Design of Solar Aero-model

S. V. Deokar[1] , Salunke S. S.[2], Said S. K.[3], Rathod S. B[4], Pawar O. T.[5]
[1, 2, 3, 4, 5] Department of Mechanical Engineering
[1, 2, 3, 4, 5] Sinhgad Institute of Technology, Kusgaon (Bk), Lonavala,

Abstract- *During the oil crisis in the 1970s, solar energy utilized via photovoltaic cells was recognized as an alternative energy source for humans. However, interest on solar energy declined as the price of oil decreased. At present, the clamor to reduce the use of fossil energy, and consequently, the emission of greenhouse gases is increasing. Solar-powered airplanes have recently received significant interest from the public and the aeronautic community because they represent the use of a renewable energy source. Solar powered airplane consumes solar energy instead of traditional fossil fuels; thus it has received a significant amount of interest from researches and the public alike. Possible future application of solar powered airplanes in the civilian and military fields is proposed. This Paper proposes that solar powered airplanes are potential alternatives to some present technologies and that they complement current satellites, traditional airplanes, airships and balloons. However, these planes require further development..*

Keywords- ESC; LiPo Battery; Mono crystalline Solar Cell etc.

I. INTRODUCTION

In1974, the first solar-powered airplane in the world, Sunrise, made its maiden voyage. Since then, solar-powered air- planes have developed significantly. In contrast to traditional airplanes, solar-powered airplanes harvest solar irradiance and convert it into electrical energy by using solar cells. The available energy compensates for energy consumption during daytime level flights. Surplus energy is stored in secondary batteries, which provide the energy consumed during night time flights. Given the environment friendly and inexhaustible characteristics of solar power, solar-powered airplanes are zero-emission and eco- friendly aircraft that fairly satisfy the requirements of global environmentalism. Solar-powered airplanes exhibit a huge potential for high altitude and long endurance (HALE) flights because of the unlimited supply of solar power. Solar-powered airplanes can be designed to fly near space, that is, above the atmospheric flight region and below the spacecraft flight region (approximately20–100km).They can fly continuously for months, or even years, depending on the reliability of the airplane system and sunlight conditions, which is impossible for traditional, fossil-fuel airplanes. Solar-powered airplanes can function as complements to low-altitude satellites, with the advantage of having a relatively low altitude, free deployment, high resolution, high frequency of coverage, and low cost. Solar-powered airplanes can also function as alternative to high-altitude balloons and airships, with the advantage of having free-manoeuvre capability, high resilience to weather, as well as being easy to launch and recover. Compared with low-altitude airplanes, solar-powered airplanes have the advantage of reaching relatively high altitudes and covering large areas. Solar-powered airplanes can perform various missions in military and civilian fields, such as uninterrupted relay communication; intelligence, surveillance, and reconnaissance (ISR); wildfire warning systems; agricultural assistance; pipeline monitoring; border patrolling; pollution and nuclear observations; and so on. Many of the sea applications fall within the category of dull, dirty or dangerous aerial work and are associated with high risks and costs.Solar-powered airplanes are products of cutting-edge technology and have small design margins. Reaching high altitudes and attaining long endurance are the perpetual objectives of most recent studies. The most difficult objective is reaching very high altitudes with low available energy. Atmospheric density at 20 km is one-tenth of that at 0 km, and thus, available dynamic pressure to lift an airplane is minimal. Moreover, the power density of photovoltaic cells is relatively low compared with that of internal combustion engines. Therefore mentioned restrictions result in an extremely narrow design space. In general, solar- powered airplanes are different from traditional airplanes because of their small wing loading, small power loading, and constant energy shortage. Thus, the lightweight structure, solar-energy collection efficiency, energy storage capacity, and propulsion systems of solar-powered airplanes should be carefully designed to enable them to attain an energy cycle and achieve long endurance flights. We should also consider multiple disciplines, such as energy and aerodynamic systems, among others. These factors should be coupled with one another to achieve a multi- disciplinary and optimized design.

II. RESEARCH ELABORATION

Flight over a long duration of time has been a pursuit of aviation for many years. On May 20, 1927 Charles Lindbergh flew “The Spirit of St. Louis” over the Atlantic Ocean for the first time, a huge duration of flight for that time period. Since then many advancements have been made in the aviation industry. In today’s world, the ever-growing, constantly evolving need for eco-friendly energy sources has become somewhat of a standard effort within the field of engineering. In recent years, engineers along with the public eye have realized the importance of contributing to the preservation of the environment as new technologies are created to further advance engineering proficiency. Renewable energy sources along with nonpolluting energy technology are quickly becoming the top priority energy research topics among today's engineers. One specific example of a renewable energy source undergoing increasingly valuable improvements of producing environmentally friendly energy is a technology that has been around for some time now. Solar energy has made significant advancements in its efficiency and its uses over the centuries of being used by human civilization. The multitude of uses regarding solar energy is vast and constantly increasing. Solar energy technology has been used to improve agriculture, natural lighting, thermal heating, and of course, electrical generation. Using the sun to create solar power is a key innovation being used to economically improve electricity consuming technical systems. One of the latest innovations in aerospace engineering is using solar power to generate enough electricity to fly a solar panel bearing airplane for a long duration of time.

Typical solar powered airplanes consist of solar panels covering the surface area of the airplanes wings, a motor running off of the solar energy, and a battery storing power for flight throughout the night. A solar powered airplane has many challenges to overcome with these components. Weight, power, and size are all issues that are problematic and key in designing an airplane.

When designing a solar powered aircraft, one of the most important things to consider is the weight of the aircraft. The weight needs to be minimized to reduce the amount of power needed to create lift in the aircraft. This can be achieved by using lightweight materials and minimizing material use, however, material minimization can reduce the structural strength. Engineers must design lightweight, yet strong, framework for the wings and body of the aircraft. As the weight of the plane increases, the power requirement to create lift is increased requiring a demand for a more powerful engine, more fuel cells, a larger battery, and increased strength that will increase the weight of the aircraft. Finding the balance of weight to available power is vital in designing a solar powered aircraft.

An appropriate size of the solar powered airplane must be decided before beginning the design. If a plane is small it will need less surface area on the wings because less power from solar panels will be required to lift the plane. If the plane is big and is required to carry bigger loads a much bigger wing surface area will be needed. A balance must be struck then in choosing a size of plane that is large enough to provide sufficient surface area to mount the solar panels, while keeping the weight of the plane to a minimum. Another factor to consider is the general shape of the plane and its wings. Traditionally solar planes do not fly very fast; as a result the wings are typically un-swept to maximize the lift of the wing. Longer wingspans are usually preferred since they not only maximize the lift, but also increase the area on which solar cells can be mounted. Basically the goal in designing the shape of a solar plane is to reduce the drag of the plane by streamlining its features such as landing gear, antennas, and the overall shape of the plane, while maximizing its lift.

Herwitz et.al. (2004), studiedin September 2002, NASA's solar powered pathfinder-plus unmanned aerial vehicle was used to conduct a proof of concept mission in U.S. national airspace above the 1500 ha plantation of the Kauai coffee company in Hawaii During 4h loitering above the plantation, ground faced pilots were able to precisely navigate the UAV along pre-planned flight lines, and also perform spontaneous maneuvers under the direction of the project scientist for image collection in cloud free zone Under mass production and operation, solar power UAV's may become cost competitive with existing airborne assets. For instance, fabrication cost may be lower than those of conventional aircraft, while operating costs for fossil fuel and on board crew are avoided. Imagers might be combined with other play boards, such as telecommunications or atmospheric samplers, to further reduce cost.

Joshi et.al. (2006), studied in this paper that Hybrid electric vehicle technology leads to automobiles with increased fuel economy and reduced emissions. Small unmanned aerial vehicle used for military, homeland security, and disasters monitoring mission cloud benefit from same technology. A parallel hybrid electric propulsion system provides stealth mode not available with gasoline powered unmanned aerial vehicle to increase the capacity of aerial vehicle. The optimization algorithm can be used to generate charge sustaining for charge depletion control surface depending on the intended mission. The control surfaces were implemented in several flight profiles to compare the different controllers.

Enrico Cestino (2006), studied airplane should be able to climb to an altitude of 17-20 km by taking advantages of direct sun radiation and maintaining a level flight; during the night, a fuel cells energy storage system would be used. a computer program has been developed to carry out a parametric study for the platform design the solar radiation over one year, altitude, masses and efficiencies of the solar and fuel cells, as well as aerodynamic performances have all been taken into account the parametric studies have shown how the efficiency of the fuel and solar cells and mass have the most influence on the platform dimension. The results of this preliminary study show that it could be possible to obtain a very long endurance high altitude platform for Earth observation and telecommunication applications, at least for low latitude sites in Europe and for several months of continuous operation. A Blended Wing Body configuration of Solar HALE Aircraft was developed as a result of the parametric study. The BWB solution seems to be the best compromise between performance, availability of surfaces for solar-cells, and volume for multi-payload purposes.

Hung et.al. (2012)**,** studied in this paper that the current developments and the analysis of Hybrid-Electric Propulsion Systems for small fixed-wing Unmanned Aerial Vehicles Efficient energy utilization on an UAV is essential to its functioning, often to achieve the operational goals of range, endurance and other specific mission requirements. Due to the limitations of the space available and the mass budget on the UAV, it is often a delicate balance between the onboard energy available (i.e. fuel) and achieving the operational goals. One technology with potential in this area is with the use of HEPS. In this paper, information on the state-of-art technology in this field of research is provided. A description and simulation of a parallel HEPS for a small fixed-wing UAV by incorporating an Ideal Operating Line control strategy is described. Simulation models of the components in a HEPS were designed in the MATLAB Simulink environment. An IOL analysis of an UAV piston engine was used to determine the most efficient points of operation for this engine. The results show that an UAV equipped with this HEPS configuration is capable of achieving a fuel saving of 6.5%, compared to the engine-only configuration. Effects of wind and weather should be investigated and incorporated into the UAVSM. The flight mission should be extended to include take-off and landing sequences. Improvements in the implementation of the IOL controller may result in greater fuel saving.

Wright et.al. (2012)**,** examines how the use of unmanned aircraft systems (UASs) for surveillance in civil applications impacts upon privacy and other civil liberties. It argues that, despite the heterogeneity of these systems, the same “usual suspects” e the poor, people of colour and anti-government protesters e are targeted by UAS deployments. It discusses how current Privacy-related legislation in the US, UK and European Union might apply to UASs. We find that current regulatory mechanisms do not adequately address privacy and civil liberties concerns because UASs are complex, multimodal surveillance systems that integrate a range of technologies and capabilities. We find that these privacy and ethical concerns are not adequately addressed by existing regulatory mechanisms or legislation in the US, EU and UK. Instead, we conclude that multi-layered regulatory mechanisms that combine legislative protections with a bottom-up process of privacy and ethical assessment offer the most comprehensive way to adequately address the complexity and heterogeneity of unmanned aircraft systems and their intended deployments.

Zhu et.al. (2014)**,** Studiedsolar-powered airplanes are studied in this research. A solar powered airplane consumes solar energy instead of traditional fossil fuels; thus it has received a significant amount of interest from researchers and the public alike. The historical development of solar-powered airplanes is reviewed. Notable prototypes, particularly those sponsored by the government, are introduced in detail. Possible future applications of solar powered airplanes in the civilian and military fields are proposed. Finally, the challenges being faced by solar-powered airplanes are discussed. This paper discusses the historical developments and future challenges of solar-powered airplanes, with the objective of providing references and overviews for research. Since 1974, when the first solar-powered airplane flew, governments all over the world have realized the tremendous potential of solar-powered airplanes. Institutes and agencies such as the ESA, NASA, and DARPA have led the research and have launched numerous projects, albeit technical demonstration prototypes, which are far from practical applications. With the developments in science and technology, solar-powered airplanes are envisioned to address daily transportation needs.

Colomina et.al. (2014)**,** they discussed the evolution and state-of-the-art of the use of Unmanned Aerial Systems (UAS) in the field of Photogrammetry and Remote Sensing (PaRS). UAS, Remotely-Piloted Aerial Systems, Unmanned Aerial Vehicles or simply, drones are a hot topic comprising a diverse array of aspects including technology, privacy rights, safety and regulations, and even war and peace.We have reviewed the UAS technology for PaRS applications with emphasis on regulations, acquisition systems, navigation and orientation. The diversity and sophistication of the involved technologies is apparent: aeronautics, satellite and inertial navigation, computer vision, robotics, sensorics and, last not least, photogrammetry. Technologically speaking, UAS-sourced PaRS are mature enough to support the development of geo information products and services. Moreover, in spite of a still emerging and uncertain regulatory frame, customer demand and general interest is present to the point that there are already some UAS geo information niche markets; in particular a growing new market for small photogrammetric and remote sensing projects.

III. SALIENT FEATURES

1. After studying above research papers we know the materials used to manufacture plane body are aluminum, alloy steel, and foam which are very costly. But we are using 'Coro-sheet' as material for manufacturing body, because it is very cheap, easy to manufacture and lightweight.
2. From using solar panels by which battery gets charged during day
3. By using battery which can power the plane during night also.

IV. EXPERIMENTAL SETUP

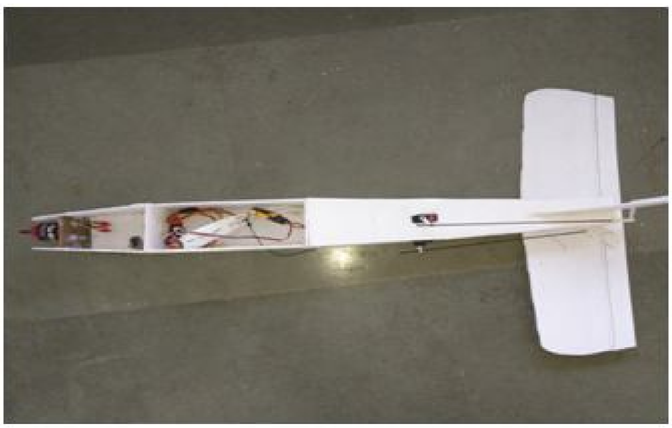

Fig. Assembly

It mainly contains various parts as show in fig.

1. MOTOR-

Fig. Motor

We have selected brushless motor to give thrust to aero model; because of its high starting torque.

2. ESC

Electronic servo controller gives signal to main motor and servo motors to operate and give required directions.

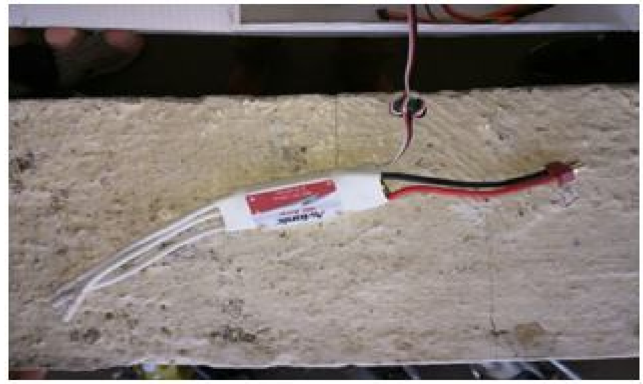

Fig. ESC

3. BALANCE CHARGER

Balance charger charges the battery on output of solar cell and also avoids over charging of battery

Fig. Balance Charger

4. SOLAR CELL

We have selected mono crystalline solar cell which has 6 volt output. So we require two solar cells.

Fig. Solar cell

5. PROPELLER

The Propeller we have selected is 10*6 inches which can supply enough thrust to fly the solar aero model
Fig. Propeller

6. SERVO MOTORS

We need 4 servo motors of 1.2Nm torque; For control surfaces.

Fig. Servo Motor

Table- Technical Specification

Component	Specification	QTY.	Price
Brushless motor	1120 rpm, 11.1V, 2200mah	1	1280
Servo motor	1.5 kg-cm	4	820
ESC	40 amp	1	990
Battery	2200mah,12V (Li-Po)	1	990
Remote Control	2.4Hz 6 channel	1	3250
Carbon Fiber Rod	6*1000 mm	1	430
Solar panel	6V (60*40*2mm)	2	525
Balance Charger	6V	1	625
Propeller	10*7E	1	95

V. PROCEDURE

DESIGN & CALCULATION

WING DESIGN:

wing area(S) = 0.24336 m^2
Aspect ratio(AR) = 6.4
wingspan(b) $=\sqrt{S * AR}$
$=\sqrt{0.24336 * 6.4}$
=1.248 m

Chord length of wing(c)

$$AR=\frac{b}{c}$$
$$c = \frac{1.248}{6.4} = 0.195$$

Mean Aerodynamic Chord(M.A.C)

$$\acute{C} = \frac{2}{S}\int_0^{b/2} c^2(y)dy$$
= 0.195

root chord(Cr)

$$c = \frac{2}{3}Cr\left(\frac{1+\lambda+\lambda^2}{1+\lambda}\right)$$

$$0.195 = \frac{2}{3}Cr\left(\frac{3}{2}\right)$$

Cr =0.195 .... (λ=1)rectangular wing section

Taper ratio(λ)
it is a ratio of tip chord to root chord
$$\lambda = \frac{Ct}{Cr}$$

tip chord(Ct)
$$\lambda = \frac{Ct}{Cr}$$

$1 = \frac{Ct}{0.195}$ = Ct =0.195(due to rectangular wing section)

Oswald Span Efficiency(e)
$e = 1.78(1 - 0.045*AR^{0.68}) - 0.64$
$e = 1.78(1 - 0.045*6.4^{0.68}) -0.64$
e = 0.8569

So, it indicates that lift distribution in non-elliptic i.e when it's equal to 1 then it lift distribution elliptical and when less than 1 then it's lift distribution non-elliptic.

Design dimension of the Solar Aero-Model :

Parameters	Symbol	Value	Unit
Wing mean chord	C	0.195	m
Wingspan	B	1.248	m
Wing area	S	0.24336	m^2
Takeoff weight	W	8829	N

Aerodynamic characteristics of the Solar Aero-Model :

Coefficient of lift C_L =1.062................(1)
Coefficient of drag C_D = 0.0424..............(2)

equation (1)and (2) from ......Héctor Manuel González Vidales

Density of Air at sea level = 1.225 kg/m^3

POWER FOR LEVEL FLIGHT

At steady level flight, the lift force generated by the wing exactly compensatesfor the weight and the propeller thrust compensates for the drag force. Usingequation (1)and(2).

$$mg = C_L * \frac{\rho}{2} * S * V^2 \text{ ....(1)}$$

$$T = C_D * \frac{\rho}{2} * S * V^2 \text{ ....(2)}$$

we can isolate the speed from equation (1) and (2)

$$V = \sqrt{\frac{2mg}{C_L \rho S}} \text{ ....(3)}$$

$$V = \sqrt{\frac{2*0.9*9.81}{1.062*1.225*0.24336}}$$

V = 7.46 m/s

Lift Force = $1.062*\frac{1.225}{2}*0.24336*7.46^2$
=8.809 N

Drag Force = $0.0424*\frac{1.225}{2}*0.24336*7.46^2$
=0.3517 N

Takeoff Weight = 900 g

Dynamic thrust force equation :

$$F = 1.254 \frac{\pi(0.254.d)^2}{4}\left[(RPM_{prop}.0254.pitch.\frac{1min}{60sec})^2 - (RPM_{prop}.0.0254.pitch.\frac{1min}{60sec})V_0\right](\frac{d}{3.29546.pitch})^{1.5}$$

$$P_{Level} = \frac{C_D}{{C_L}^{3/2}}\sqrt{\frac{(mg)^3}{S}}\sqrt{\frac{2}{\rho}} \text{.............(4)}$$

$$P = \frac{0.0424}{1.062^{3/2}}\sqrt{\frac{(0.9*9.81)^3}{0.24336}}\sqrt{\frac{2}{1.225}}$$

P = 2.6312 KW

From the use of dc brushless motor some standard data given

Motor RPM = 1100/v
Thrust Force = 15.69 N
LiPo Battery = 11.1 V
ESC = 30 amp
Propeller = 10*7E

VI. METHODOLOGY

This point is the theoretical heart of this project as it describes in detail the conceptual design methodology. Whether it is intended to achieve surveillance at low altitude or serve as a high altitude communication platform, a solar aircraft capable of continuous flight needs to fly at constant altitude.

In fact, the first one would be useless for ground surveillance at high altitude and the second one wouldn’t cover a sufficient area at low altitude. For this reason, we concentrate the following study on straight level flight only, storing the surplus of solar energy in the battery.

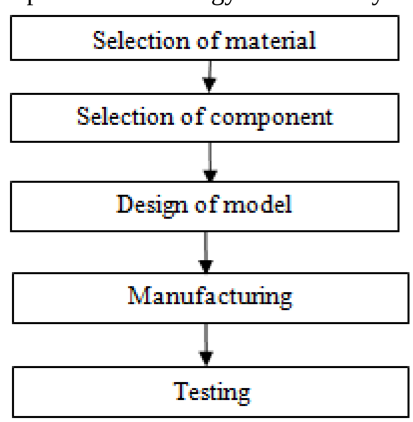

Fig. METHODOLOGY

ACKNOWLEDGMENT

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CONCLUSION

In this Design of solar aero model we have studied different research papers to analyse the different materials and specification of other components such as motor, solar cell, battery.

So we have selected Coro sheet as material for body and mono-crystalline solar cell to charge the battery. This solar cell has maximum efficiency.so we have selected these materials for solar model From above research.

REFERENCES

[1] S.R. Herwitz a, b,, L.F. Johnson c, d, S.E. Dunagand, R.G. Higgins b, D.V. Sullivan d, J. Zheng c ,d, B.M. Lobitz c ,d, J.G. Leung e ,B.A. Gallmeyer e, M. Aoyagi e, R.E. Sly e d, J.A. Brass d ," Imaging from an unmanned aerial vehicle: agricultural surveillance and decision support", *Computers and Electronics in Agriculture*, a Graduate School of Geography, Clark University, Worcester, MA 01610, USA b UAV Applications Center, NASA Research Park, Moffett Field, CA 94035, USA c Earth Systems Science and Policy, California State University, Monterey Bay, Moffett Field, CA 94035, USA d Earth Science Division, NASA Ames Research Center, Moffett Field, CA 94035, USA e Technology Development Branch, NASA Dryden Flight Research Center, Moffett Field, CA 94035, USA, 44 (2004)pp 49–61.

[2] Frederick G. Harmon, Andrew A. Frank, Sanjay S. Joshi,"The control of a parallel hybrid- electric propulsion system for a small Unmanned aerial vehicle using a CMAC neural network", Neural Networks,Department of Mechanical and Aeronautical Engineering, University of California-Davis, Davis, CA 95616, USA, 18 (2005)pp772–780.

[3] Enrico Cestino," Design of solar high altitude long endurance aircraftfor multi payload & operations", Aerospace Science and Technology, Department of Aerospace Engineering, Politecnico di Torino (Turin Polytechnic University), CorsoDuca Abruzzi 24, 10129 Turin, Italy, 10 (2006) pp541–550.

[4] J.Y. Hung,L.F. Gonzalez,"On parallel hybrid-electric propulsion system for unmanned aerial vehicles",Progress in Aerospace Sciences,Australian Research Centre for Aerospace Automation (ARCAA), Queensland University of Technology, 22-24 Boronia Road, Eagle Farm, QLD 4009, Australia,51 (2012)pp 1–17.

[5] Rachel L. finn, David Wright," Unmanned aircraft systems: Surveillance, ethics and privacy in civil applications",computer law & security review, Trilateral Research & Consulting, London, UK 28(2012)pp184-194.

[6] Xiongfeng Zhu, ZhengGuo, ZhongxiHou,"Solar-powered airplanes: A historical perspective and future challenges",Progress in Aerospace Sciences,College of Aerospace Sciences and Engineering, National University of Defense Technology, Changsha 410073, China,71(2014)pp36–53.

[7] I.Colomina, P. Molina,"Unmanned aerial systems for photogrammetry and remote sensing",ISPRS Journal of Photogrammetry and Remote Sensing, Centre Technologic de Telecommunication's de Catalunya, Carl Friedrich Gauss 7, 08860 Castelldefels, Spain.92 (2014)pp 79–97.