



e-ISSN: 2319-8753 | p-ISSN: 2320-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 10, Issue 3, March 2021

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 7.512

9940 572 462

6381 907 438

ijirset@gmail.com

www.ijirset.com



Solar Endurance Flight with Surveillance and Geographical Mapping

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ABSTRACT: The objective of this paper is to develop the solar endurance unmanned aerial vehicle of fixed wing for the purpose of surveillance and geographical mapping. The main problem faced by the UAVs is endurance or flight time. Nowadays, the world is moving towards the inexhaustible source of energy. Hence, solar is a foremost alternative. For this, the model is designed and analyzed using Catia and Ansys softwares. As a power source this UAV uses photovoltaic cells, which convert the energy of light directly into electricity. The electricity produced is used for the working of the components of the UAV i.e.; surveillance camera, motor and other parts. Mapping of a geographical area and surveillance is done by the videotaped recordings.

KEYWORDS: - UAV, Photovoltaic cell, Geographical area, surveillance.

NOMENCLATURE

δ = Solar declination angle. H_d = Daily average irradiance.

I_{sc} = Solar constant. ω = hour angle.

ϕ = Latitude of the aircraft. W = weight force.

S_{max} = Max sunshine hours. C_l = coefficient of lift.

P = Power required. C_d = coefficient of drag.

S = Wing area. ρ = Density.

L = lift force.

I. INTRODUCTION

Now mankind is shifting from nonrenewable resources such as fossil fuels to renewable energy. These solar endurance UAVs have long endurance capability, especially in the extreme form of continuous multi-day flight, or perpetual endurance, is particularly interesting for applications such as large-scale mapping, observation, or telecommunication relay. Such functionalities may be applied to Search-And-Rescue (SAR) missions, industrial or agricultural inspection, meteorological surveys, border patrol and more.

Here is some basic terminology used in the paper. "Unmanned Aerial Vehicle" is an aircraft without a human pilot and a type of unmanned vehicle. UAVs are a component of an unmanned aircraft system. Which includes a UAV, a ground-based controller, and a system of communication between the two. It is operated by various degrees of autonomy, either under remote control by a human operator or autonomously by an on board computer. The UAV is a "Radio-Controlled Aircraft". It is a machine which controls aircraft remotely by an operator using a held-radio transmitter. The transmitter communicates with a receiver within the craft that sends signals to servomechanisms which moves the control surfaces based on the portion of console on the transmitter.

A "Solar cell", or "Photovoltaic cell", is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect.



II. LITERATURE REVIEW

Solar aviation, understood as flown in the atmosphere, was born in 1974, when the Sunrise I UAV flew in California (USA). It completed twenty-eight successful flights before being destroyed by turbulence. The first manned powered aircraft exclusively by solar energy was the Gossamer Penguin in 1980. One year later, Paul MacCready flew across the English Channel on board of the Solar Challenger. Eric Raymond crossed the United States with the Sun seeker in 1990 over 21 flights with a total duration of 121 flying hours. Solar aircrafts, mainly UAVs, thrived in the 90s as the technologies and efficiencies of the solar cells improved. NASA studied new configurations in the late 90s with Pathfinder, Centurion and Helios HALE UAVs, but they were not a total success and fragility problems lead to the in-flight destruction of the Helios. So Long UAV and the manned Solar Impulse, flew at night in 2005 and 2010 respectively relying only on the stored solar energy; the latter recently crossed the United States and it has achieved many records of endurance and distances.

The Centurion is a lightweight, solar-powered, unmanned aircraft which was developed by NASA in the 19's and used technology of applying solar power for long-duration and high-altitude flight. It is considered to be a prototype technology demonstrator for a future need of solar powered aircraft that can be flown for weeks or months on scientific testing and missions or while serving as telecommunications relay platforms. The Centurion has a wingspan of 206 feet and 70% longer than the Pathfinder-Plus 121-foot span.

The Sky-Sailor was developed by the Swiss Federal Institute Of Technology in Zurich in 2004 as a Robotic Aerial vehicle with embedded solar cells on its wing. It is in a small Aeroshell that would be attached to a carrier spacecraft. Upon reaching the red planet, the Aeroshell would be released for direct entry into the Martian atmosphere. It has a distance of 1700 km during a 12-hour period. This allows the airplane to reach many different areas of interest. The exploration mission will end when the airplane crashes normally due to the battery's life cycle and dust deposition on solar panels.

Solong is an electric-powered UAV (unmanned aerial vehicle) that collects solar energy from photo-voltaic arrays laminated into its wings. It is possible to fly for one night just by discharging the batteries, but for two or more nights, the plane has to fully recoup and store the energy used at night while flying in the sunlight the following day. Once that is achieved, the cycle can repeat continually, and keep the plane airborne indefinitely.

III. DESIGN METHODOLOGY

The design process of the entire aircraft is composed of three phases: conceptual, preliminary and detailed. In conceptual design, the basic configuration arrangement, size, weight, and performance are calculated. Then, designing the CATIA modeling of individual parts in order to meet the required targets and optimizing it are done in detailed design. The design requirements are used to guide and evaluate the development of the overall aircraft configuration. There are two simple balances:

Weight balance: The lift force has to be equal to the weight of all the elements constituting the airplane. **Energy balance:** The energy that is collected during a day from the solar panel has to be equal to or higher than the electrical energy needed by the airplane during its level flight.

IV. SELECTION OF SOLAR CELLS

There are different types of solar cells available namely :-

- A. Amorphous silicon solar cells
- B. Monocrystalline
- C. Polycrystalline
- D. Thin-film solar cells

A. Amorphous silicon solar cells: Amorphous silicon solar cells are the most well-developed thin-film solar cell. The structure usually has the p-i-n type of duality, where p-layer and n-layer are mainly used for establishing an internal electric field comprising amorphous silicon. Because amorphous silicon has a good absorption capacity. Its efficiency ranges from 15 to 7 percent.

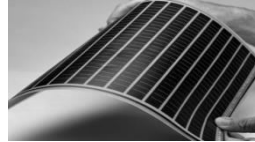


Figure.1: Amorphous silicon solar cell

B. **Monocrystalline Solar Cells:-** Monocrystalline silicon, more often called single-crystal silicon, in short mono c-Si or mono-Si, is the base material for silicon-based discrete components and integrated circuits used in virtually all modern electronic equipment. Mono-Si also serves as a photovoltaic, light-absorbing material in the manufacture of solar cells. Its efficiency ranges from 15 to 20 percent.

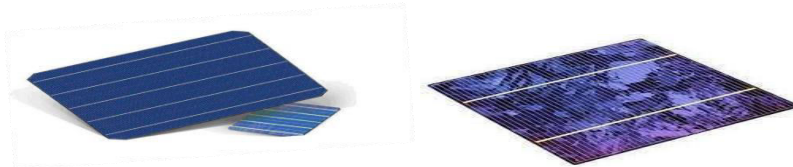


Figure.2: Monocrystalline and polycrystalline solar cells

C. **Polycrystalline silicon solar cells:-** Polycrystalline silicon, or multicrystalline silicon, also called polysilicon or poly-Si, is a high purity, polycrystalline form of silicon, used as a raw material by the solar photovoltaic and electronics industry. Polysilicon is produced from metallurgical grade silicon by a chemical purification process, called the Siemens process. This process involves distillation of volatile silicon compounds, and their decomposition into silicon at high temperatures. Its efficiency ranges from 15 to 17 percent.

D. **Thin-film solar cells:** A thin-film solar cell is a second generation solar cell that is made by depositing one or more thin layers. Thin film of photovoltaic material on a substrate, such as glass, plastic or metal. Its efficiency ranges from 4 to 12 percent.

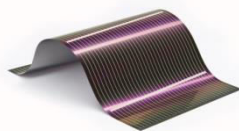


Figure.3: Thin film solar cell

By considering efficiency as the main factor we picked monocrystalline solar cells.

V. SELECTION OF AIRFOIL

By considering the stall characteristics and flat bottom outline, we picked clark Y airfoil. It has a high camber which allows for an efficient lift to drag ratio on a typical light weight RC model.

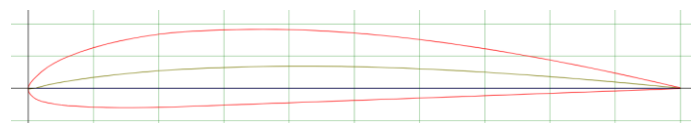


Figure.4: CLARK Y AIRFOIL

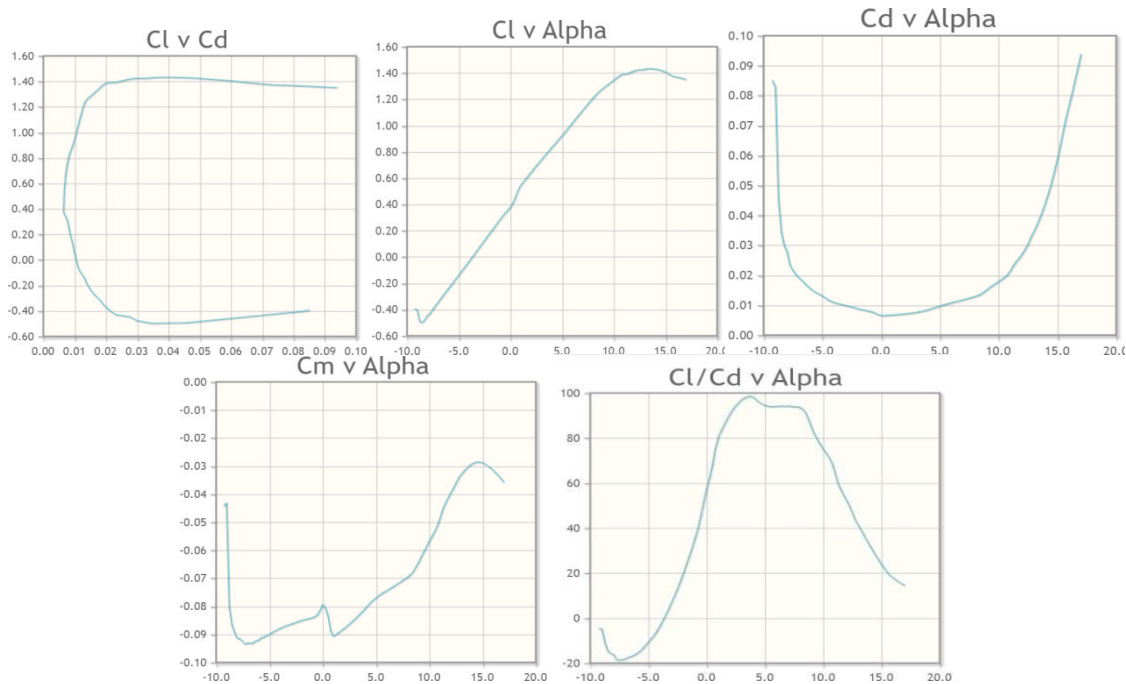


Table 1:

Alpha	Cl	Cd	Cm
3.7500	0.8090	0.0082	-0.0819

V. POWER REQUIRED FOR LEVEL FLIGHT

At steady level flight, the lift force generated by the wing exactly compensates for the weight, and the propeller thrust, for the drag force

$$W = mg = L = \frac{\rho}{2} C_L S V^2 \tag{1}$$

where: m is the mass of the aircraft (kg); L is the lift force; ρ is the air density ($\text{kg}\cdot\text{m}^{-3}$); S is the surface area of the wing (m^2); V is the cruise velocity of the aircraft ($\text{m}\cdot\text{s}^{-1}$).

The axial thrust is calculated as:

$$T = D = \frac{\rho}{2} C_D S V^2 \tag{2}$$

where: D is the drag force. The induced drag is obtained as:

$$C_{Di} = \frac{C_L^2}{\pi \cdot e \cdot AR} ; C_D = c_d + C_{Di} \tag{3}$$

where: c_d is the coefficient of drag of airfoil. The power required for level flight is:

$$P_{req} = T \times V \tag{4}$$

The required parameters for calculating the level flight are shown in Table 2. As the mass of the plane was initially fixed as 1.5 kg, the total weight of the plane becomes 14.7 N. From the above two equations, the cruise velocity of the plane that can be obtained as the lift coefficient for the airfoil is 0.7898, and the surface area of the wing can be calculated as the chord equal to 15 cm and the length of 80 cm, which is 0.12 m^2 . Hence, the velocity of the plane at cruise is 15.9 $\text{m}\cdot\text{s}^{-1}$. From the total drag force and the cruise velocity, one can find the power required for a cruise: $P_{req} = T \times V = 4 \text{ W}$.



Table 2:

Parameters	S.I units
Gross weight	1.5 kg
Gravity	9.8 1 m/s ²
Airfoil lift coefficient	0.7898
Airfoil chord	0.12 m
Airfoil drag coefficient	0.0115
Aspect ratio	5.34

VI. POWER AVAILABLE FROM SOLAR ENERGY

Here, the power available from solar energy is calculated for March 24, 2021 since April and May represent the hottest seasons in which maximum solar radiation occurs ($n = 83$, as the numeric sequence starts with 1 for January 1st). Then, the latitude (ϕ) of Parul University, vadodara, India, for the calculation, is 22.3072°. From this, the declination angle (δ) is calculated (Eq. 5), which represents the angle between the equator and a line drawn from the center of the earth to the center of the sun.

$$\delta = 23.45 \sin \left(360 \frac{284+n}{365} \right) \tag{5}$$

By using latitude and declination angle, the hour angle (ω_s) can be found, which is the angle through which the Earth must turn to bring the meridian at a point directly in line with the Sun’s rays. It is equivalent to 15° per hour.

$$\omega_s = \cos^{-1}(\tan \phi \times \tan \delta) \tag{6}$$

Thus, daily average irradiance (H_o) is:

$$H_o = \frac{24}{\pi} I_{sc} \times 3600 \left(1 + 0.033 \left(\cos \frac{360n}{365} \right) \right) (\omega_s \sin \phi \sin \delta + \cos \phi \cos \delta \sin \omega_s) \text{ kJ/m}^2 \cdot \text{day} \tag{7}$$

Table 3:

Parameters	S.I units
Declination angle	1.63°
Hour angle	89.33°
Daily average irradiance	19805.71 kJ·m ⁻² ·day ⁻¹
Day length	12.08 h



VII. DESIGN OF THE MODEL

According to the airfoil selected,

Wing: balance point 25% average chord length back from leading edge, no more than 33% back from leading edge. Aileron area 10% of total wing area. Aileron length is 8 times its width.

Airfoil: Airfoil high point 25% back of leading edge. Airfoil thickness 12% to 15% of chord, including covering.

Fuselage: Fuselage length is 75% wing length. Nose length from prop to wing leading edge is 20% fuselage length. Tail length from wingback edge to horizontal surface front edge is 40% fuselage length. Fuselage height 10% to 15% of fuselage length.

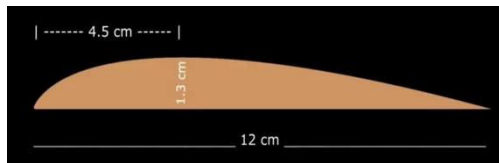


Figure.5: Wing rip

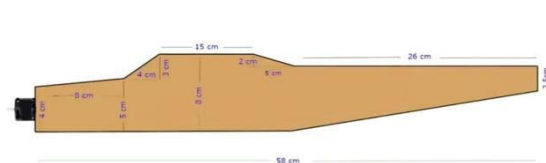


Figure.6: Fuselage sides

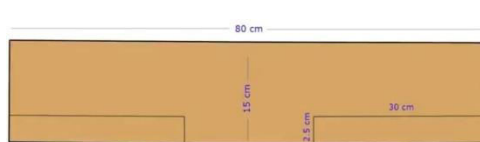


Figure.7: wing

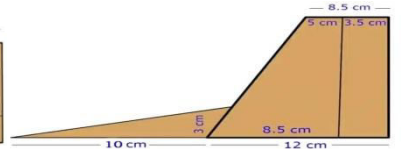


Figure.8: Rudder

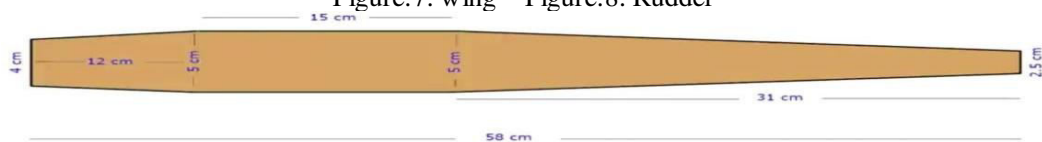


Figure.9: fuselage bottom

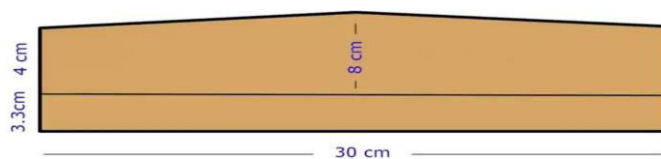
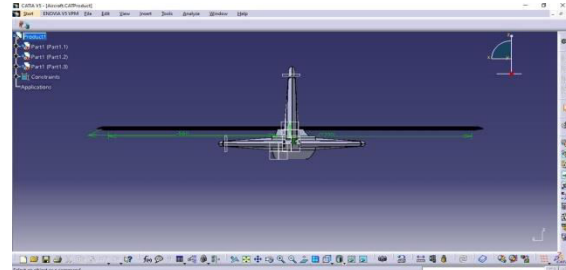
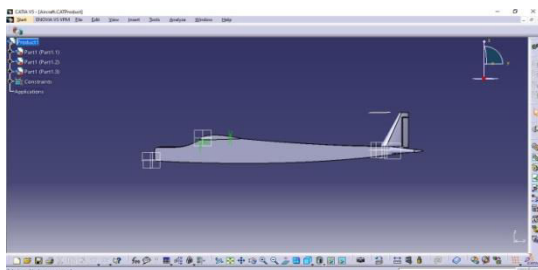
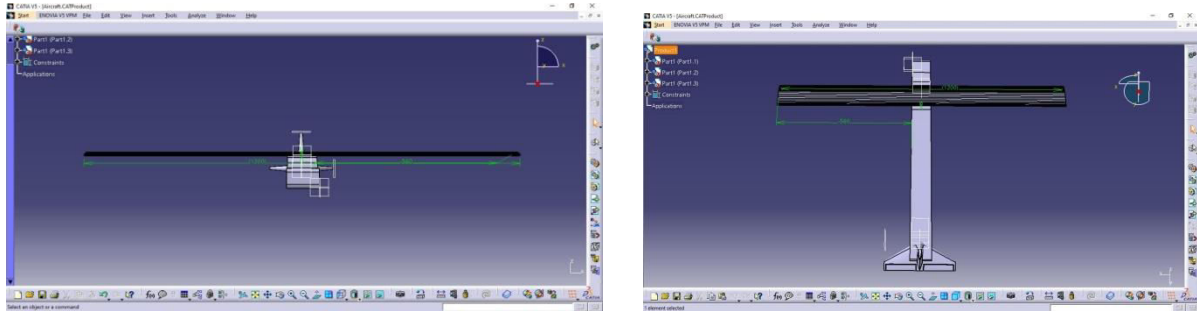


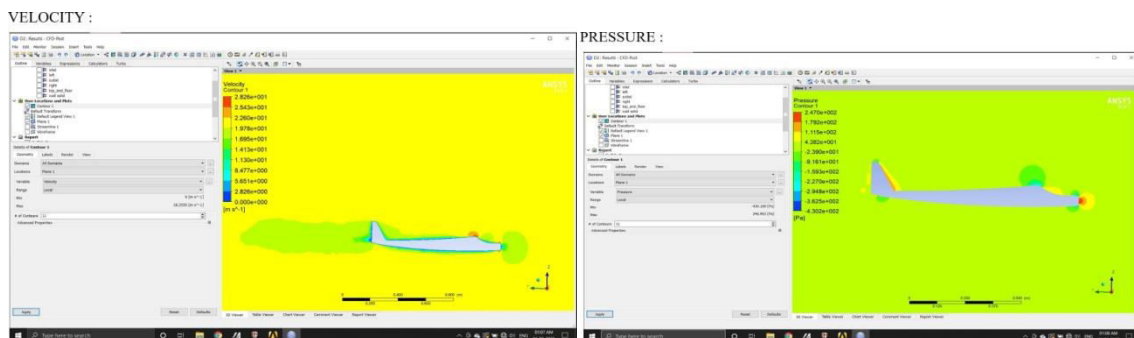
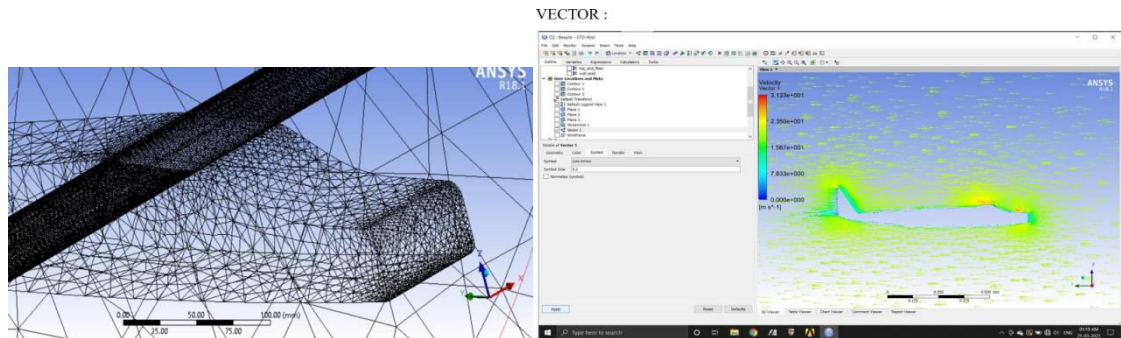
Figure.10: Elevator





VIII. ANALYSIS

CFD analysis of constant pressure at inlet velocity 20 m/s. Considering the density at sea level and meshing is tetrahedron (It has 6 edges, 4 vertices and is bounded by 4 triangular faces).



IX. CONCLUSION

Here, 28 solar cells of 75× 75 size of output power 0.8 w is mounted on the top of the wing. A total power of 22.4 w is produced . By even considering losses of 80 % flight can be achieved.

X. RESULTS

Successful flight with proper working of the all uav parts is achieved. Mapping & surveillance is done with the help of obtained footage collected by a 700 TVL wide lens camera.

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