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# Solar-powered airplanes: A historical perspective and future challenges

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ABSTRACT

Solar-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 study proposes that the 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 and enormous technical obstacles must be addressed.



**Contents**



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## 1. Introduction

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 [1]. 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. In 1974, the first solar-powered airplane in the world, Sunrise, made its maiden voyage. Since then, solar-powered airplanes 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 nighttime 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 (approximately 20–100 km). They can fly continuously for months, or even years, depending on the reliability of the airplane system and sunlight conditions [2], which is impossible for traditional, fossil-fueled 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 [3]. Solar-powered airplanes can also function as alternative to high-altitude balloons and airships, with the advantage of having free-maneuver 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 these applications fall within the category of dull, dirty, or dangerous (DDD) aerial work and are associated with high risks and costs [4].

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 [5]. Atmospheric density at 20 km is one-tenth of that at 0 km [5], 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. The aforementioned 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 multidisciplinary and optimized design.

The remainder of this paper is organized as follows. The history of solar-powered flight is reviewed first. Then, expected applications are introduced. Finally, the challenges faced by solar-powered airplanes are discussed.

## 2. History of solar-powered flight

### 2.1. The Sunrise project

Designed, built, and flown by Astro Flight, Inc., the Sunrise was the first solar-powered airplane in the world. The prototype airplane, the Sunrise I, made its maiden flight on November 4, 1974, and demonstrated for the first time that an airplane can fly on solar power alone. The Sunrise I had a wingspan of 9.8 m, a length of 4.4 m, a wing area 8.4 $m^2$, and a gross weight of 12.3 kg. In 1975, the Sunrise I was damaged in a windstorm during a test flight. Fig. 1 shows the maiden flight of the Sunrise I [6–8]. An improved version, called the Sunrise II, was then constructed. The Sunrise II had the same configuration but was 13% lighter, that is, 10.3 kg, and had 33% more power than the Sunrise I. The Sunrise II was expected to reach 50,000 15.2 km on September 27, 1975, but only reached 5.2 km because the command and control system failed. The aircraft was severely damaged and the test flight program was terminated. Five years later, the solar panels of the


**Fig. 1.** The Sunrise I demonstration flight (1974) [10].

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