

# Increased autonomy for UAV using solar panels and take advantage of updrafts through algorithm

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## ABSTRACT

The purpose of this research is to join more than one research and create an electric UAV that uses solar plates to recharge the battery and explores the benefits of the upward winds to be able to make autonomous flights of long distances, such as border monitoring, among other types of flights. In this way, we can observe that with the improvement of these two techniques we can gain a very large autonomy increase, increasing the flight coverage distance, transforming the electric UAV into a very viable alternative for some types of service, managing to eliminate its biggest problem which would be the time of discharge of the battery.

## 1 INTRODUCTION

Unmanned aerial aircraft are increasingly being used for various purposes such as forest monitoring, locating endangered people or objects in a large area.

For countries where there is a vast border airport where it is difficult to monitor even manned aircraft where it ends up being a very high price, due to the fact of the fuel, maintenance of the aircraft, then there are emerging alternatives of using unmanned electric aircraft for being a cheaper solution and letting manned aircraft be used in more emergency locations.

However it still has a very big problem because the autonomy of the batteries used by these UAVs

are of very short duration, having to be forced at some time to land them to replace these batteries and continue their mission. There are many works being done to lower the energy consumption of the aircraft's embedded system, as well as altering its design [1,2,3,4,5], but the focus of this work is to use the researched ones carried out on flights with electric aircraft using solar cells in order to recharge the battery, where for Brazil that is a tropical country we can have many benefits of this technology and use the research done on upwinds that can be much used to take the expenses of the engines, letting only the air current keep the aircraft flying.

In the next Chapter will be presented some historical projects on flights of aircraft that used solar plates [6], then will be presented historical facts about the use of rising winds [7] and to finish I will talk about the experiment that will be carried out.

## 2 HISTORY OF SOLAR-POWERED FLIGHT

I will present a summary of important projects involving unmanned aircraft using solar panels.

### 2.1 *The SoLong*

There are many projects carried out using solar panels to increase flight durability such as the SoLong project that was made by AC Propulsion Inc., a company that specializes in high efficiency electric propulsion. Alan Cocconi who is the founding chairman and chief engineer of AC Propulsion has carried out project financing. SoLong's goal was to be able to demonstrate that the aircraft could fly for several days powered by

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solar energy. SoLong was a solar powered monoplane with a wingspan of 4,75m, a wing area of  $1.5 m^2$ , with a battery that weights 5.6kg [Sanyo 18650 lithium-ion battery with 220 Wh / kg] 76 SunPower A300 solar cells and a total mass of 12.6kg. The plane was controlled remotely by six experienced pilots who concentrated on trying

## 2.2 The Helios platform (Heliplat)

Heliplat was developed to fly in the stratosphere, where it was the first unmanned aerial vehicle (UAV) with this capability and long duration in Europe. The monoplane had eight brushless motors, a double boom tail and two rudders [10]. The Heliplat was designed to fly at altitudes over 17km up to 25km, aiming to provide information assistance services in parts of the Mediterranean Sea area. The project was an offshoot of the HELINET project, where his objective was to create a network of stratospheric platforms to carry out traffic monitoring, environmental surveillance and broadband services coordinated by Politecnico di Torino. In January 2000, the project was funded by the European Commission under the Fifth Framework Program and developed at the Polytechnic University of Turin. The goal was to create a UAV that would have resistance to flights at high altitudes using solar panels and fuel cells that could extend flight durability in up to approximately 9 months. But this project was not finalized by limited financial support, a scale-sized solar-powered prototype was fabricated from it [11, 12, 13, 14].

## 2.2 The Sky-sailor

to use upward currents and avoided downward currents. SoLong was successful in making its flight at Desert Center Airport on June 3, 2005, which is located east of the Colorado desert in California, establishing a 48-hour flight without landing. They did not continue the flight test any longer because the pilots were exhausted [8,9].

Sky-sailor was a project created by Space Technology Advances by Resourceful, Targeted and Innovative Groups of Experts and Researchers of the European Space Agency (ESA).

The project began at the end of 2003, aiming to get a very light aircraft that uses solar panels to fly night and day. The research was conducted by the Autonomous Institute of Systems Laboratory of EPFL. The Sky-sailor's overall configuration was similar to that of a motorized glider, with a base layout similar to Glider Abance, where it had won world records, distance and duration. The aircraft had a wingspan of 3.2m, a lithium-ion battery that weighs 1056kg and a total weight of 2444kg. His first flight was held in 2005.

In June 2008, a demonstration flight was held where it lasted 27 hours, setting a record [15].

## 2.3 The Venture

In 2007, the US Defense Advanced Research Projects Agency (DARPA) was looking for an alternative to expensive satellites. The purpose of the alternative was to meet ISR requirements or to relay communication. With it a project named Vulture, which was a solar powered aircraft that

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could stay in the air for up to five years. The Vulture weighed 450kg and had a payload of 5kW. In 2009 the project entered a second phase, with the aim of being an unmanned aerial system of high altitude and long duration that could remain for three months flying. After a competition for three team to build the plane the winner was the SolarEagle, with an extended version of Zephyr and made its first flight in 2014 [15, 16].

## 3 HISTORICAL FACTS OF AIRCRAFTS USING UPWARD WINDS

First studies involving upward winds were conducted through bird flight studies [17], where winds are coming from the ground upwards and greatly assist the birds to glide as for UAVs to save battery during flight. The benefits from these winds are that the aircraft manages to increase its resistance and to save energy. A study conducted by NASA using theoretical calculations demonstrates that a 2 hour resistance UAV can achieve a flight of maximum 14 hours using updrafts in good weather conditions [18].

I will present some studies on thermo exploitation strategy using UAV.

The first to propose an autonomous simulation for the UAV was John Wharington in 1998 [19].

In this work an updraft modeling structure for simulations of increasing UAV strategies was presented. He used a simplified thermal model based on measurements and theoretical calculations. In the model presented the thermal is considered a circle or ellipsoid, with a distribution of Gaussian vertical velocity. In other

simulations performed later, others ended up using very similar thermal vertical velocity distributions, in a quadratic function [20] or ray dependent [21].

First he used a strategy that is well known among glider pilots, based on the rules of the famous racing glider pilot, Helmut Reichmann [22]. The rules are:

If the climb is good, lower the seat angle.

If the climb improves, increase the angle of the seat.

If the rise remains constant, keep the bank angle constant.

This strategy worked very well in simulations, but the method used as previously mentioned was a simplified good where it would have other methods more effective than it. With the theoretical calculation already solved he developed an orientation algorithm using reinforcement learning and a neural network system that located the center of a thermal for an optimal autonomous exploration of the thermals. But his algorithm with neural network-based thermal center locator consumed a lot of time for real-time online applications.

Stephane Doncieux and his colleagues developed a growing strategy using evolutionary algorithm to optimize the connection weights in a neural network [23], where altitude gain during the allocated evaluation period was used as fitness function. The input parameters of the neural network were the vertical speed, the angle of rotation and slope of the glider. The exits of the

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network controlled the elevator and the rudder of the airplane. Using simulations, this strategy was successful for ideal thermals, modeled similar to those proposed by Wharington [19].

NASA during the Autonomous Ascent Project at Dryden Flight Research Center developed the first successful UAV [24]. Michael Allen and a team of engineers programmed a small UAV (4.27 m, 6.8 kg glider called Cloud Swift) to detect if it is in an upward current and use that circling current. During the project, the UAV flew 17 times, gained an average altitude of 173m in 23 updrafts and climbed 844m in a strong thermal. In one of the flights of this project, the UAV added 60 minutes to its resistance rising autonomously.

More recently, even more successful location and thermal orientation algorithms were designed and implemented at the State University of North Carolina and the US Naval Research Laboratory by Daniel J. Edwards [25]. The UAV in this project participated in the Valley Valley Cal Race in May 2009, where he defeated the humans in a cross-country competition and covered over 113km. On another flight remained in the air for more than 5.3 hours.

## 4 EXPERIMENT

We will use for this experiment a model airplane known as wing-zags with a wingspan of 2.25 meters, has a angle of 30 degrees, ZAGUI12 wing profile, done on styrofoam type 5 (P3). Figure 1 shows the UAV previously referenced already with the embedded system, but without the solar plates.



Figure 1 - UAV that will be used in the experiment without solar plate

An amount of 20 solar cells will be allocated in the wing where on the one hand will have on average 10 cells connected in series and each wing will be connected in parallel. The solar panels are made of monocrystalline silicon material, measuring 63 x 125 mm, which generates 0.574 volts, generate a chain 2,915 amperes, with a 21.8% efficiency.

For the autonomous flight will be used a pixhawk controller board where with it will be a zybo zynq 7000 type computer that has 650 MHz dual-core ARM Cortex-A9 processor, DDR3 memory and programmable logic equivalent to FPGA Artix-7, where it will be running Ubuntu 16.04 with the ROS program to do optimization of performance in a thermal. The algorithm for optimization will be implemented in python.

The purpose is to generate a mission autonomously for aircraft and to measure the time that it has been accomplished this mission to obtain results in the part of autonomy.

## 5 CONCLUSION

We can conclude with this paper that many works of UAV using solar panels and rising winds gave a very significant increase of autonomy. With this information, its being

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built an electric UAV with solar panel coupled in the fuselage, an algorithm is being implemented so that the UAV can autonomously identify that it is entering a rising wind and take advantage of this benefit to save battery power with the engine.

## 6 FUTURE WORKS

It will be creating an electric circuit for charging the battery efficiently and the code will be developed in Python where when entering a thermal the motor shuts off until it has passed the terminal to have a consumption of battery assisting in moments that the solar plate does not generate enough power to charge the battery.

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