Minimizing Pressure Changes within a High-Altitude Balloon Payload

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Abstract

We have constructed a payload that will be launched via a high altitude balloon in order to test a pressure containment vessel we have designed. Many balloon experiments require that the pressure remain relatively constant and close to one atmosphere. In the past, many students have found that the most effective way to meet this challenge is to use chambers made of pvc plastic. However, these chambers tend to be relatively high in mass. Our goal was to design a chamber that effectively maintains a constant pressure, yet is lightweight and simple to construct. We chose to examine how PLA plastic performs in this capacity. We utilized a 3D printer to print the container and an ABS frame. This frame supports the general structure in which the chamber and its supporting devices are housed. We placed one barometer inside the chamber and a second one outside to collect control data. We attempt to maintain a relatively constant temperature within our payload by utilizing a heating system that uses an Arduino microprocessor to turn the heater on and off when the temperature falls outside a predetermined range.

Background

We constructed a container that is initially filled with a small amount of air. As the payload carrying this container increases in altitude, the external pressure will decrease reaching pressures as low as one kilopascal, or 0.00987 atm, (based on past DemoSat data). Normally, the pressure in a payload will decrease during ascension. For an ideal gas within a container, pressure (P), volume (V), and temperature (T) have the following relationship:

$$\frac{PV}{T} = Const.$$

Given this, to maintain a constant pressure within our vessel, we will attempt to maintain a constant temperature and volume within it. Because the external pressure will decrease as the payload ascends, the pressure within the vessel will have the tendency to rise. Therefore, the frame of the compartment must be airtight and strong enough to combat this increase in pressure.

Objectives

- To attempt to minimize pressure changes within our payload without doing any active work on the system.
- We hope to discover an optimal method for maintaining relatively constant pressure to be used for future payload experiments
- Examine the use of PLA plastic as material with which to construct a lightweight chamber that maintains constant pressure
- To learn how build a payload

Design

The design of our payload is centered around two key features. The first being mass and the second being the experiment to be contained. Attempting to minimze the mass of the payload, we used as few parts as possible without having to sacrifice any necessary sensors and their supporting electronics and structure. We mounted all primary sensors on to two circuit boards, or shields, with the only exceptions being the experimental pressure sensor and the external temperature sensor. The frame of the payload is 3D printed using ABS and is surrounded by XPS insulation. The insulation serves a dual function: providing structure to the walls and ensuring that heat loss within the payload is minimized. The outside of the payload is covered with aluminum tape and aluminized non-stretch polyester to further protect the payload from heat loss and also to shield the electronics from radiation. Finally, we placed the heater in a strategic spot to keep the entire payload at functioning temperatures. Below are some figures depicting various aspects of the design.

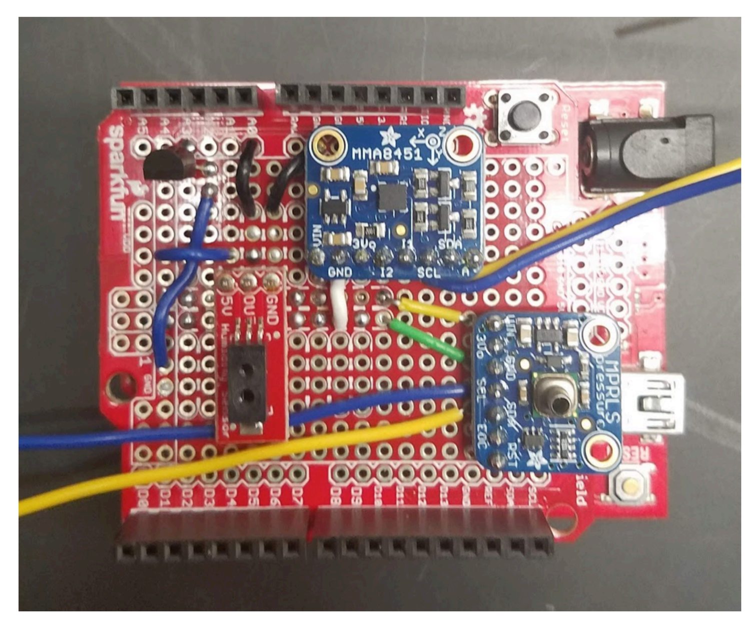


Figure 1: The first shield houses the inside temperature sensor, humidity sensor, accelerometer, and the control pressure sensor.

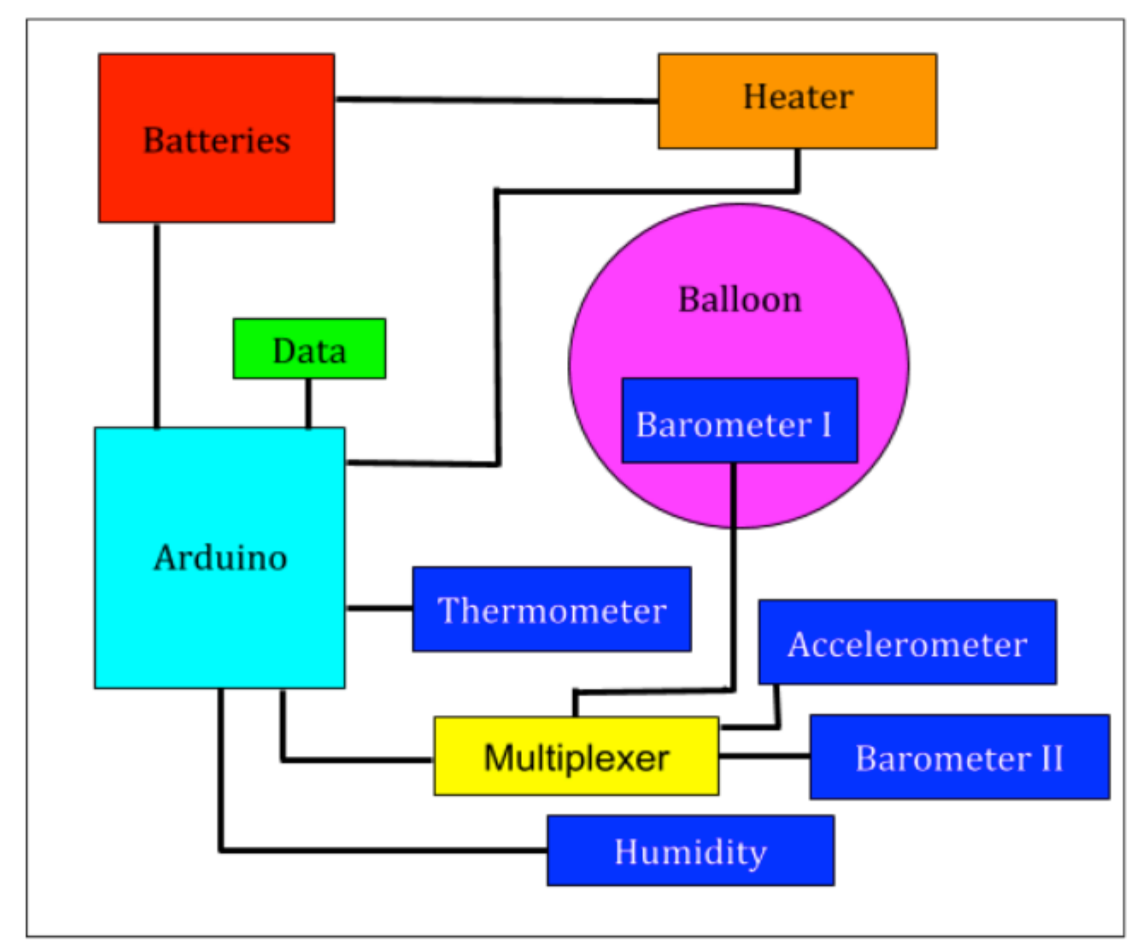


Figure 3: This is a schematic of our Arduino circuit. The heater is placed in such a way so that a constant temperature will be maintained throughout the payload.

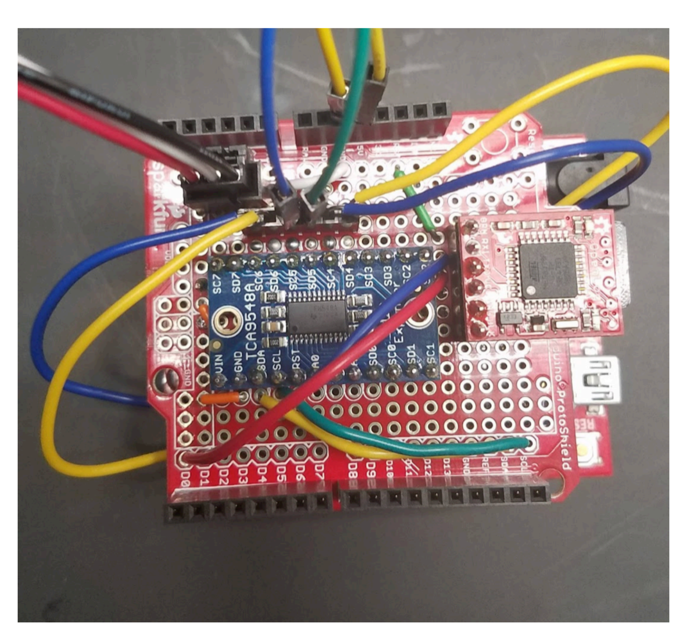


Figure 2: The second shield houses the multiplexer, the SD card loger, outside temperature and the experimental pressure sensors.

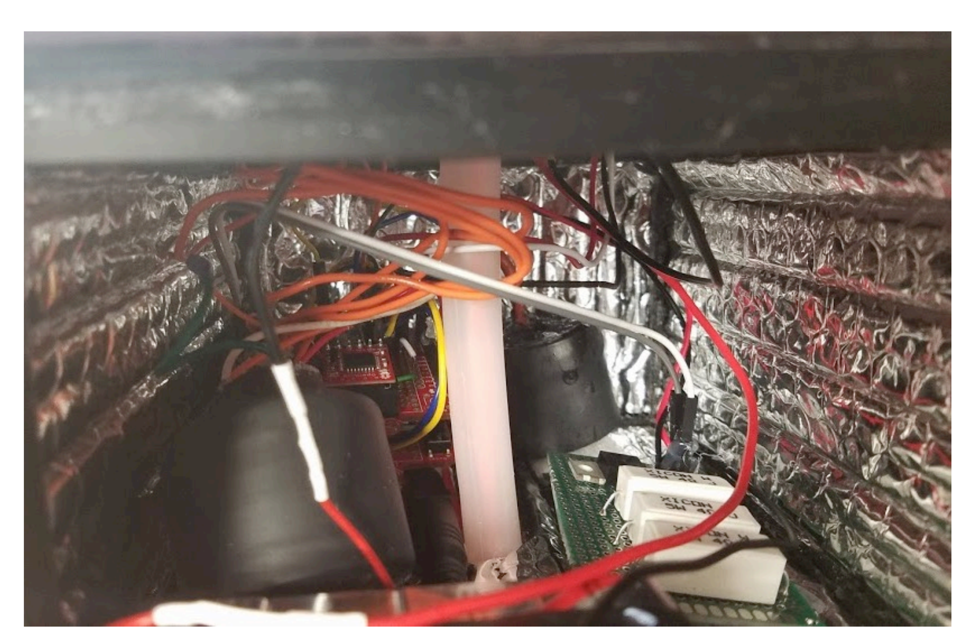
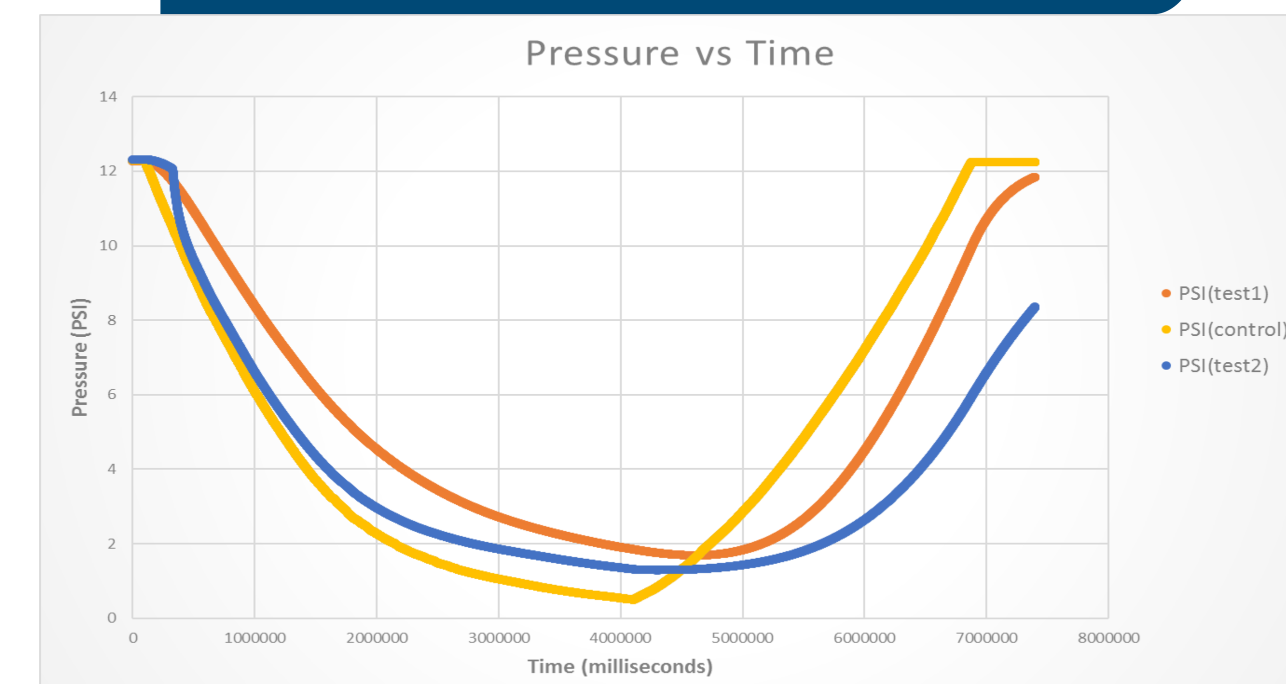
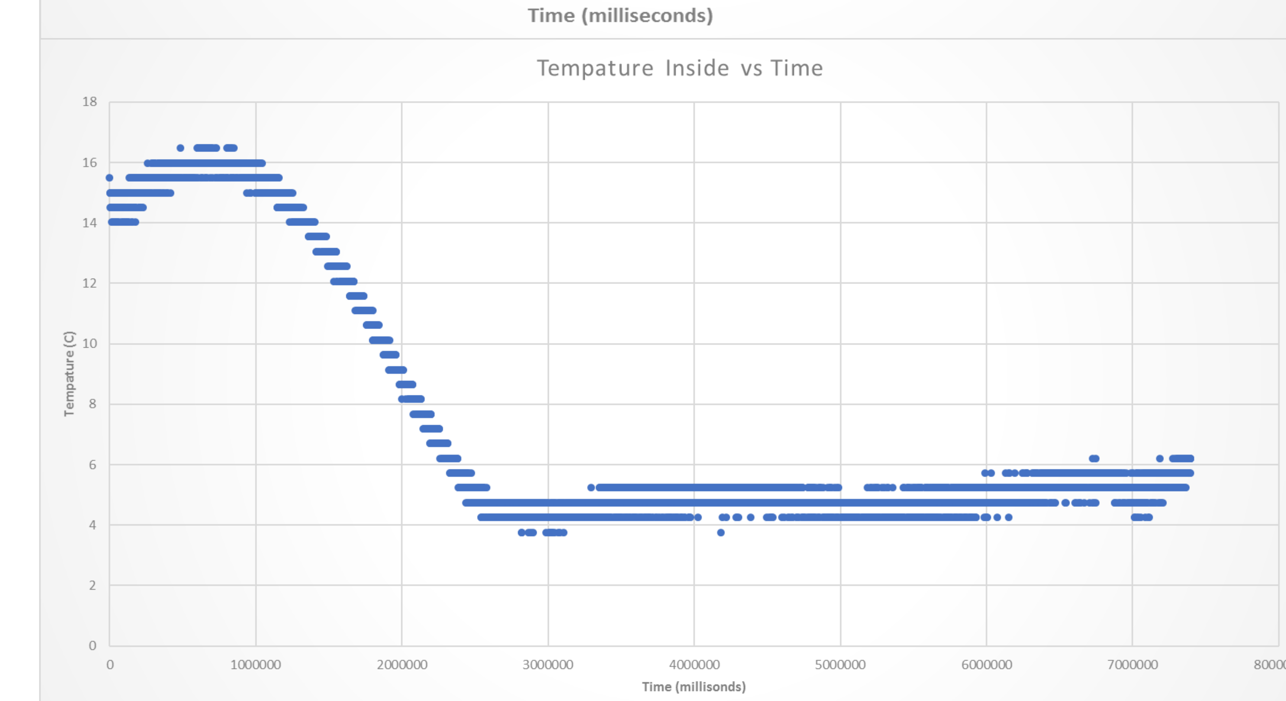


Figure 4: Our payload is designed in such a way that space is optimized for each component.

Flight Results





Shown above are data collected for our vessels during flight. The first graph shows the pressure of each vessel versus the control. The test1 vessel was sealed with Scigrip 16 acrylic adhesive, along with being shrink-wrapped with a layer of silicone. The test2 vessel was sealed with JB weld along with being shrink-wrapped with silicone as well. The second graph shows the temperature inside the payload during flight the temperature was kept around five degrees Celsius.

Conclusion

We saw that the PLA chambers did not preform as well as anticipated. This could be from several variables, the main one being the low temperatures the vessels experienced during the flight. This is possibly from the PLA itself becoming more brittle and permeable in the cold. It could also be from the silicone allowing air to flow out where the wires are attached. Maintaining a higher temperature in the vessel during flight may solve some of these problems.

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