The “Stratospheric Cricket Keeper” – Developing a Simple “Life-Support” Payload for High-Altitude Balloon Missions

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Abstract

Exposure to the environmental conditions of “near-space” (AKA the stratosphere) is quickly fatal to nearly all forms of animal life. It is even challenging to build a sealable enclosure that can keep insects (crickets) alive through the dramatic and simultaneous pressure and temperature drops experienced during a high-altitude balloon mission. This poster describes the development of a rugged “cricket keeper” in which we were able to fly crickets to the stratosphere and, quoting the words of JFK, “return (them) safely to the earth!” This “life-support” payload had large windows (for the view!) and included Arduino-logged temperature and pressure sensors, an autonomous resistive heater circuit to maintain a comfortable internal temperature even when the outside temperature fell below -50° C, and a radio telemetry system by which internal conditions could be relayed to the ground and commands (to reset the Arduino or to query it for sensor data, for example) could be uplinked in real time. The status of the “crick-o-nauts” was monitored during the flight with a video camera and also assessed upon recovery. Due to the relatively short duration of the flight – about two hours – supplementary oxygen was not provided. Food was provided, but was optional for this flight duration. This educational payload project gave us new insights into some of the many of the challenges that NASA, and other space agencies, must overcome to provide life-support for human spaceflight missions.

Introduction

As a general rule, we forbid flying unprotected live animals on near-space flights since they will not survive the severe cold and the near-vacuum exposure. To keep crickets alive in near-space one can glue-seal them into PCV pipes (see https://www.youtube.com/watch?v=ccuWJc5Y2Ok), but the in-flight temperature drop from about 80° F to about -50° F is 25% on the Kelvin scale suggesting, by the Ideal Gas Law, that the pressure in the enclosed (fixed) volume may also go down by 25%, which might not be fatal but certainly cannot be considered comfortable/healthy for the crickets.

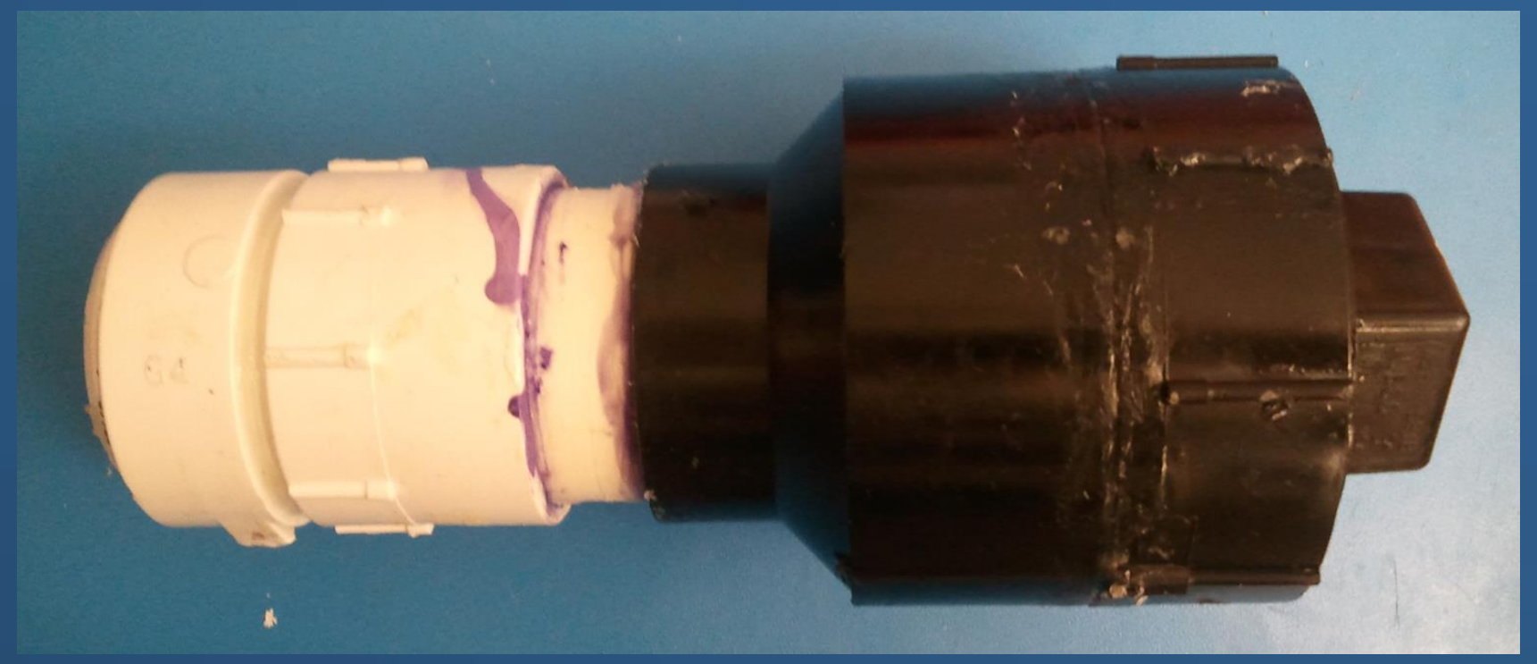
We wanted our design to have more features: an open-able “life-support” canister with windows, logged temperature and pressure sensors, a heater to maintain temperature, a video of the crickets, and a 2-way radio system to report sensor values and accept commands from the outside world.

Challenges and Early Designs

The original design for the payload was to simply include everything, including the control Arduino, video camera, crickets, etc. in a chamber made of PVC pipe with screw-off end caps. However, weight calculations showed that this would be impractically heavy.

The second version, which was built and is pictured above, is essentially a scaled-down version of the first concept. The Arduino and camera were moved out of the chamber, and the crickets would be viewed through a Plexiglas window. The internal heater and sensors would be connected with electrical feed-throughs in the chamber wall.

Getting the threads to seal was quite a challenge. After several attempts, a good seal was finally achieved using a combination of Teflon tape and petroleum jelly. However, once electrical feed-throughs were added, the chamber failed to seal despite the application of large amounts of silicone both inside and outside the chamber. It was finally concluded that it was simply too difficult to achieve a reliable vacuum seal, especially on the electrical feed-throughs.



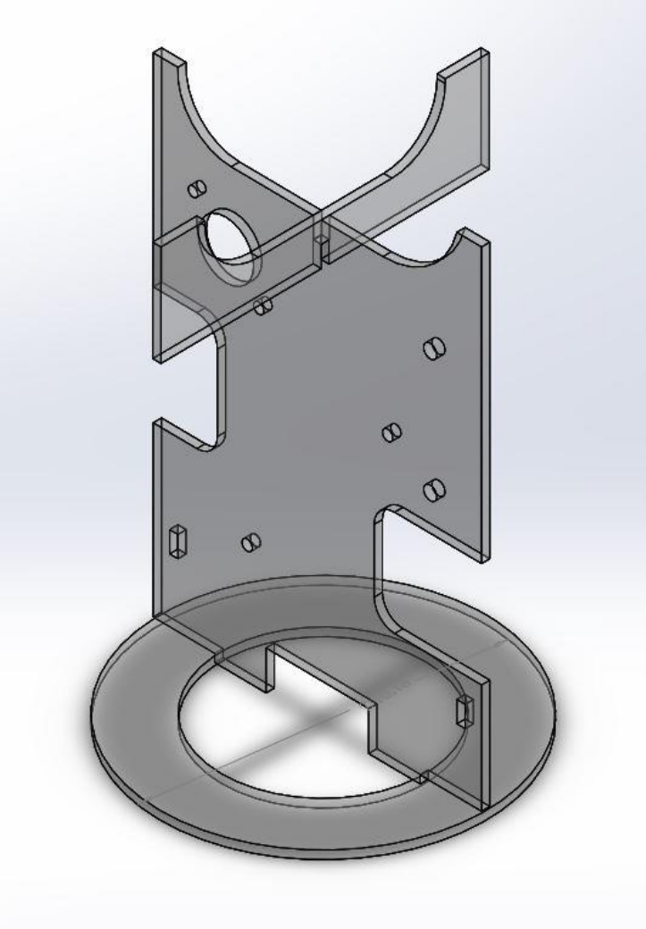
The third chamber design, shown above, was similar to the second design, except that it was a larger diameter at one end to house the Arduino internally, and screwed shut at both ends to permit access to the Arduino. The window portion of the chamber was re-used from the previous design but the main body of the chamber was made of lighter-weight ABS plastic (black). This turned out to be the major problem; despite numerous attempts (including the petroleum jelly and Teflon tape combination that worked before), the chamber wouldn't seal reliably, either due to inferior vacuum sealing properties of ABS or the presence of the ABS/PVC interface.

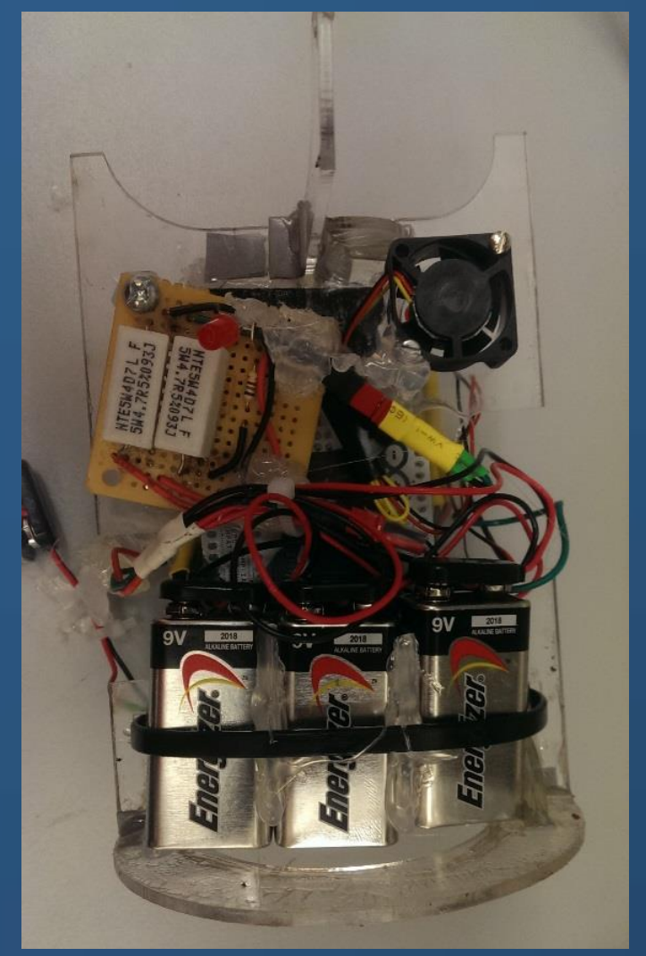
Final Design

Our final flight canister (shown above) was based on a design for a “High Altitude Test Chamber” by H. Brooks at DePauw University (www.tinyurl.com/basedepauw). It consisted of a (tape-wrapped) section of 4” diameter PVC pipe, with Plexiglas plates at either end. Threaded rods with nuts were used to tightly compress the Plexiglas plates on rubber gaskets to the ends of the pipe. Silicone-based vacuum grease was applied to the gaskets.

The gaskets were originally made of a trimmed-down L-shaped rubber foam seal, super-glued into a ring. Despite the use of liberal amounts of vacuum grease, these gaskets leaked, most likely at the glue seams. The gaskets were replaced by flat, seamless rubber rings cut from a sheet of rubber. The final chamber sealed well under all tested conditions, including cold-soak-under-vacuum and in flight.

The electrical system consisted of an Arduino Uno, with an Xbee/data logging shield. Also included were an I^2C temperature/pressure sensor and a real-time clock. Several LEDs indicated status information, and a MOSFET controlled the heater, which was powered by separate batteries. Also wired with the heater were a fan and a status LED indicator.



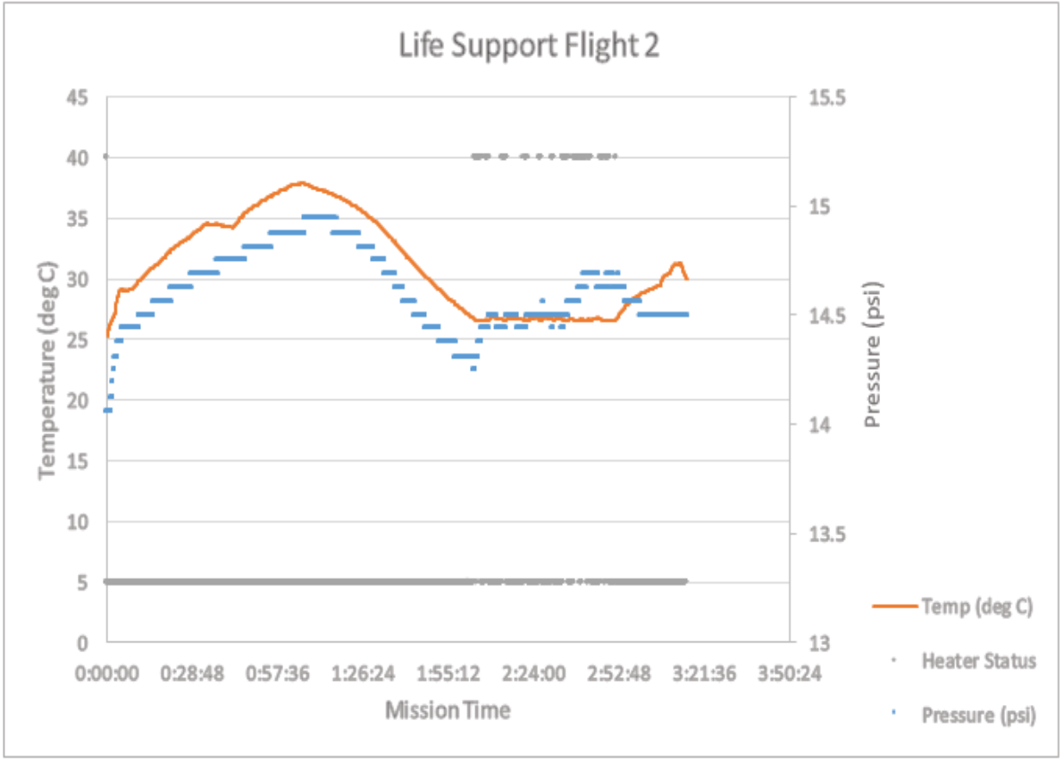


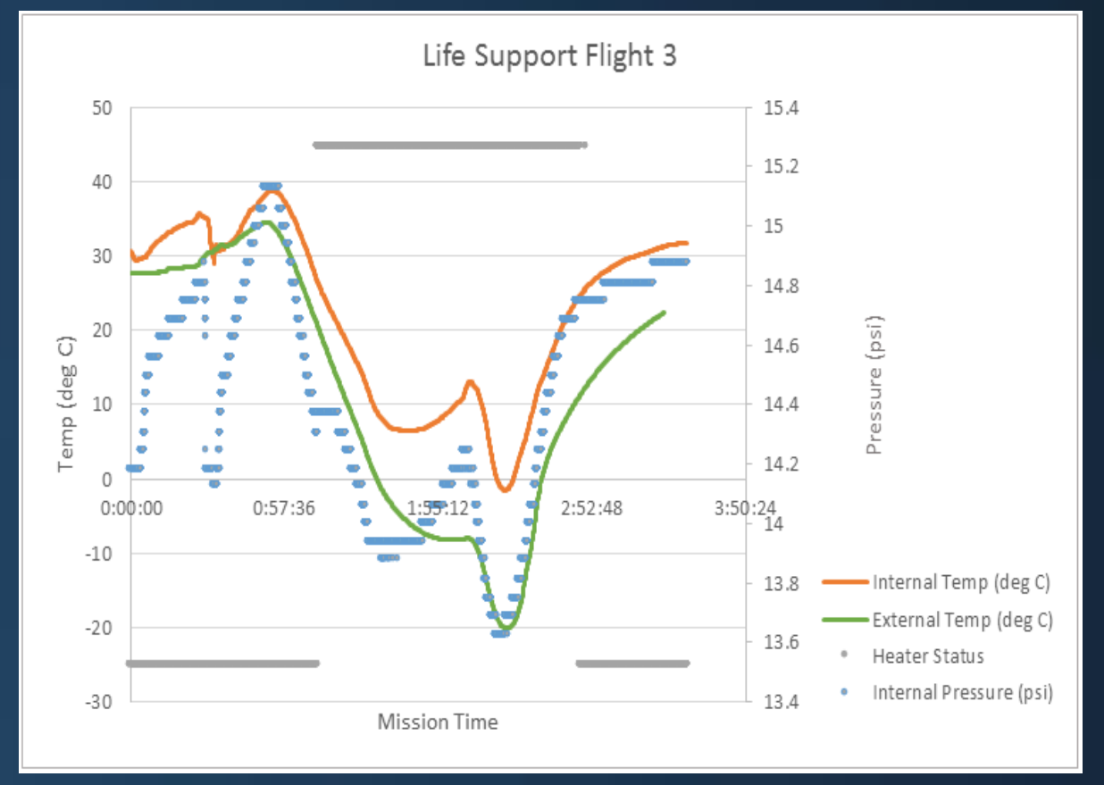
For the first flight, the electronics, batteries, and cricket holder were simply hot-glued in place. However, turbulence just after burst led to the glue attachments failing. In later flights a removable ‘sled’ for mounting electronics was built from laser-cut acrylic sheets (see above).

For the first two flights, the chamber was placed in an insulated box, with a nearby camera viewing the crickets. The third flight tested the performance of the chamber flown bare, viewed by a video camera in another payload.

Summary of Results

On the first flight, the recorded video showed the crickets survived until burst. However, turbulence caused the electronics to come loose and fail. No data was recorded, since the SD card apparently became corrupted.





The second flight was much more successful, with the crickets (and sowbugs included on this flight) surviving. However, the camera overheated just before launch, so no video was recorded. On the third flight, flown without insulation, the heater was not quite capable of keeping up with the low external temp. so the internal temp. dropped to just below freezing. Despite this, the crickets still survived.

We are considering future flights with this payload. Some changes that will be made if this is to be done are to wrap the chamber in a thin layer of insulating foam and/or to color it black. Changes have also been made to the heater to allow it to generate more heat.

Lessons Learned

- **Life support is harder than it looks!** This admittedly-simple project gave us a deeper appreciation of the hurdles that must be overcome before considering actually putting animal life, culminating in astronauts, in outer space.
- **Life support is heavy!** We favor light-weight materials for most of our ballooning payloads, but openable canisters capable of maintaining near-atmospheric pressure during the dramatic temperature and pressure changes in a stratospheric balloon mission had to be quite heavy.
- **Life support is complicated!** Our canister maintained an air-tight seal and a target internal temperature while exposed to large external temperature and pressure drops. Long-termer near-space or outer space missions also will need atmospheric conditioning - CO_2 scrubbing and/or supplementary oxygen - plus additional food and water.

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