Zero Pressure Balloon Descent Valve

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ABSTRACT

In the field of high altitude ballooning the use of a zero pressure balloon has become common for its ability to stay at altitude longer than traditional latex weather balloons. This opens the doors for a new variety of high altitude experiments; however these balloons can often present challenges when it comes to flight control and termination. For environment and safety reasons it is ideal to bring the balloon and payload system down together. The purpose of this project is to create a reliable form of termination for zero pressure balloons with the long term goal of being able to accurately control the balloon descent rate. While many companies already use a similar system, this valve grants amateur ballooning groups a more accessible way of flying these zero pressure balloons.

DESIGN CONSTRAINTS

- Valve will undergo temperatures as low as -50C
- Must remain operable at -30C
- Leak rate must be as small as possible
- Iridium system will need to communicate between two termination systems
- Communicate over a distance of 50 feet.

METHODS

Testing for this system encompassed communications between XBEEs as well as functional ability at low temperatures.

In order to interface the valve into the apex a special zero pressure balloon was crafted by Raven Industries that includes a ring in the apex. Besides electronics and elastomer seal, all valve parts were 3D printed using ABS and PLA plastics. The circular base as seen in Figure 1 was individually sealed into the apex while being cautious of damaging the balloon envelope. An ATV sealant was used for its ability to withstand cold temperatures.

Figure 1: Process of sealing valve base into balloon apex

LOGISTICS

The valve utilizes the same OCCAMS board previously used between MSGC cutdown and tracking systems. In order to maintain two unique forms of termination as per FAA regulations the valve needed to be flown alongside a cutdown device and the XBEE radios programed as a meshed network. Commands are sent through the Iridium satellite constellation and then can be communicated through the OCCAMS boards to either the valve or cutdown systems.

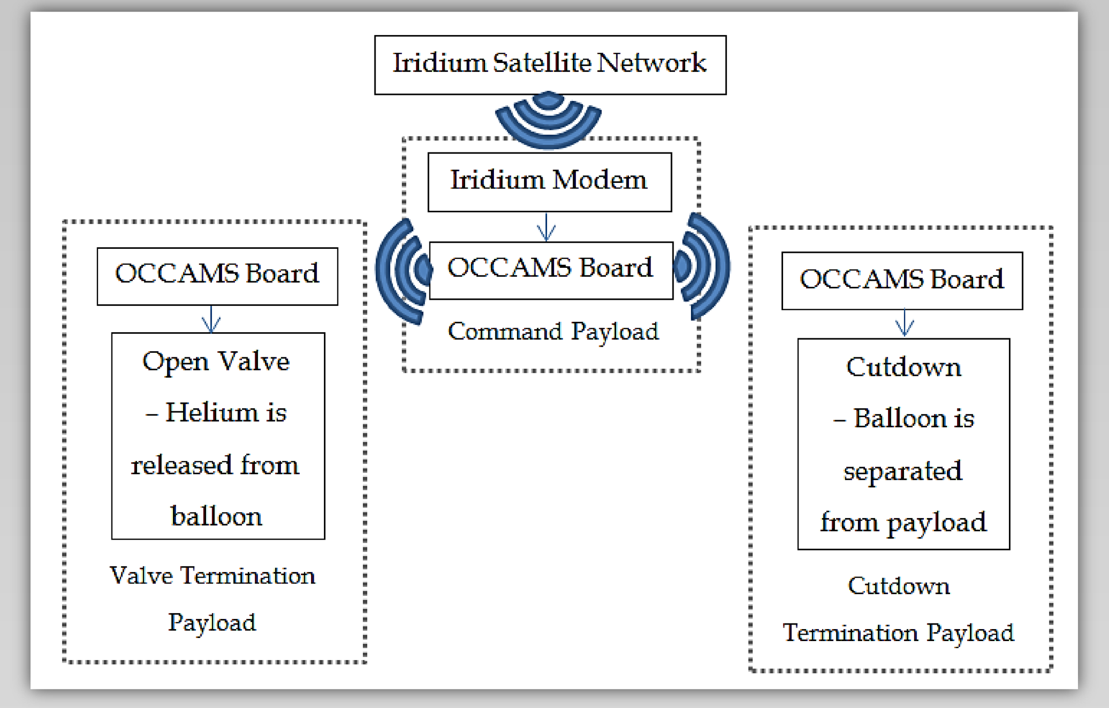

Figure 2: Communications between command payload and termination systems

DESIGN

After much consideration the chosen design for the valve utilizes a threaded rod attached to the DC motor as seen in the exploded view in Figure 3. The rod is threaded through the top of the lid and two 3D printed pegs prevent the lid from rotting when the motor is powered. The mechanical advantage provided by the shaft was enough to keep the lid sealed throughout flight. In order to promote the best possible radio communications the OCCAMS board is mounted with the SBEE facing the command payload. An additional feature that was added was an extra battery connected to a group of resistors to keep the motor warm.

Exploded View add here!

Figure 3: Exploded view of valve system. Not shown here: OCCAMS board, heater, foam housing and batteries.

DATA

A graph of the altitude over time is depicted in Figure 4 for the eclipse zero pressure balloon. During totality the balloon dropped altitude as expected due to the decrease in temperature. However after totality the balloon continued to descend at a constant rate. In between float altitude and the descent rate change that occurred at about 1:40 PM the open valve command was sent three times. After cycling the valve and resending open valve command the descent rate changed. At about 40,000 feet the balloon was separated from the payload chain via the cutdown termination system.

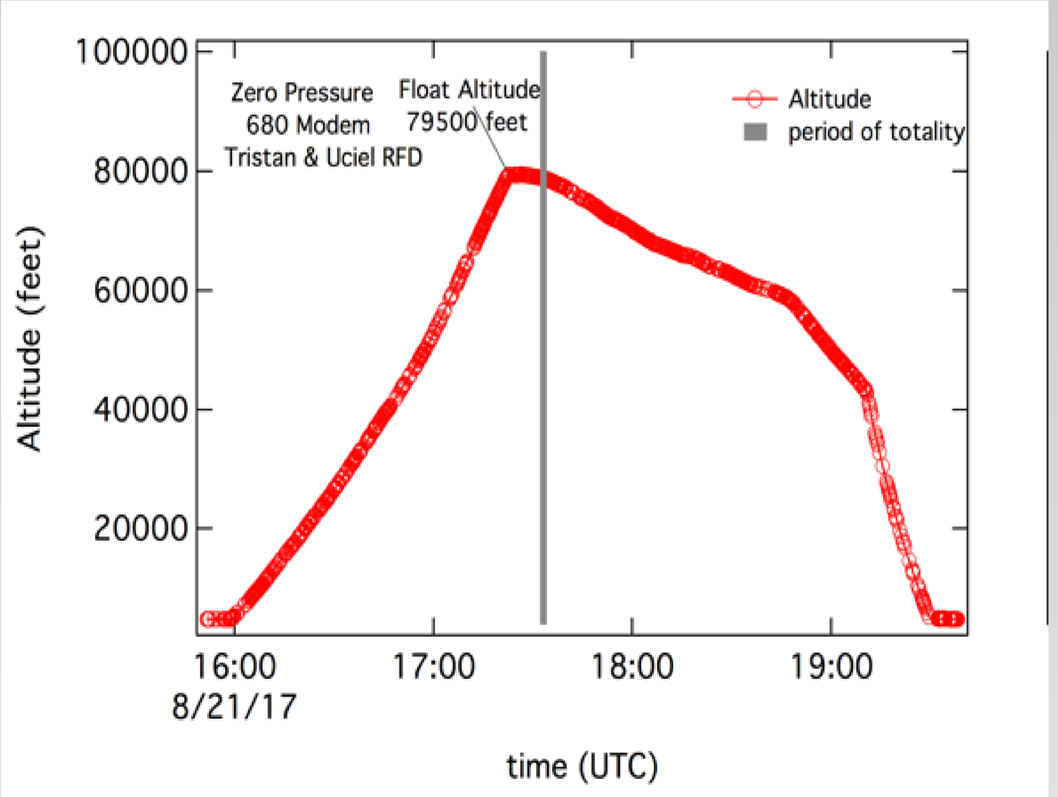

Figure 4: Altitude changes during eclipse flight including totality period and sent commands.

DISCUSSION AND RESULTS

The placement of a SPOT tracking system into the balloon fill arm allowed our team to recover the valve and zero pressure balloon. Upon retrieval of the valve it was discovered that it had only opened partially.

It was concluded that the valve didn't open until after sending the cycle command, which is designed to open and close the valve repeatedly. From the command timeline of the eclipse flight it was determined that the cause for the valve not opening fully is that something was restricting its movement. The most likely reason for this would be that the cold temperatures created too much friction in the threaded rod. However it is also possible that the different materials and corresponding coefficients of thermal expansion interfacing in the lid resulted in the inability to open the valve.

CONCLUSION

Results of the eclipse flight show that the valve has room for improvement. The next step in this project will be attempting to recreate the failures that occurred during the eclipse flight. Theories as for why the valve didn't fully open question the low temperature effects on both the plastic elements and threaded rod.

Future alterations to the valve include the addition of a limit switch to ensure that the lid will open to its full height. Along with this all printed parts will be the same material to avoid different thermal expansion or contractions occurring during flight. This change is particularly important for the lid interface.

Even though the flight was far from perfect, the valve still demonstrated functionality through its ability to communicate with the command payload. In addition the leak rate leading up to float altitude appeared low enough that the ascent rate and peak altitude were not greatly affected.

Figure 5: Completed valve recovered from eclipse flight

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