Sun-Powered Aircraft Designs

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Two piloted aircraft have been developed by AeroVironment Inc. and flown powered solely by photovoltaic cells. The 30.8-kg 21.6-m-span Gossamer Penguin was used as a test bed, making a low-altitude 2.6-km solar flight in August 1980. The 98.6-kg 14.3-m-span Solar Challenger was developed for long flights in normal turbulence. Stressed for +9*g* ultimate, it is constructed almost entirely of plastics and filamental composites. With a 55-kg pilot, it sustains level flight on a minimum of 1400 W photovoltaic power in calm conditions. Ninety-four purely solar-powered flights were made in 1980-1981, culminating in a 262-km, 5-h 23-min flight from France to England on July 7, 1981. Maximum flight duration of over 8 h and altitude in excess of 4 km MSL were achieved in tests in California in May 1981. Maximum level flight speeds of 19.7 m/s were achieved in Europe with 2500 W of developed photovoltaic power.

Introduction

THE aim of the AeroVironment Inc. solar aircraft program, sponsored by the DuPont Company, was to make some pioneering and dramatic piloted solar-powered flights and thus increase people's awareness of the potential of photovoltaic energy as an alternative energy resource.

The first unmanned, controlled, solar-powered flight was made in 1974 when Sunrise II, a remotely piloted solar aircraft, flew to an altitude of over 5 km. Sunrise II was designed by Robert J. Boucher of AstroFlight, Inc., who has served as a key consultant on the Gossamer Penguin and the Solar Challenger.

The main aircraft of our solar program is the Solar Challenger, designed for the specific task of safely making long flights in normal, turbulent, sunny weather. As a stepping stone toward development of the Solar Challenger, we applied solar power to an existing airplane, the Gossamer Penguin, a 3/4-size version of the Gossamer Albatross II. The significant dimensional features of these aircraft and the initial Gossamer Condor are shown in Table 1.

Gossamer Penguin

Configuration

The Gossamer Penguin (Fig. 1) is an externally wire-braced, single-place aircraft of extreme light weight, with an electric motor drive replacing the foot cranks of its human-powered predecessors. A further modification, to improve yaw/roll response of the Penguin and free one hand for power control, was to add foot-pedal control of the wing warp system in lieu of the hand-operated warp control used on the Albatross. This aircraft served as an expedient test vehicle which could be expected to fly with the relatively small number of photovoltaic cells available to us at the start of the program.

The power plant was provided by AstroFlight, Inc. (Venice, California), and consisted of an "Astro-40" double-brush, dc electric motor and two-stage 27-to-1 belt drive reduction, coupled to a 5.17-to-I chain drive at the airframe interface, for a total gear reduction of from 133 to 1. Nominal motor speed was 12,500 rpm.

The energy source for the motor during initial flight testing and pilot training periods was a battery of 28 "D"-sized nickel-cadmium cells weighing approximately 3.6 kg. Control of the battery power was effected by a transistorized series regulator with an emergency "kill" switch actuated by a lanyard attached to the pilot's right wrist. For solar-powered flights, the batteries were removed and a panel of 3920 solar cells [2240 (2 x 4)-cm, 700 (2 x 6)-cm, and 980 (2.4 x 6.2)-cm cells] was installed, capable of producing 541 W of power in an Air Mass 1 (AM-1) environment (equivalent to average conditions of clear sky of low turbidity and sun directly overhead, 100 mW/cm^2). The solar cells were manufactured by Spectrolab, Inc. Solar panel fabrication, testing, control, and instrumentation were provided by AstroFlight, Inc., which also supplied some of the cells. The remaining cells for the Gossamer Penguin (and all for the Solar Challenger) were rejected cells obtained from the U.S. Air Force via a loan from NASA to AeroVironment Inc.

The cells were arranged in four discrete subpanels with individual switches for each. This electrical subdivision obviated the need for the electronic control (whose heat sink weighed ½ kg) used with the batteries. This digital power control of the electric motor was made possible by the self-limiting short-circuit current characteristic of the photovoltaic cells, which reduces inrush current to a maximum of approximately 25% greater than that for maximum power. The fragility and limited controllability of the airplane required flying only early in the day when wind and turbulence were low but sun angle was also low. Therefore it was necessary to have the cells mounted on a panel which could be tilted toward the sun, and only flights headed north or south were feasible.

Instrumentation for the Penguin included airspeed, voltmeter, and ammeter. The voltmeter was located on an external wing wire and the ammeter on the battery pack in positions where they could be read by a ground-crew member; they were ultimately removed for the solar-powered flights.

Weight of the Penguin without the solar panel installed was approximately 23.5 kg. The solar cells weighed 4.3 kg. Total weight for the panel, including support structure and wiring, was 7.3 kg, producing an empty weight for the solar-powered craft of 30.8 kg. Wing area was 27.6 m^2 and the canard stabilizer area was 3.25 m^2. The stabilizer was 5.5 m ahead of

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