Flight Testing a Venus Aerial Platform in Earth's Atmosphere

The Application of Biodegradable Materials for High Altitude Solar Balloons

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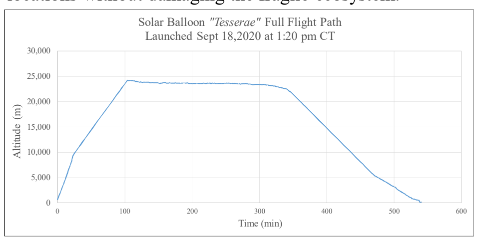
Introduction

Direct seismic measurements on the surface of Venus have proved very challenging to collect. The surface temperature on Venus reaches 460 °C, and the pressure is around 90 atm[1]. However, there is a region in Venus's atmosphere where earth-like temperatures and pressures exist (approximately 0°C and 1 atm). Here it is possible to collect data using solar balloon. Solar balloons, which are heated by solar irradiance to provide a buoyant lifting gas, are a unique option for low-cost high-altitude flight of small payloads. The bottom of the balloon is open to atmosphere, so it does not burst at the apogee of its ascent. A 6 m diameter solar balloon can carry a one kilogram payload to an altitude of 21 km. A standard flight profile is given in the figure below. Biodegradable balloons would provide the opportunity to fly in remote, environmentally locations without damaging the fragile ecosystem.



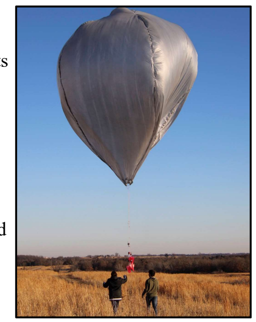
Material Analysis

Biodegradable film samples were collected from several companies and compared to the original solar balloon materials. Two small scale balloons were made from the top material candidates – Biobag 0.8 MIL and Plascon 0.5 MIL. These small scale tests demonstrated heat sealing as a viable constructed method for these films. The Plascon 0.5 MIL was selected for the full scale flight test. A 6m balloon made from the original).31 MIL HDPE was estimated to lift a maximum of 4 lbs. to a float altitude of 70,000ft. The Plascon balloon should support a 3.4 lb. payload to a similar altitude. A full scale balloon was constructed using traditional construction methods and the Plascon film.

Material Name	Thickness	Density	Biodegradable
Biobag 96G5559	0.80 MIL	147.9 lb/ft3	✓
Biobag MF02G1517	0.64 MIL	152.6 lb/ft3	✓
Biobag CP1517	0.48 MIL	151.2 lb/ft3	✓
Plascon Clear	0.5 MIL	64 lb/ft3	✓
High Density Polyethylene - Clear	0.31 MIL	55 lb/ft3	✗
High Density Polyethylene - Black	0.64 MIL	58 lb/ft3	✗

Flight Testing

Over the past year, 5 solar balloon flight tests have been conducted to test different solar balloon designs, materials, launch techniques, and instrumentation. Two flight tests occurred in the fall of 2020 to develop new launch techniques to ensure that solar balloon flights can occur in harsh weather conditions. This launch technique involves attaching a helium balloon to the top of a solar balloon and "towing" it to 80,000 ft. before dropping it at its float altitude. This flight technique has proved to be effective for solar balloon flights in high wind or cloudy conditions. This is the launch technique that will be used to test the full scale biodegradable balloon. Due to material shortages, there was only enough material available from Plascon to construct one panel on a five panel balloon, the remaining panels were constructed using the 0.31 MIL HDPE. This should still provide adequate insight into the materials performance when exposed to the extreme conditions and temperature variations of the upper atmosphere. This will also allow us to attempt to decompose material that has been flown. As seen on the left figure, these balloons frequently land in environments where they could negatively impact wildlife, so its critical to ensure proper recovery and disposal.

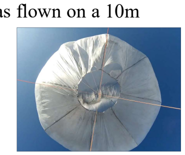


Perhaps the most important flight tests for the project thus far occurred in February of 2021. A 6m solar balloon was flown with a 6lb payload, which was double the amount that it was previously thought the solar balloon could carry to altitude. This solar balloon rose to 52,000 ft. before the radiosonde tracking it lost power. Several days after this test was conducted, a 10m solar balloon was launched to test it's payload capacity. Unfortunately this balloon failed after reaching a 30,000 ft. altitude, due to unstable flight dynamics and propagating tears in the solar balloon materials. These tests prove that not only is it possible for solar balloons to carry more weight, and thus be constructed of thicker films, but it may also be necessary to use thicker films to have successful flights with larger solar balloons.

Flight Dynamics

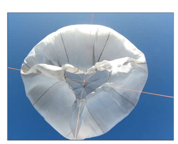
Solar Balloons experience altitude oscillation referred to as "breathing". This cause of these were not well known until an upwards facing camera was flown on a 10m balloon.

Stage 1: Balloon is at the maximum inflation size and rising in altitude



Stage 2: A ripple starts at the top of the envelope and propagates to the bottom, causing the balloon to contract

Stage 3: The ripple reaches the mouth of the balloon, causing the mouth to collapse as hot air exits the envelope and the balloon descends.

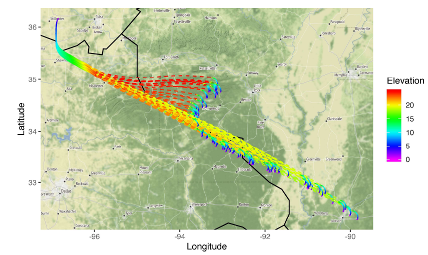


Material Degradability

Three different material thickness and brands were exposed to the elements over the course of three months to determine how biodegradable these materials are. This material set was left outside and exposed to equivalent conditions to a landed solar balloon. Over time, the most significant change in the three materials was shrinkage. The thinnest of the three films (0.5 mil, far right) showed the greatest change, followed by the 0.8 mil. The top image shows the three films at the start of the experiment, and the bottom is after three months. This experiment will continue over the next year. The films are still far from significant degradation.

Conclusions

The heavy lift test proved the initial assumption made regarding the maximum payload capacity of the 6m solar balloon was false. The results of the heavy lift test greatly expand the range of materials that could be used to construct a 6m solar balloon. This data shows that the balloon envelope weight could be doubled, and still support a 2lb payload up to a minimum of 52,000 feet. This also gives promising results for the 10m balloon, as it would have an even greater material weight margin, and may need the thicker film to prevent in-flight failure. Although poor flight conditions have prevented the full scale biodegradable balloon from flying, it's trajectory has been modeled with help from Sandia National Labs. These trajectory models show that this flight would have nominal behavior similar to that of a heavy payload solar balloon.



Future Work

This Wentz project has been extended for the upcoming 2021 – 2022 school year, although there are still several flight tests that we aim to finish this semester. Within the next week the full scale biodegradable balloon will be flight tested. Future work will continue to expand the work done on balloon materials, and their resulting impact on flight dynamics. Materials such as black polyethylene, Mylar, and thicker HDPE will be considered. The main objective will be to increase the durability of the balloon.

Acknowledgments

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