The Adler Planetarium Altitude Control System for Flight Control and Stability of HAB Missions

Background

The Adler Altitude Control System (ACS) is a flight control system for latex HAB missions designed to allow controlled venting of helium. In the absence on any mechanism to vent helium a typical latex HAB will rise at a constant rate until it reaches burst altitude. Flight times "at altitude" are well under an hour and involve a constantly changing altitude. The Adler ACS was developed to maintain extended flight time at altitude for imaging and to expand the scientific research potential for latex HAB missions. An unexpected, but extremely important, side benefit has been dramatically improved stability of the HAB platform for imaging experiments.

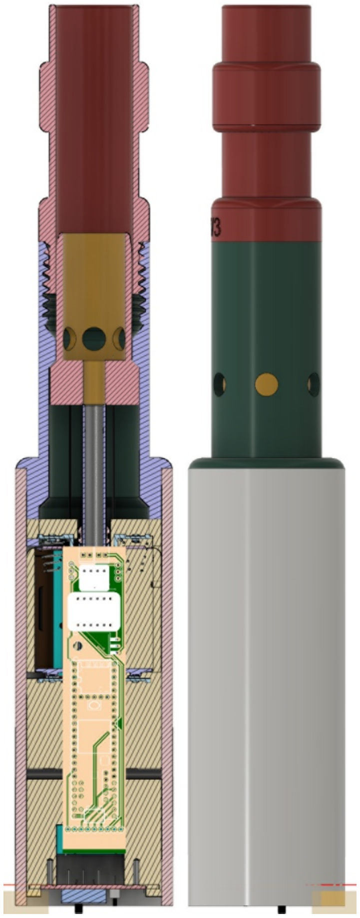

Fig. 1 Cross-sectional view and external view of the Adler ACS

Mechanical and Software Design

The Adler ACS is a self-contained venting mechanism inserted into the nozzle of the balloon after filling (Fig. 1). It consists of a number of key components including a stopper, an actuator, a Teensy based controller, and a pressure sensor housed in a PVC enclosure. Most mechanical components are custom designed and 3D printed. The unit is pre-programmed with a mission profile describing the desired sequence of operations. A typical example might be to retract an actuator at a chosen altitude opening to allow lift gas to vent, followed by closing the vent when neutral buoyancy has been detected. After a chosen time based on mission requirements, the actuator opens the vent to begin descent. With outside temperatures reaching below -50C for extended periods during flight, a major challenge has been maintaining operational temperatures. By using lithium thionyl chloride batteries, an outer insulation layer and a nichrome wire heated wrap functional temperature can be maintained.

Flight Results

The Adler ACS has been flown on nearly a dozen test flights to date with a variety of flight profiles. A typical "venting over the top" mission profile opens the vent at 60,000ft and allows helium to escape continuously from then on or until neutral buoyancy is achieved.

One observed benefit of achieving neutral buoyancy in our test flights has been to dampen - indeed nearly eliminate - swaying, rotation and instability. An ascending HAB moves with the wind. It therefore experiences no forces from horizontal airflow. At typical ascent speeds (~5m/s), however, it experiences vertical airflow with forces equal to the buoyancy. Since a latex HAB is far from rigid, it wobbles and deforms under the influence of the vertical airflow. The power delivered to oscillatory modes is proportional to the third power of the vertical velocity, while the amplitude of motion scales as the 3/2 power. By lowering the ascent/descent speed we have achieved angular velocities as low as a few×0.1°/sec for extended periods of time (Fig. 2). Payloads flown on latex balloons are notoriously unstable. Thanks to the stability achieved with this system, we have been able to perform relatively long exposure nighttime Earth imaging for light pollution research.

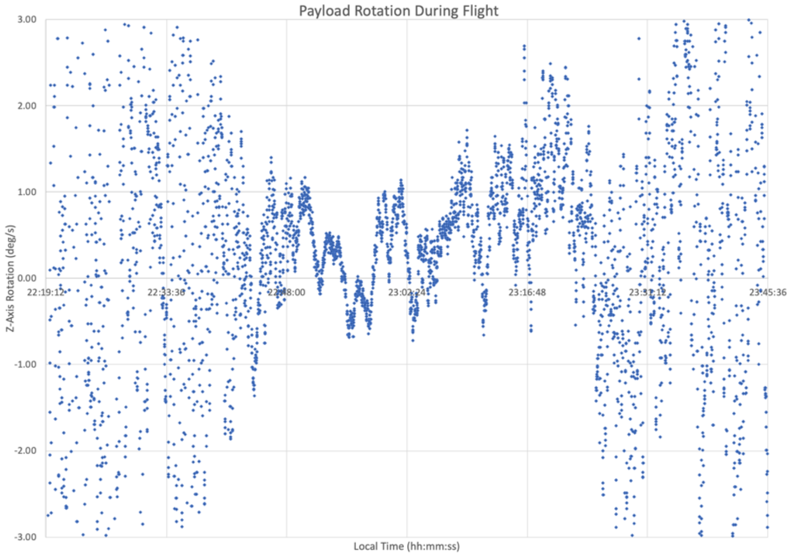

Fig. 2 Rotation rate of payload in z-axis in flight before venting, during period of relative neutral buoyancy and after venting is reestablished.