Flight Testing a Venus Aerial Platform in Earth's Atmosphere

High Altitude Solar Balloon Design and Instrumentation

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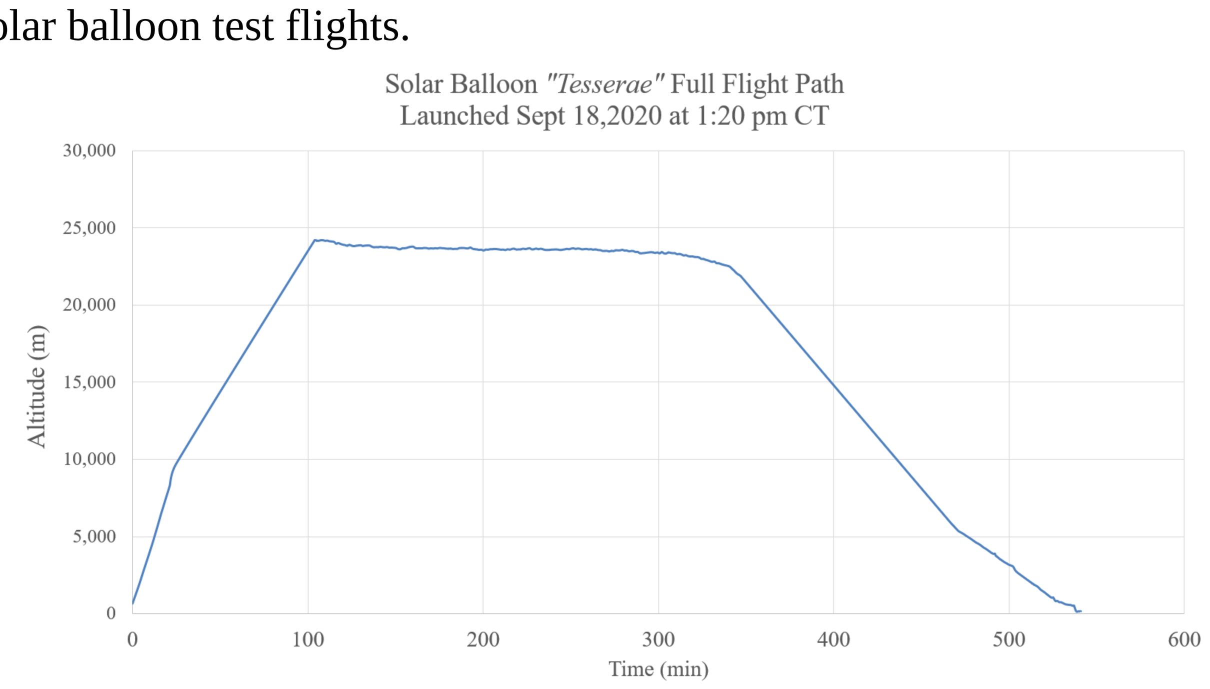
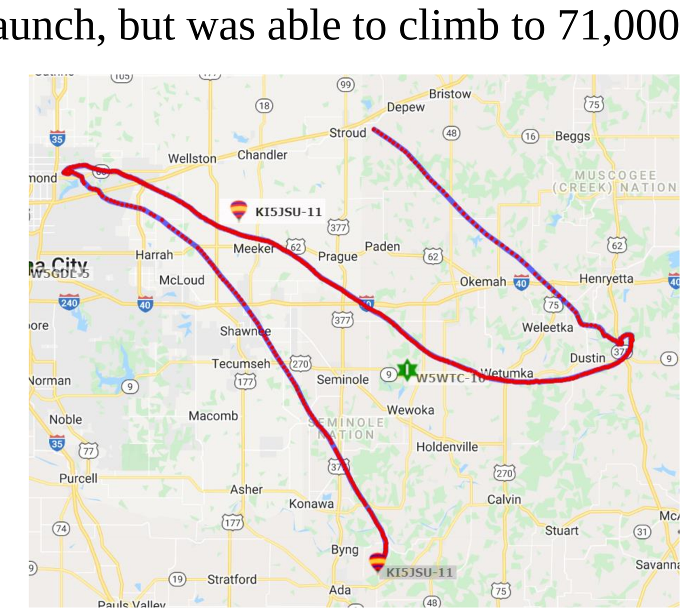
Introduction

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 . 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. In the summer of 2021, a major solar balloon flight campaign collaboration between OSU, JPL, and Sandia National Labs began. Several dozen balloons were launched over the course of four months in order to study seismic events in Oklahoma as an earth analog to potential Venus missions. Challenges during this flight campaign led to the development of new balloon instrumentation and designs, as well as an exploration of balloon materials. These experiments aimed to increase the success rate of solar balloon test flights.



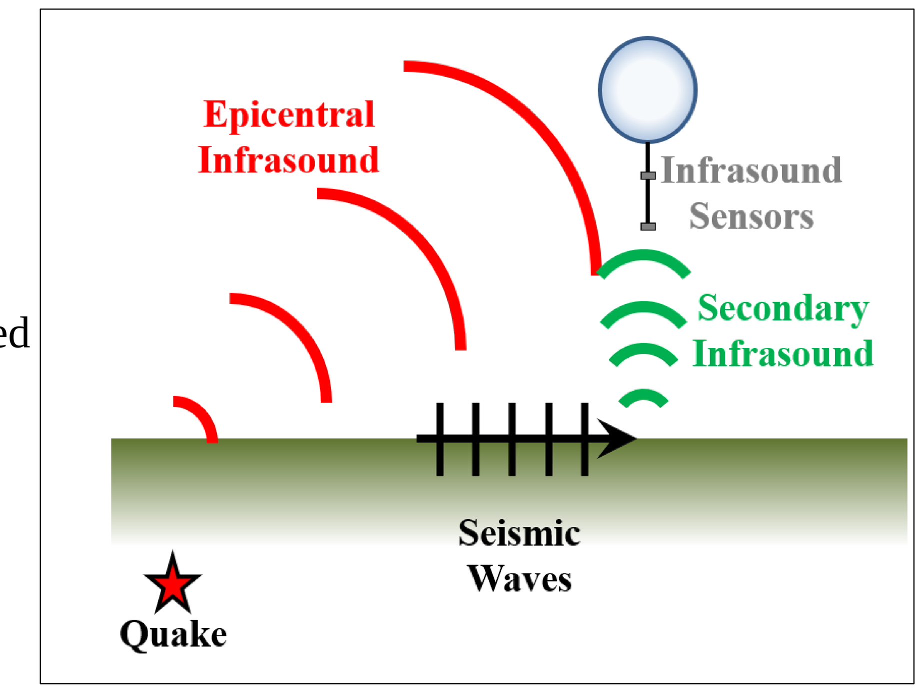
Previous Work

This project is a continuation of a 2020 – 2021 Wentz research project that focused on the use of biodegradable materials for solar balloon construction. Biodegradable balloons would provide the opportunity to fly in remote, environmentally locations without damaging the fragile ecosystem. 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. The Plascon 0.5 MIL was selected for the full scale flight test. A 6m balloon made from the original 0.31 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. This balloon could not be launched during that year, but was flight tested in fall 2021. The balloon had Some difficulty inflating on launch, but was able to climb to 71,000 ft, exceeding original estimations.



Flight Testing

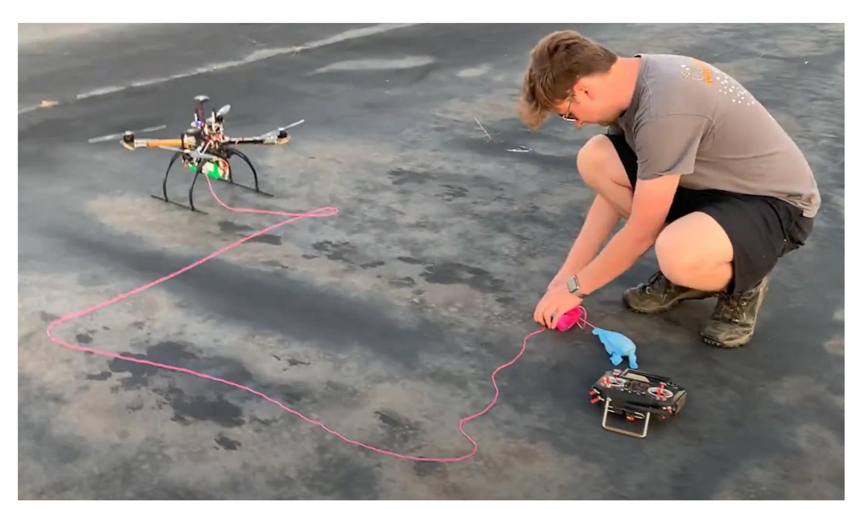
The 2021 summer flight campaign involved launching dozens of solar balloons over the course of four months, often two balloons per day. The goal of this campaign was to collect airborne infrasonic data during seismic events, such as the minor earthquakes that frequently occur in Oklahoma. Two balloons were launched per day, and each carried two infrasonic microphones separated by significant lengths of flight line. This payload configuration was required in order to do source location with the infrasonic data, unfortunately it was difficult to launch this payload configuration successfully.



During launch it was common for balloon lines to snag on fences, trees, or other debris, which led to the payload separating from the balloon. Balloons ascended slowly enough that teams had to follow them for several hundred feet to ensure they got off the ground safely. A combination of launch procedure changes and instrumentation development were used to alleviate this problem. On later launches, helium was used to assist ascent.

Instrumentation Development

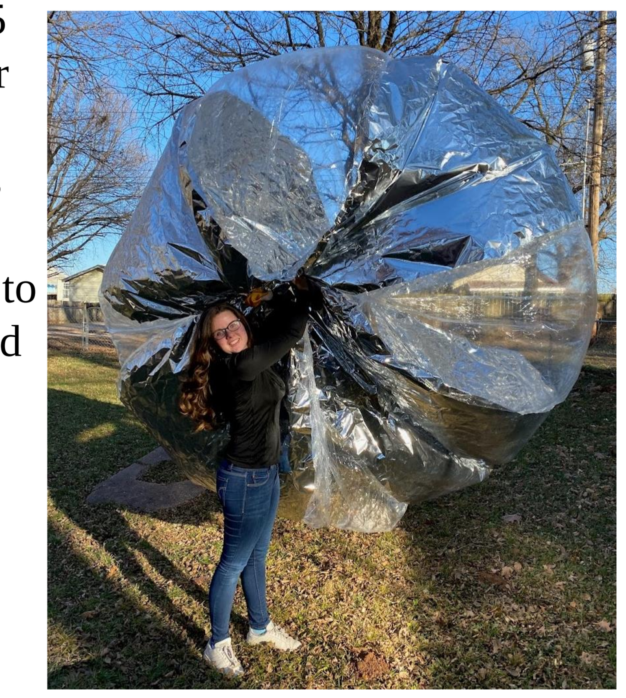
After several failed launch attempts, it was clear that the long flight lines would need to be better controlled. A device designed to release the payload lines in a controlled manner was manufactured and tested. This reeldown device used an Arduino, altimeter, and a servo to unspool the flight lines at a set altitude. This was tested and incrementally modified using a large UAV. Ten prototypes of the device were tested before the final iteration was ready for flight testing.



The reeldown successfully deployed its full flight line during its first flight test in September 2021. After that test, the reeldown was modified to trigger using a timer, as well as a GPS fence trigger. Although the flight test of the reeldown proved that it could be used to make launches safer, the balloon was still very difficult to recover after landing due to the long flight lines catching on the top of trees. In order to resolve this issue, another device was designed to sever these flight lines and other unnecessary connections to the balloon. A second instrument was developed to ensure that the solar balloons separate safely from the helium balloons during a grand slam style launch. This cutdown used an Arduino, servo and a gps sensor to "cut" the balloon lines. These could also be used to cut the payloads loose from the solar balloon if the balloon drifts too far from the launch area. Both of these instruments make launches safer, and recoveries faster for the flight team.

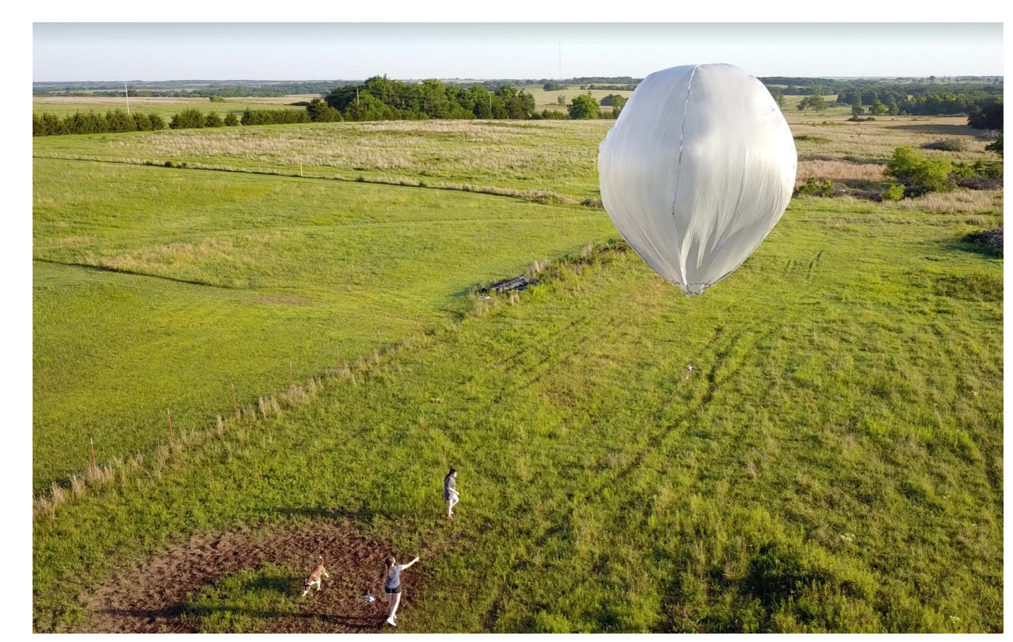
Material Testing

Solar Balloons are typically made from a 0.31 MIL polyethylene clear film. This film is darkened with charcoal before launch so that it is better able to absorb solar irradiation. While this material is light, it is extremely fragile. In order to build a more durable balloon that could sustain greater thermal stress, mylar was tested as a solar balloon material. 0.5 MIL clear and reflective mylar were used to build and 8 gore balloon. While these materials were difficult to cut and seam due to ripping, they did prove to make a strong balloon that held pressure well. The reflective mylar did not prove to be a viable material due to weight concerns. The clear mylar would be viable balloon material as long as it could be darkened with charcoal. Full scale testing should proceed with the clear mylar as main build material.



Conclusion

Although significant progress has been made in ensuring the safe launch, flight, and landing of solar balloons, further testing and experimentation will be needed to refine these methods. This coming May, the second year of solar balloon flight tests will resume in collaboration with JPL and Sandia. These will continue throughout the summer. Reeldowns and cutdowns will be used on flights to ensure easier, safer balloon launches. Collaboration on solar balloon research between JPL, Sandia, and OSU is expected to continue in the coming years



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