UNIVERSITY OF MARYLAND EASTERN SHORE
DEPARTMENT OF ENGINEERING AND AVIATION SCIENCE
AND
HAWK INSTITUTE FOR SPACE SCIENCES

HawkHASP2

Final Report

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1. Introduction

Mission

The purpose of the project entitled "HawkHASP2" was to develop and launch a payload that contains several experiments to the edge of space. This mission was flown on board the High Altitude Student Platform (HASP) sponsored by Louisiana State University (LSU) and NASA Balloon Program Office (BPO) in conjunction with University of Maryland Eastern Shore (UMES). The overall mission of the payload was to perform the following experiments:

1. To discover the effectiveness of an inexpensive heating system in a high-altitude environment.
2. The viability of using a Fresnel lens to intensify solar ray intensity on a high altitude balloon platform. In addition, cells or photodiodes are attached on each side to identify HASP orientation.
3. Tri-axial accelerometer for recording flight events as well as internal temperature readings.
4. Digital camera for orientation, altitude, ground track, and applicable algorithms. Photos taken from low earth orbit.
5. Solar intensity in the troposphere and stratosphere as compared to solar intensity at ground level.
6. External temperature sensor for comparison with Standard Atmosphere temperature readings.
7. Internal temperature sensor(s) for health monitoring and evaluation of insulation.

2. Experiments

Solar Energy System

Four Spectrolab Triple Junction ITJ-G (30227) solar cells with a 24% efficiency rate were used on the HAWK HASP2 payload. Within this system was our primary passive experiment aimed to increase the efficiency of solar cells by covering one with a Fresnel lens. A control cell with no lens covering it was placed on a vertical axis below the Fresnel lens cell. As Fresnel lenses were used before to increase solar cell efficiency at solar power plants, we theorized that our experiment would be a success. This experiment was conducted both in flight and at ground level simultaneously. Within the Solar Energy System there were also two solar cells mounted on opposite sides of the payload to determine the orientation of the payload for the duration of the flight. A data logger recorded the voltage output of the four cells in both experiments.

Imaging

The primary purpose of this system was to image the earth from altitudes up to 36 km. Olympus donated two refurbished Stylus 1030SW digital cameras. The cameras were rated for shock-resistance in addition to water and extreme temperature tolerance. One camera was flown on the flight payload and the other was used for ground testing. The camera's shutter button was controlled by a commercial off-the-shelf timing circuit allowing the camera to take pictures on a thirty second time interval. The goal was to take a picture every 1000 feet of ascent and during the flight envelope. We estimated that the camera would take 3,500 images of the earth. The camera was powered with a flight battery we designed, built and mounted behind a Plexiglas window.

Electrical

The electrical system was supported by the power supplied to the payload from LSU's main platform. Provided were 28 Volts at .5 amps through an EDAC 516 connector attached to the payload mounting plate. A system of regulators and resistors divided the power between components in order to fully utilize the power provided to us. According to a power budget calculated by incorporating all parts in need of power, the final current amount needed to power our payload during flight was .49 amps. The electrical system was critical to the payload because most of the subsystems of the payload depended on the supplied power.

Thermal

Although the payload encountered temperatures as low as -60° C, many of the components were not rated to handle these extreme temperatures. In addition, there was very little air pressure at 36 km making transfer of heat within the payload inefficient. The thermal system was designed to protect these components and incorporated two heating subsystems. The subsystems utilized conductive metals such as aluminum in order to transfer heat effectively from the heat sinks to specific components in need of temperature control. The primary subsystem used voltage regulators attached to heat sinks for heat distribution within the payload. The secondary heating subsystem was built using a Minco heater attached to the copper plated-fiberglass walls and behaved much like a car window defroster. The heater was activated by a thermostat triggered by an internal temperature reading of 10° C. The thermostat controlled heater was our active experiment in addition to serving as our secondary thermal subsystem.

Acceleration

The ShockLog accelerometer recorded data that measured ascent and descent events as well as anomalies during the flight envelope. In addition, the accelerometer measured the internal temperature of the payload.

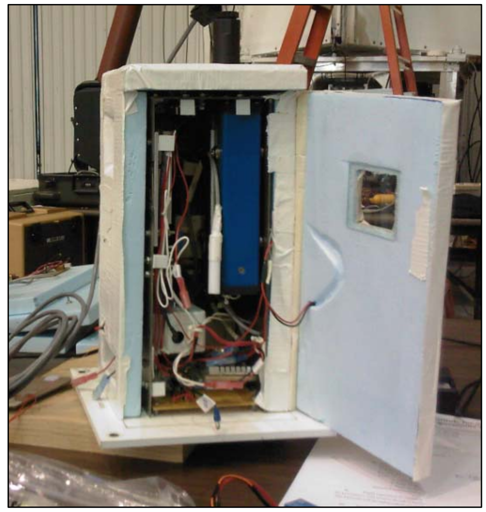
Solar Irradiance

There was a pyranometer on both the flight payload and the ground station for a comparison between solar intensity at ground level and the upper atmosphere to an altitude of approximately 36 km.

3. Design

Construction

The payload was attached to the provided base plate from LSU with a footprint of less than or equal to 15 cm by 15 cm and a weight that did not exceed 3kg. The payload was constructed of copper-lined fiberglass walls with an exterior constructed of insulating foam. A heater was attached to the copper lining in order to assist in the dissipation of heat throughout the payload. The insulation protected the payload from the extreme temperature of the stratosphere. White tape protected the exterior from radiation burn. Large interior components were bolted to the fiberglass frame or base plate. As the use of hook-and-loop fasteners had experienced a proven success rate in previous HASP flights, smaller components and wires were secured with hook-and-loop fasteners in addition to surface mount hooks. The most significant change this year was the copper lining added to the interior walls for heat dissipation.



The interior of the payload prior to launch

Request for Proposal (RFP) Compliance

1. Internal temperature shall remain above 0^{o} C.	1. A thermostat will regulate internal temperature by sending power to heaters when the internal temperature drops below 10˚C.
2. Design shall be capable of measuring ascent and descent rates.	2. Ascent and descent rates can be computed from data recorded by an accelerometer using post processing techniques.
3. Design shall accommodate an accelerometer package provided by NASA Wallops Flight Facility.	3. Payload design includes mounting the provided ShockLog accelerometer to record accelerations experienced by the payload.
4. Design should image the Earth.	4. A digital camera donated by Olympus will face through the side of the payload and take pictures during the flight.
5. Design shall have at least two additional experiments including at least one active and one passive.	5. An additional passive experiment performed by the payload will utilize a pyranometer to measure solar irradiance. The additional active experiment will compare the voltage and current outputs of two solar cells with the use of a Fresnel lens as compared to a control cell.
6. Design shall be made of aluminum, fiberglass, or foam.	6. Design will be constructed out of foam, fiberglass, and aluminum.
7. Design shall accommodate attachment and mass/volume/operations restrictions set forth by LSU.	7. Design plan meets size/mass/operations requirements established by LSU.

RFP Non-Compliance

1. Design shall accommodate an RF transmitter provided by AMSAT.	1. RF transmitter was never received from AMSAT.
2. Total design cost should not exceed $750.00.	2. Design exceeded budget. Multiple data loggers are needed since no data will be transmitted via HASP student power interface. Some components from last year's payload were no longer functional and needed to be replaced.

Budget

Total cost was not to exceed $750.00. $600.00 was to be used before testing and troubleshooting.

Purchased Items:

HOBO 4 channel input data logger	2 @ 99.00	198.00
Voltage input cable	5 @ 8.00	40.00
Interval Timer	2 @ 4.28	8.56
HOBO UTA	2 @ 115.00	230.00
AL ESQ-113-37-6-5	4 @ 1.88	7.52
Thermostat	2 @ 38.00	76.00
ON Semiconductor Diodes	4 @ .31	1.24
ON Semiconductor Lin	3 @ .46	1.38
ON Semiconductor Diodes	4 @ .31	1.24
Temperature Sensor	1 @ 5.00	5.00
Pyranometer Recalibration	2 @ 100.00	200.00
Fresnel lens	1 @ 11.00	11.00
Plexi-glass	1 @ 5.27	5.27
Foam Insulation Board	1 @ 12.12	12.12
DC-DC 5 v regulator	1 @ 1.59	1.59
PC board	1 @ 3.49	3.49
Switch	1 @ 2.99	2.99
Narrow hinge	1 @ 3.99	3.99
Aluminum tape	1 @ 10.49	10.49
Angle aluminum	1 @ 4.49	4.49
Heat sink grease	1 @ 3.99	3.99
Adapter plug	1 @ 5.99	5.99
Quick disconnects	2 @ 2.99	5.98
3M Clips	2 @ 2.84	5.68
3M Clips	1 @ 7.47	7.47
Lithium Batteries	10 @ 4.92	49.20
Temperature Probe	2 @ 10.00	20.00
TOTAL COST		**$922.68**

The actual cost of the project exceeded the budget by $172.68

4. Results and Analysis

Flight Summary

On Monday, September 15, 2008 the LSU student HASP balloon was launched at 7:28 a.m. MDT time from NASA Columbia Scientific Balloon Facility in Ft. Sumner, NM. It remained in flight until Tuesday, September 16, 2008 when flight was terminated at 5:23 p.m. MDT time. The balloon's impact was at approximately 6:00 p.m. with a total flight time of about 36 hours.

There were three experiments in the payload that did not yield any results due to one of the data loggers not being activated at launch. The pyranometer and the internal and external temperature probes were the experiments that no data could be collected for.

Solar Energy System

The ground station did not yield any data for the Fresnel solar panel experiment as the connection between the data logger and solar panels was not properly secured.

The in flight Fresnel lens experiment taught us that capturing direct solar rays consistently on a High Altitude Balloon Platform through a Fresnel lens is not feasible due to the fact that the payload was in constant motion. By analyzing the solar cells used for orientation and the camera images taken during flight, we determined that the balloon continuously experienced pitch and yaw variations making the angle of the sun's rays on the two solar panels within the experiment to be inconsistent with one another. The sun's rays refracted through the Fresnel lens at certain angles while the control cell received direct rays. There were times when the control lens would receive no sun light and the Fresnel cell would. This inconsistency did not allow for an accurate comparison between the two solar cells.

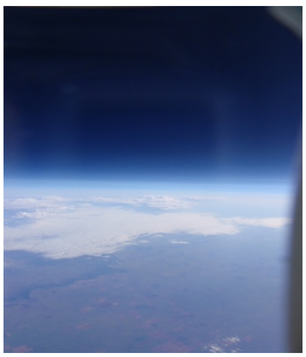
Imaging

The Olympus Stylus 1030 SW digital camera was estimated to take 3,500 images of the earth while powered by the flight battery. The timer attached to the camera successfully took an image every thirty seconds while under power.

The following is a list of how many pictures were taken:

- *Saturday, September 13, 2008 - 338 before the launch was rescheduled.*
- *Monday, September 15, 2008 - 2,117*
- *Tuesday, September 16, 2008 – 836*

The camera took 3,291 images of the earth, only 209 photos less than the estimated 3,500. During the time the camera was operational the internal temperature of the payload fluctuated between -2.3˚C and 24˚C as recorded by the ShockLog accelerometer. The flight battery powered the camera for 31 hours. The final picture was recorded at 7:00 a.m. MDT time Tuesday morning, at termination of LSU power. We did encounter a small problem with glaring at high altitudes as the Plexiglas used to protect the camera reflected it with sunlight. Some photos were also slightly blurred by condensation in the view, assumedly from the temperature contrasts. A few select photos such as the one below are available in Appendix 10 along with their descriptions



This image was taken on 9/15/08 at 8:33 a.m. MDT as the payload exited the troposphere one hour post launch. The altitude was ~19 km.

Electrical

The electrical system operated effectively and did not fail as long as power was provided from LSU. However, during the course of the flight the allowable amperage was exceeded. During operation of the timer while the secondary thermal system was on there was a recorded current of .52A, .02A above allowance. At a minimum the payload drew .01A while only the LED indicators were operational. The discrepancy in the standby current data could be due to truncation as all of LSU's current data was limited to two decimal places. Table 1 illustrates the current draw during flight as compared to the values at integration.

Table 1

Component	Test I(A)	Flight I(A)
Standby	.0026	.01 - .04
Photo Timer	.07	.05 - .08
Heater	.452	.44 - .48
Heater & Timer	.492	.49 - .52

Thermal

The thermal system operated as intended. During power on the internal temperature of the payload never dropped below 7.5°C as measured from the ShockLog internal temperature probe. Following power off the internal temperature reached a low of -2.3°C during descent through the Troposphere while the external temperature dropped as low as -69.71°C. While the payload was power on the external temperature briefly reached 28.71°C and the thermal system maintained an internal temperature as high as 24.4°C.

The thermostat appeared to activate the secondary thermal subsystem as expected. The following table illustrates the thermostat operation, and a graph of this data can be found in Appendix 6. The final shut down at less than ideal temperatures was due to the termination of power from LSU and the discrepancies in time are due to the ShockLog reporting data once every thirty minutes while the LSU-provided power data accurate to the second. The ShockLog also recorded both low and high temperatures. The graph in the appendices averages the two, while the table below illustrates the low.

Table 2

Event	Ext. Temp.	Event UTC	Int. Low Temp.	Int. Temp UTC
Secondary Heater On	13.4°C	9/15/08 14:05:20	13.4°C	9/15/08 14:08:43
Secondary Heater Off	1.33°C	9/15/08 16:25:43	21°C	9/15/08 16:28:43
Secondary Heater On	-21.14°C	9/16/08 1:19:55	13.4°C	9/16/08 1:28:43
Secondary Heater Off	-14.69°C	9/16/08 12:59:33	10.3°C	9/16/08 1:08:33

Our data indicated that the thermostat activated at 13.4°C although it was set to activate at 10°C. The internal data interval may cause the data to be misleading, and the location of the internal probe within the ShockLog may have altered the readings. Despite these factors, the graph seems to illustrate a successful thermostat operation.

Acceleration

The peak acceleration of the payload was measured at 53.5cm/s occurring at 6:28:43 p.m. MDT on Tuesday September 16, 2008 during the last 6.39 seconds of descent. The ShockLog identified key events during the mission such as transport to the launch pad from the hanger, launch, termination, and impact. It also recorded events during shipment back to Hawk Institute for Space Sciences in Pocomoke City, MD. (Appendix 9).

Solar Irradiance

The data logger connected to the pyranometer was not activated so high altitude solar irradiance was not able to be documented for this mission. The pyranometer on the ground station did record data although without the readings from the pyranometer on the flight payload, there is no way to have comparison data.

5. Conclusion

Lessons Learned

One of the most important lessons learned this spring was to communicate both within and outside the group. Group meeting attendance was inconsistent due to poor communication. The integration of systems is the responsibility of each system manager and we realize now that we needed to communicate with other group members about their individual task in order to understand the entire mission's progress. Using outside resources wisely such as presenting new ideas to advisors as soon as they are created is valuable to the overall project. If a change is made to a subsystem, everyone involved with the project should be notified. Another lesson we learned was to be more organized. Early in the project we were unable to follow our original schedule due to lack of organization but after some constructive criticism we were able to establish better guidelines for ourselves. We also learned that is important to fully understand the scope and details of the project.

Message to Next Semester

Our group gained many valuable lessons this semester by being involved with the Hawk HASP2 payload. There is gained knowledge to impart to the students who will be working on this project the next available semester. Hopefully our experience will benefit the next class.

One of the most important factors to consider when working with a group is organization. There are three suggestions we would like to make in order to create productive organization for the project. First, we recommend an initial group meeting to outline a conference schedule. Meeting regularly will allow the project to progress smoothly and give each member exposure to all aspects of the project. Second, we suggest that weekly or bi-weekly goals be set providing a reasonable timeframe for work to be completed. A third organizational strategy would be to record contact data for any source you talk to or web site visited from which information is obtained. Good organization is vital to the success of a project.

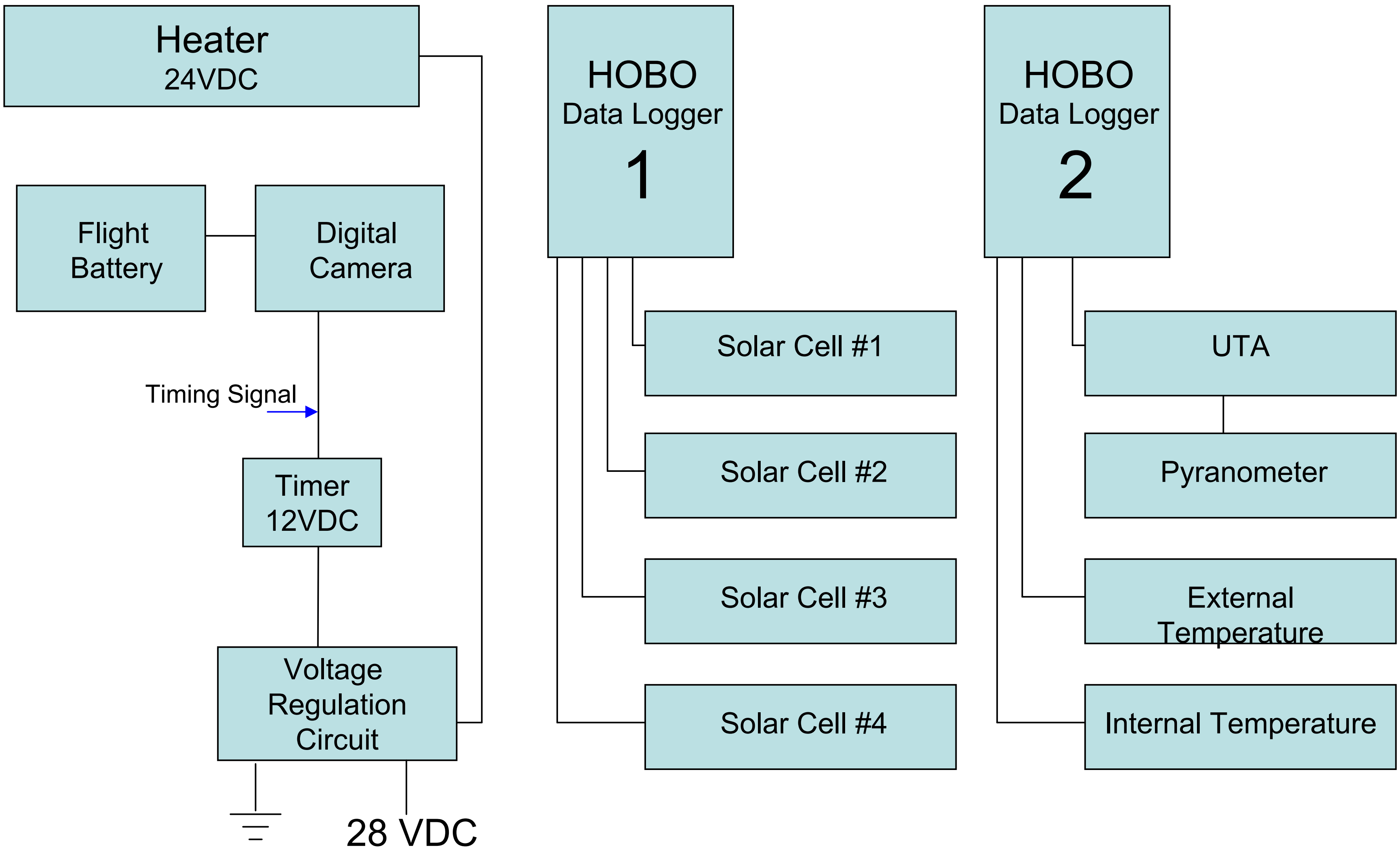
Another extremely important aspect to a group project is communication. It is imperative to have effective communication both among group members and with outside sources. Outside sources such as the instructor and advisors are available to offer suggestion and direction. All group members should be informed of any changes to a subsystem as a change one individual makes can potentially affect the entire project. By having clear communication, a project can expect to progress with a lesser margin of error.

Since it is probable that original students involved may not be available for the duration of a project, concise record keeping and data backup is necessary. In the weeks following launch, our team experienced an irreversible hard disk failure. Fortunately, most of our critical data was backed up and our project was able to continue successfully. It should be mandatory to have both a hard copy and a flash drive with records of notes, presentations, and drawings on it. Be sure that final diagrams of all subsystems are readily available. Keeping a copy of all receipts for a project is important so that a complete budget analysis can be performed determining whether or not the mission was cost effective. Having an efficient record keeping system will provide the background data necessary for the final analysis and report of the project. Be sure to submit all this documentation to the instructor at the close of the semester.

Our concluding recommendation to the next participants in the HASP project is to configure the payload for remote command. Dr. Guzik of Louisiana State University made this strong recommendation during the 2008 launch at Fort Sumner, NM.

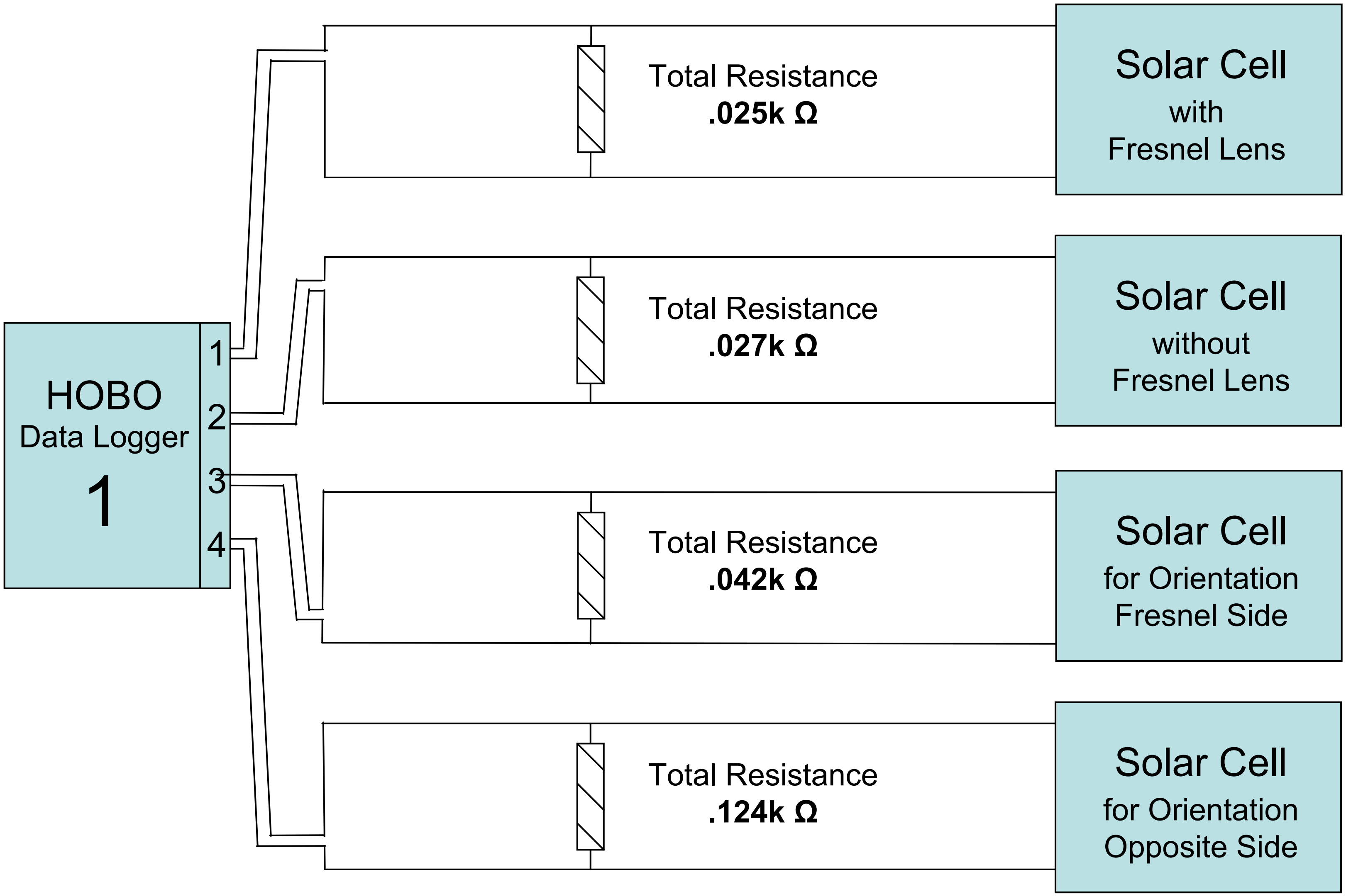
Appendix 1

Subsystem Diagram

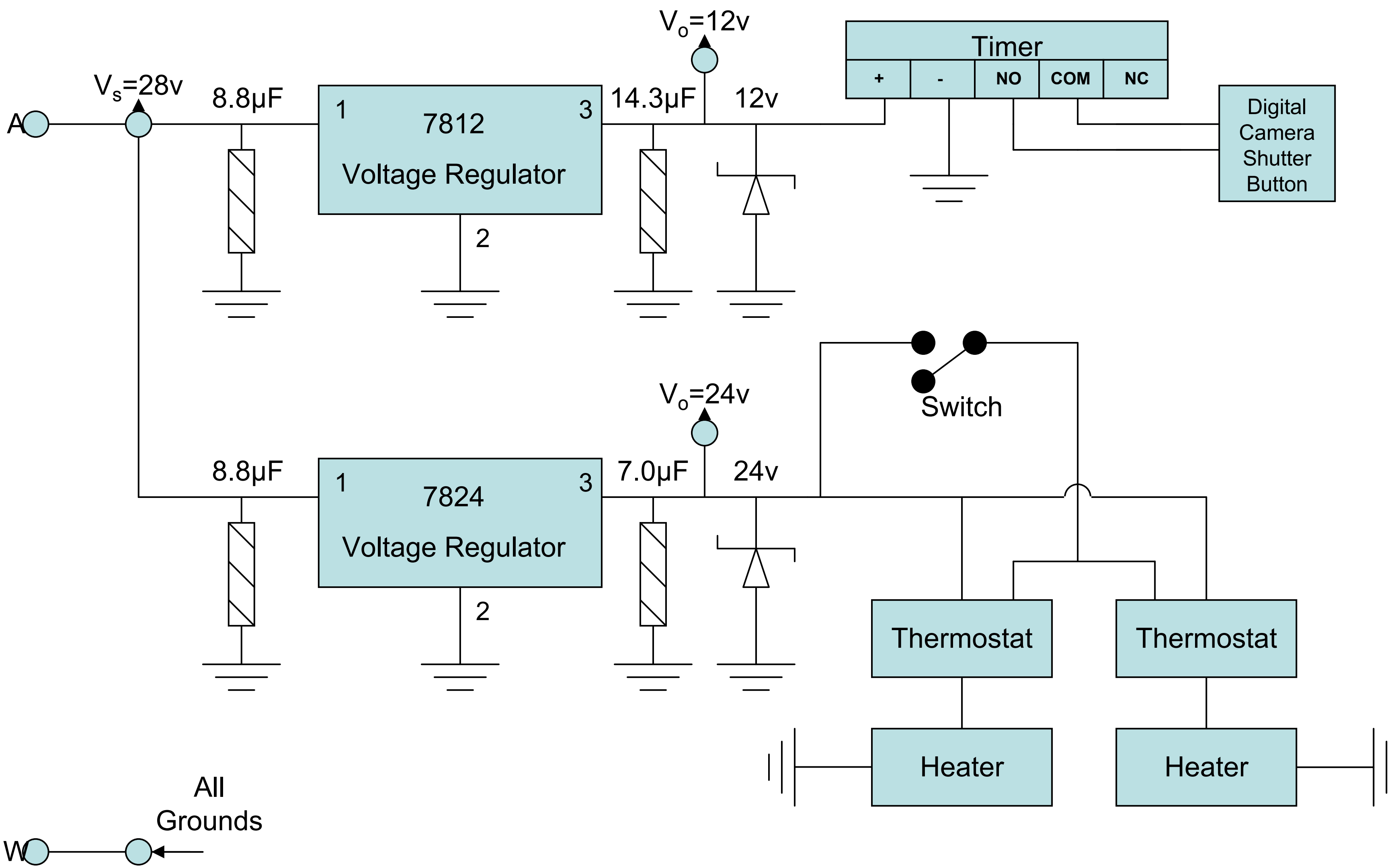


Appendix 2

Solar Cell Experiments

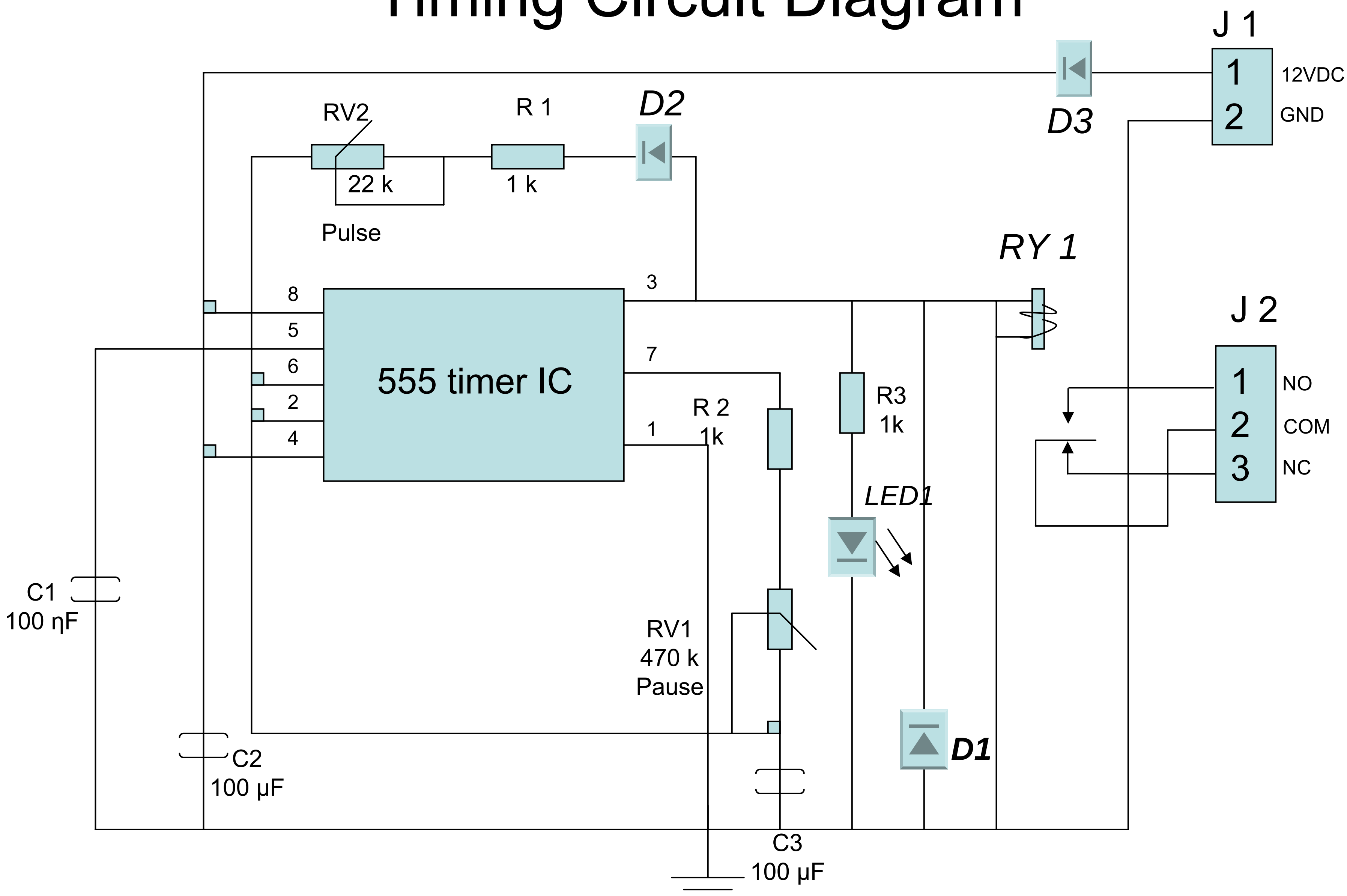


Payload Wiring Diagram

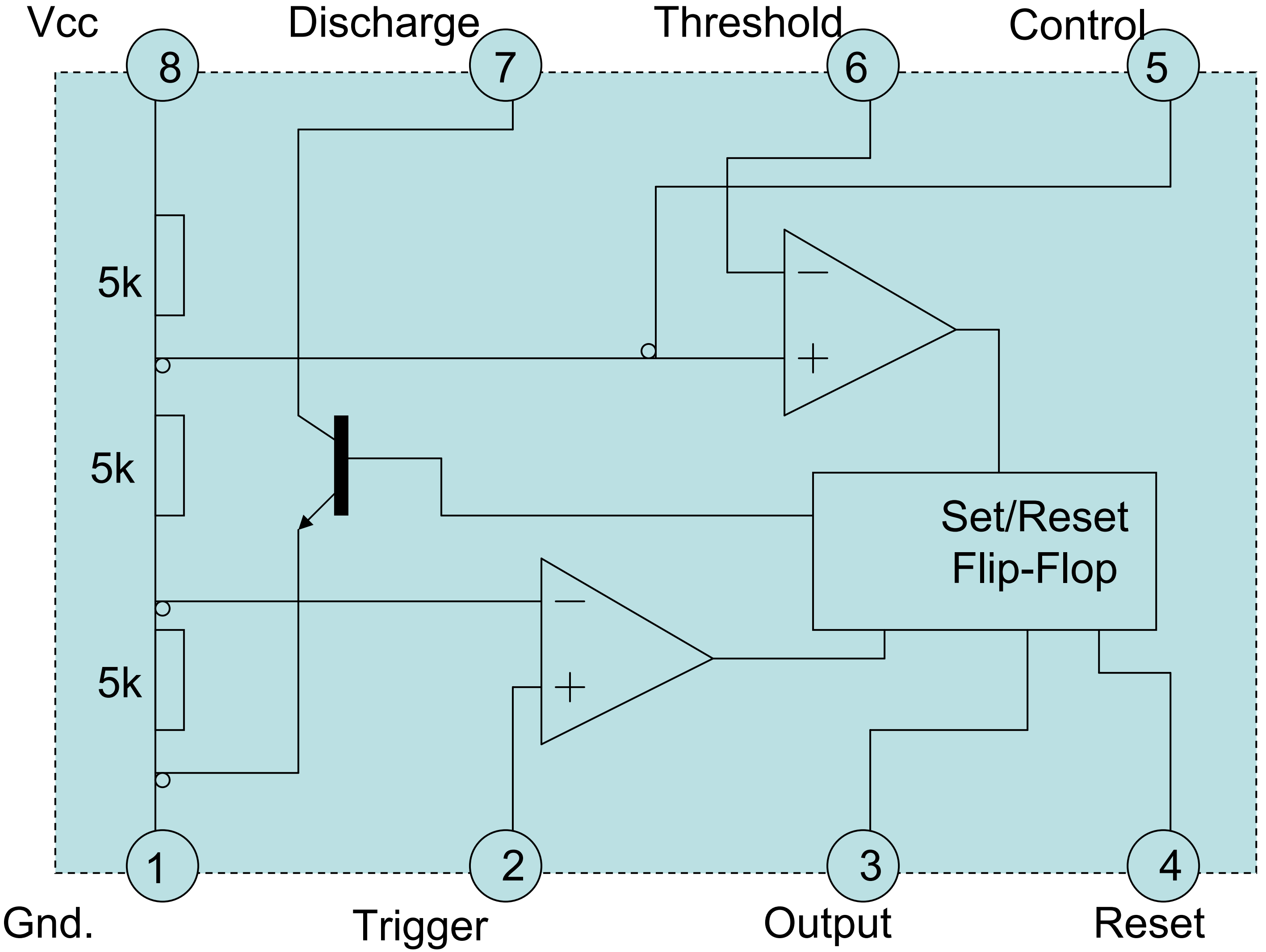


Appendix 4

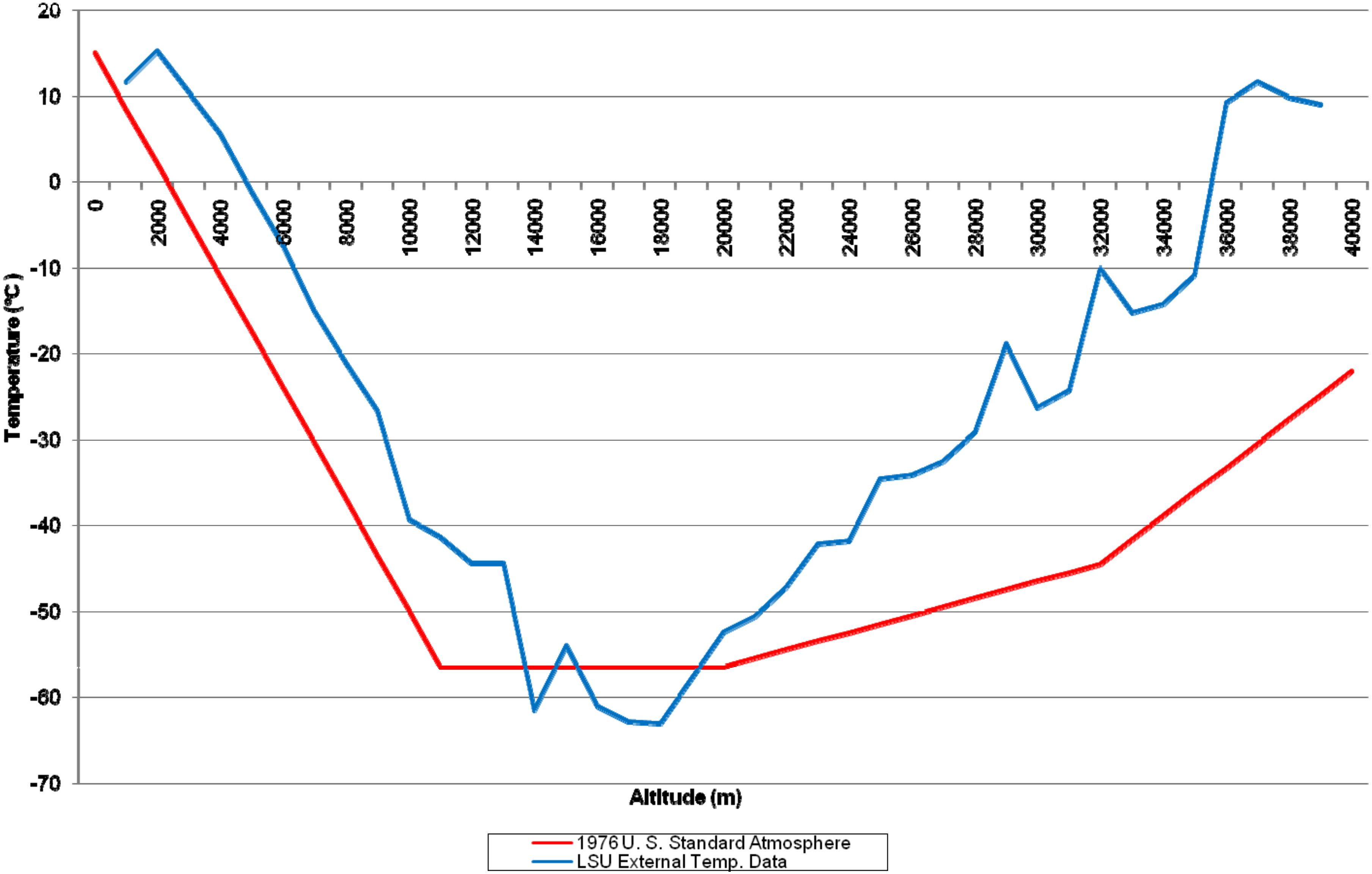
Timing Circuit Diagram



LM555 Timer Internal Circuit Diagram

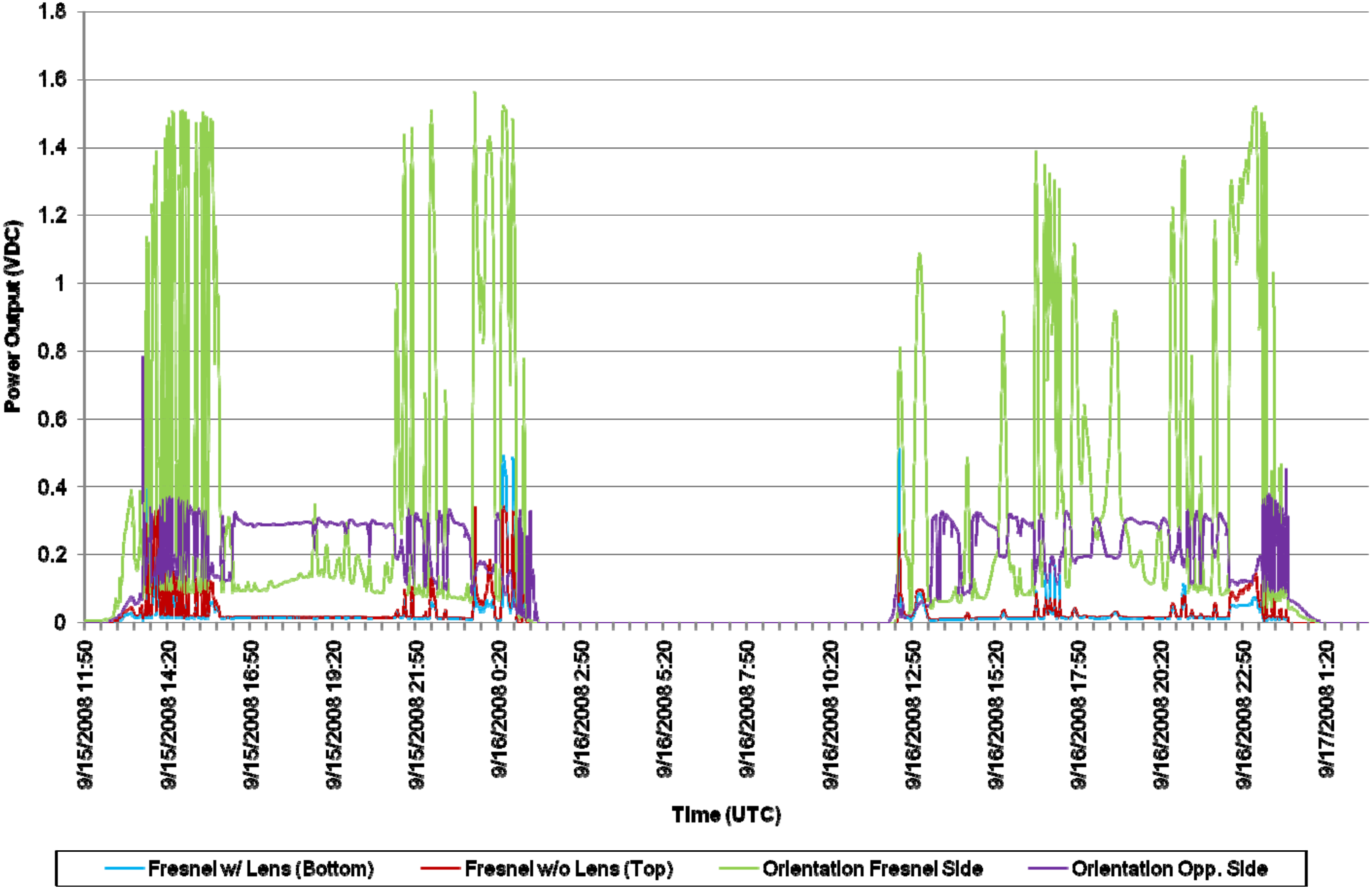


External Temp. vs. Standard Atmosphere



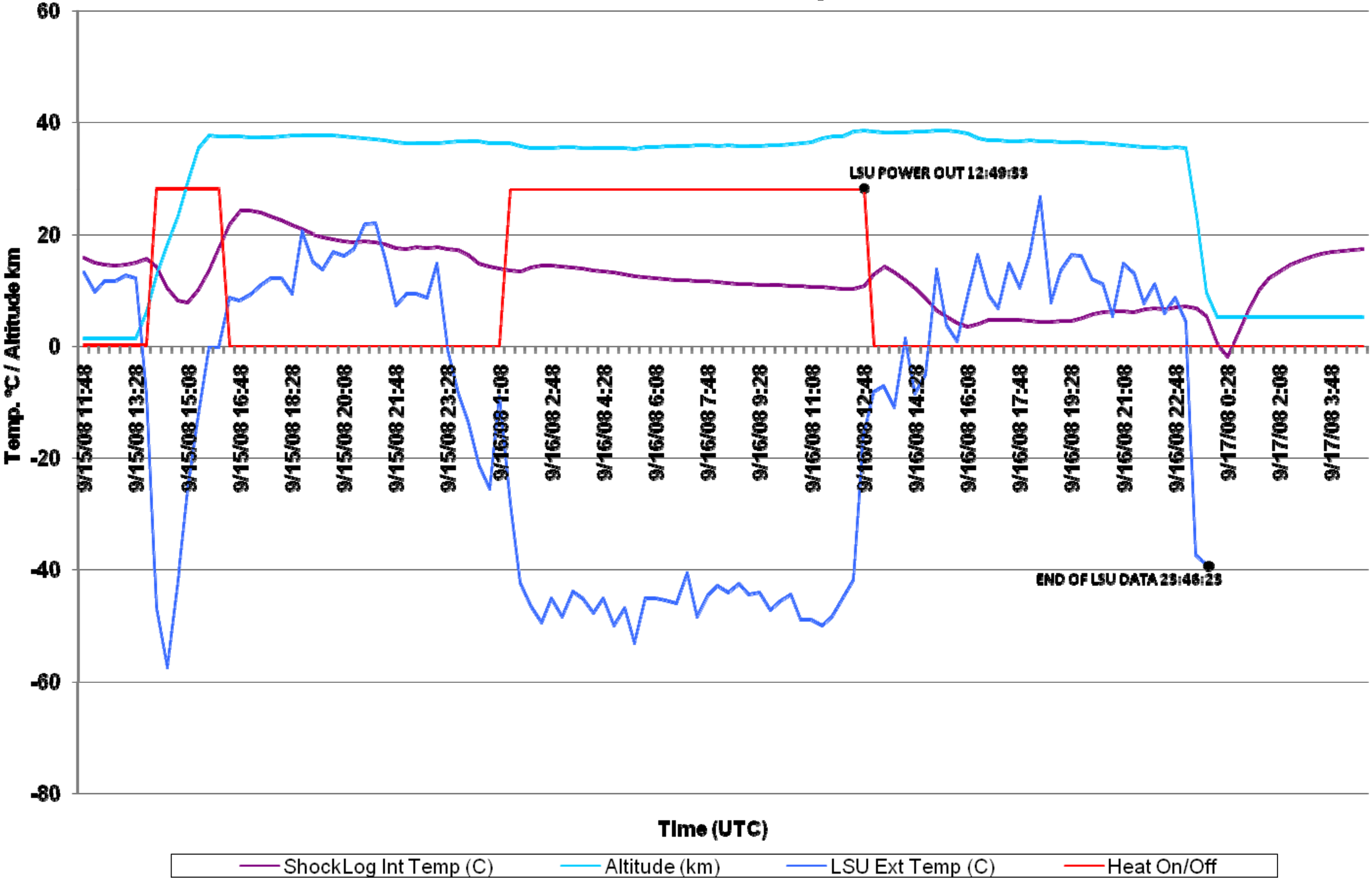
Appendix 6

Solar Panel Data

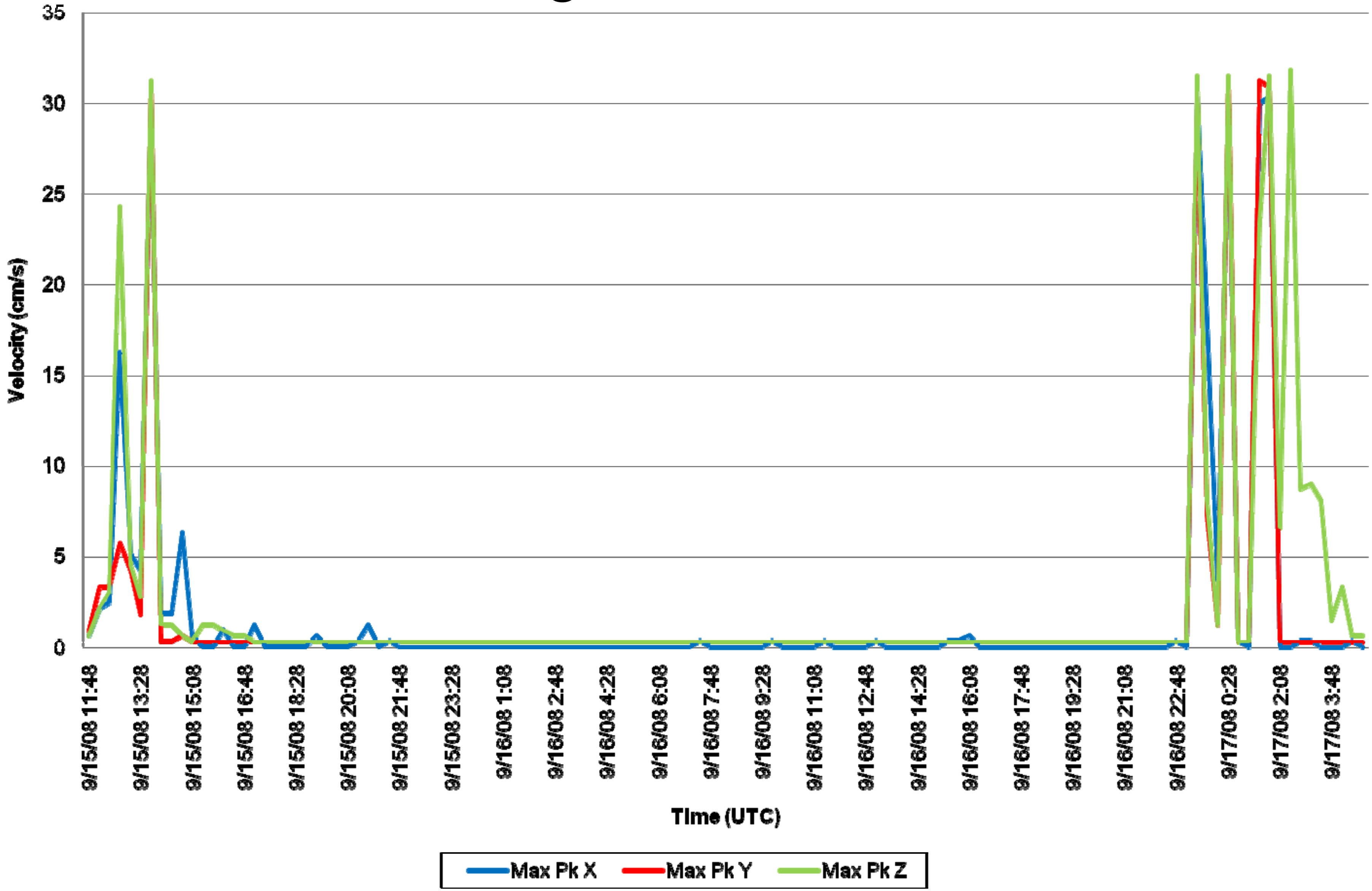


Appendix 8

Thermostat Operation



ShockLog Accelerometer Data



Pre-launch.
On the ground.
Altitude approximately 1270 meters.

Appendix 10

Photo on the left taken Monday, September 15, 2008, 6:38:28 AM MDT
Photo on the right is from LSU’s HASP website and is probably from the same moment.

Up, up, and away!
Ascent through the clouds.
Altitude approximately 2400 meters.

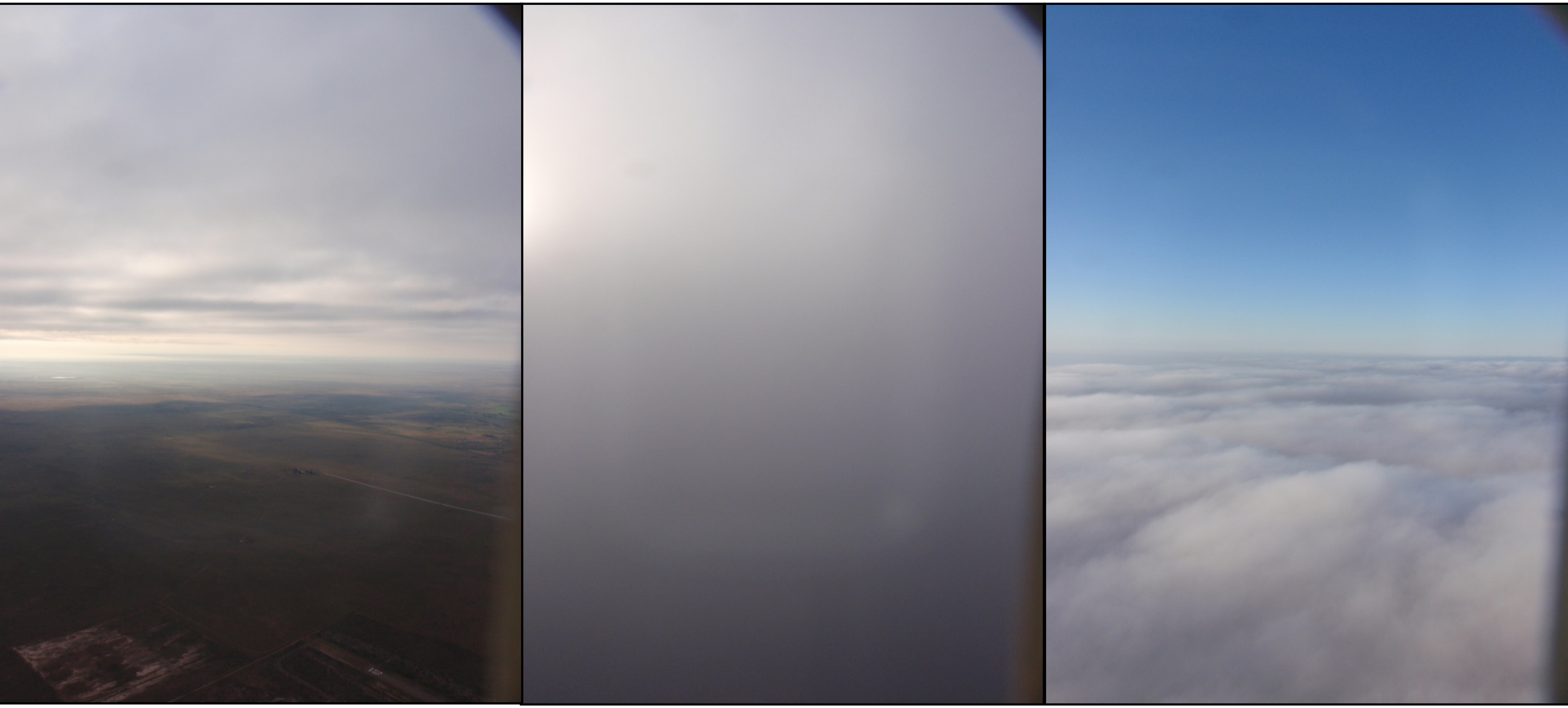


Photo on the left taken Monday, September 15, 2008, 7:37:10 AM
Photo in the middle taken Monday, September 15, 2008, 7:37:42 AM
Photo on the right taken Monday, September 15, 2008, 7:38:14 AM

Climbing through the troposphere.
This is where the temperature hits an extreme low.
Altitude approximately 6000, 8000, and 10000 meters respectively.

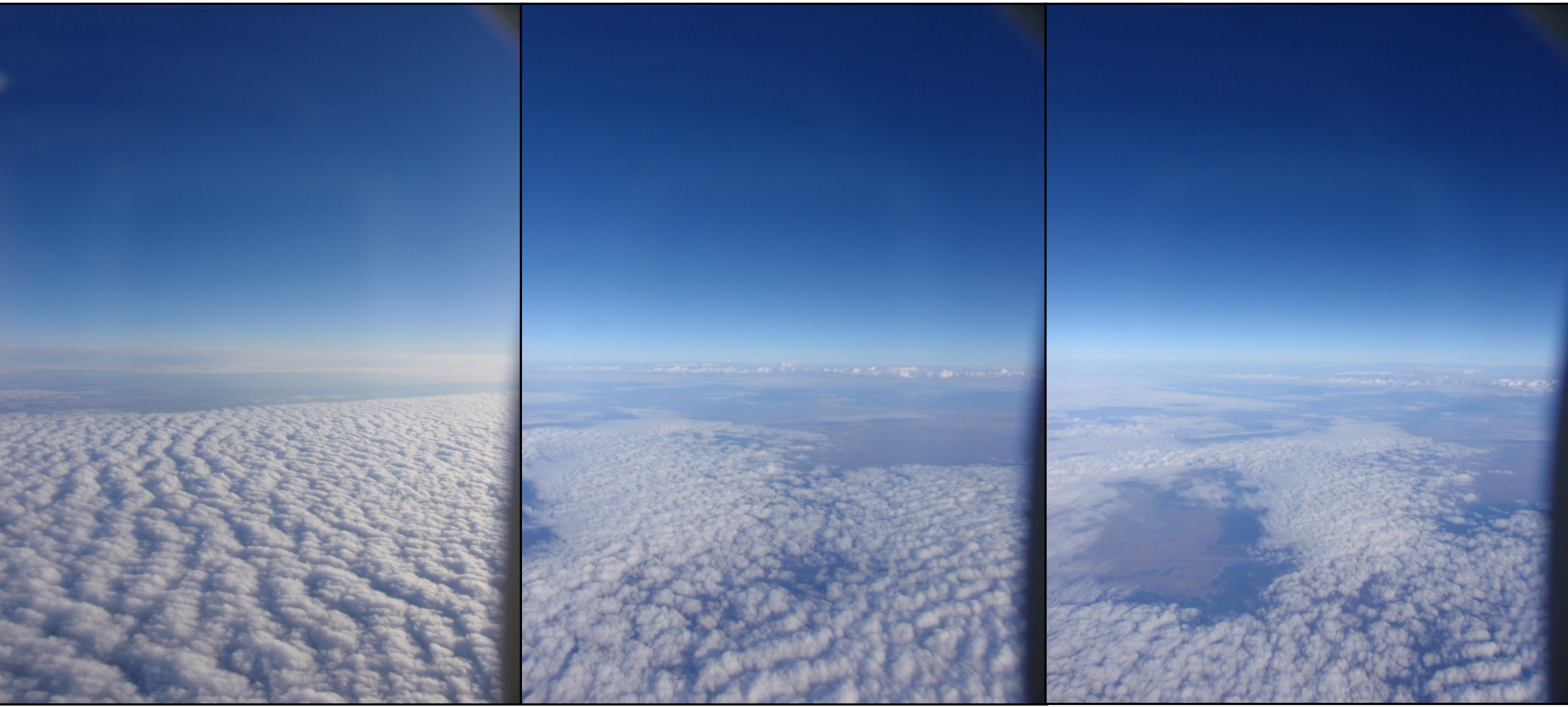


Photo on the left taken Monday, September 15, 2008, 7:48:21 AM
Photo in the middle taken Monday, September 15, 2008, 7:54:20 AM
Photo on the right taken Monday, September 15, 2008, 8:00:16 AM

Floating in the Stratosphere.
This is where the payload spent a majority of its time.
Altitude approximately 35000 - 37000 meters for the three pictures.

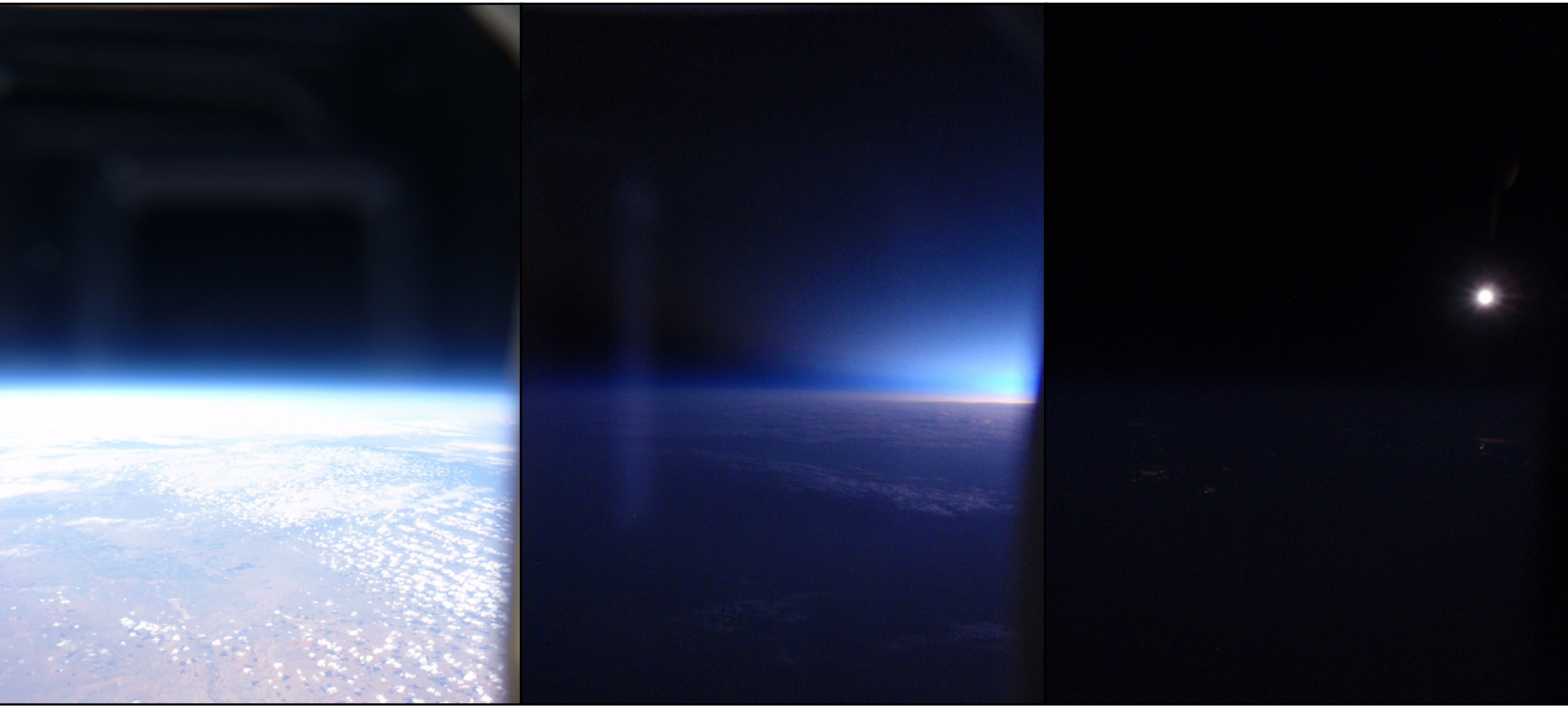


Photo on the left taken Monday, September 15, 2008, 11:32:34 AM
Photo in the middle taken Monday, September 15, 2008, 7:35:06 PM
Photo on the right taken Monday, September 15, 2008, 7:38:08 PM