An Overview of A Solar Eclipse Video Payload

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The HABET group at Iowa State University has been designing and building balloon payloads for years, giving students hands on experience with the engineering involved in creating and launching payloads to near space conditions. After attending the AHAC conference in 2014 the group begain to design a balloon for the 2017 solar eclipse. Working closely with the Space Grant Consortiums design team, HABET has designed and completed preliminary testing on a Solar Eclipse Video payload. This payload uses multiple subsystems to complete the mission. The mission required an altitude control system, live video downlink, and a camera pointing system. Our proposed system will use density control rather than ballast and helium venting to control the altitude of the balloon. For video downlink it will be using the Ubiquity Rocket M5 Wifi radios. The camera pointing will use a custom built gimbal with specially programed pointing algorithms. These algorithms will automatically point the camera at the sun allowing for the focus of the balloon crew to be on recovery and maintaining radio connection. This design should allow for a relatively inexpensive and advanced balloon payload for launch by groups from all over the country.

I. Introduction

Over the past year the HABET group has been working to design a payload to stream video for the 2017 solar eclipse. This has been done in collaboration with the Eclipse Payload Design Team headed by Randy Larimer of the Montana Space Grant Consortium. The goal of this design is to have a relatively inexpensive payload that can be repackaged and re-flown by the group when the flight is completed. For the solar eclipse the balloon will need to maintain altitude for an extended period of time, maintain camera positioning relative to the eclipse, and provide a live downlink of the video. While this work has incorporated pieces tested and designed by multiple members of the design team it is currently only one of the design under consideration.

II. Communications

The downlink of live video requires a larger data throughput than normally required for the HABET balloon flights. The proposed solution is to use a 5.8GHz wireless ethernet link, the same technology found in daily life allowing for fast data transmission for everything from smart phones to laptops. This technology is already used for long distance transmission, often as a link between an apartment complex and their internet service provider. It has also been experimented with in Google's Project Loon. Project Loon is an experimental system for providing internet to rural areas and is currently undergoing tests in New Zealand.

Radio

The radio currently being explored in this design is the Ubiquiti Rocket M5 5.8GHz radio. This radio has been used previously by Google's Project Loon for their wireless ethernet link. The benefits provided by the Rocket M5 radio are its low cost ($90) compared to equivalent long-distance radios and the high level of configurability available inside the radio firmware. To reduce the weight of the radio flown on the balloon, the plastic case was removed. The case itself was 158 grams of the total mass of the radio (which was 226 grams), so by simply removing the case a 70% reduction in mass was obtained

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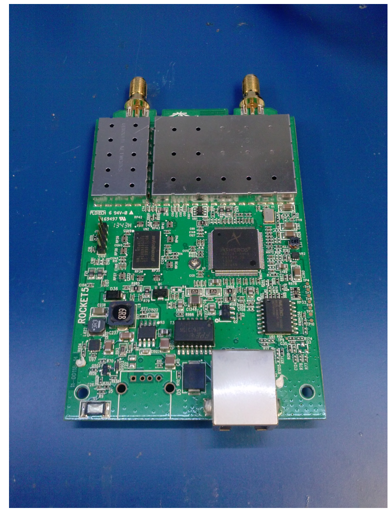
(a) With Case, mass is 226g
Image From ubnt.com



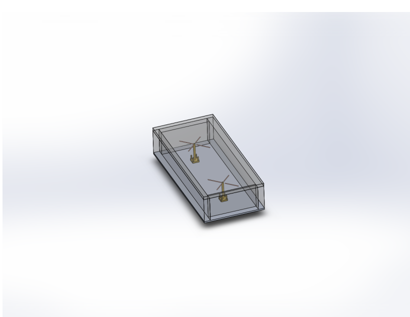
(b) Without Case, mass is 67g

Figure 1: Ubiquiti Rocket M5 wireless radio used for data transmission

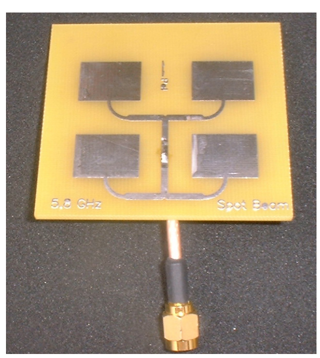
Antennas

Radio communications are heavily reliant on good antenna selection. Chosen antennas must provide good gain on both transmission and reception to overcome the atmospheric noise in the receiver. This system makes use of two distinct sets of antennas, ground station and payload. The ground antennas must have a high gain, but are not restricted in weight or beam width. The payload antennas must be light weight, small, and omnidirectional. The omnidirectional requirement will allow the payload to remain in contact with the ground station from any angle.
Ethan Harstad, a former HABET team member, designed a set of circularly polarized split sheath dipole antennas, shown in Fig 2a. With proper tuning these circular polarized antennas would have a gain of 4.5dBi. This would have helped to increase the effective range of the payload. These antennas would also have a slightly directional beam width. The antennas proved problematic since they required hand tuning. HABET was unable to find the equipment for tuning and as a result the four antennas that were constructed were not optimally tuned. This resulted in antennas that were unable to maintain connection durring flight.

After experimenting with the dipole antennas the group returned to searching for prebuilt options. One



(a) Split Sheath Dipole Antenna



(b) Quad Patch 5.8GHz

(c) Fat Shark 5.8GHz Skew Planar Antenna
Image From Amazon.com

Figure 2: Balloon wireless radio antennas explored in this project

possibility discovered was a 5.8GHz quad patch array manufactured by Kent Electronics shown in Fig 2b This antenna is vertically polarized and has a gain of 11dBi. When tested by the University of Montana using their ground station the antenna successfully maintained a wireless link over four miles while on the

ground.
While the quad-patch antenna has promise as a light weight and inexpensive WiFi antenna, currently the Fat Shark antenna shown in Fig 2c used on the University of Montana's payload shows the most promise. On their flight in February they were able to downlink live video from a range of more than 40 miles. The Fat Shark antennas are skew planar style with four lobes, but the gain is unfortunately not provide by the manufacturer.
HABET selected the L-Com HyperLink HG5817Y-NF 5.8GHz yagi antenna for the ground station. This antenna has a gain of 16.5dBi with a 30° beamwidth. Two of these antenna were then attached to a pointer on the roof of Howe Hall such that one provided a horizontal polarization and the other a vertical polarization.

Future Communication Plans

HABET will be continuing to use the M5 Rcoket from Ubiquity but will be performing more tests on our antennas. The Kent Electronic antenna seem to be working very well for the payload. The gain that is achieved by these antennas is difficult to improve upon without having an unacceptably narrow beamwidth. The yagi antennas used for the HABET ground station on the other hand seem to be lacking. HABET is currently looking into purchasing a new dish antenna similar to the antenna used by the University of Montana in their ground system in the hope that it will improve the in flight Radio connection.

III. Altitude Control

The Payload for this project will require the ability to stay at altitude for a prolonged period of time. There are multiple ways to extend the length of a balloon flight with the majority being classified as either passive or active altitude control.

Passive Altitude Control

Most long duration flights use passive altitude control as either a Zero Pressure balloon, or a Super Pressure balloon. These balloon styles are often difficult to obtain in our size limit and are often expensive. These balloons are also intended for flights lasting weeks or months rather than hours.
Zero Pressure balloons work by releasing excess helium through a hole in the bottom of the balloon at altitude. This avoids the burst experienced by latex balloons since the pressure in the balloon should be essentially equal to that of the surrounding atmosphere. The benefit of this style of balloon is that it can stay up for days without using any extra ballast to maintain its altitude. There are a few draw backs to this design. Obtaining a Zero Pressure balloon is often difficult when looking to carry payloads less than 20 pounds. HABET has attempted to build two Zero Pressure balloons. Both failed to reach the design altitude and the flights were shorter than anticipated. While it is possible to build a Zero Pressure balloon it is very difficult and requires a large space.
Super Pressure balloons hold the volume constant, this leads to the internal pressure being larger than the external pressure. These balloons use patterns specifically designed to relieve the stress on the balloon by re-enforcing the seams. A common pattern is called the pumpkin due to the gord like shape caused by bulges around the re-enforced seams. This type of design is often used by NASA and other organizations for very long duration with heavy payloads. This type of balloon is great for long duration testing because it will stay at a more consistent altitude than Zero Pressure balloons and have a longer duration while using less ballast.

Active Altitude Control

These methods are added to a balloon to increase time at altitude and to accurately hit a given altitude for the flight. These can be designed to fit on existing balloon designs, including those with passive altitude control to increase the duration of a flight.
Many flights use ballast to control their altitude. Ballast is an extra weight carried by the balloon that can be released when the balloon has lost too much altitude. This is often combined with another control method to avoid gaining too much altitude after the ballast has been deployed.
Venting the balloon is another active altitude control method. This method uses a valve to release helium into the atmosphere reducing the lift created by the balloon. This method is currently being looked into

by the University of Montana Borealis group and was presented at the Academic High Altitude Balloon Conference in 2014. Venting is a much more precise control method than any of the passive methods and can be added to a standard latex balloon as shown by the University of Montana.
Another method for altitude control is by controlling the density of the gasses in the balloon or stack line. By increasing the density of the gasses the buoyancy of the balloon decreases. This process is used by the Google Loon Project to control the flight path of their balloons. To increase the density ambient air is pumped into a bladder attached to the balloon. As the pressure in the bladder increases the balloon will lose lift and drop in altitude. When the air is released the balloon will then regain altitude. This system provides altitude control with a longer duration since it will never release helium or ballast permanently and will instead pull the ballast from the surrounding atmosphere. This means the altitude control system is instead limited by the power in the battery. A density controlled balloon will need a much larger battery, a mechanical pump, and a valve system adding a considerable amount of weight to the design.
Over the last year the HABET group has worked on designing a density control system. This system would include a standard latex balloon as the lifting balloon and a smaller shrouded latex balloon as the bladder. The shroud material is currently envisioned to be polyester due to the weight and cost of the material. After searching for pumps and attempting to build one the group found a 12 volt vacuum from Sparkfun Electronics. This pump has performed well during bench top testing, but further testing is needed to verify it will work for the altitude control system.

IV. Video

The goal of the payload is to downlink live video of the flight in high definition. This goal requires that the proceeding sections work to keep the payload in position to take the video and to downlink said video to the ground.

Camera

HABET selected the Raspberry Pi and the Raspberry Pi camera with a CS lens mount. This combination was selected due to the Raspberry Pi's ability to compress the video before streaming it to the ground using the program *gstreamer*. During tests conducted by both HABET and the University of Montana the Raspberry Pi has worked well throughout entire flights.

Gimbal

The payload must look at the eclipse throughout the entire flight. This requires both a way to point the camera and an algorithm to control the pointer or a way to actively control from the ground station.

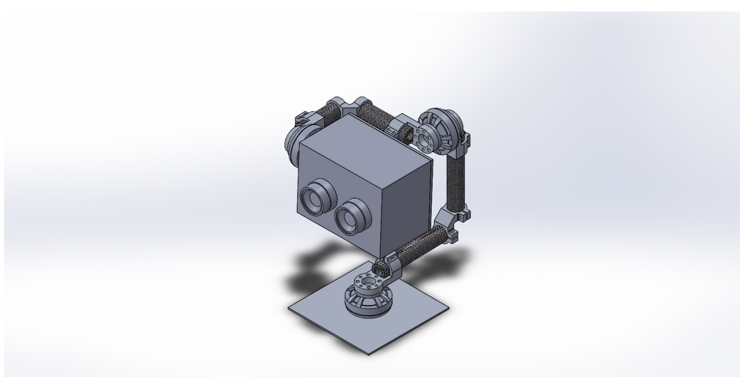


Figure 3: HABET gimbal design

The gimbal shown in the Fig 3 was designed to use off the shelf components for all but the camera box which is 3D printed. The gimbal currently has physical ability to rotate 360 degrees in all three axes. Durring the flight the gimbal should only require full rotation in the yaw and roll axes with the pitch axis only required to be able to turn 180 degrees. To allow for better cable management and for reduction in weight, carbon fiber

tubes were used for the structure. It was envisioned that this would allow for the gimbal to rotate without tangling on the wires. During the test launch the stiffening of the solid core wire due to the temperature change led to the motors stalling and the gimbal controller shutting down. Cable management is one of the most important areas of improvement for future gimbal work.
The gimbal is useless unless it can be pointed at the sun for the entirety of the flight. HABET is currently developing a two part system to control the direction of the camera. The first part uses a modified algorithm for solar panel adjustments. This should point the camera at the eclipse during the entire flight. For fine pointing while looking at the sun the second part would then be used. The image currently being taken would be compared to an image taken with the sun centered in the frame. The controller will then move the camera to center on the sun. This system should be able to smoothly follow the sun when flown on a relatively steady payload.

V. Conclusion

During the last year HABET has designed and begun preliminary testing on a Solar Eclipse Payload design in collaboration with the National Space Grant Consortium's design team. HABET's design will use the Ubiquity Rocket M5 WiFi radios with patch antenna's for communications to the ground station. On board there will be a gimbal using an algorithm to follow the sun during flight. This gimbal will be designed such that it can be built with nothing more than a screw driver and a hacksaw. The video will be taken using a Raspberry Pi and Raspberry Pi camera. For altitude control a density controller will be used. This should allow for finer control of the balloon without loss of lift. This payload design should allow for an inexpensive but impressive payload that could be launched and re-used by schools across the country.

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