Design and Fabrication of Solar R/C Model Aircraft

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Abstract: *The Generally domain Aircraft uses conventional fuel. These fuel having limited life, high cost and pollutant. So there is great demand of use of non-exhaustible unlimited source of energy like solar energy. Solar aircraft is one of the ways to utilize solar energy. A few manned and unmanned solar powered aircraft have been developed and flown in the last 30 years. Solar aircraft uses solar panel to collect the solar radiation for immediate use but it also store the remaining part for the night flight. This experiment intended to stimulate research on renewable energy sources for aviation. The basic challenges for a solar powered aircraft are Geographical area of operation, payload, Energy collection and utilization, and design parameter. This research runs over an extensive period of time, which will provide us with sufficient opportunities to do research and create designs. Assuming we will be able to make accurate calculations, our expectations are that we will actually produce an aircraft capable of flying on solar power. A simulated Remote Control (RC) model size solar airplane allowed to vary altitude proves to be capable of flying multiple day-night cycles at medium and high latitudes during summer. Still, it should be noted that the plane we manufactured is a prototype only. We gathered enormous amounts of knowledge. For if development continues, solar powered aircraft might truly be used in future for different types of aerial monitoring and unmanned flights.*

Keywords: *Aircraft, Bernoulli's principle, Reynolds number, solar energy, Solar cells*

I. Introduction

The Energy comes in different forms. Light is a form of energy. Sun is source of energy called "sunlight". Sunshine is free and never gets used up. Also, there is a lot of it. The sunlight that heats the Earth in an hour has more energy than the people of the world use in a year. A little device called a solar cell can make electricity right from sunlight. The dream of flight powered only by the sun's energy or sunlight has long motivated scientists and hobbyists. A solar aircraft is one which collects energy from the sun by means of photovoltaic solar cells. The energy may be used to drive electric motor to power the aircraft. Such airplanes store excess solar energy in batteries for night use.

Also there are rapidly increasing traffic problems in world and in our country also, so it is required to go for such small solar aircrafts which can be used for transporting goods or materials between places at short distance. Using solar panels there is more space due to escape of engines and turbines.

In 1783, dream of flying became reality "Historians credit France's Montgolfier brothers with the first pioneering balloon flight". Next revolution was in 1903, when Orville and Wilbur Wright made their 'Flyer 1' and flew 36 meters with their plane. Flyer 1 was a petrol engine, just like later aircraft. Nowadays, aviation accounts for three percent of all CO2-emissions produced by mankind. This doesn't seem much, but more important is that profit of commercial aviation strongly relies on the oil price. Due to high prices of crude oil lately, profits of commercial aviation have been diminished and aviation industry is now looking for alternative energy sources to propel modern-day aircraft. Options that are being considered are bio fuels, hydrogen and ethanol. An option which is rarely considered is solar energy, an option we wanted to investigate.

II. History

The Solar Impulse is a project with the construction of an initial prototype with a 61-metre wingspan, referred to by its registration number "HB-SIA". It is the research of four years and studies, calculations and simulations. Its mission is to verify the working hypotheses in practice and to validate the selected construction technologies and procedures. On 24 July, 2012, it has taken-off at 05:01am with flight duration of 13hours 29mins and average speed of 34 kts. It has an average altitude of 3596 meters without any fuel. However there are many projects based on solar system which were tried and: Characteristics of various solar-powered airplanes are in table below.

[15]**Table 1: History**

Model	Year	Solar Cells	Energy (W)	Weight (lbs)	Wingspan (ft)	Altitude (ft)	Battery	Control
Sunrise I	1974	1000	450	26	32	20,000	N/A	Remote
Sunrise II	1975	4480	600	4	32	75,000	N/A	Remote
Solar Challenger	1980	16,128	2600	200	47	12,000	N/A	Remote
HALSOL *	1983	N/A	N/A	N/A	98	N/A	N/A	Remote
Pathfinder	1993	Silicon	7,500	560	98	50,500	N/A	Remote
Pathfinder-Plus	1998	Silicon	12,500	700	121	80,201	N/A	Remote
Centurion	1998	Silicon	12,500	1,900	206	100,000	N/A	Remote
Helios	1999	62,120	12,500	2,048	247	100,000	LiPo	Remote
Sunseeker I	1986	N/A	N/A	N/A	N/A	N/A	NiCd	Pilot
Sunseeker II	2002	N/A	N/A	N/A	N/A	N/A	LiPo	Pilot
SoLong	2005	76	225	25	15.6	26,250	LiPo	Remote
Sky-Sailor	2004	216	90	2.5	3.2	6,500	LiPo	Remote
Zephyr	2007	N/A	1,500	66	59	60,000	LiPo	Remote
Solar Impulse	2007	12,000	6,000	3307	200	27,887	LiPo	Pilot

III. PROJECT WORK

3.1PRINCIPLE OF OPERATION

Our basic principle is to use solar power by means of aircraft. And this thing can be done by solar panels which is composed by solar cells connected in a certain configuration, cover the whole surface of wing. With help of sun irradiance and inclination of the rays this panels converts radiative energy into electric energy. This electric energy is used to charge battery which drives electric motor. Maximum amount of power is obtained from the solar panels. Propeller which is mounted on motor shaft produces thrust continuously. Because of this, aircraft is moved and force is produced on wing by dynamic effect of air which opposes the downward Force of weight. During the night, the only energy available comes from the battery. There is a transmitter and receiver, which are used to send and receive signals from a control panel. The receiver, located inside the plane, will send signals to elements called servos. They can move the rudder, ailerons and elevator. Besides, the receiver also controls the engine throttle.

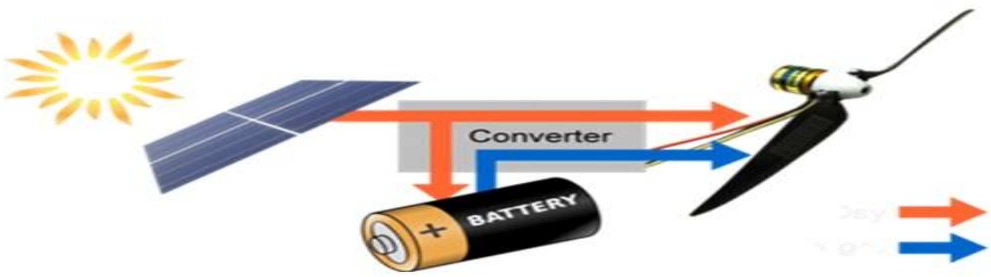


Figure 1: Basic principle of operation

3.2 Design

Table 2: Parameters

Mass(gm) = 650	Wing chord(cm) = 15.04	Tail span(cm) = 31.46
Wing loading = 0.456	Coefficient of lift = 0.373	Tail root chord(cm) = 9.64
Wing area(cm^2) = 1425	Angle of attack = 4.2	Tail tip chord(cm) = 4.34
Aspect Ratio = 6.3	Tail area(cm^2) = 220	Tail moment arm(cm) = 43.94
Wing span(cm) = 94.74	Aspect ratio of tail = 4.5	Volume ratio = 45.106
Reynolds no. = $3*10^6$	L/D ratio = 64.9	Pitch moment = -0.002

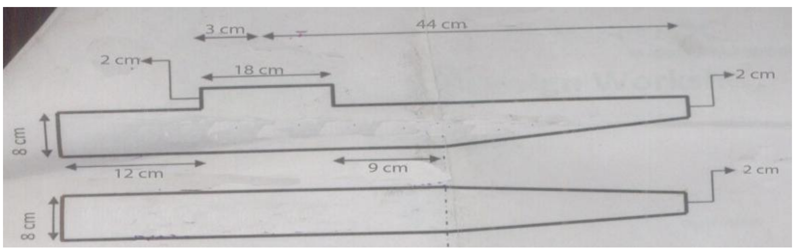


Figure 2: Fuselage Design

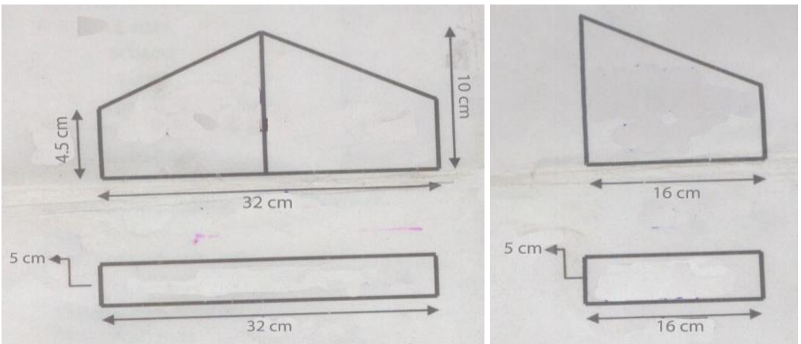


Figure 3: Elevator and Rudder Design

3.3 Aerofoil selection

We have used symmetrical aerofoil because the wings will be hand fabricated and developing a cambered airfoil will be difficult. That means there will be no camber. We have selected NACA aerofoil of 4 digit i.e., NACA 0015, where 0 camber and 15% thickness to chord length ratio. The ‘NACA’ aerofoils are shapes for aircraft wing developed by the National Advisory Committee for Aeronautics (NACA).

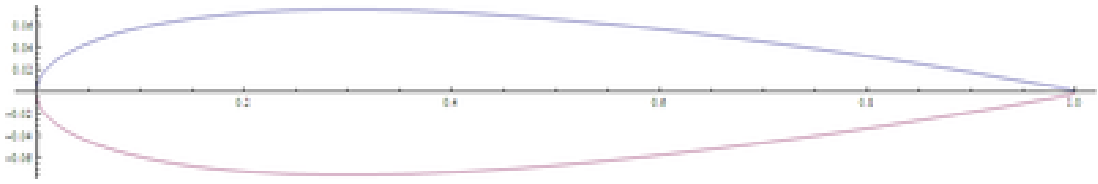


Figure 4: NACA0015 Aerofoil

By choosing proper Angle of attack we use software by which different parameters are generated. We also use FoilSim- a simulator for aerofoil. With this software we investigate how an aircraft wing produces lift and drag by changing the values of different factors that produce aerodynamic forces.

After many, such type of iterations and simulations we select aerofoil for our model.

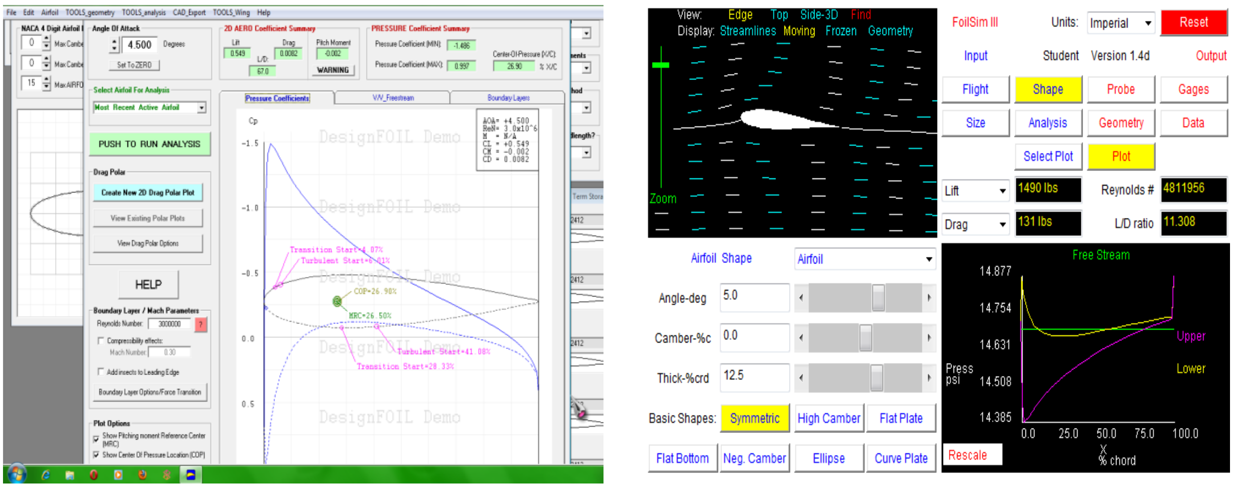


Figure 5: Aerofoil analysis

3.4 Solar cells

The solar cells should provide enough power during flight to extend flying range drastically or even power the aircraft entirely. Just as with all materials used on our plane, mass is a crucial element, so the solar cells can’t be too heavy. Cells are often being integrated in glass, something that would contribute far too much weight. Three solar cell types are in current use. They include amorphous solar cells, monocrystalline solar cells, and multicrystalline solar cells. Each type has its advantages and disadvantages that make it suited to specific applications. For the purposes of Solar Power Industries, multicystalline solar cells represent the greatest efficiency for manufacturing and the greatest value to the customer.

Amorphous cells have been used for a long time in products like solar powered calculators, and garden lamps. The entire panel consists of one piece, making individual solar cells less identifiable. This has long been the least efficient solar cell type, but they have begun to improve to the point where they may become a viable alternative to crystalline solar cells. Theoretically, monocrystalline cells are the most efficient cell type, but in practice poly-crystalline cells produce nearly the same energy output. Moreover, since monocrystalline silicon crystals form circular cross-sections, more silicon is wasted when squaring the wafer than when manufacturing multicrystalline cells since they naturally produce square cross-sections. SPI focuses solely on the production of polycrystalline solar cells because of these advantages.

We are going to use solar monocrystalline silicon cells, each 150 microns thick and chosen for their lightness, flexibility and efficiency. Monocrystalline wafers produce the highest efficiency Photovoltaic Solar Cell or the most power output. But, usually will cost more than multicrystalline cells for the same power output.

3.5 Plots and Pro-E design

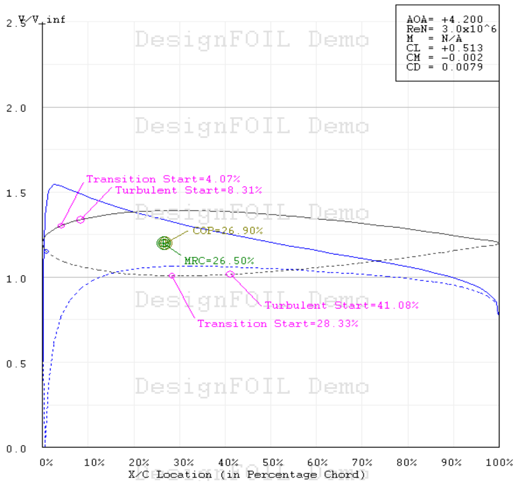


Figure 6: V/V Freestream

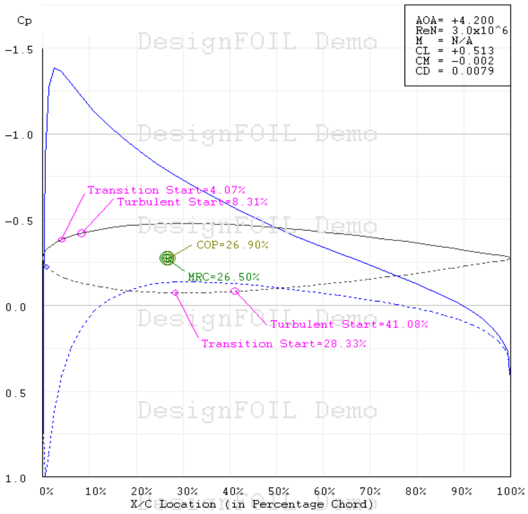


Figure 7: Pressure Coefficients

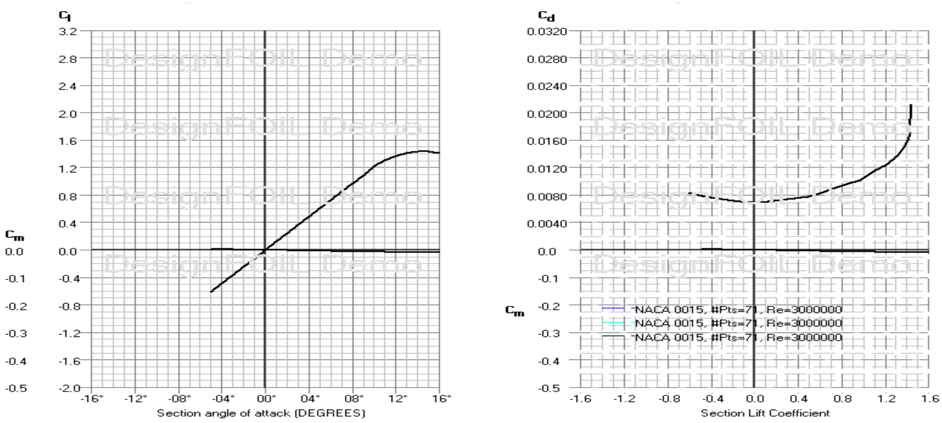


Figure 8: NACA Plot

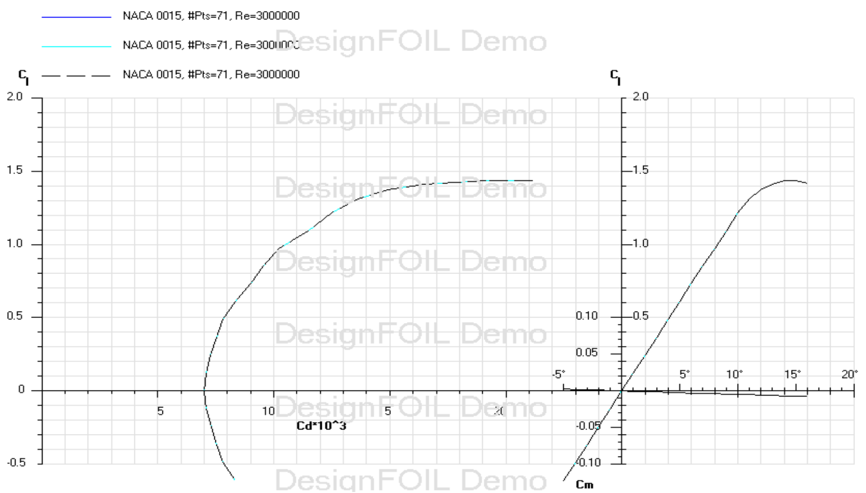


Figure 9: EPPLER Plot

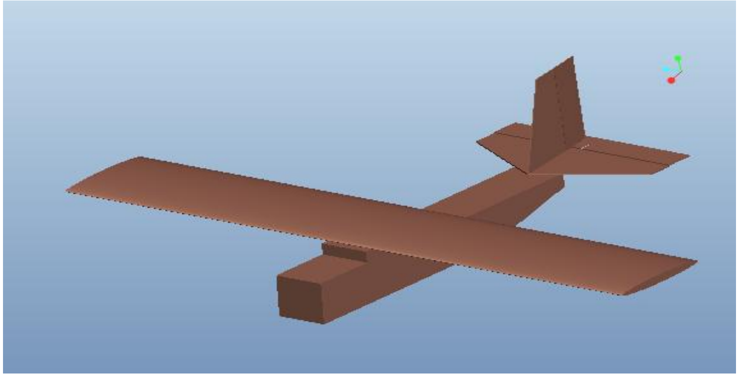


Figure 10: Pro-E model

3.6 Electrical Parts selection

Brushless outrunner motor is a recent type. These motors have the rotor "outside" as part of a rotating outer case while the stator is located inside the rotor. This arrangement gives much higher torque than the conventional brushless motors, which means that the "outrunners" are able to drive larger and more efficient propellers without the need of gearboxes.

As we want to carry weight of about 650gm, this is not so heavy so we decide to choose brushless outrunner motor. The dimensions of motor are shown in figure. The motor has max pull of about 890gm.
It has 1000rpm/v with max power of 210watt.

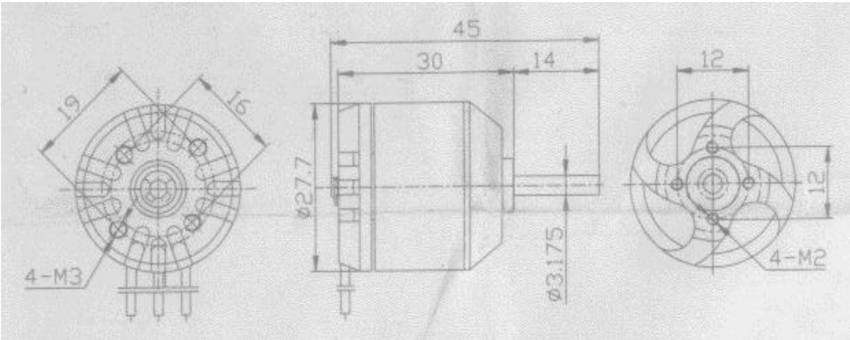


Figure 11: Motor dimension

A common way to control the electric motor's speed is by using an Electronic Speed Controller (ESC). An electronic speed controller specially designed for the brushless motors, which converts the battery's DC voltage into three pulsed voltage lines that are 120^o out of phase. The Electronic Speed Controller is based on Pulse Width Modulation (PWM), which means that the motor's rpm is regulated by varying the pulses' duty-cycle according to the transmitter's throttle position.
We choose ESC with max current 25A. It has BEC and burst of 3A and 30A respectively.

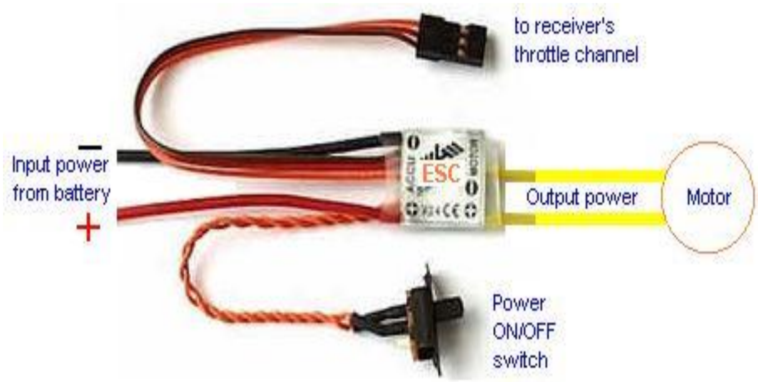


Figure 12: Electronic speed control

To move elevator and rudder required torque is about 1.6 kg-cm. Also, 2.3 kg torque is required to move aileron. Here servo 1 is used for elevator and rudder while servo 2 is used to operate aileron.

Table 3: Servo 1 parameters

Weight (g)	9
Torque (kg)	1.6
Speed (Sec/60deg)	0.12

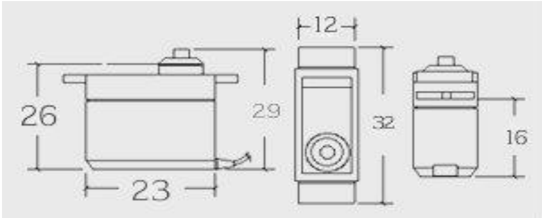


Figure 13: Servo 1 dimensions

Table 4: Servo 2 parameters

Weight (g)	25
Torque (kg)	2.3
Speed (Sec/60deg)	0.08

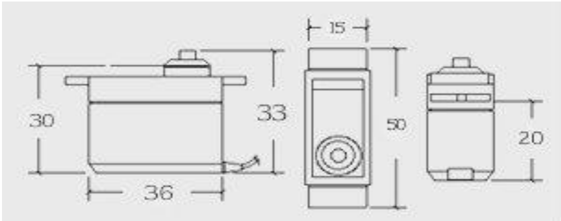


Figure 14: Servo 2 dimensions

Batteries are available in different sizes, weights, voltages and capacities C, which refer to their stored energy expressed either in amps-hour Ah or milliamps-hour mAh. A battery with a capacity of 1500mAh should deliver 1500mA during one hour before it gets totally discharged (flat). This is suitable for motor and ESC we choose.

Table 5: Battery parameters

Capacity(mAh)	1500
Config(s)	3
Discharge(c)	20
Weight(g)	146

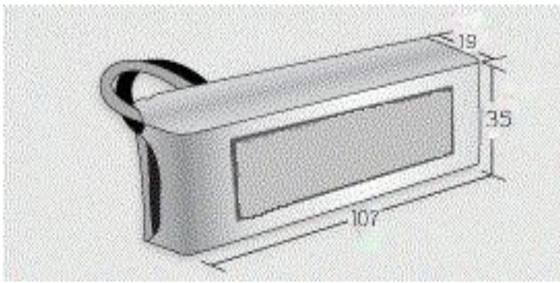


Figure 15: Battery dimensions

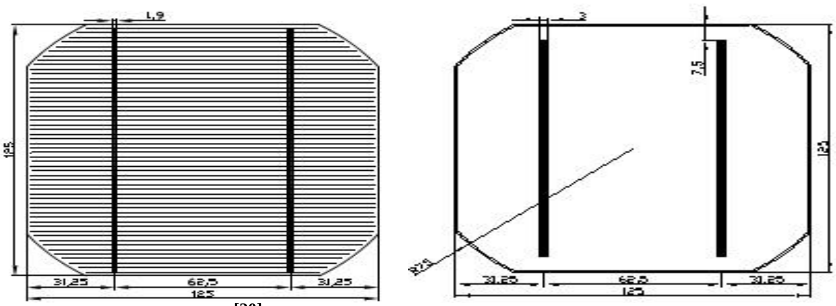
Also we have used clevis, control horns and like some others items to move elevators, rudders, ailerons etc.
As discussed earlier monocystaline silicon cells is used. Because of the chosen batteries and the 0.1-0.2 volts lost over the diode, solar cells we use on the airplane must have a total output of 12 volts. This would require about 20 solar cells of following type.

[20]Table 6: Solar cell parameters

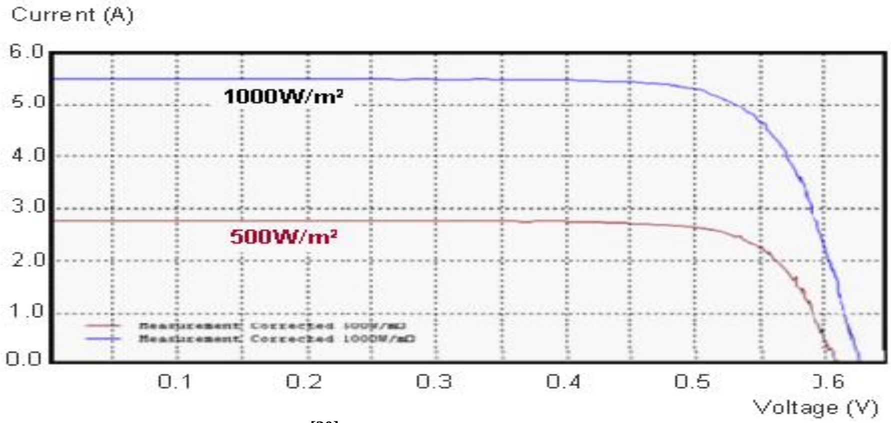
Dimension	125mm×125mm±0.5mm
	Diagonal 150mm±1mm
Thickness	Final Cell: 210µm±40µm
	Silicon: 200µm±30µm

Test accuracy: Pmpp: ±1.50% rel.
Efficiency: ±0.25% abs.
Typical Temperature Coefficients:
Pmpp: -0.47%/℃,
Voltage: -0.38%/℃, Current: +0.10%/℃

weight: about 8.4 gm/cell



[20]Figure 16: Solar cell dimension



[20]**Figure 17: I-V Curve**

IV. CONCLUSION

In this paper all performance parameter calculations, analysis and parts selection are discussed. This type of aircraft can be used to fly day and night. Main advantage of it is use of non-conventional source of energy. As discussed in paper the dimensions and number of solar cell of specified type, we have almost made solar aircraft so now we are going to test it. After testing we will make modification as per requirement.

REFERENCES

[1] Vineet Kumar Vashishtha, Ashok kumar, Rahul makade and ShashiLata, “Solar Power the Future of Aviation Industry”, International Journal of Engineering Science and Technology.

[2] Prof. Alpesh Mehta, Shreekant Yadav, Kuldeepsinh Solanki, Chirag Joshi, “SOLAR AIRCRAFT: FUTURE NEED”, International Journal of Advanced Engineering Technology T/Vol.III/ Issue IV/Oct.-Dec., 2012.

[3] A. Noth, R. Siegwart, W. Engel, Version 1.1, December 2007,”Design of Solar Powered Airplanes for Continuous Flight”.

[4] Moran Jack (2003), An introduction to theoretical and computational aerodynamics, Dover. P. 7. ISBN 0-486-42879-6.

[5] William H. Phillips, “Solar aircraft”, U.S. Patent.

[6] Howard J. Fuller, “Solar Powered aircraft”, U.S.Patent.

[7] Andrew T. Klesh and Pierre T. Kabamba, “Solar-Powered Aircraft: Energy-Optimal Path Planning and Perpetual Endurance”, Journal of Guidance, Control, and Dynamics.

[8] Stefan Leutenegger, Mathieu Jabas and Roland Y. Siegwart, “Solar Airplane Conceptual Design and Performance Estimation”,J Intell Robot Syst (2011) 61:545–561DOI 10.1007/s10846-010-9484-x.

[9] Noth, W. Engel and R. Siegwart, “Recent Progress on The Martian Solar Airplane Project Sky-Sailor”, 9th ESA workshop on Advance Space Technologies for Robotics and Automation, ‘ASTRA 2006’ ESTEC, November 28-30, 2006.

[10] Adam M. Wickenheiser and EphrahimGarcia, “Conceptual Design Considerations for Microwave-and Solar-Powered Fuel-Less Aircraft”, JOURNAL OF AIRCRAFT Vol. 46, No. 2, March–April 2009.

[11] Andr´eNoth, Stefan Leutenegger, Walter Engel, and Roland Siegwart, “Designing solar airplanes for continuous flight”.

[12] E. N. Jacobs, K. E. Ward, & R. M. Pinkerton, 1933 The characteristic of 78 related airfoils sections from tests in the variable-density wind tunnel, NACA Report No. 460.

[13] Andr´eNoth, Walter Engel and Roland Siegwart, “Design of an Ultra-Lightweight Autonomous Solar Airplane for Continuous Flight”.

[14] Hannes Ross, Member of the Solar Impulse Team, 85640 Putzbrunn, Germany, “Fly around the World with a Solar Powered Airplane”.

[15] Senior Design Team 96, Solar-Powered Airplane, Southern illinois university Carbondale.

[16] Daniel P. Raymer, President, Conceptual Research Corporation, Sylmar, California, “Aircraft Design: A Conceptual Approach”.

[17] John D. Anderson, Jr, third ed, “Fundamentals of aerodynamics”, chep 4.

[18] Richard Hantula, science and curriculum consultant, “How Do Solar Panels Works?”

[19] “Trainer Design” (http://adamone.rchomepage.com)

[20] (http://www.fqes.demon.co.uk/cfd/naca.html#07)

[21] “Solar Panel Manufacturer in China” (http://www.shinesolarworld.com)

[22] Andy Lennon, Basics of R/C Model Aircraft Design.