POSSIBILITIES AND REQUIREMENTS FOR LONG ENDURANCE HIGH FLYING SOLAR POWERED PLATFORMS

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Presented at XXV OSTIV Congress, St. Auban, France

Introduction

Solar power is the right energy source for long endurance, high altitude flyers, because it is not air demanding. Whereas solar power increases by about 50%, power demand increases similar until about 30,000 ft but progressively at higher altitudes.

Solar aircraft like "Icare" can climb up to 30,000 to 35,000 ft. A pure optimum glide down from 100,000 ft would last only some 8 hours.

In order to stay overnight at high altitudes the following is necessary:

- A high total solar system efficiency of over 8%,
- a high wing area with maximum solar cell covering,
- the lowest weight possible,
- good aircraft aerodynamics,
- lightweight, high capacity and efficient energy storage and conversion system (i.e. fuel cell and electrolysis system),
- good control-, navigation-, survey-, and management system,
- all components and systems efficient, safe and reliable.

All technologies required are available not only from space flight but also from submarines and other applications, but have to be redesigned for solar flight requirements.

PATHFINDER from Aero Vironment (Paul MacCready) is the first stage of such an aircraft that climbed over 50,000 ft in 1995.

The first long duration high flyer could be HELIOS, a 200 ft span mono-wing, fulfilling many research-, survey, and communication duties much cheaper and more flexibly than satellites or high flying conventional aircraft.

Following the invention of the photovoltaic cell in 1954, Dr. A. Raspet pointed out the possibility of longer-duration flights with solar-electricity powered airplanes.

The first solar plane "Sunrise I" realized by R.J. Boucher (ASTRO Flight Inc.), in 1974, had already been designed for climbing up to the stratosphere (l) (Figure 1).

Nearly all pioneers involved in solar flights had been stimulated by the idea of creating a solar current-powered airplane cruising over long periods at high altitudes.

So, the 84-HALSOL project had been focusing on a research airplane soaring at a 60,000 ft altitude for several weeks. However, this project could not be followed up since the energy conversion and storing components were still too heavy and lacked in efficiency (2).

This report mentions requirements and possibilities on how to attain this goal within the next decade with the help of presently available technologies and developments.

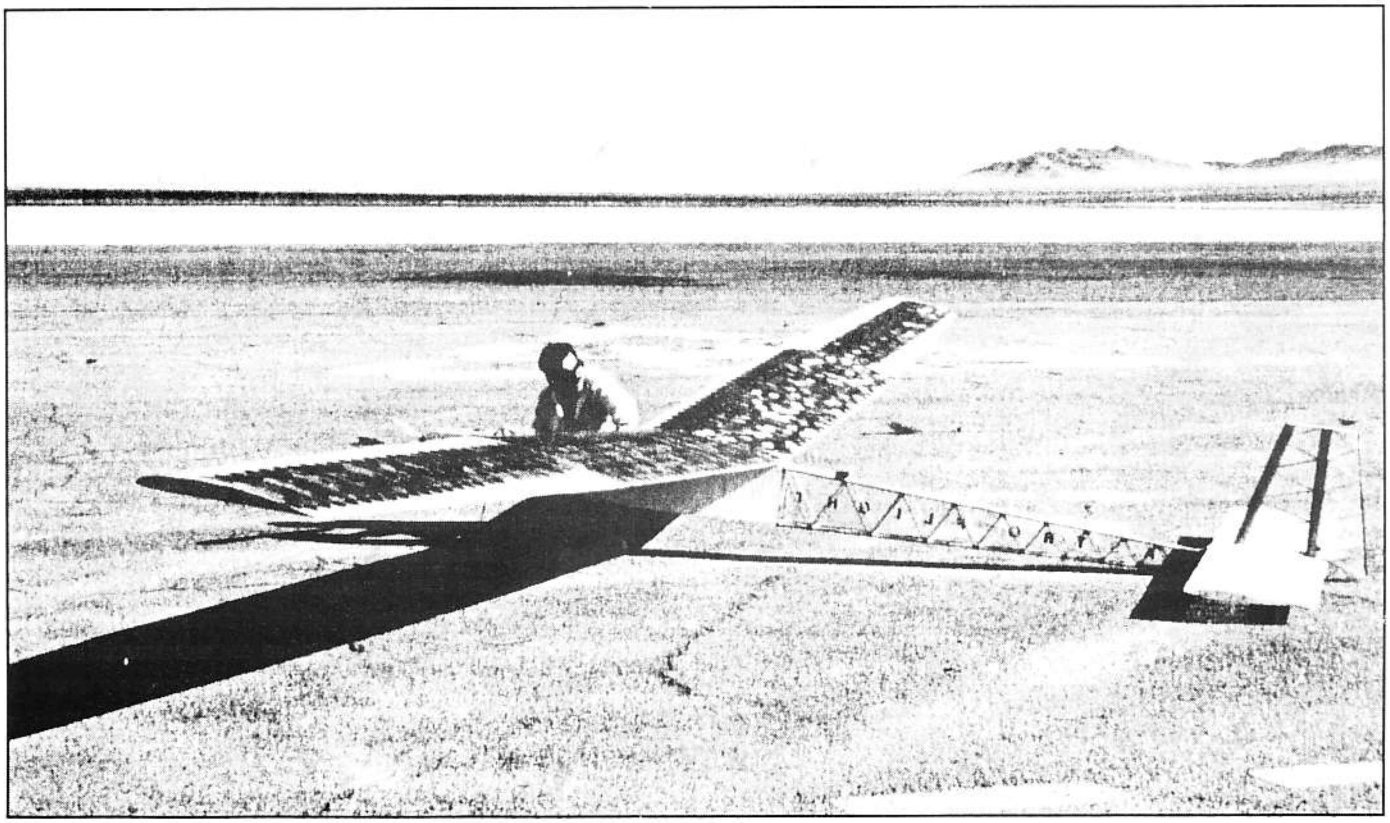

Figure 1. First solar plane, "Sunrise 1" realized by ASRTO FLIGHT Inc. In 1974; from [11, pg.27].

Requirements

Unfortunately, the idea of a solar plane climbing with the solar energy captured during the day to a sufficiently high altitude to permit its gliding down during nighttime by means of the collected potential energy cannot be realized. This is because the flight conditions encountered by an even adequately adapted solar airplane are deteriorating drastically above the troposphere (about 30,000 ft).

Diagram 1 shows that up to an altitude of 20,000 ft the power demand for constant level flight which increases due to the lower air density will be compensated by the solar power rising likewise with higher altitude. This solar power increase is due to the more intensive solar radiation as well as the solar cells efficiency improving at decreasing temperature.

The captured solar power no longer rises when the airplane enters the tropopause (about 35,000 ft), whereas its power demand increases dramatically. This is primarily due to the lower higher altitudes.

This may be demonstrated by a computation made for an airplane descending in standard atmosphere with 1.33 ft/s (0.4 m/s) (Diagram 2).

Upon having reached a 100,000 ft altitude (about 30,000 m) at sunset and descending during the night with optimum speed and in calm air, this plane will touch down after only 8.5 hours.

Therefore, an efficient and ultralight system will be needed for storing sufficient solar energy during the sunlight hours for the night flight at, if possible, constant altitude.

In order to keep an aerodynamically optimized ultralight airplane (weighing not more than 200 kg) at an altitude of 60,000 ft, electric power of about 5 kW and an energy supply from a 70 kWh- (or 250 MJ-) store would be needed for a 14 hour night operation.

Actual projects and developments

At the present state of technology, a Ni-Cad Battery weighing nearly 2,000 kg – as it is used for example in the ICARE (3) – would be necessary for this purpose. There are no other battery systems offering much better weight conditions.

Even with rather conservative efficiency assumptions, comparison calculations with the fuel cell technology show that an identical amount of net electric energy can be stored when using slightly more than 3 kg H_2 and 27 kg O_2.

The benefits of maximum chemical energy storage density (MJ/kg) offered by the H_2/O_2-system with its relatively easy technological handling (non-toxic and non-corrosive) and its high efficiency of energy conversion had already been utilized at an early state of space flight (e.g. for the Apollo moon program).

For submarine propulsion, for instance, the complete storing and converting system (6) with electrolytical water decomposition and high-pressure storage of H_2 and O_2 is state of the art.

More comprehensive investigations within the Pathfinder Program (Figure 2) (2, 4) have evidenced consider-

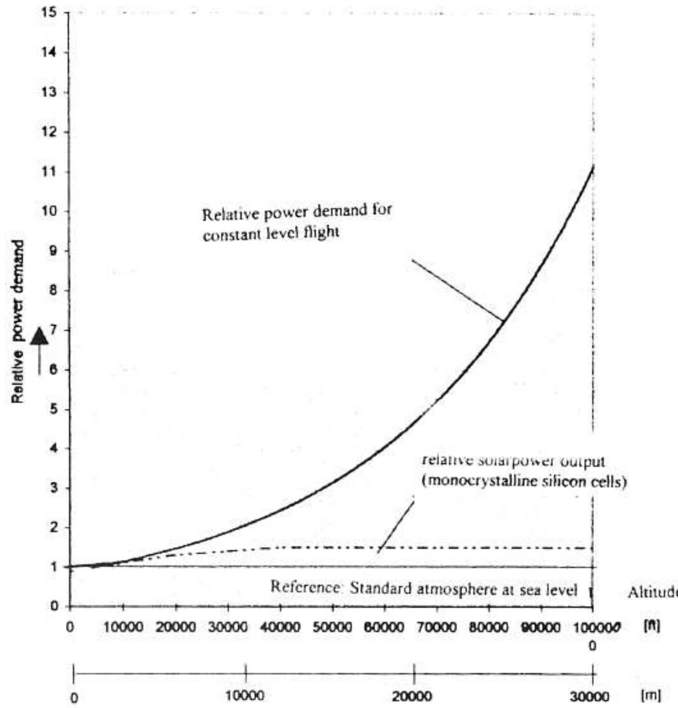

Diagram 1. Relative power demand and solar power output of a solar aircraft as a function of altitude.

able advantages of this energy conversion and storage system, a finding that also applies to solar planes.

The photovoltaic generator has to be designed for a three times higher power demand to provide a constant level at pertinent flight altitude. The surplus power is used to eletrolyze water into hydrogen and oxygen and to compress, dry and store the gases.

At night, the fuel cells provide electricity by recombining the gases. The produced water is stored. The dependable application of these submarine-proven technologies to the solar flight with its extreme lightweight requirements, space limitations as well as low ambient temperatures constitute a very presumptuous development project even at medium term.

Additionally, various auxiliary and secondary systems have to be partly adapted or newly developed.

The "Pathfinder," damaged during a storm in a hangar and repaired in the meantime, is serving as development carrier, though without energy storage device for the time being. Long duration flights at high altitudes were to take place in Hawaii in 1997. Arctic endurance flights starting from Fairbanks, Alaska, during the midnight sun period are likewise planned.

The successor project called "HELIOS" (7) (Figure 3) is a solar plane with a wingspan twice as large as that of "Pathfinder," and which initially will be tested without energy storing system.

A similar Isrealite project called "Satellites for the Poor" provides a somewhat smaller unmanned high-flying solar-powered platform. The propulsion system for the first prototype (Figure 4) has been designed by the author and successfully tested by the customer.

Among presently available fuel cells, polymer electro-

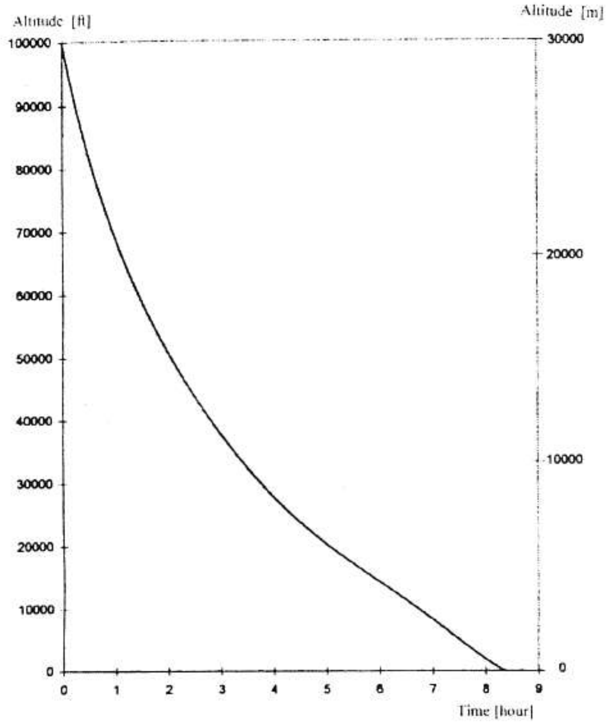

Diagram 2. Night descent gliding flight of a good aircraft from 1,000 ft. Sinking velocity at standard atmosphere condition is 1.33ft/s(0.4 m/s).

lytic fuel cells (PEFC's) are the most suitable ones (6, 8, 9). In view of the future market requirements (calling for small stationary plants or vehicles) these cells are preferably developed according to priorities other than high degree of efficiency together with minimum weight and mounting space as well as operation with compressed almost pure H_2 and O_2.

The fuel cells and electrolyzers presently available from the car and submarine technology have proven to be too heavy and not efficient enough for aircraft applications.

Future developments and prospects

Advanced development of fuel cells for airplane applications will enable 1.5 to 2 kg/kW that means 7.5 to 10 kg for a 5 kW device. Further, 50 to 80 kg have to be taken into account for gas (H_2 and O_2) compression, drying and storage, as well as water feeding, and also possible catalytic post-oxidation of flushing losses and water feed return. About 12 kg have to be considered for the electrolyzers, not forgetting pipings, fittings, heat exchangers and electric, measuring, controlling and automation equipment. Even a cautious mass estimation would mean over 120 kg so that for the airplane itself, its solar and propulsion system and the mission equipment (e.g. emitters and receivers) 80 kg at the most would be left: a hopeless situation.

Therefore, it is essential to have most everything upgraded by a series of improvements, especially:

- by reducing the power requirements of the airplane. Boundary layer suction as it has been described by Boermans in a convincing manner would be most efficient (10).

- by minimizing the structure mass by a suitable application of fibre composite materials, foils and foams and by temporary monitoring and telecommunication in areas afflicted with disasters and crises.

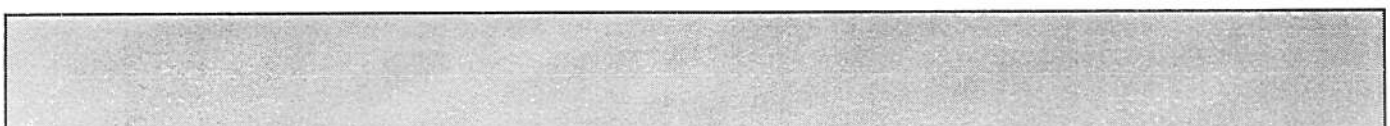

Figure 2. "PATHFINDER" at a test flight in 1994. 30m span; approx. 180 kg T.O. mass; from [11. pg. 199].

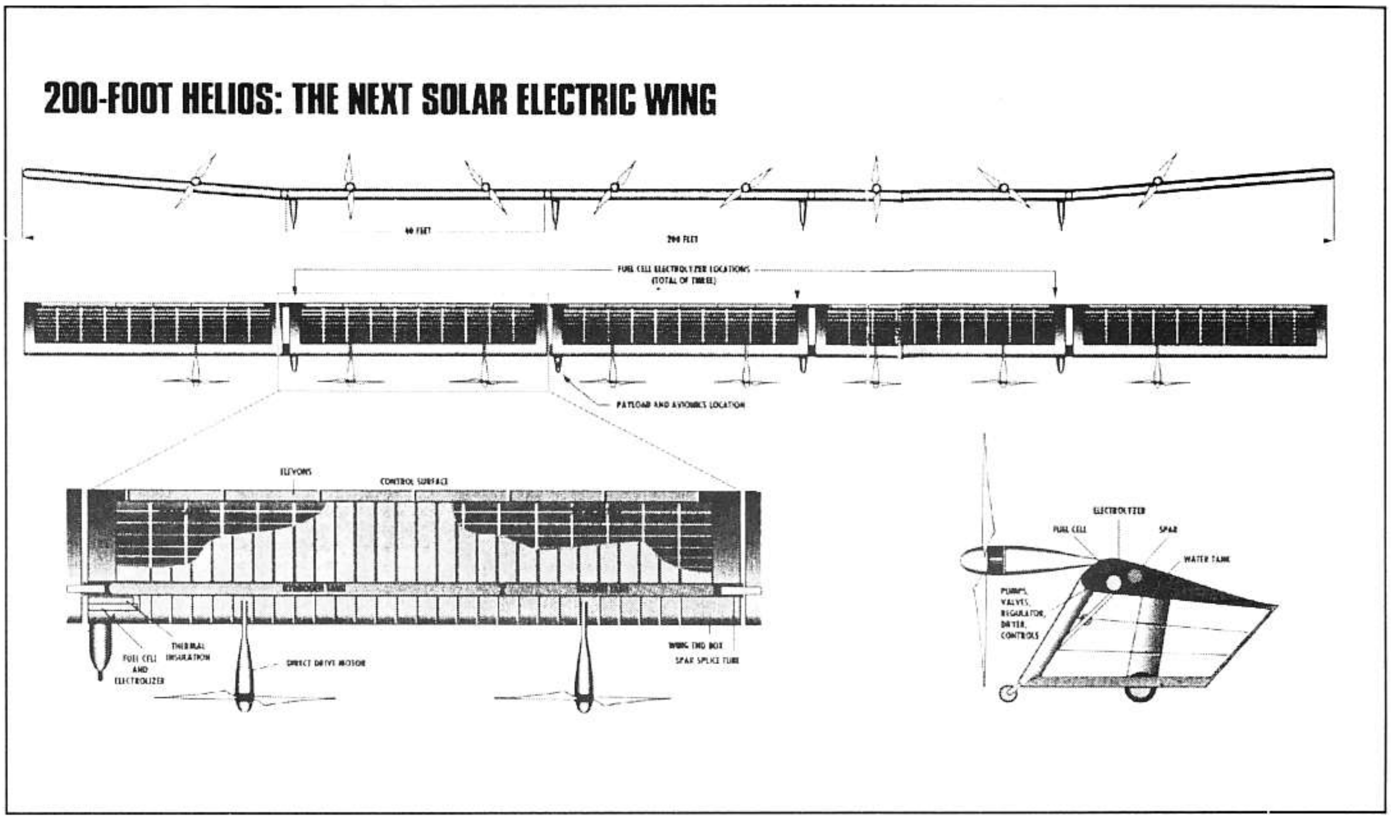

Figure 3. Next generation solar aircraft; from [7]. An even larger prototype had its maiden flight in November 1998.

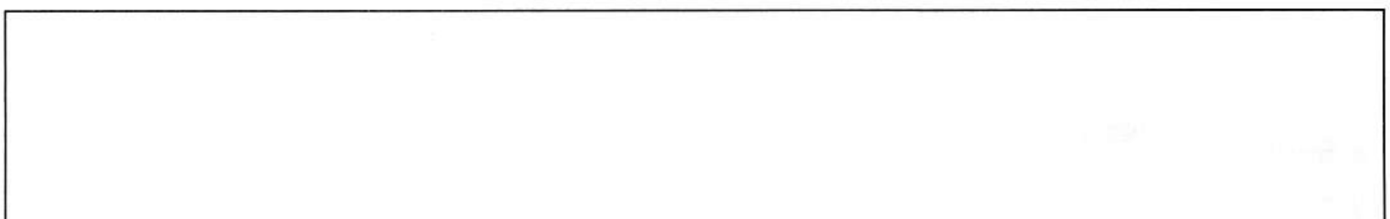

Figure 4. First prototype of Israel's long endurance Solar aircraft at a test flight in 1996; from [11, pg. 200].

Thus, high-flying sun-powered planes could permanently follow a hurricane from its origin up to the end of its activity over the continent and coastal areas. Without producing emissions the airplane could transmit information on disaster-stricken areas in a much faster, more flexible and far cheaper way than any conventional systems including satellites.

Further objectives:

The solar-powered airplane with "unlimited range" or "eternal flight duration" is a dream with the realistic background of useful missions in the intermediate atmosphere layers between earth station and satellite. These missions primarily exist for two types of measuring platforms:

a) The remote-reconnaissance platform for atmosphere and earth surface exploration by means of stationary line or surface scanning using measuring instruments of various wave lengths and

b) The telecommunication platform for the transmission of media products, but could also be used as receiving and relay stations.

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