Autonomous Altitude Control Device for Latex HAB

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Abstract

The advent of latex High Altitude Balloons has dramatically reduced the costs associated with conducting research at altitudes reaching the stratosphere. Latex balloons are less expansive than zero-pressure and super-pressure alternatives, but they have an important disadvantage: while zero-pressure and super-pressure balloons can float at a desired altitude for long periods of time, latex balloons ascend continuously, flying only around two hours before reaching a bursting altitude (usually around 100,000 ft) and falling back to earth. Enabling latex High Altitude Balloons to float at a constant altitude for extended (and specifically defined) periods of time could make them significantly more useful and cost-effective.

An autonomous altitude control vent for latex high altitude balloons was designed and fabricated. The vent releases helium during the balloon's ascent, first to cause the balloon to reach neutral buoyancy at a specified altitude, and again later in the flight to cause the balloon and payload to descend for a soft landing. The vent is completely autonomous; it makes decisions using altitude and ascent rate feedback, which is measured using an external pressure sensor.

Two preliminary test flights were conducted. It was found that the vent allows gas flow rates sufficient to achieve a soft landing. At an altitude of roughly 30,000 ft, the balloon achieved negative lift in under two minutes. A faulty altimeter, which was used only on the second flight, prevented the vent from operating on altitude and ascent rate feedback. Several additional test flights are planned in the coming months.

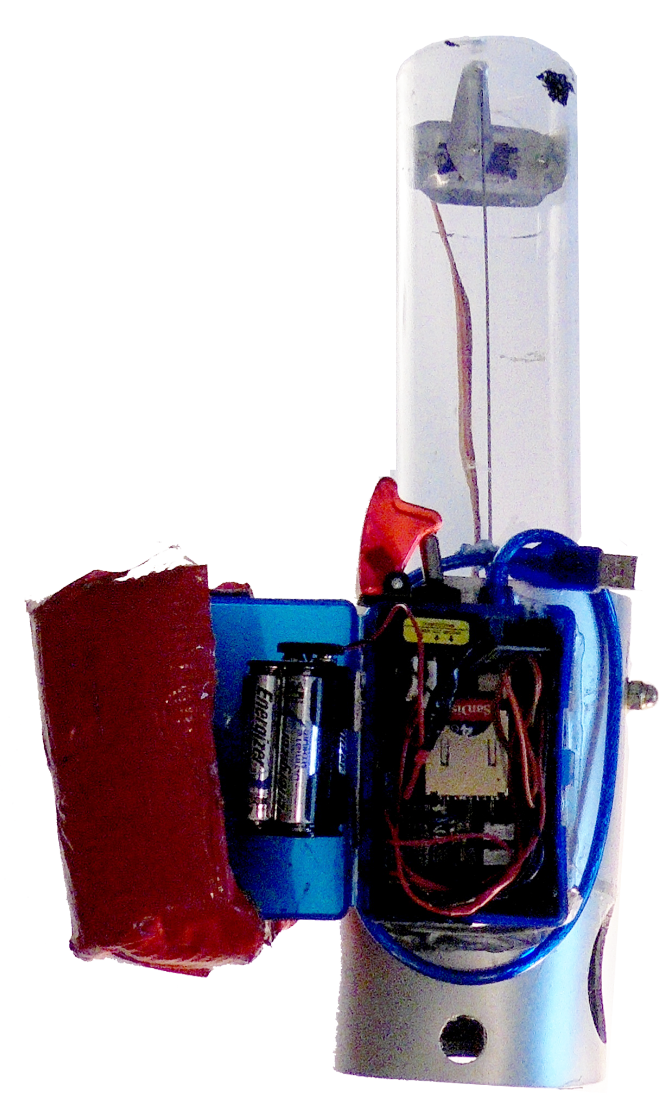
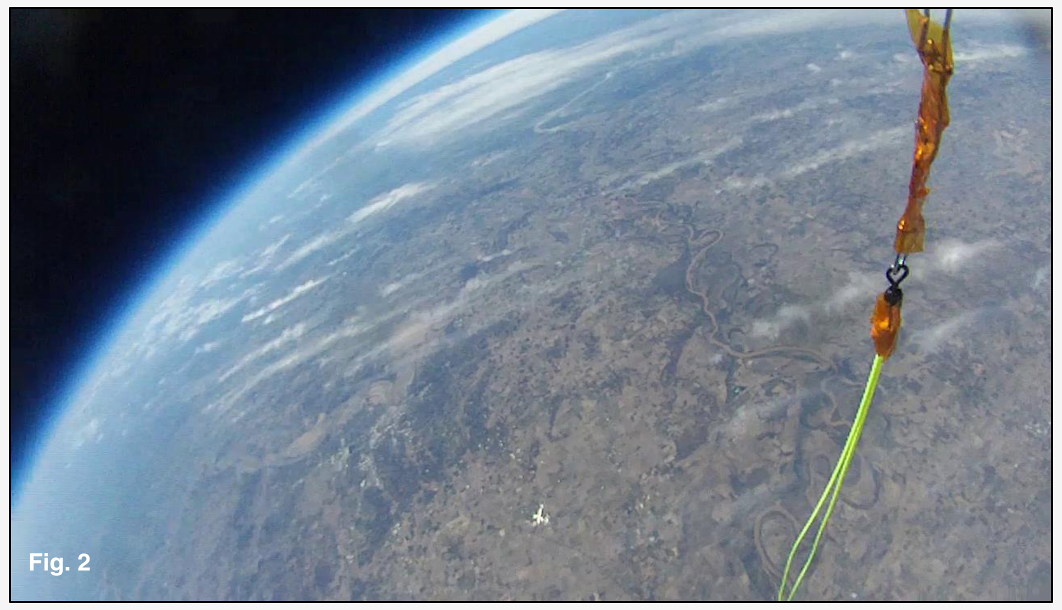


Figure 1: The Autonomous Altitude Control Vent prototype



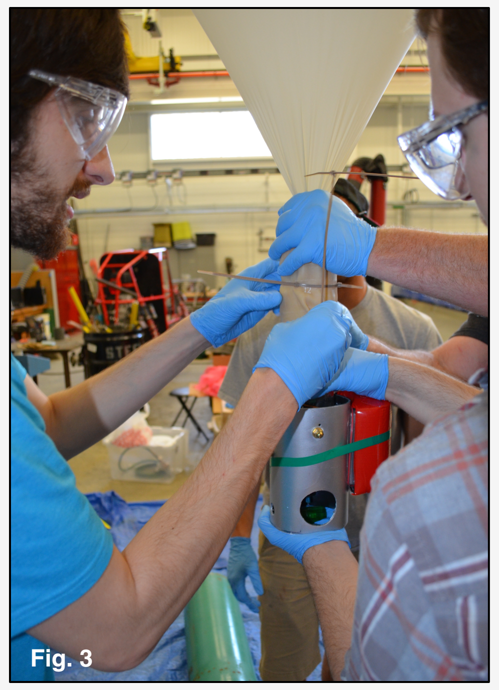


Figure 2: Still from downward-facing camera second flight test
Figure 3: Inserting the prototype into the balloon neck
Figure 4: Moving the balloon outdoors during the tethered test

Design Overview

Form Factor
The device is completely self-contained. All electronics are stored in an insulated box attached to the side of the tube. An external USB port and a protected on/off switch are located on the top of the electronics box. The vent is designed for a 1600g Hwoyee balloon.

Control System
The device is controlled with an Arduino microcomputer. It operates automatically using altitude and ascent rate data gathered using a barometric pressure sensor. The sensor is rated for accuracy within three feet at altitudes up to 120,000 ft. Altitude and temperature data, taken every two seconds, is stored locally on an SD card.

Vent Orifice
The vent opening, located at the bottom of the device, is sealed using a rubber stopper. The vent is opened and closed using an actuator rod attached to the interior of the tube, with minimal reduction in cross-sectional area of the tube.

Key Interfaces
The top portion of the tube is inserted directly into the neck of the balloon, and secured using zip ties. Lines from the balloon's payload are attached to holes in a short PVC pipe that surrounds the bottom portion of the vent.

Flight Tests and Simulations

Initial Flight Test • October 25th, 2014
The prototype used for this flight did not feature an altimeter, but instead operated on a timer. The test was conducted with the assistance of USI's High Altitude Balloon team.

The vent successfully opened at just under 30,000 ft, demonstrating that the device performs nominally in the harsh conditions associated with high altitudes. However, the gas flow rate from the vent was much larger than anticipated, and the balloon achieved negative buoyancy in less than two minutes.

The balloon carried a glider, which was released at ~24,000 ft, as a secondary payload. Altitude data from the glider and its release pod are plotted below. Note the change in ascent rate after the glider is released.

Vent and Glider Data (Altitude vs. Time)

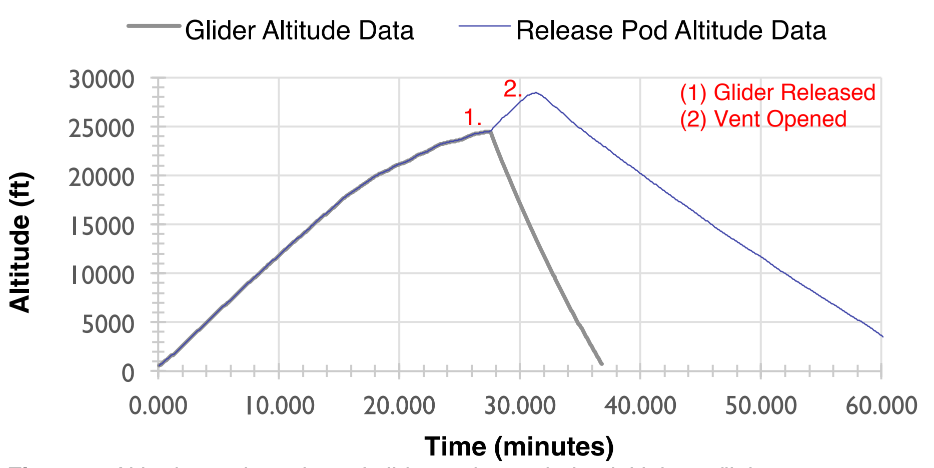


Figure 5: Altitude vs. time plots of glider and vent during initial test flight

Vacuum Chamber Tests
In the weeks before the second flight test, a series of flight simulations were conducted using a vacuum chamber provided by USI's chemistry department. The chamber simulated altitudes reaching 30,000 ft. Changes in ascent rate were also simulated, to test the venting process. The device performed nominally. Accurate pressure data was logged locally on the device during each trial.

Tethered Test • March 16th, 2015
One week before the second flight test, a tethered test was conducted with USI's high altitude balloon team. All procedures leading up to launch were rehearsed, using a fully inflated 1600g balloon. The balloon was inflated indoors, to take a precise initial buoyancy measurement. The balloon and payload were then moved outdoors to conduct a launch rehearsal.

When the rehearsal was completed, a series of tests were conducted on the vent prototype. The device successfully measured and recorded altitude and ascent rate data; it successfully opened and closed when those values reached scripted parameters. The balloon was periodically moved back indoors to measure changes in buoyancy. It was found that the opened vent induced a mean reduction in lift of 15 oz. per minute at ~400 ft above sea level. This value roughly corresponds to values calculated using models provided in *Oxley 2012.*

Second Flight Test • March 28th, 2015
The prototype used in the second flight test featured an altimeter and data logger. The device functioned nominally until it reached an altitude of 31,451 ft (*just* beyond the vacuum chamber's peak simulated altitude). At this point, the altimeter failed to detect any further change in altitude. As a result, the vent never executed a command to open its orifice. Accurate altitude data resumed upon descent below 31,451 ft.

Summary and Future Work

Findings from initial testing:

1) Vent induces flow rate sufficiently large to quickly achieve neutral buoyancy and subsequent soft landing.
2) Soft-landing-capable; no cut-down method necessary.
3) Mechanical components function nominally in high altitude conditions.
4) Negligible helium leak from closed vent orifice.
5) Vent does not disrupt conventional flight profile.

Priorities going forward:

1) Determine cause of altimeter fault. Consider replacement options.
2) Add GPS receiver as redundant altitude sensor.
3) Enable two-way radio communication with vent.
4) Conduct additional test flights and demonstrate extended high altitude float.

References

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Acknowledgments

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