equation 3.5: Stall Speed

$$V_{stall} = \sqrt{\frac{2W}{\rho S C_{L_{\max}}}}$$

Our aircraft's cruising altitude is decided to be at 2,001 m., which corresponds to a density of 1.0067 kg/m^3. Other variables such as the wing area, maximum lift coefficient, and the total mass of the aircraft need to be defined at this point in order to make the full calculations, which as shown before, these values are 2.12 m^2, 1.51, and 10.1 kg, respectively. To conclude, the stall speed can now be determined using the following equation:

$$V_{stall} = \sqrt{\frac{2W}{\rho S C_{L_{\max}}}} = \sqrt{\frac{2(10kg)(9.81\, m/s^2)}{(1.0066\, kg/m^3)(2.11m^2)(1.5)}} = 7.85\, m/s$$

3.2.7 Calculation of Lift

The calculation of lift equation

L = 1/2 *rho * velocity ^2 * coefficient of lift * surface area

Rho at sea level = 1.225kg/m^3

Velocity = 5.5m/s

Cl of naca 0012 at angle of attack = 0.805

Surface area in relations to the weight gotten from notchs matlab software = 2m

According to equation 3.1 we substituted this values of the parameters and the answer is given below:

Lift = 1/2 * 1.225*5.5^2 *0.805*2

Lift = 29.83 N

The drag of the wings

Drag = 1/2 *rho * velocity ^2 * coefficient of drag * surface area

Rho at sea level = 1.225kg/m^3

Velocity = 5.5m/s

Cd of naca 0012 at angle of attack = 0.0605

Surface area in relations to the weight gotten from notchs matlab software = 2m

we substitute the parameters and got the answer below

Drag = 1/2 * 1.225*5.5^2 *0.0605*2

Drag = 2.4 N

3.2.8 Dynamic Thrust Equation

F=1.225*(π (0.0254*d) ^2)*(RPMprop*0.0254*pitch*1/60) ^2((RPMprop*0.0254*pitch*1/60)*VO))*(d/3.29546*pitch) ^1.5

Pitch = 5inches

Diameter = 9inches

RPM = KV* volt = 1400*11.1 =1540rpm

Velocity = 5.5m/s

F=1.225*(pi (0.0254*9) ^2)*(15540*0.0254*5*1/60) ^2((15540*0.0254*pitch*1/60)*5.5))*(9/3.29546*5) ^1.5

F = 1.225*3.324*182-(164.465*0.4)

F = 494.458 - 65.786

F = 428.67N

3.3 Wing Configuration

3.3.1) Wing Configuration, advantages, disadvantages

The arrangements of UAV's may contrast starting with one then onto the next, yet picking the best setup would be founded on some components, for example, strength, power of the structure, plan straightforwardness, weight, most extreme lift. There are diverse sorts of wing arrangements,

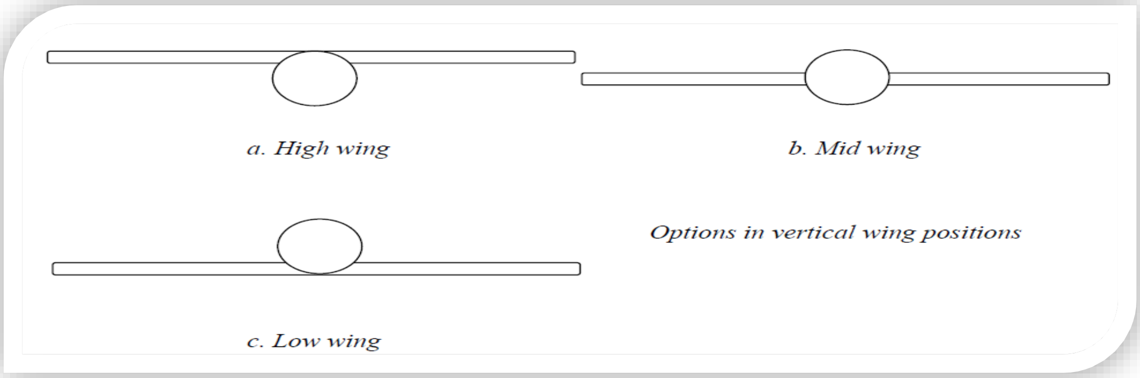
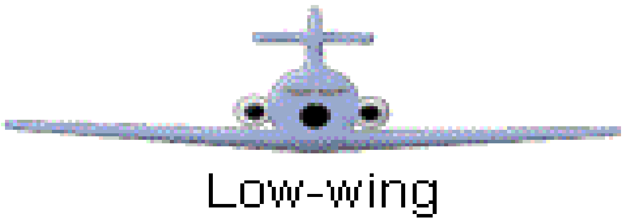
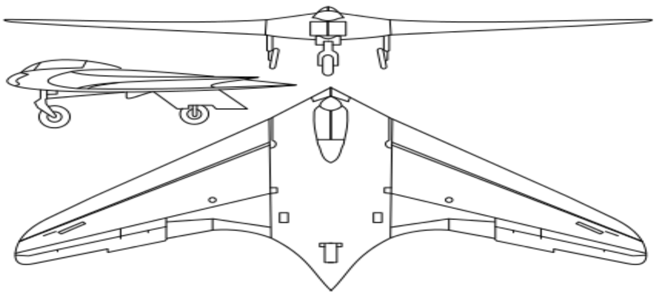


Figure 6 wing types

Table 9Type of wing configurations and advantages

Type of wing and advantages , disadvantages	Configuration
High wing 1. The air ship gives steady execution and operation qualities over an extensive variety of payload, force plants, fuel frameworks, working situations, sensor and information recording gear and mission profiles.	 **manufacturing difficulty: Easy**
Mid wing he mid wing has certain inconveniences with regards to basic outline similarly as traveler and payload flying machine are concerned-the wing will need to either go through the fuselage, eating into usable volume or the structure must be fortified around the fuselage to convey the heaps..	 **manufacturing difficulty: medium**
Low wing 1. Most planes convey fuel in the wings and the fuel ports of a low wing general flying plane are anything but difficult to reach. 2. The apparatus on a low wing plane are altered or drop down from the wing and can be dispersed more extensive separated than landing gear which must be appended to the fuselage of a high wing plane. 3. The arrival rigging of a low wing plane can be mounted straight here and there, which permits a more powerful stun assimilation framework. 4. Low wing arrangement on a plane give better visibility above and then the sides of the air ship	 **manufacturing difficulty: hard**
Flying wing With the absence of a back stabilizer, flying wings rush to change pitch and can likewise roll quickly. Not for the average amateur	 **manufacturing difficulty: hard**

1. High wing 2. Mid wing 3. Low wing

aircraft with different wing vertical positions

1. Cargo aircraft Lockheed Martin C-130J Hercules (high wing) (Courtesy of Antony Osborne)

2. Passenger aircraft Boeing 767 (low wing) (Courtesy of Anne Deus)

3. Military aircraft Hawker Sea Hawk FGA6 (midwing)

Figure 7wing type examples

Based on the design requirements and flight patterns desired for the solar UAV a pughs matrix would be used to analyses various criteria and select the one that best meets our design requirement

Criteria analysis for selection matrix

2= totally meets the reference criteria

0 = neutrally meets the reference criteria

-2= reference criteria doesn't meet the configuration

Table 10Selection Matrix for wing configuration

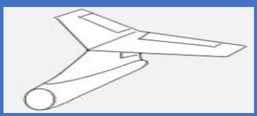
	High Wing	Mid Wing	Low Wing	Glide Wing
cost	2	0	2	0
availability	2	2	0	0
Stability	2	2	2	-2
Manufacturing	2	0	-2	-2
Assembly	2	0	-2	2
Net 2	10	4	4	2
Net 0	0	0	0	0
Net -2	0	0	-4	-4
Net total	10	2	0	-2
Configuration	High	Mid	Low	Glide
Select?	Select	Select	Do not select	Do not select

3.3.2) Tail Configuration

The configuration of the tail of an aircraft directly affects the flight characteristics, its determination is related to various parameters which includes security, mass, glide ratio, yaw effect etc. There are different tail configuration, each of them having a distinct characteristic

The tail of an aircraft determines the stability of the aircraft while in flight, climb, cruise or landing. Evaluation of different tail configuration against certain criteria's are done to determine the tail configuration that meets our design requirement

Table 11various tail configuration

Types of tails	Advantages	Disadvantages
T-tail 	• Enables smaller area of tail • It has a good glide ratio • Aerodynamically efficient	• Stalls easily • Difficult to manufacture • Difficulty in assembly
V-tail 	• Easy to assemble • Stable flight properties • Enables easy takeoff and landing	• Difficulty in assembly • Yaw effect on the plane • Induced drag
Conventional Tail (inverted T) 	• Provides easier control • Better yaw and twist ratio • Steady flight	• Has a low glide ratio • Produces a lot of drag

Criteria analysis for selection matrix

2= totally meets the reference criteria

0 = neutrally meets the reference criteria

-2= reference criteria doesn't meet the configuration

Table 12Selection Matrix for tail configuration

	T-tail	V-tail	Inverted T-tail
Cost	0	2	0
Availability	2	0	2
Stability in flight	0	2	0
Glide ratio	2	-2	0
Weight	-2	2	-2
Net 2	4	6	2
Net 0	1	0	0
Net -2	-2	-2	-2
Net total	2	4	0
Configuration	T	V	Inverted T
Select?	Select	Select	Do not select

3.4 Material selection

The properties of the material that would be used in the assembly and manufacturing of the solar UAV play a key role in the dynamic efficiency of the UAV , different parts and components require different materials properties to suite the propose of the application . The overall basic characteristic of the material should have great strength values both in tension and compression, the loading experience by the aircraft is a dynamic transient load, and it varies with time and location. To select a suitable material which meet the design criteria we are going to use analysis derived from Ashby charts.

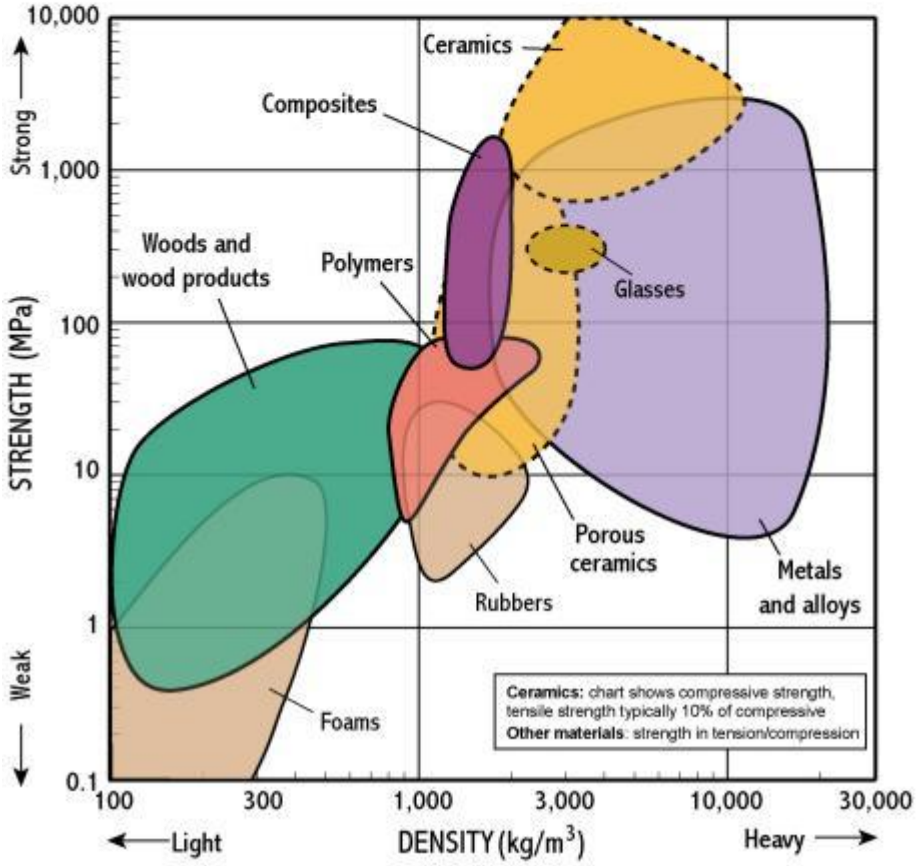


Figure 8strength vs density from Ashby chartFrom the Ashby chart above it can be seen that wood as high strength compared to density here by having the great value of strength to density ratio which is suitable for our design.

Table 13selection matrix for wood type

Wood	Beech wood	Balsa wood	Mahogany wood	Oak wood
cost	2	0	2	0
availability	2	2	0	0
Stability	2	2	2	-2
Manufacturing	2	0	-2	-2
Assembly	2	0	-2	2
Sum 2	10	4	4	2
Sum 0	0	0	0	0
Sum -2	0	0	-4	-4
Net	10	2	0	-2
Rank	T1	T2	T3	T3
Continue?	Yes	Yes	No	No

3.5) Electrical component

3.5.1) Propeller

For the selection of the propeller there a lots of parameters to be taken into consideration. This parameters are directly related to the operation of the propeller such as speed, pitch and diameter of the propeller. The pitch is the lateral distance the propeller ravels in one full revolution, the sped is how fast the propeller revolves per minutes or seconds. The diameter is a function of the size of the diameter, it is related to the swept area of the diameter. The effect of having a large propeller size makes the propeller spin slowly while generating more torque, this makes it easier for takeoff and landing of the aircraft. The smaller propeller spins faster which generates less torque and makes taking off of the aircraft more difficult but the aircrafts flies faster. The selection of the propeller is directly related to the voltage of the motor. Various motors have a specified kV range for which the motor can operate, motors with lower kV would spin less while those with higher kV would spin faster

3.5.2) Motor

Distinctive components ought to be considered amid selecting an engine for the air ship. The initial phase in selecting an engine is to decide how the engine will be introduced in the air ship. In the event that the engine will be settled in an encased region and can't turn, an in-runner ought to be utilized as all the moving parts of the air ship with the exception of the propeller shaft are inner. An out-runner ought to be utilized, if the engine is proposed to be put in a region where it is allowed to turn. In light of higher torque is asked for, so we would choose brushless out-runner for the configuration. The determination of the engine is as per the detail of the propeller, to get the greatest push and productivity.

3.5.3) Electric speed controllers (ESC)

The electronic rate control (ESC) is an electronic circuit which is utilized to shift electric engine's speed, its course and in the event that it is conceivable to go about as a dynamic brake. ESCs are for the most part utilized on electrically fueled radio controlled models and the reason for existing is to alter the battery’s dc voltage to a three beat voltage line, the three beat voltage line exist out of stage by 120 degrees. The pulse width modulator affects the electrical control speed of the aircraft assembly. This means the rpm of the aircraft engine is controlled by altering the betas obligation cycle by changing the throttle position on the transmitter.

The electronic speed controller is an individual component which connects the position of the throttle on an aircraft radio control to the speed of the engine (RPM), the esc is a control unit of the aircraft in terms of the speed of the aircraft

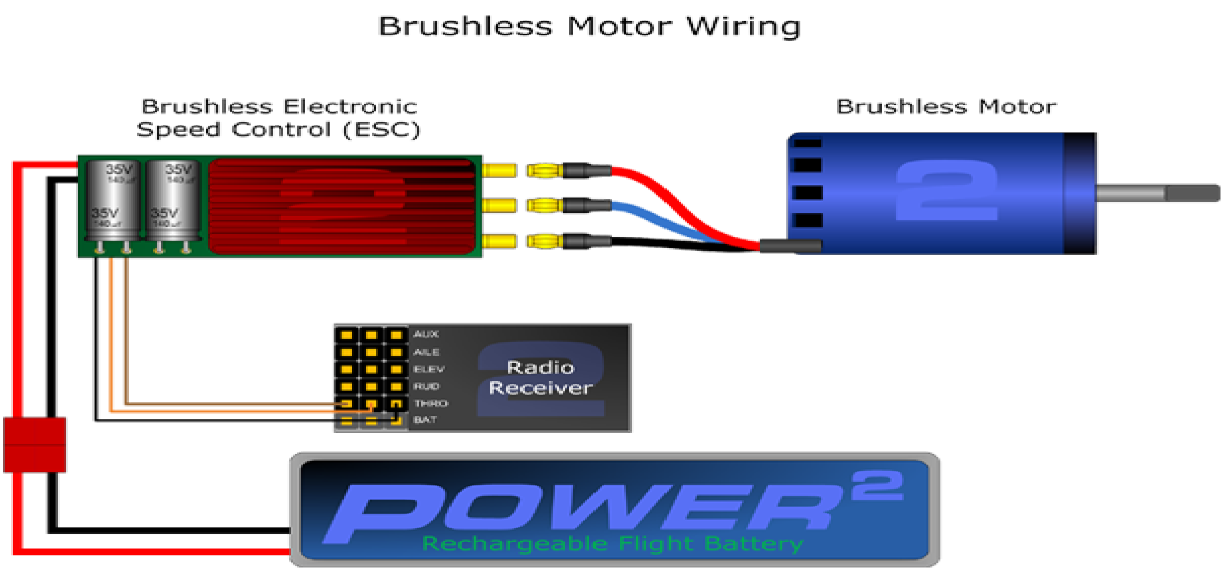


Figure 9Electric speed controller

The components connection structure is shown in (figure 9), from the figure three connections exist the first one goes from the battery to the solar panel. A lot of parts of the aircraft like motor and receivers need some amount of electric current to function .the electric speed controller distributes the required amount of current to various subsystems , signals are sent from the receiver to the ESC ,this signals are sent by the second connection, and the third is to the motor. Signals are sent from the receivers to the ESC these singles are used to calculate the power required to keep the motor at a desired speed.

3.5.4) Servos

the flight pattern of an aircraft are controlled by certain subassemblies built into the wings. These parts are elevators and ailerons, servos mission is to control these parts. The receiver sends pulses to Servos, based on the signals received by the servo and the orientation of the servos, the servos then turn, which would change the position of the flaps or aileron which then affects the flight pattern and the direction the aircraft flies. The control of this parts by the servos is possible due to the connection from the servos to the ailerons and flaps by the help of a push rod.

3.5.5) Batteries

some characteristics are important for the selecting of the battery, one of the important is the math. The discharge rate is another characteristic, it shows the maximum rate at which a selected battery can discharge its current, the second most important characteristic is its voltage, and this is the most important part of any battery. The battery should be selected carefully because if the wrong one is selected it may damage the ESC and the motor. So after the calculation of the power requirement from the battery has been made, the selected battery must not exceed the required power output in order to avoid damaging the subsystems.

Figure 10lithium polymer battery turnigy

3.5.6) Transmitters

Transmitters are radio operating devices which controls the aircrafts flight, throttle speed through radio signals sent from the transmitter to the aircrafts reciever.the receiver converts the radio signals to electrical signal which is then directed to the sub-components of the aircraft. There are four main operating modes

Control mode 1

The elevator and the rudder is controlled by altering the left stick, while the throttle and aileron is controlled by altering the right stick.

Figure 11Control mode 1

Control Mode 2

The elevator and the ailerons is controlled by altering the right stick, while the throttle and rudder is controlled by altering the left stick.

Figure 12Control mode 2

Control Mode 3

The elevator and the ailerons is controlled by altering the left stick, while the throttle and rudder is controlled by altering the right stick.

Figure 13Control mode 3

Control Mode 4

The elevator and the rudder is controlled by altering the right stick, while the throttle and aileron is controlled by altering the left stick.

Figure 14: Figure 14Control mode 4

All the arc transmitters operate the same, the only difference is in the configuration of the receiver

3.6 Solar Irradiation

The light even worldwide guide of Cyprus depends on the information gotten in the month of April 2009 till the month of March 2010 on a year's normal daylight gave by solar GIS database

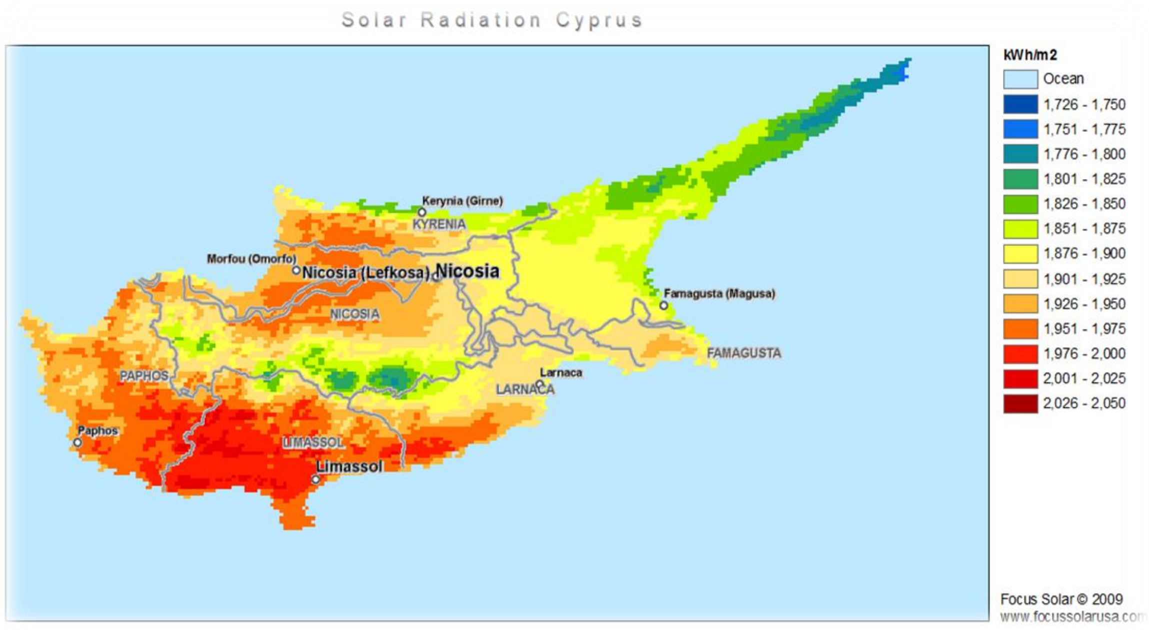


Figure 15solar radiation map at different geographic location in Cyprus

Cyprus worldwide level radiation climate information is appeared in figure 15 it distinguishes the worldwide radiation all during that time of the month. As appeared in the figure, in the late spring the worldwide radiation tops amid late morning which has a value of 1001W/m2

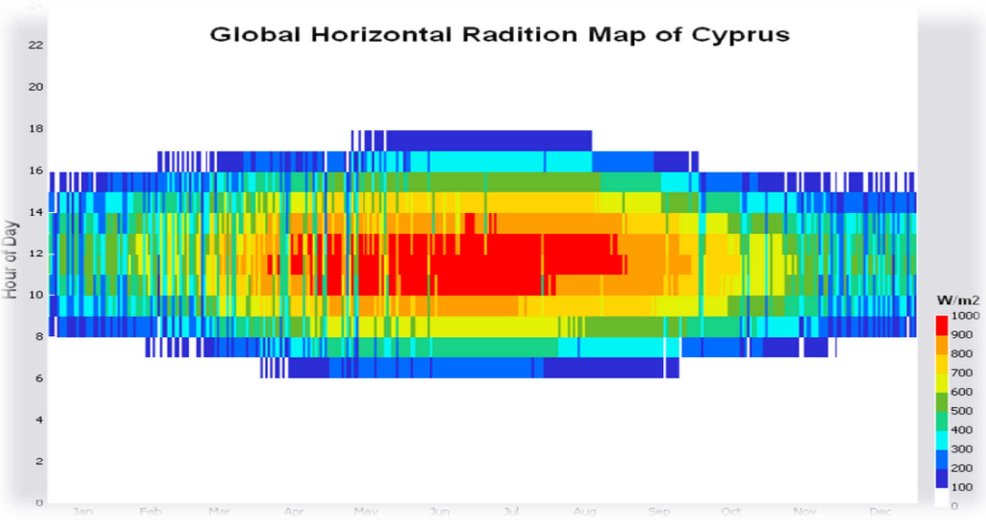


Figure 16map of average global radiation in Cyprus

In figure 16 it is clearly seen that the worldwide flat radiation lowest values occur at the winter time of around 451W/m2 and persistently increment occurs in the mid-year and achieves the most extreme amid in between the months of june qnd july around 951W/m2. Additionally it was shown in figure 15 that irradiation drops amid the period of winter .The sky becomes more cloudy which overshadows the incoming beam which results in lower efficiencies of the sun oriented cells.primarily two parameters are generally considered , The highest value of IMAX and the lowest value. The region under the bend is the day by day sun powered vitality per square meter which would be computed utilizing the condition. Efficiency is a consistent for overcast days with qualities 1 for a crisp morning and 0 for haziness.

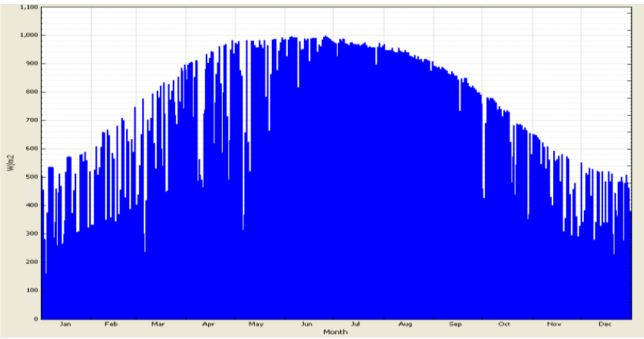


Figure 17The average Global continuous radiation in Cyprus

The estimations of IMAX and Today are acquired from the figures over, that gives data about our area which is Cyprus.

3.7) system break down structure

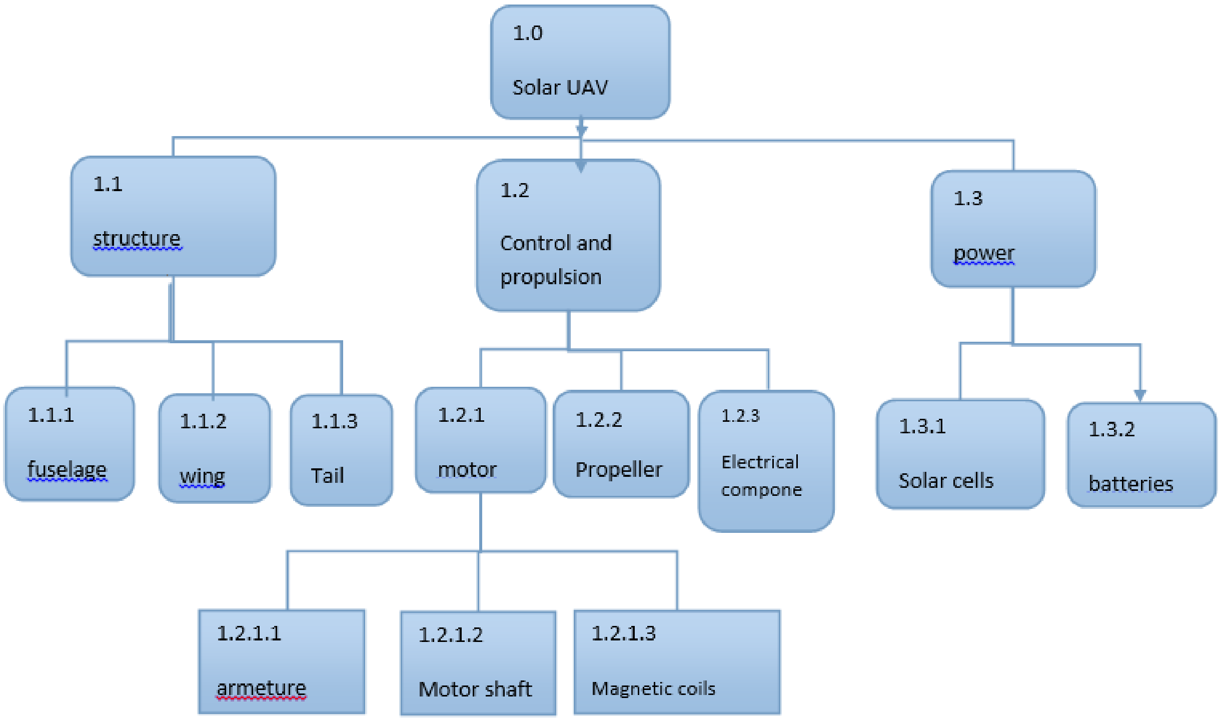


Figure 18system breakdown structure into subcomponents

3.8 Design Technique and Application

The design approach and technique applied in this design is based on notchs design of a solar-powered plane, the variable parameters in the design such as aspect ratio, wing load, wing area are varied and iterated with the help of a MATLAB program, inserting this design parameters in the program provides a preliminary results that are applied to the design process

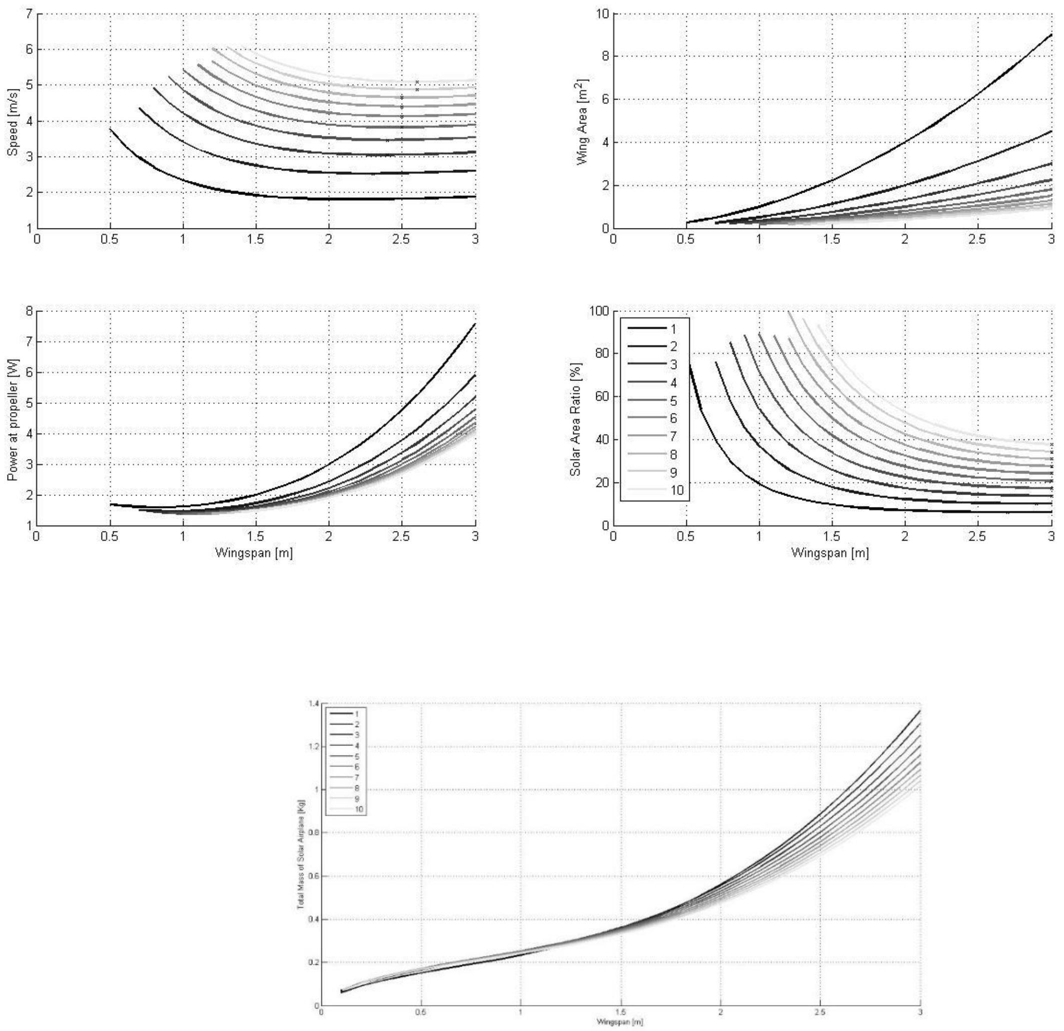


Figure 19Conceptual design graphs for different aspect ratios

The graph shown above was gotten from mat lab software, certain analysis were made to decide the final design concept, the graph was iterated for a combination of certain parameters the most suitable wing configuration was gotten to be 0.5m - 1.7m which is suitable for a mini uav . A problem encountered with small wing area is the small solar area ratio, the most favorable aspect ratio lies between 6-8.

3.9) Airfoil selection

An airfoil is the cross sectional shape of the wing of an aircraft, the airfoil characteristics have a great effect on the performance of the aircraft, in this design the aerodynamics characteristic of the airfoil would be selected that would enable the solar cells be placed on them and having minimal effect on the aerodynamic performance of the wing. A selection was made from the National Advisory Committee for Aeronautics (NACA). A NACA 0012 airfoil is selected, various iterations were performed using XFLR5 software to determine the various performance of airfoils, and the NACA 0012 airfoil was most suitable for the design

Figure 20 NACA0012 Airfoil

3.9.1) Airfoil Analysis with XFLR5

The analysis of the flow of winds and its effect as a function of the Reynolds number, angle of attack and camber on the airfoil would be gotten from analysis carried out on the software xflr5, this analysis would be done for the ranges of Reynolds number from 30000 to 100000

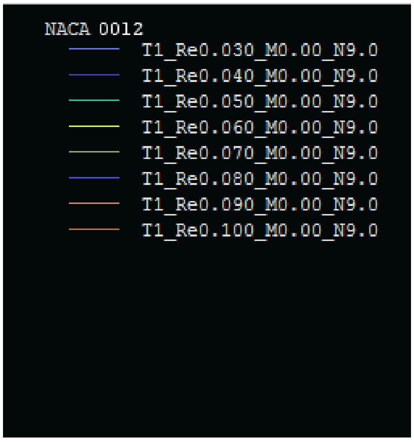


Figure 21The ranges of Reynolds number used in analysis by XFLR5

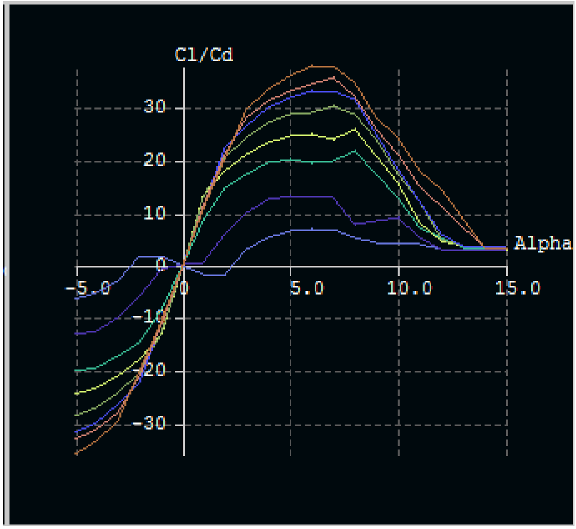


Figure 22A graphical representation of the ratio of coefficient of lift against coefficient of drag for NACA0012 gotten from XFLR5

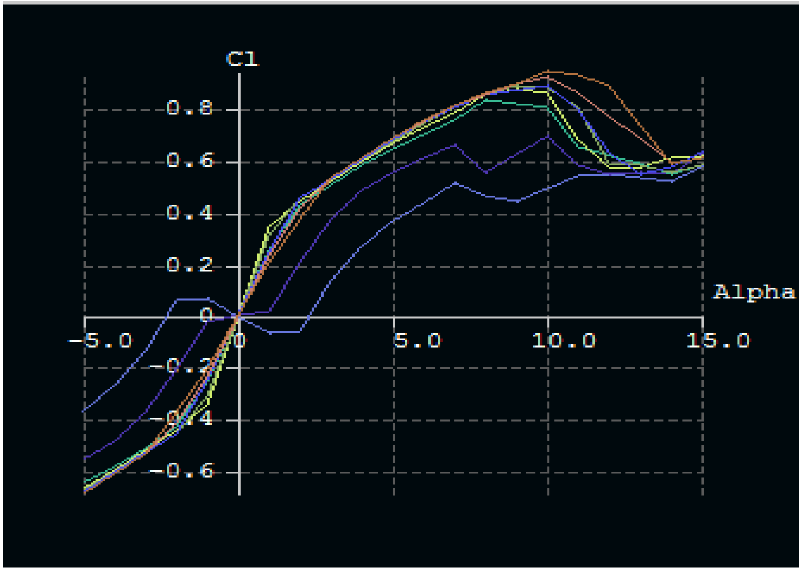


Figure 23A graphical representation of the ratio of coefficient of lift against angle of attack for NACA0012 gotten from XFLR5

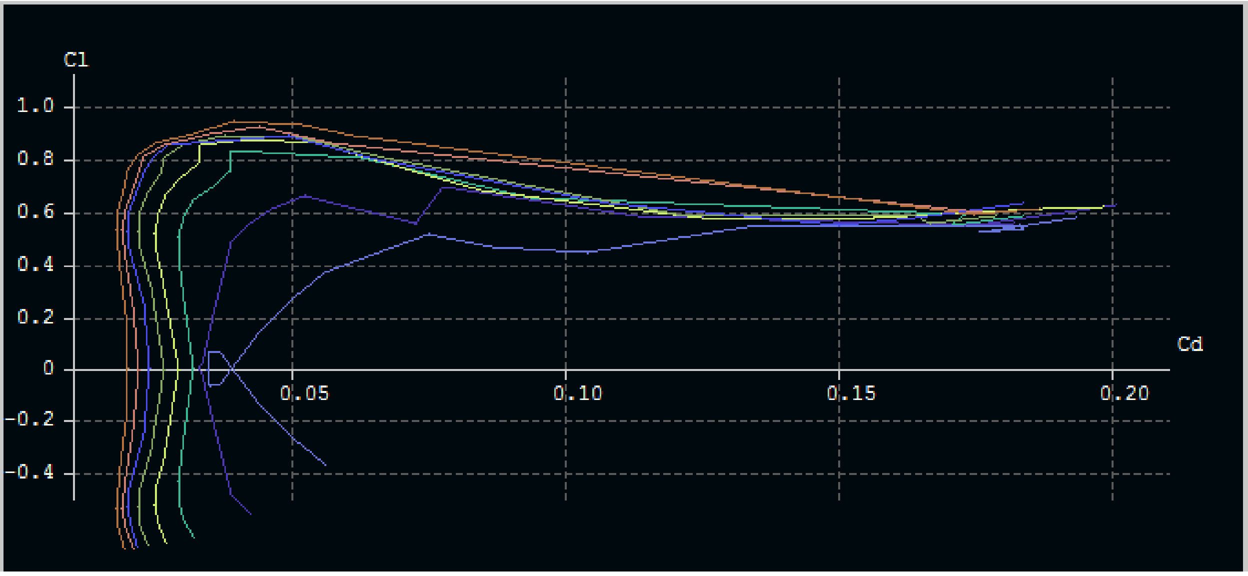


Figure 24A graphical representation of the ratio of lift to drag for NACA0012 gotten from XFLR5

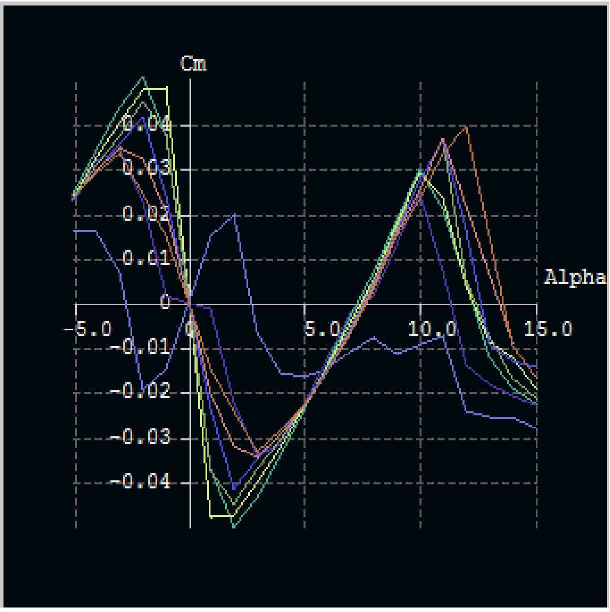


Figure 25A graphical representation of the ratioof the coefficient of moment against angle of attack for NACA0012 gotten from XFLR5

3.9.2) Tail Airfoil Analysis

The tail wing configuration a NACA 0006 the reason for selecting this airfoil is due to the simplicity in creating it, the symmetric property of the airfoil. This makes it easier to control in flight and it possesses great in flight stability

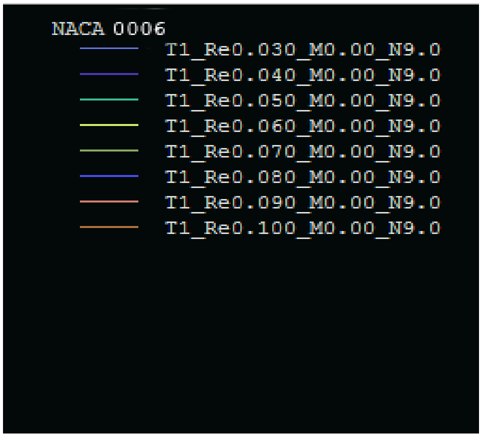


Figure 26The ranges of Reynolds number used in analysis by XFLR5

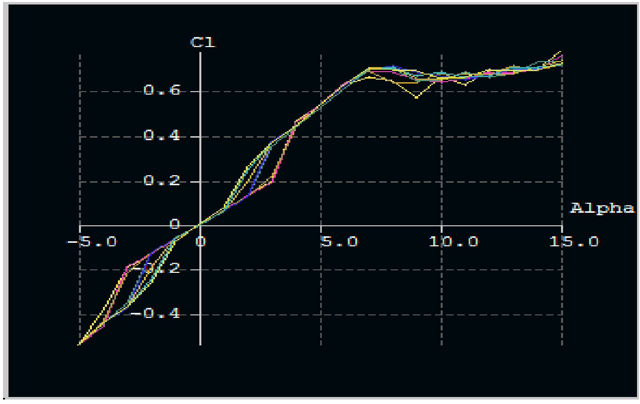


Figure 27A graphical representation of the ratio of coefficient of lift against coefficient of drag for NACA0006 gotten from XFLR5

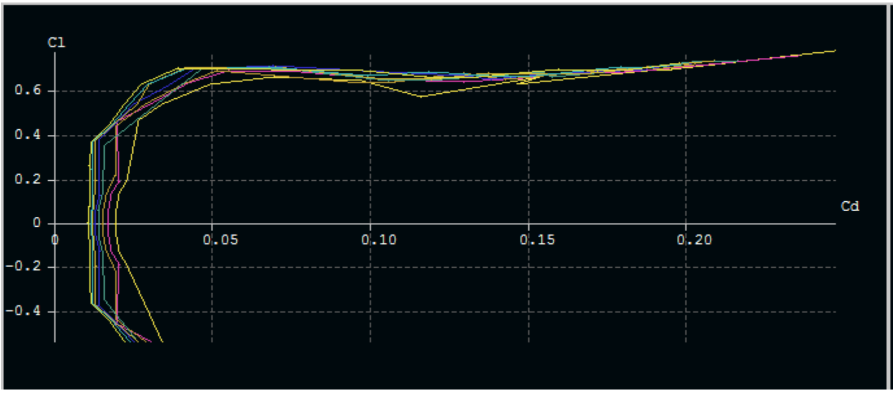


Figure 28A graphical representation of the ratio of lift to drag for NACA0006 gotten from XFLR5

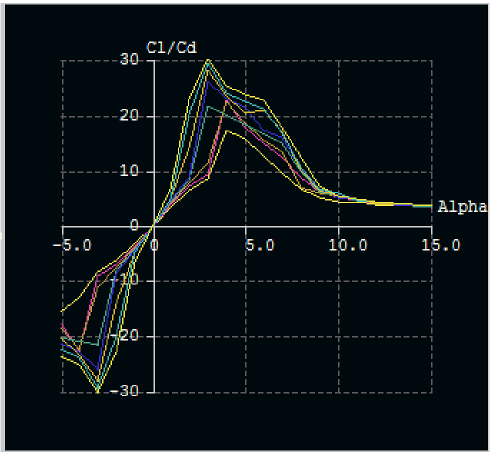


Figure 29A graphical representation of the ratio of coefficient of lift against angle of attack for NACA0006 gotten from XFLR5

3.10 Manufacturing and Assembly

The manufacturing process to be followed for the fabrication and assembly of the solar UAV would be done in accordant with quality function dialysis [QFD]. The main constraint of the solar uav is that it should be light weight, high tensile and compressive strength for dynamic and transient loading experience by the solar UAV in flight. The material which was selected based on the Ashby chart of strength vs density for our design was balsa wood. Airfoils section of the wings would be cut out using a CNC machine which would produce an asymmetric airfoil based on the data of NACA0012 airfoil.

The wings would then be covered by thin slices of balsa wood, with the help of cyatonnate glue which will then be sandpapered to have a smooth finishing. The section of the fuselage would be cut in concentric series following the shape and details of the fuselage drawn in solid works, stripes of thin layers of balsa wood would be assembled in series and fitted onto the fuselage to assume the fuselage desired shape, the excessive parts would be sand papered. The motor of the UAV would be mounted onto the front section of the UAV. There would be a vibration dynamic damper to help reduce the vibration from the motor transmitted to the solar UAV. A rectangular section would be cut out on the wings of the UAV to fit in the solar panel. Which would be protected by an insulated enclosure from all sides. The tail section would be connected to the fuselage with the help of carbon fiber.

Conclusion

Solar oriented UAV has been analyzed in details in this report, which includes the design considerations, assembly technique and configuration selection for the uav depending to the purpose of the. Various configurations were considered and were weighed against fixed design parameters in the election matrix, the configuration which was selected is that of a high wing owing to the fact that a high wing poses more inflight stability , gives room for error and possess steady flight properties which is most suitable for our design purpose. The tail configuration is a vtail configuration, this provides stable takeoff and landing and steady cruise. The design iteration for the power in relation to the mass was gotten from the matlabcode for RC planes by NOTH's configuration. For the material selection the two primary criteria were cost and availability, the materials were compared against other fixed criteria and the most cost efficient material which suits our design purpose was chosen. The selected solar uav configuration is cost effective and efficient.

APPENDIX A

APPENDIX A

LOG BOOK

Ibrahim akandes log book

DATE	DURATION	TASK PERFOMED	OBJECTIVE
4/4/2016	3 HOURS	First meeting with our supervisor , disused about the capstone project	Explanation of the capstone design
6/4/2016	2 hours	Meeting with group members to brainstoirm on possible concepts and ideas	To find the best and most suitable idea to implement for the capstone
7/4/2016	1hour	Research and reading on various designs of solar uav	To gain understanding and theoretical knowledge of the design of a UAV
9/4/2016	3 hours	Design and implementation of matlab program for the selection of mass, wing span , aspect ratio configuratiuon	Using matlab program to determine critical design factors
12/4/2016	2 hours	Meeting with group members , discussion of design parameters and constraints	Determination of certain variables that can be varied to best suit the design
14/4/2016	1 hours	Selection of aerofoil, length of the wing, overall camber of the plane fuselage	Selection of the characteristics attribute of the uav assemble

15/5/2016	4 hours	Perfoming of airflow simulation o ver the wing, wing analysis using the software X5FLR	To ascertain if the flow of wind and the effect of the aerofoils shape are good enough to be implemented
17/4/2016	6 hours	Drawing and design of the uav body parts on solidworks software	To have a visual prototype of the uav, and also develop a proof of concept
19/4/2016	2 hours	Running notch matlab code for solar uav	Writing of the first chapter of the report
20/4/2016	2hours	Varying the input parameters in notchs matlab code to suit our design	To maximise efficiency of our design
21/4/2016	3 hours	Definition of range of reynolds number for the uav flight	To adjust the flight pattern of UAV
21/4/2016	1 hour	Drawing up of pughs matrix for selection of tail configuration	To select a robust wing and tail configuration
22/4/2016	1 hour	Writing of chapter 3 design and calculation	For the literature aspect in the report
23/4/2016	2hours	Calculation of aerodynamic forces for chapter 3	Determination of the forces experienced by UAV
24/4/2016	1 hour	Drawing of the wings of the uav solidwork	To have a visual representation of the part

25/4/2016	1 hour	Drawing of the fuselage uav solid work	To have a visual representation of the part
27/4/2016	1 hour	Drawing of the tail uav solid works	To have a visual representation of the part
30/4/2016	30 minutes	Drawing of the propeller uav in solidworks	To have a visual representation of the part
2/5/2016	3hours	Drawing of the motor in solidworks	To have a visual representation of the part
4/5/2016	1 hour	Assembly of the individual components in solid works	To have a visual representation of the total assembly

DATE	WORK PERFORMED
2016/03/28	**Drawing solid work part 2 assembly**
2016/04/04	**Meeting with the supervisor , Writing literal review.**
2016/04/28	**Research about future consideration of solar UAV Writing other UAV studies**
2016/04/30	**Doing research about history of solar-powered flight Defining initial parameters in matlab**
2016/05/02	**Conceptual design calculation analysis For flight endurance**
2016/05/04	**Iterations of defferent mechanical Component efficiency against the overall Dynamic flight efficiency in matlab**
2016/05/06	**Doing a research on stall speed and power analysis writing the power analysis**
2016/05/12	**Studying wing configurations. advantages , disadvantages making the table and comparison**

2016/05/13	**Performance constraints Analysis And comments**
2016/05/14	**stall speed –power analysis performance sizing graph**
2016/05/15	**Mating of mechanical component In the assembly Solidworks**
2016/05/16	**Making solar radiation tail configuration**

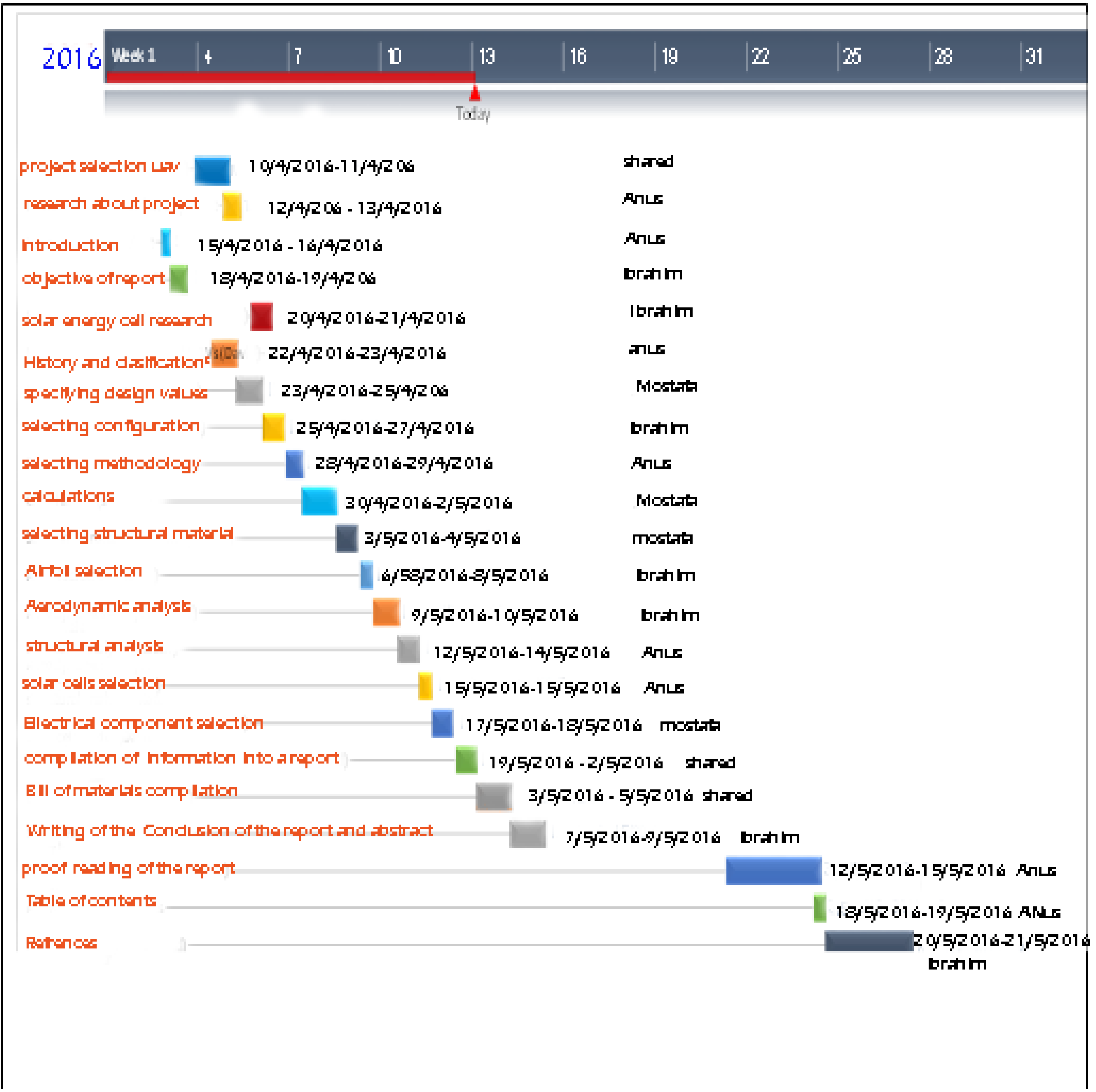
(ANOOSHIRAVAN ENSAFIAN LOG BOOK)

DATE	DURATION	TASK	INFORMATION
15/3/2016	2 hours	**History of UAV and Time line**	It is a studying about the history of (UAVs) which were first used during the American Civil War .
16/3/2016	3 hours	**COMPARATIVE STUDY OF SIMILAR AIRPLANES**	Helios Prototype ,Pathfinder , Venus exploration Solar Solitude, Solar Excel, SoLong, Zephyr, and the Sky-Sailor are used to make a comparison between similer UAVs types
17/3/2016	1 hour	**COMPARISON OF IMPORTANT DESIGN PARAMETERS**	Weight (kg), Endurance, Wingspan (in m) , Aspect Ratio are choosen to be studied for the studied types of the UAVs
19/3/2016	3 hours	**Drawing the fuselage**	Drawing the Fuselage of the aircraft using solid works software
21/3/2016		**Electrical Components**	It is a research about electrical components (propeller ,Motor , Electric speed controllers (ESC) ,Servos, Batteries, Solar panels ,Transmitters)

Moustafa hassan Log book

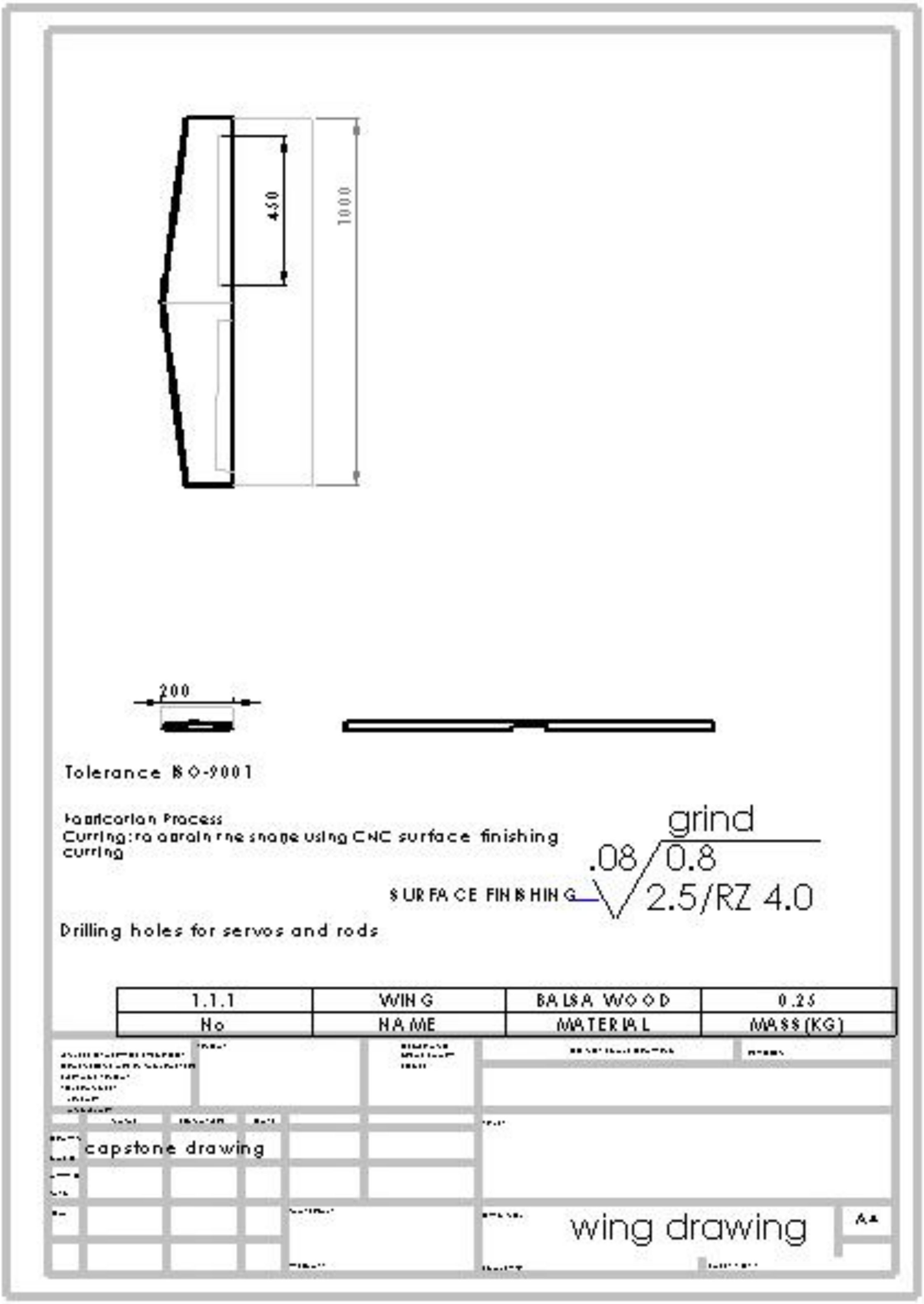
APPENDIX B

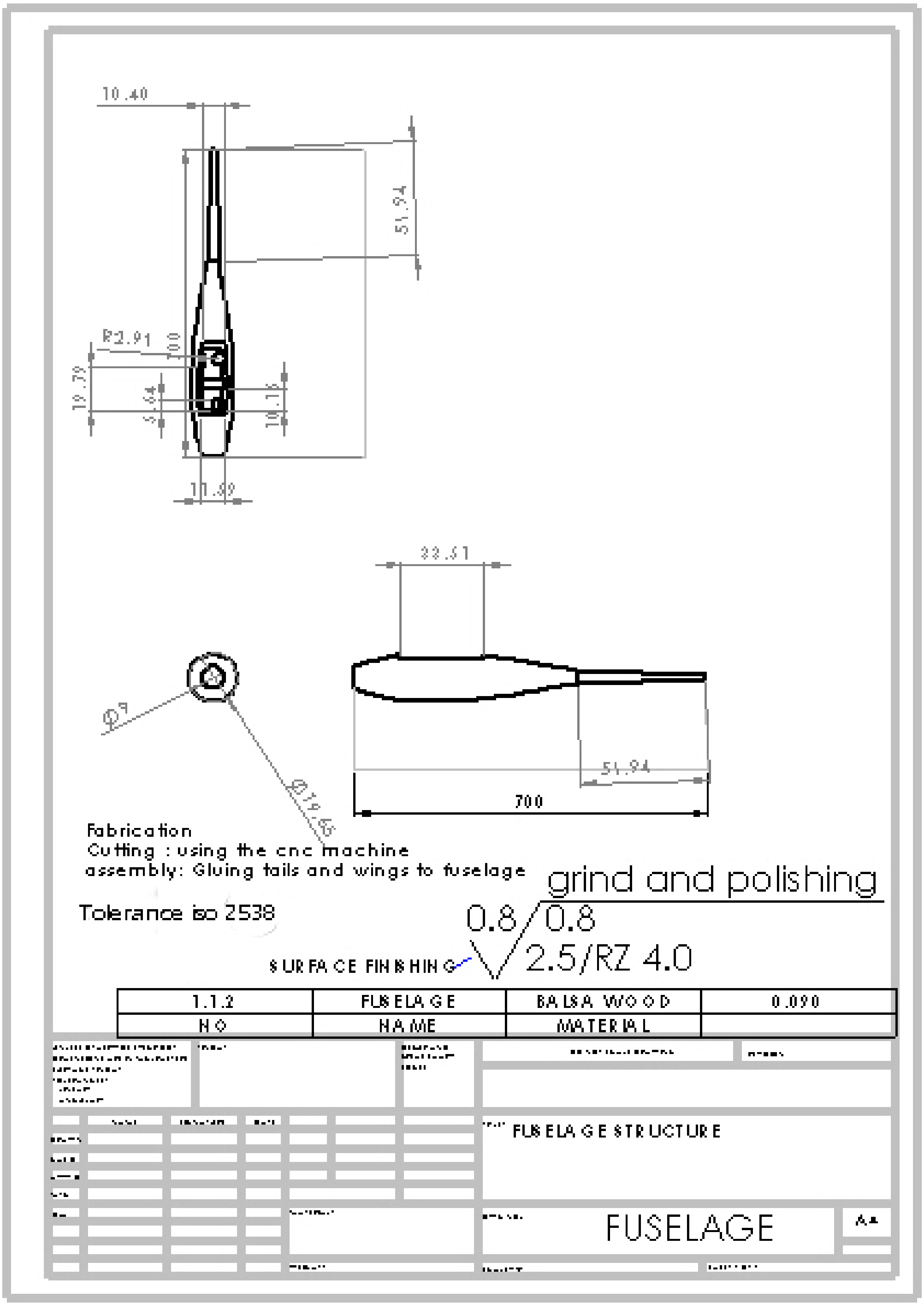
GANT CHART

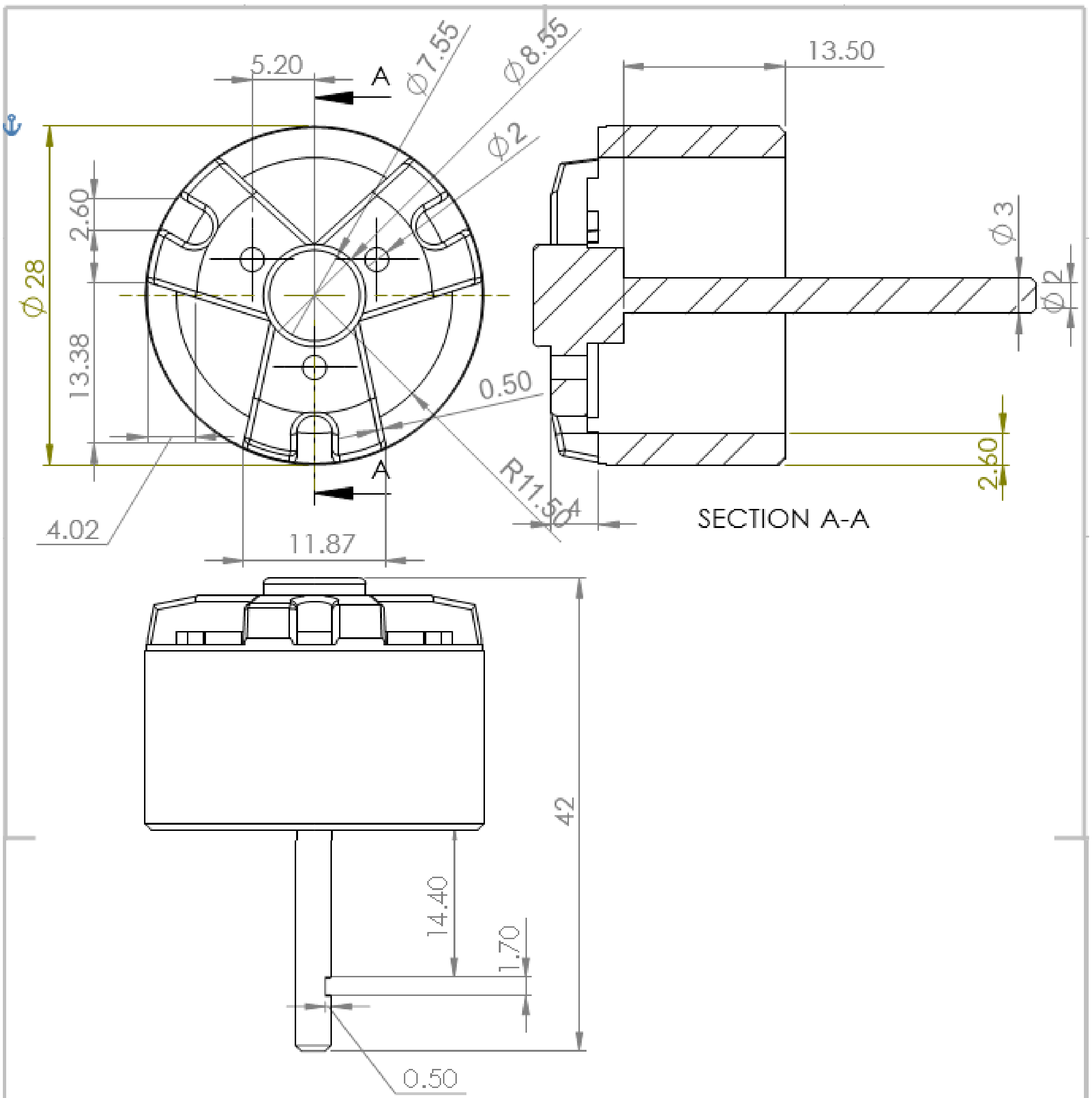


APPENDIX C

DRAWINGS




10.40
51.94
R2.91
19.70
5.64
10.15
11.82
22.51
Ø9
Ø19.65
51.94
700
Fabrication
Cutting : using the cnc machine
assembly: Gluing tails and wings to fuselage
Tolerance iso 2538
grind and polishing
0.8 / 0.8
2.5/RZ 4.0
SURFACE FINISHING
1.1.2
FUSELAGE
BALSA WOOD
0.090
NO
NAME
MATERIAL
FUSELAGE STRUCTURE
FUSELAGE
A4



NOTE

The Motor was adapted from GrabCAD.com

Tolerance: unless otherwise stated +/- 0.1mm

1.2.1	MOTOR	CARBON STEEL	0.067
NO.	NAME	MATERIAL	MASS(kg)

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION

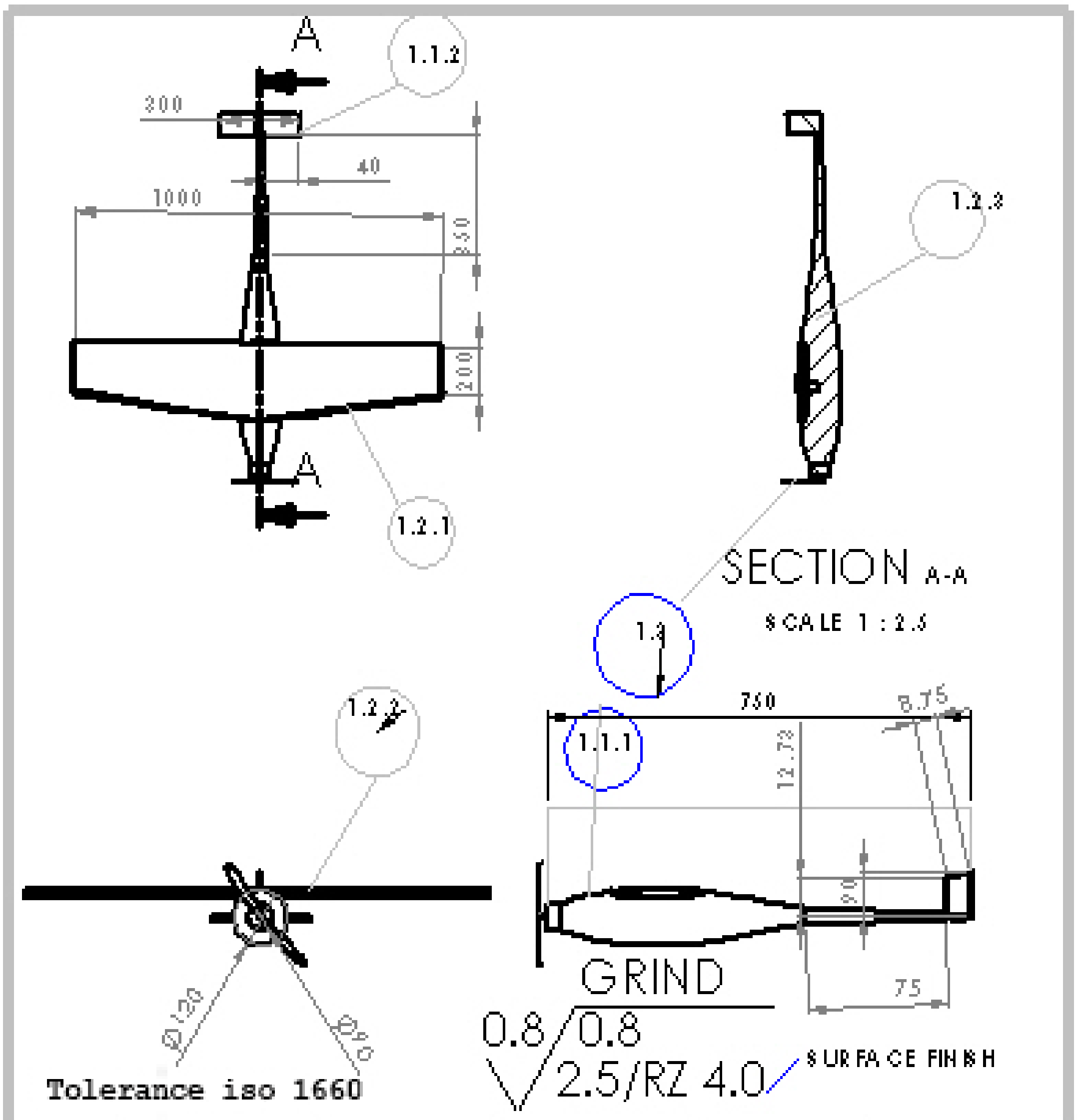
	NAME	SIGNATURE	DATE
DRAWN	D.D		12/12/2015
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE:

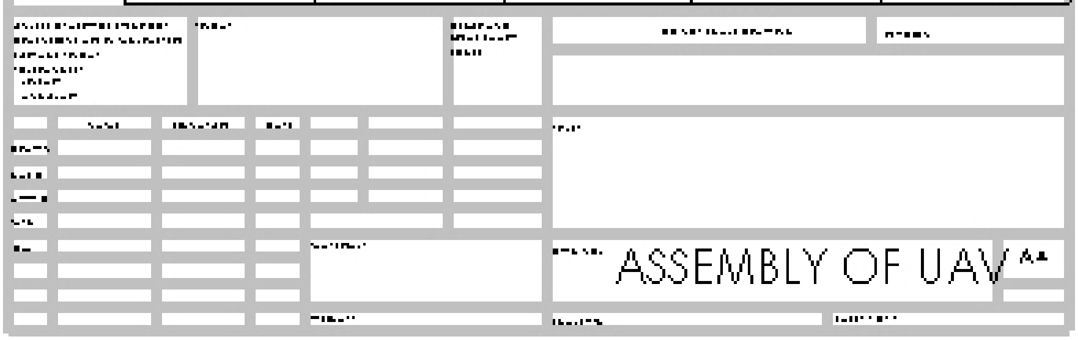
THE MOTOR

DWG NO.	DWG NO.	
1.2.1	MOTOR	A4
WEIGHT:	SCALE:2:1	SHEET 1 OF 1

1.1.2



1.1.1	FUSELAGE	BALSA	0.125	1
1.1.2	H TAIL	BALSA	0.075	1
1.2.1	WINGS	BALSA	0.44	1
1.2.2	AILERONS	BALSA	0.02	1
1.2.3	SECTION V	BALSA	0.085	1
1.3	PROPELLER	CARBON FIBER	0.03	1
DRAWING NO	NAME	MATERIAL	MASS	AMOUNT



APPENDIX D

	SOLAR UAV	SOLAR EXCEL	SUN SAILOR 1/	THE SOLARINE
Range (km)	33.5	48.5	140	11
Aspect ratio	14	13	13.45	5
Wing area m^2	1.5	0.35	1.65	0.145
Altitude m	1200	2065	200	450
Endurance minutes	30	690	-	60
Weight (kg)	0.45	0.72	3.6	0.75

TABLE D-1 TECHNICAL PARAMETERS OF OUR UAV WITH REFRENCE TO OTHER UAVS

mass	0.356kg
Total electric power	15.5w
Power for flight	1.085w
Max solar electric power	4.6432w
Level flight speed	5.69m/s
Total drag	0.1856
Wing surface area	0.1458m^2

Table D-2 the estimate for power and the mass of UAV gotten from mat lab code

SUBSTANCES	TIME (SECONDS)
STEEL (DEGREASED)	20-45
ALUMINIUM	2-10
ZINC DICHROMATE	10-30
ABS	1-2
PVC	3-10
BALSA WOOD	1
OAK WOOD	10-30
PLASTIC	10-20
FABRIC	5-10
LEATHER	10-20
CHIPBOARD	5-10

TABLE D-3 TIME TAKEN TO ACHIEBVE SHEAR STRENGTH OF 0.1N/M ON VARIOUS SUBSTANCES AT 72°F/50%

APPENDIX E

The information and description of electrical parts were all obtained from hobbyking.com

Electrical components description

Turnigy Glider Drive SK3 Competition Series - 3850 - 3.5 1400kv

Figure D-1: DC brushless motor

Specifications of motor

Specs:

Turns: 8T
The Voltage of the battery: 3~4S Lipoly
Revolution per minute/Voltage: 1400kv
The Poles of the motor: 14
The possessed Internal resistance: 0.016 Ohm
The Maximum Loading of motor: 47A
The Maximum Power of motor: 680W
The Shaft Diameter of the motor : 5mm
The Shaft Length of the motor: 20mm
Mounting screw Spacing: 25mm (M3x4)
The Connector wires of the motor: 3.5mm bullet
The Weight of the motor: 142g

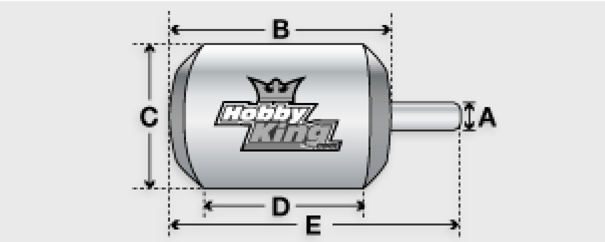


Figure D-2: brushless motor dimensions

Kv(revolutions per minute/Voltage)	1400
Weight(gramms)	142
The Maximum voltage	12.5
The length of Shaft A (millimeter)	6
The length of Length B(millimeter)	57
The Diameter C (millimeter)	32
The Total length E (millimeter)	40
The Can length c (millimeter)	80

Propeller

Carbon Fiber Propeller 10x5 Black (CW/CCW)

Figure D-3 carbon fiber propeller
Specifications
The Diameter of the propeller: 10 inch
The Pitch of the propeller: 5 inch
The Hub Thickness: 6.9mm
The Shaft Diameter of the propeller: 6-7mm
The Weight of the propeller: 15g each propeller

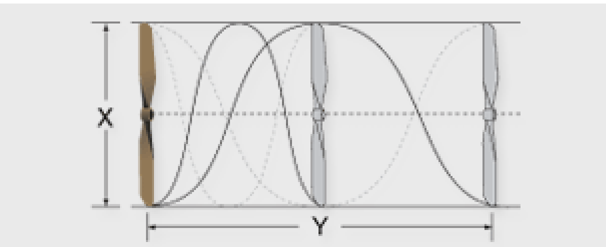


Figure D-4 Propeller dimensions

Length inch (x)	10
Pitch inches (y)	5

Batteries

Turnigy 2200mAh 3S 20C Lipo Pack

Figure D-5 Turnigy battery

Specifications
Spec.
Minimum Capacity: 2300mAh (True 100% Capacity)
Configuration: 3S1P / 11.1v / 3Cell
Constant Discharge: 20C
Peak Discharge (10sec): 30C
Pack Weight: 200g
Pack Size: 103 x 33 x 24mm
Charge Plug: JST-XH
Discharge Plug: XT60

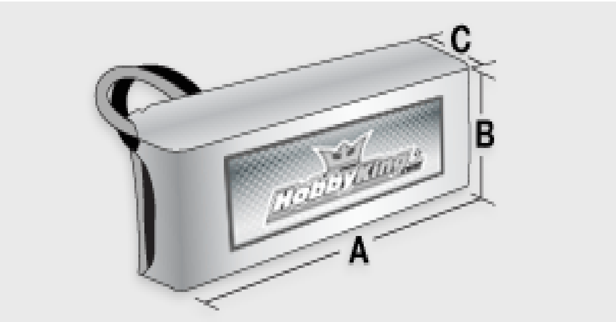


Figure D-6 : battery dimension

Capacity (mah)	2300
Config (s)	2.5
Discharge (columbs)	18
The Weight (grams)	200
Max charge rate (c)	4
Length A (millimeter)	150
Height B (millimeter)	40
Width C (millimeter)	30

Electronic speed controller

Hobbyking™ SS Series 50-60A ESC

Figure D-7:Electronic speed controller

Default settings:
• Brake off
• Lipoly battery
• Low voltage 3V per cell
• Standard rotation
• Auto timing
• Soft start
• Helicopter off
• Frequency 8kHz
• Low voltage-decrease power
Features:
• High performance microprocessor
• High RPM - Up to 210,000RPM (2 poles)
• Smooth linear throttle response
• Unique circuit design, strong anti-interference
• Low voltage cut-off protection
• Overheating protection
• Auto shut down when signal lost
• Easy throttle range calibration
• TX programing options
Specs:
The Maximum Current: 40 ampere
The Burst current :50 ampere
The Weight of the esc: 70gramms
The Size of the esc : 52x35x13mm
LiPoly: 2-7 cells
BEC: None

Servos

HobbyKing™ HK15178I High Speed Digital Metal Gear Servo BB 0.85kg / 0.06sec / 9.

Figure D8 servos

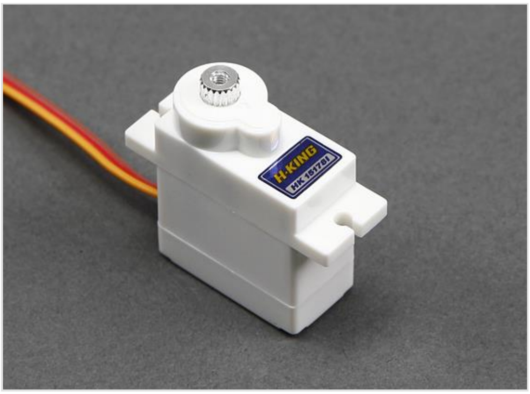


Figure D-9: A great little high speed digital servo suitable for many applications.

Spec:

Torque: **0.75kg/cm @ 4.8v, 0.85kg/cm @ 6v**

Speed: **0.08/60deg @ 4.8v, 0.06/60deg @ 6v**

Voltage: **4.5~6v**

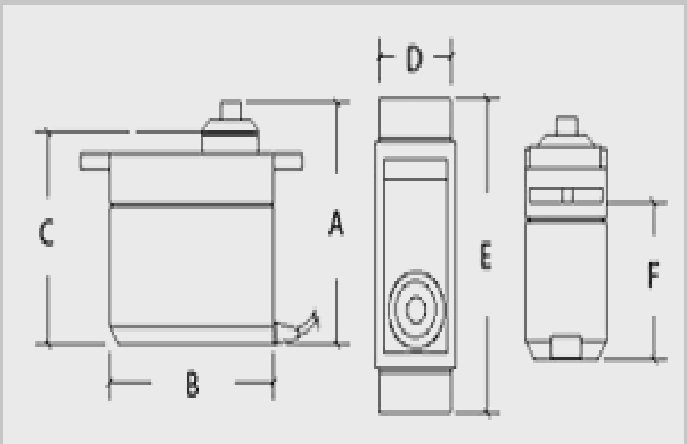
Plug: **JR style**

Dimensions: **22.9 x 12 x 27.3mm**

Weight: **9.8g**

Product Config Table

Weight (gramms)	9.8
Torque (kilogram)	0.85
Speed(Sec/60deg)	0.06
A(millimeter)	40
B(millimeter)	26
C(millimeter)	30
D(millimeter)	10
E(millimeter)	28
F(millimeter)	17



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Servos

A combination of two servos would be used. The first servo would be used to control the aileron, while the other one would be used to control the rudder

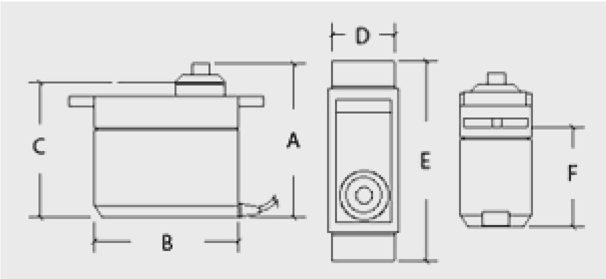

Figure D-10: the description of the servo dimension

A(millimeter)	45
B(millimeter)	30
C(millimeter)	25
D(millimeter)	15
E(millimeter)	32

Table E-4: Servo 1 dimensions description

Second servo

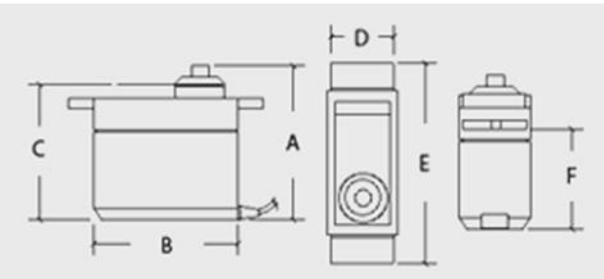

Figure D-11: Servo 2 dimension

Weight (g)	3.8
Torque (kg)	3.5
Speed (Sec/60deg)	0.04

Table E-6: specification of servo 2

Polycrystalline cells

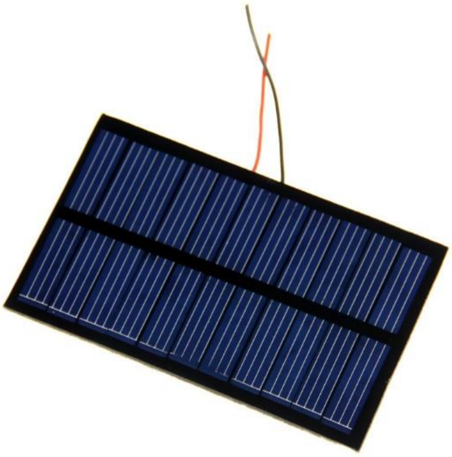

Figure E-9: polycrystalline Solar cell

Specifications
The solar cell configuration Category: Polycrystalline cell
The solar cell power output: 2.25 Wp
The normal voltage in closed circuit: 3.5 voltage
The voltage in open circuit :5.5 voltage
The maximum current in the closed circuit: 252milli ampere
The maximum current in the open circuit: 300milli ampere
TheWidth of the solar cells: 70millimeter
The height of the solar cells: 10millimeter
The Length of the solar cells: 160 millimeter
The mass of solar cell: 33grams

Parts/Materials	Required Units	Weight (g/quantity)	Price (EU)	Estimated Shipping cost
Motor:DC Brushless Out runner 1400kv	1	80	32.4	20
Propeller: Dynamo Carbon Fiber	2	16	7.41	15
Batteries: lithium polymer	1	60	25	20
Electronicspeedcontrollers:Hobbyking™ Series 50-60A ESC	1	20.3	10.5	10
Connecting cable	3	10	2.65	10
Hobby King™ HK15178I High Speed D Metal Gear Servo BB	1	55	7.5	25
Hobby King™ HK15178I High Speed D Metal Gear Servo BB 0.05	1	55	7.5	25
Push rods	2	15	1.63	10
Styrofoam	3	500	15	None
Balsa wood	4	400	10	None
Solar cells	15	30	100	None
Transmitter	1	1450	35	15
Total			144	150

Bill of materials

This bill of materials includes the shipping cost from the sellers country, the website is http:// www.hobbyking.com and http://www.hobbypartz.com

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