High Altitude Research Platform (HARP) All Sky Camera

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The High Altitude Research Platform (HARP) at Taylor University utilizes latex balloons to explore the near space region. Through HARP, the Model ASC-N1 All Sky Camera from Moonglow Technologies can be used to observe both day and nighttime skies without the blinding effects of the Sun and with a wide field of view. The All Sky Cam offers a hemispherical, 190^0 field of view allowing a unique perspective to these launches. Taylor University is believed to be the first to launch such a camera into the stratosphere. The first launch of the ASC payload was made during the daytime at 11:42 AM on March 9, 2013. The camera worked well in the harsh stratosphere conditions with a few minor issues such as frost forming on the glass encasement surrounding the camera lens. The fish-eye view of the camera was large enough to have a picture of the balloon, the last pod on the HARP in the dark near space, the sun, the glowing circular limb of the Earth, and the ground all in one shot. A solar cell, pyranometer, and temperature sensor helped gather data that would help with future launches. Unfortunately, no stars were seen due to the scattering of the sunlight, turbulence, and the rotation rate of the HARP platform. The second launch was on the very early morning of April 22, 2013 during the Lyrids meteor shower and not quite as successful as the daytime launch. The shutter speed was automatically slowed due to the low to no light conditions extending the exposure time of the lights from Earth and moon. No stars were seen due to this exposure time and the unusually high turbulence experienced. For the third flight on June 05, 2013 at 9:02 AM, a new camera, the HackHD, was used instead. This was a test run to see how this camera would react in Near-Space. The launch went well with a promising result from the new camera. The main goal of future launches will be to capture images of the nighttime sky, Earth limb without the blinding effects of the sun, and a meteor shower in ways that have never seen used before using the HackHD.

I. Introduction

The Model ASC-N1 All Sky Camera from Moonglow Technologies was sent into near space in hopes of gathering clear images not restricted by atmospheric interference. In order to gather these useful and interesting images, the experiment took place over three flights thus far. The camera was first flown on a day flight as a trial run and was accompanied by temperature sensors, a pyranometer, and solar cell for data collecting. These additional sensors were added to take in situ measurements to profile the environment the camera was in. This enables us to better understand the performance of the camera and make improvements accordingly. Then, the camera was flown again on a night flight in hopes of capturing images of the night sky and the meteor shower occurring on April 22, 2013. A third flight on June 05, 2013 was flown with a different camera to further the goal of capturing unique images.

Problem Statement: The All Sky Camera or HackHD is sent into the stratosphere in hopes of obtaining clear images of stars and Earth without atmospheric interference.

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II. Project Design

Before executing the problem statement above, the following specifications had to be considered. Additionally, the problem statement relied on the project structure which will follow.

A. Project Specifications

All Sky Camera Specifications are as follows:

1) Effective Pixels across Field of View: 546x457
2) Field of View: 190°
3) Exposure time: (1/100,000) – 4 seconds
4) Sensitivity: Min 0.002 Lux

The HackHD Specifications are as follows:

1) Resolution: 1080P HD
2) Frame Rate: 30 FPS (frames per second)
3) Aspect Ratio: 16:9
4) Lens: Interchangeable M12 Lens. Includes 2.5mm (EFL), F2.8, 160 degree (diagonal) wide angle lens
5) Video Output: Composite video 480P resolution
6) Dimensions: 65mm x 40mm x 25mm LxWxH
7) Power Supply: External 3.7V, 1100mAH minimum. 5V safe
8) Power Output: 3.7V DC, 500mAH
9) Working Temperature: -10degC to +45degC
10) Storage Temperature: -20degC to +70degC

B. Instrumentation

i. Flight One

For flight I (the daytime flight) a temperature sensor inside the glass encasement of the camera, a pyranometer (with a 180 degree view), and solar cell was flown along with the camera to monitor the conditions that it went through. There was also another temperature sensor connected to a separate pod on the same flight that was recording the outside environment to compare to the one inside the glass encasement. To obtain the video images we wanted, a recording system that used an SD card was utilized.

The All Sky Cam was positioned to protrude out of the thick plastic canister and foam insulation wrapped around the canister just enough for the lens to gather the full 190 degree field of view. The pyranometer was positioned on the top tier while the solar cell was taped to the side of the insulation. Both sensors were powered with the same 8 V battery pack completely separate from the camera power supply. Before flight, the sensors were all calibrated and the camera and recorder were tested for functionality.

ii. Flight Two

Learning from flight one; we developed a heating element to melt away any frost that would form due to the cold climate of space. This heater was created using Niacrom wire and a conducting heat fin made out of aluminum foil contained inside of the glass encasement. The wire was connected to two 8V batteries producing a current that heated the wire and fin. Additionally, we realized that the camera was upside down. To fix this, the camera was attached to the bottom of the middle tier. Also attached was an inertial boom on the bottom of the canister with 5 ounce weights on both sides and a tail for a stable recording.

ii. Flight Three

The All-Sky Cam was a great start to achieving our goal of capturing images of meteors. However, we wanted to explore our options. We changed to the HackHD camera which is a small HD camera connected to a circuit board that can be programmed. We launched the camera during the day just see how it would be affected by the harsh climate in Near-Space. The camera was positioned at a 45^{o} angle to the bottom of the pod using brackets and connected to a 7.4V battery with a 3.3 volt regulator. By having the 45^{o} angle, the camera was able to view the dark part of Near-Space to look for objects outside the Earth's stratosphere even when the pod was straight up and down.

C. System Block Diagrams

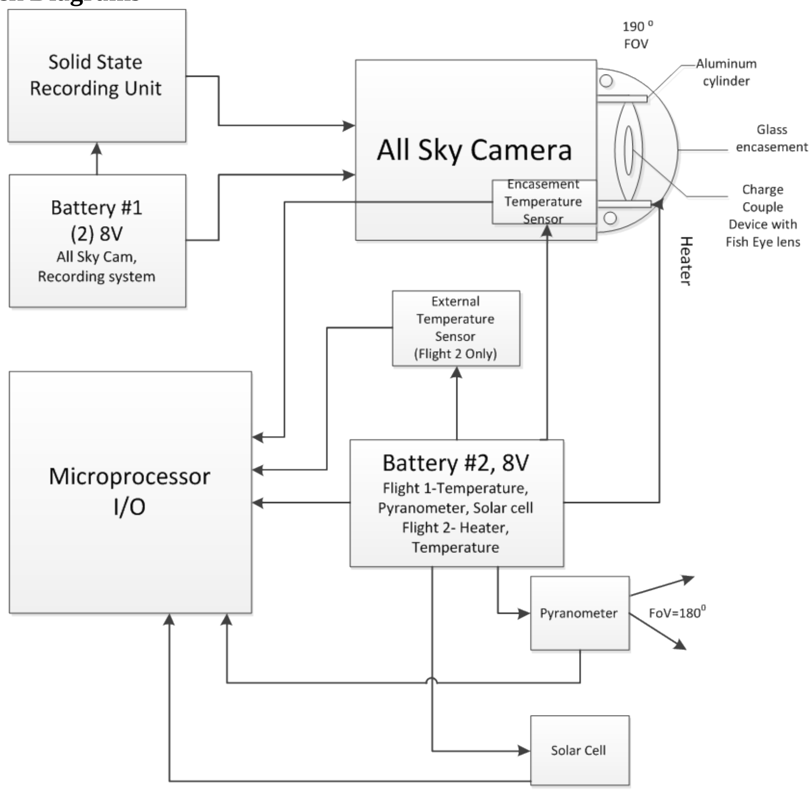


Figure 1. Block Diagram of both Flight #1 and Flight #2 (System varies per flight)

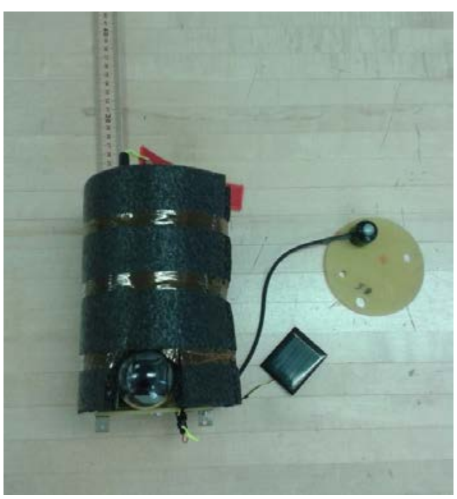


Figure 2.
Pod complete and ready for Flight #1

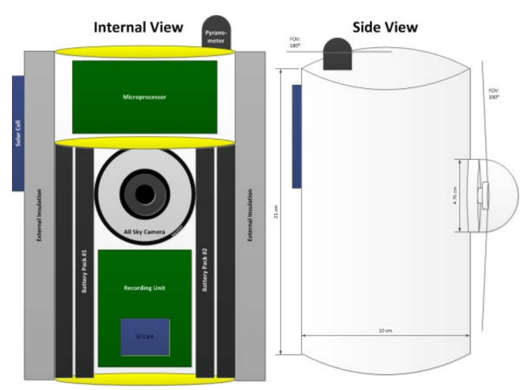


Figure 3. Mechanical Diagram. Pod structure of Flight #2 with sensors from Flight #1

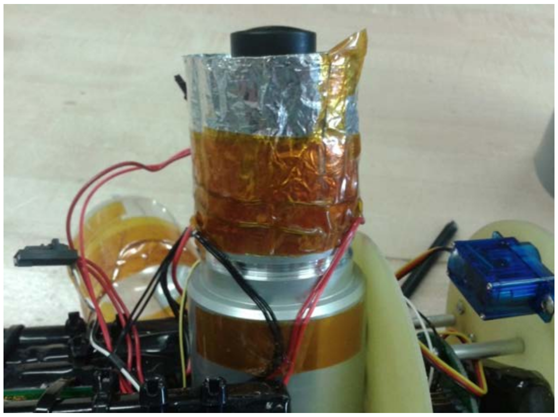


Figure 4. The Niacrom wire wrapped around the aluminum and connected to the batteries for Flight #2.

Figure 5. The finished pod with the inertial booms and tail about to launch. We also signed the tail for that personal touch for Flight #2.

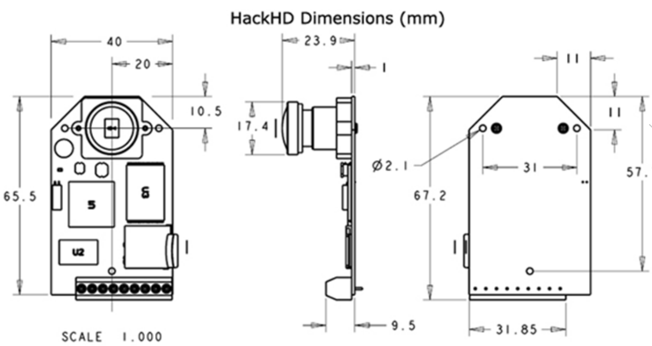


Figure 6. The dimensions of the HackHD in mm

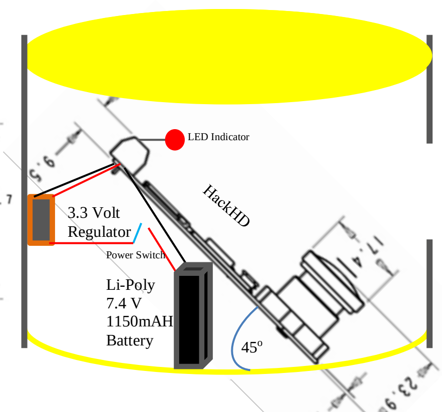


Figure 7. Mechanical Diagram. Pod structure for flight #3.

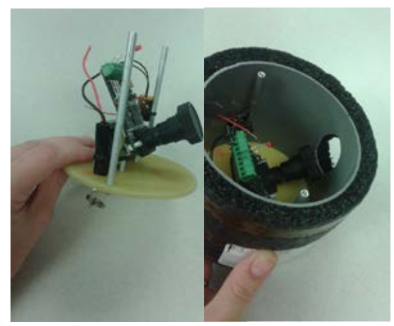


Figure 8. Visual for pod structure for flight #3.

III. Flights and Data Collection

In order to address the problem statement above, more than just image gathering had to be considered. As previously mentioned, the first flight was essentially a trial run to understand new performance in space. In order to best understand the characteristics of an ideal flight for the All Sky Camera, additional instrumentation was sent up in the flight pod. These instruments included temperature sensors, a pyrometer, and a solar cell. These were flown in hopes of better understanding the conditions and reactions of the pod, and its data was incorporated into the design of the second flight. The second flight included a heater and an inertial boom which will be addressed later. The third flight was a trial run for a new camera system.

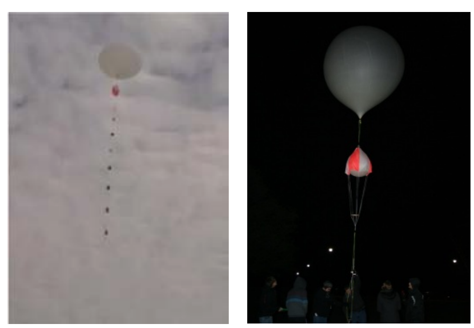


Figure 9. Day and Evening HARP Launches

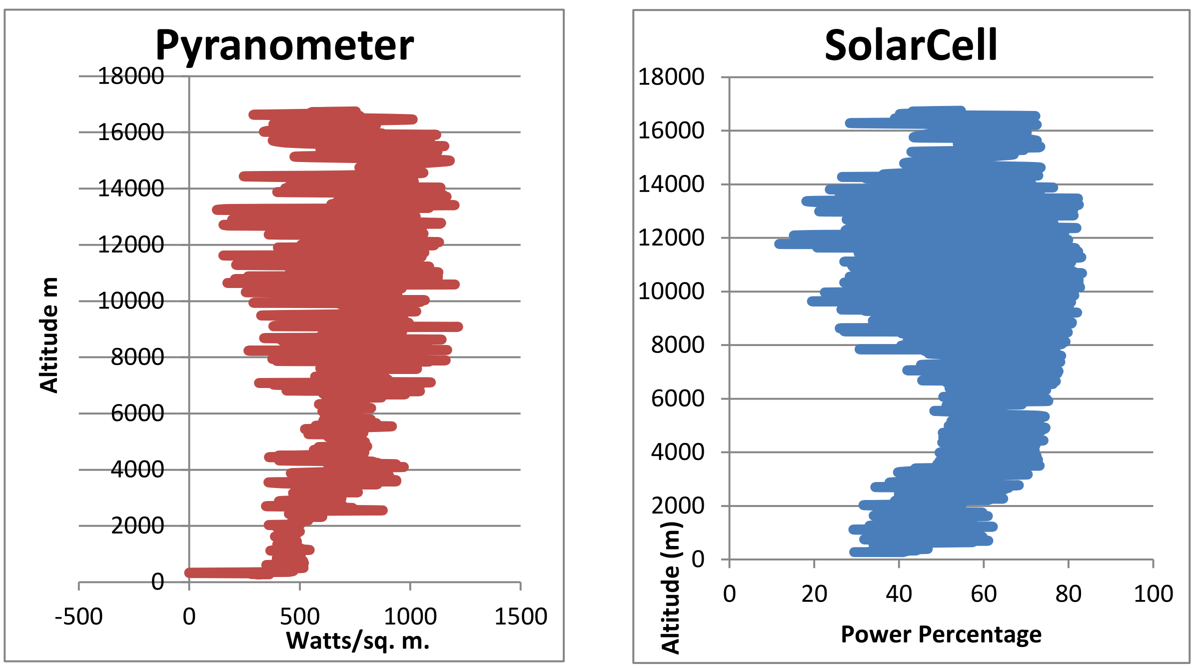
A. Flight One

As previously stated, flight one was a set-up flight for a successful second flight. With this in mind, we included three additional sensors to essentially profile the course of the flight. These sensors were a pyranometer, temperature sensor, and solar cell. We hypothesized that if the All Sky Camera is sent into the stratosphere, the environment will not affect the functionality or the recording quality of the camera.

i. Data Analysis

The two temperature sensors generally followed the same pattern as the pod changed altitude. However, the inside of the encasement remained much warmer than the exterior which dropped far below freezing. The camera must have been generating heat through the recording process, keeping the interior warmer. The “inside” temperature stayed at about 22^0C until about 3700 meters where it spiked to 24^0C where it probably broke through the clouds and gained heat from the sun. It then steadily decreased from there to a minimum of 5^0C. However, the “outside” went as low as -60^0C.

The following data was taken from the pyranometer and solar cell. Pyranometer-a type of actinometer used to measure the broadband solar irradiance on a planar surface and is a sensor that is designed to measure the solar radiation flux density (in watts per square meter) from a field of view of 180^0. The irradiance measured is the power per unit area. Thus, this sensor is measuring the power of the sun on the pod. One should note the similarities of the curves and shapes as they both rely on solar input. One quite obvious observation is the oscillating nature of the graphs due to the pod spinning in flight. The pod experienced quite a bit of turbulence. Also one can infer information based on the data in reference to the flight. For example, the pyranometer is getting readings as it faces the sun and then the irradiance being reflected off the clouds when it is further from the sun. As the pod goes higher, the reflection of irradiance off the clouds becomes less and less. This makes the differences between max and min values greater. Perhaps the particularly narrow section near 5000 meters is due to a concentration of clouds at that altitude. According to the video taken from the All Sky Camera, the pod entered the clouds around the 22-minute mark at approximately 4000 m. This is reflects the theory of the narrowing of difference in that region. Additionally, before the narrowing at lower altitudes, the differences between minimums and maximums are varied most likely because of the cloudy sky above. Various amounts of sunlight are allowed to reach the pod depending on the sky at each moment. This can explain the varying nature of the graph at lower altitudes.



Figures 10, 11. Pyranometer and Solar Cell Data

ii. Failure Analysis

Clearly, there were some issues in the first flight that needed correction before the second flight. One main issue was the frost that developed on the glass encasement. The other issue was the lack of stability of the pod. Another problem was the camera was upside down. Though not very significant, it can be even more disorienting than the video already is. These issues were addressed to the best of our ability for the second flight.

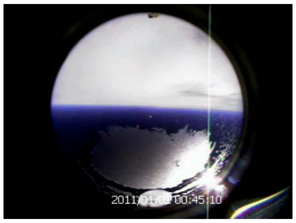


Figure 12. Shot in mid-flight with frost on encasement and wrong orientation.

B. Flight Two

Right before the dawn of April 22, 2013, the camera was sent on its second flight in hopes of capturing the Lyrids Meteor shower. The main goal of the launch was to capture images of the nighttime sky, Earth limb without the blinding effects of the sun, and the meteor shower in ways that have never seen used before.

i. Flight Two Results and Failure Analysis

The heater performed quite well and was able to keep the internal temperature well above freezing for the entire flight by at least 25 degrees Celsius (as opposed to the minimum -3 degrees Celsius measured from an external temperature sensor.)

Unfortunately, the original programming for the camera was too smart for our experiment. The shutter speed slowed way down in the dim-to-no-light conditions, resulting in a longer exposure time. The videos were streaks of light coming from the Earth and Moon but nothing distinct. However, we can tell how far our pod traveled during that exposure time and how much our pod was oscillating. There was also some unusually strong turbulence that resulted in our inertial booms snapping off. Instead of frost, condensation collected on the glass resulting in a small patch (or as we affectionately nicknamed it "Antarctica") where light was too scattered to see.

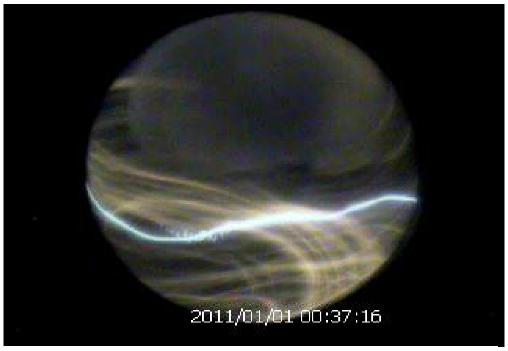


Figure 13. The bright white streak is the moon.

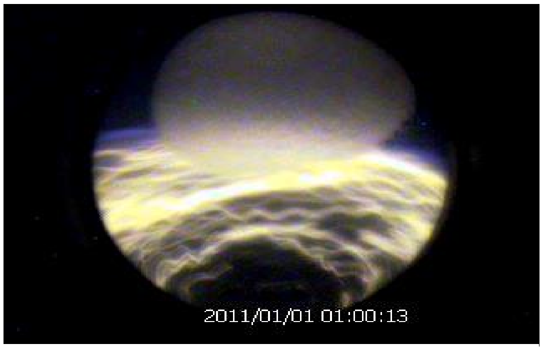


Figure 14. Here you can see the condensation and the yellow streaks of the lights coming from Earth.

C. Flight Three

On June 05, 2013 at 9:02 AM, the HackHD was sent 100,000 feet up into Near-Space to determine whether the camera would survive the harsh environment. For minimum success, the camera had to be able to take video recordings of the nighttime sky while in the stratosphere with -60^{o} temperatures and survive the turbulence. For maximum success, the camera had to be able to take videos where the moon and/or stars could be seen.

i. Flight Three Results and Failure Analysis

The camera worked well in the environment and was able to take videos which recorded screen shots of stars and the moon. It was also able to take pictures of great detail of the Earth, rivers, lakes, houses, and even roads can be seen. The only error in the process was that the camera assembly should have been oriented 90^{o} so that it would be parallel to the horizon.

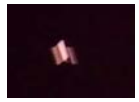
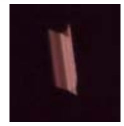
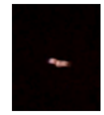
				
28097 feet/ 8564 meters 24:48 into the flight	28445 feet/ 8670 meters 24:59 into the flight	28465 feet/ 8676 meters 25:03 into the flight	28465 feet/ 8676 meters 25:08 into the flight	29058 feet/ 8857 meters 25:35 into the flight

Figure 15. Sequence screen shots of a star

Figure 16. High resolution screen shot of the Earth with lakes and rivers

Figure 17. Identified as the crescent moon.

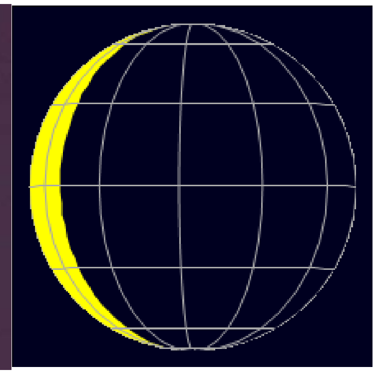


Figure 18. The Phase of the Moon at 09:27:38 on June 05, 2013 according to http://www.heavens-above.com/moon

III. Educational Value

For most of the students working on this project, it is their first time dealing with such a professional experiment. The students gain skills on problem solving, communicating with each other and the advisors working with them, and how to examine real data. The data collected will be used in the future for other classes such as Astronomy and for information in our observatory.

This experiment was also a great stepping stone for a bigger project, the ELEO Satellite project that will be worked on by the students this summer (summer 2013) and for the next couple of years. The HARP project is helping prepare the students for the many reviews by the Air Force for the ELEO project and the different techniques for problem solving that will arise during the course of both projects. By starting with a smaller experiment, the students are able to prepare for the bigger projects to come.

IV. Conclusions and Next Step

Although the first two flights were not a complete success, both came back with valuable data that can be used for future flights. The All-Sky Cam was great for the daytime flight, with the exception of the frost forming, but not so great for the nighttime flight.

Before the third flight, the All-Sky Cam was tested in our observatory. This was to ensure that the All-Sky Cam was not damaged after the 2nd flight. The test was stationary so that we would not get the streaks again. Figure 12 proves that the All-Sky Cam was not damaged. Some stars and even constellations can be seen along with the intensity of the Moon. The HackHD was thoroughly tested during the third launch to see if it could withstand the constant motion and the low temperatures that a pod goes through while in the stratosphere. It proved to be quite effective and will be used again in future flights with confidence.

Figure 19. This is a picture from the All-Sky Cam from the stationary experiment to demonstrate that it will capture images of stars.

V. Acknowledgments

We would like to thank Dr. Hank Voss and Professor Jeff Dailey for helping us make our launch possible. Without them we would never have gotten off the ground. We also thank our fellow classmates for all the support and encouragement they provided and thanks to Moonglow Technologies and the HackHD for giving us this unique perspective and opportunity. Also, we would like to thank the UNP-AFSOR for the Student Satellite Grant, NSF CCIL Grant and the Indiana Space Grant Consursion for support of this project.