

HALE Solar Hybrid Applications

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Abstract

High Altitude Long Endurance (HALE) systems are created to fly high in the atmosphere while staying aloft for long periods of time. The Unmanned Aerial Systems (UAS) that use this design are intended to be utilized as a 24+ hour flying vehicles that relays some type of information to or from in both commercial and military domains. This information ranges from providing internet to rural or remote areas such as the Facebook Aquila to acting as a communications relay to warfighters such as the Northrop Grumman BACN. The Battle Airborne Communications Node (BACN) is used as a persistent relay in the sky that joins and distributes communication to warfighters in a battle zone. (Northrop Grumman, n.d.) They also provide real time weather information on approaching hurricanes or long endurance Earth science missions by National Aeronautics and Space Administration (NASA). New technology from MIT takes advantage of recent advances. While many researchers have been working on new solar cells, the MIT team is the first to create one that absorbs more energy than the photovoltaic cell alone. (Temple, 2017). This technology would require cooler than normal temperatures to operate. If used correctly, this technology can be combined with current solar powered batteries to keep an HALE UAS airborne almost indefinitely. Combining new technology for solar arrays with high altitude temperatures, it can conceivably HALE UAS the power required to operate for longer than normal periods of time.

Keywords: HALE, UAS, solar, NASA, BACN, battery

Introduction

Unmanned Aerial Systems (UAS) have been in use for many ways since World War I. Militaries around the world and commercial companies have been building and improving these systems to take on many roles. Technology has advanced in the recent years to help expand limitations that have been difficult for these systems. One of those systems in the High Altitude Long Endurance

(HALE) aircraft. HALE aircraft by contrast are typically capable of flying as high as 60,000 feet and can endure missions as long as 32 hours. (Pomerleau, 2015) HALE aircraft are used for many purposes and have accomplished many missions around the world.

The company Facebook has created an UAS called Aquilla that is powered by battery packs charged by the sun during the day and the power is used to stay aloft at night. (Zuckerberg, 2016) This solar powered aircraft will beam internet to remote areas and eventually break the world record of the longest unmanned aircraft flight. (Zuckerberg, Facebook, 2016) This type of aircraft will help give internet to large populations that do not have easy access. The company Northrop Grumman built and maintains the RQ-4B Global Hawk. (Northrop Grumman, n.d.) This aircraft is used as a Battle Airborne Communications Node (BACN) to act as a relay for warfighters in combat zones. (Northrop Grumman, n.d.) The National Aeronautics and Space Administration (NASA) uses the RQ-4B Global Hawk to monitor hurricane paths and perform science experiments by observing the earth from the atmosphere.

There is a need for a HALE aircraft that can reliably for 24+ hours. One common function that HALE aircraft perform is persistence. Maintaining a presence over one point of interest gives the most information possible over time. In the summer of 2017, two hurricanes named Harvey and Irma landed on the southern United States. During the predictions for this hurricane, the models and predictions for their path changed considerably throughout its approach to the United States. This is due to variables changing many times during the approach to landfall. The forecast for the path of a hurricane is dependent upon predicted winds and forecast models. The direction in which the winds carry the hurricane vary by altitude. (NASA, n.d.) If NASA and the National Oceanic and Atmospheric Administration (NOAA) had been able to have an aircraft flying over the hurricanes for the entire approach, it is possible that the information would have been more accurate and better relayed for evacuation or preparation.

This paper features a proposal of Solar powered HALE hybrid UAS that can fly longer than current jet fueled UAS. These solar aircraft have the potential to fly for extremely long periods of time without landing. This type of flying gives the persistence required to perform many functions that are normally done by jet fueled aircraft that must land and refuel. Current solar aircraft use photovoltaic (PV) cells in their wings to charge their batteries. This process happens during the day and in direct sunlight. Most PV Systems are individual small squares of only a few inches. Each cell only generates a few watts of power, so they are grouped together to form panels. (UOCS ,2015) These panels usually only provide approximately 32 percent of the power received by the sun due to the nonconductive nature of silicon. Recent breakthroughs at MIT have shown the possibility of using solar thermos photovoltaics to double the current efficiency

through heat. Since the power increase comes from thermal energy, this would not require direct contact with the sun at all times. An increase in capabilities from solar panels like this would mean a complete change in how solar aircraft are viewed and operated.

Literature Review

The literature review for this topic focused on the use of HALE aircraft and their power source. Research has been done by different teams highlighting the importance of Solar Powered HALE aircraft for various missions. There is also research in different methods for storing energy to be utilized by solar powered UAS other than the sun.

Alternate Energy Storage

In Gao et al.'s 2012 article titled Energy management strategy for solar-powered high-altitude long-endurance aircraft, the authors find that HALE aircraft have a great impact on military and civil aviation due to the fact that the power source is inexhaustible. Due to solar flight requirements of flying through the night, the authors propose an Energy Management Strategy based on the theory that solar energy can be stored in gravitational potential in the daytime. Gao et al. explains that the flightpath of HALE aircraft is divided into three stages. During the first stage, the solar energy is stored in a battery and gravitational potential. The gravitational potential is released in the second stage by gravitational gliding and the required power in the third stage is supplied by the battery. (Gao et al., 2012)

This indicates the possibility of potential techniques other than raw power to keep the aircraft aloft at night. This is a hybrid technique of using solar power to charge batteries. These batteries are used to power the engine and payload. These engines are then used to climb as high as possible to store the energy from the sun as a gravitational force to be used at night. The article however, does not cover using a different power source or capability. This kind of premise requires an energy management capability of the aircraft to be successful.

In Gao et al.'s 2015 article titled Reviews of methods to extract and store energy for solar powered aircraft, the authors explain that current technology to operate solar aircraft are based on photovoltaic cells, rechargeable battery, and component of maximum power point tracking (MPPT). (Gao et al, 2015) The authors explain that although this is the primary way that solar aircraft utilize the sun to fly, there are studies into other methods to keep the aircraft aloft. One of the methods mentioned is extracting energy from wind shear and store it by gravitational potential.

Gao et al explains that when incorporating dynamic soaring, it can be expecting that the long-endurance performance of solar powered aircraft will be greatly enhanced since the power requirements can be reduced without adding additional weight on the aircraft. (Gao et al, 2015) This is another example of hybrid power for HALE aircraft. Utilizing wind shear and solar power to turn the energy into gravitational potential allows the aircraft climb to higher altitudes without using the batteries to do so.

Needs and Concepts for Solar HALE UAS

In Zhu et al.,s 2014 article titled Solar-powered airplanes: A historical perspective and future challenges, the authors write about historical aircraft that have taken advantage of solar power to fly for long periods of time. They explain that solar aircraft have the capability to fly much longer than gas powered aircraft. Zhu et al explains that solar-powered airplanes can be designed to fly near space (approximately 20– 100km). They can potentially fly continuously for months or even years, depending on the aircraft and sunlight conditions, which is impossible for traditionally fueled aircraft. (Zhu et al., 2014) The fact that conventionally fueled aircraft cannot stay airborne for extremely long periods of time is a great indicator that there is a clear avenue for solar UAS growth.

The article considers various aircraft such as the Zephyr. The Zephyr flew in Yuma, Arizona for 82 hours nonstop while reaching an altitude of over 60,000 feet. (Zhu et al., 2014) Aircraft like this show that we are currently not to the point of flying for weeks or even months at a time, however, the authors indicate that due to low energy output by the solar panels, the aircraft do not produce enough power to maintain flight using today's Photovoltaic cells and use its payload at the same time for extended periods of time.

Solar Technology

In the 2016 article by Abbe & Smith titled Technological development trends in Solar-powered Aircraft Systems, the authors go into detail on various aspects affecting solar HALE aircraft. The paper considers issues related to structures, systems, propulsion, aerodynamics, and system integration on solar powered aircraft. (Abbe & Smith, 2016)

For solar aircraft, the authors explain HALE aircraft's major aspects are structure and manufacturing aspects, energy source, energy storage, propulsion, avionics systems and operations. These concepts are the core of the most important factors that must be efficient to properly perform. One of the most important areas covered by the authors is the photovoltaics cells. These solar cells can be created using different materials and each one has pros or cons that can affect the overall capabilities of the aircraft.

In an article 2016 written by Bierman et al from MIT titled Enhanced photovoltaic energy conversion using thermally based spectral shaping, the authors explain a new way of creating the solar panels that HALE utilize. The Photovoltaic panels are used to reduce the temperature generate by the panels and turning the heat into energy that can be utilized by the aircraft as power. When the sub-bandgap photon emissions are suppressed, a higher efficiency is attained from the spectral shift. The absorbed photo heat in the PV cell is reduced and excessive heat is dissipated. (Bierman et al, 2016) Lowering operating temperatures on the panels allows them to operate more efficiently. The system operates more efficiently by reducing overall heat generation of the photovoltaic cells by two but still matching output power densities. (Bierman et al, 2016)

This article indicates that it is possible to increase the amount of power created by the solar panels. The usage of heat as a source emitter allows the panel to use the sun and the heat generated for more power to the aircraft and battery. This is relevant to the paper because the solar panels can still produce energy when the sun is not visible through heat alone. This opens the door for other opportunities for power as a hybrid system.

Design Overview

The design for Solar Hybrid Application in HALE aircraft would start with the power source. The breakthrough from MIT would be the most beneficial system to incorporate in a HALE UAS powered by solar panels. By using heat to generate power, it creates the possibility to generate more electricity from the same sunlight. Another design aspect the energy stores in gravitational potential. Utilizing the weight and location in space could potentially provide stored energy without storing it in the batteries.

MIT Photovoltaic Energy Conversion

The new solar thermal photovoltaic cells shown in Figure 1 allows light to be funnel into the solar panel. This is then used to generate heat of 1000 degrees Celsius. (Bierman et al, 2016) The heat is then turned back into the light waves that normal photovoltaic cells use to generate energy. The ability to generate light from heat increases the possibility of doubling the amount of energy created by the solar panels for the same area. (Chandler, 2016)

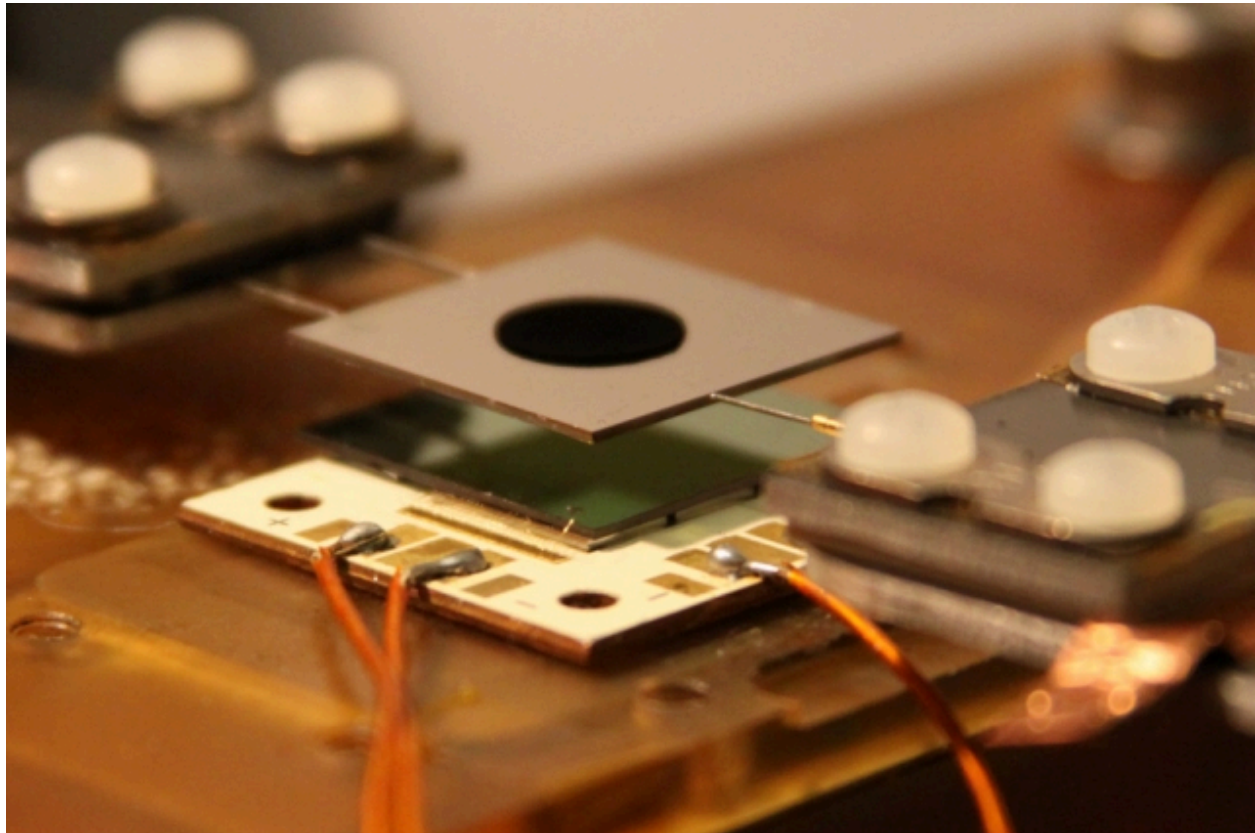


Figure 1. Solar Thermal Photovoltaic Cell from Enhanced photovoltaic energy conversion using thermally based spectral shaping (page 4), by D. M. Bierman et al. MIT: Nature Energy. Copyright 2016 by the Bierman.

Gravitational Potential Energy Storage

Solar aircraft can charge their batteries during the day. Batteries are only capable of holding their rated charge before they can't be charged anymore. Utilizing gravitational potential to store the excess energy may allow the HALE UAS to store more energy than their batteries can provide. Gravitational potential energy is created when the aircraft uses the energy from the solar panels to power the engines. (Gao et al., 2012) By climbing higher into the atmosphere on solar energy, the aircraft will be physically higher in the sky. The weight of the aircraft would have been carried upward using the solar energy and not the stored battery power. (Gao et al., 2012) When

the sun sets, the batteries will be required to maintain the aircraft aloft until the sun rises again. If the aircraft is at a higher altitude, the engines will not have to run as hard or at all to keep the aircraft aloft. The HALE UAS can simply start a glide down to a designated altitude over the course of the night. This lack of usage of the engines preserves battery power for when the aircraft levels off.

Once the aircraft has leveled off, the engines will use more battery power to maintain altitude. By using gravity to allow the aircraft to glide down from the original higher altitude, the aircraft wouldn't be required to expend battery power, thus storing the original solar energy in gravity. This type of technique has the potential to increase a solar aircrafts capability to stay aloft at night when the sun isn't providing any power. (Gao et al., 2012)

Design Limitations

Solar Panels

Limitations of solar panels are very basic in that they require the sun to produce energy. The solar panels themselves require direct contact from the sun to produce the electricity required to charge the batteries. This limitation is seen at night when the sun sets and the aircraft must maintain flight from the batteries onboard. Since the solar panels cannot charge the batteries at night, the batteries must be capable of holding a charge long enough to keep the aircraft aloft until sunrise.

Gravitational Potential

The limitations for gravitationally stored energy is related to the aircrafts ability to climb to higher altitudes. (Gao et al, 2015) If the aircraft cannot climb to a higher altitude or does not encounter any wind shear to drive it up vertically, it cannot store the excess energy into the altitude climbed. Without excess altitude, the aircraft will not be able to glide down to a lower altitude thus saving energy at night. This loss of stored energy can potentially cost the aircrafts ability to stay aloft at night due to lack of stored battery power.

Conclusion

Solar powered HALE UAS have the ability to stay aloft for long periods of time as shown by the Zephyr. This capability combined with the current use of HALE conventionally fueled aircraft such as the Northrop Grumman BACN would allow for 24/7 coverage in any area in the world. The breakthrough at MIT using thermal spectral shaping indicates that it is possible to use heat to double the energy output from solar cells thus increasing the energy potential stored on the aircraft. Gravitationally stored energy research indicates that it is possible to simply fly the

aircraft a different way to store energy from day time to be used at night while reserving the batteries for later in the night. A combination of these two methods of energy creation and storage shows that it is possible for Solar HALE UAS to use a hybrid approach to energy creation and conservation.

Further research would need to be done to examine the actual capabilities of the new thermal photovoltaic cell. Research would also need to be done to examine the combination of the new cells with different flying techniques to maintain the aircraft aloft for extended periods of time. These two methods open the door to possibilities of flying Solar UAS indefinitely.

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