Science Report
High Altitude Student Platform – 2008

Passive High Altitude Particle Capture Experiment

Prepared for Dr T. Gregory Guzik
Department of Physics and Astronomy
Louisiana State University
Baton Rouge, LA 70803-4001

By
BOREALIS Team
Montana State University
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Overview

The BOREALIS team from Montana State University originally designed, constructed and deployed their Passive High Altitude Particle Collection Experiment as part of the 2007 High Altitude Student Platform (HASP) balloon program; the experiment was improved and flown again as part of the 2008 HASP program. The purpose of this experiment was to capture cosmic particles and to verify their extraterrestrial origin using modern microscopy methods. This report summarizes the results of the 2008 flight, and provides an update of the analysis performed on last year's samples. The BOREALIS team for HASP 2008 consisted of four student members and these individuals are recognized here: Jayson Nissen (Senior, Physics), Nathan Martin (Junior, Physics), Jennifer Susan Hane (Sophomore, Electrical Engineering), Michael Lenander (Senior, Physics).

Design and Construction

Conceptually the particle capture box is simple. It is an aluminum box possessing lids that are opened at altitude to expose four Plexiglas plates covered with a silicone oil capture fluid. Any cosmic dust entering the box becomes trapped in the fluid. Prior to descent the lids are closed and sealed to protect the contents from terrestrial contamination. Two servos are used to open and close the lids. Because the minimum operating temperature of the servos is $0^{o}C$, they must be heated if they are required to operate at nighttime. The box is controlled by a Parallax Basic Stamp 2 microcontroller, which can receive commands from the ground though the main HASP control system. The experiment includes an assortment of sensors to monitor the temperature and current draw of the servos, the temperature of the DC/DC converter, and the position of the lids. Data from these sensors is continuously down-linked via the main HASP control system.

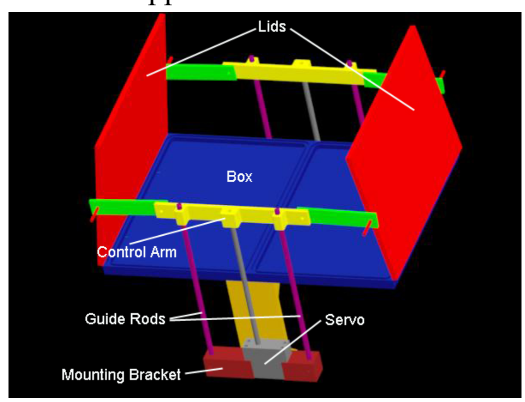


Figure 1. Drawing of the particle capture box showing major components.

Performance Summary

The 2008 flight of the BOREALIS HASP experiment was partially successful, but has raised several concerns which must be factored in to future projects. The box successfully opened and closed in response to up-linked commands. It opened shortly after the HASP reached its target float altitude. However, there is some question as to whether both lids of the box closed completely. Images from CosmoCAM reveal a pronounced black bar at the border between the lids, suggesting that one may have been open slightly. However, drawing firm conclusions from these images is difficult because they are of such poor quality, due to the weakness of CosmoCAM's battery power at this point. The experiment's push-button lid status sensors failed to report that the box had closed. It is important to note that these sensors are not capable of monitoring the two lids separately; however, they will indicate closure if either lid closes properly. Therefore, either these sensors failed or neither lid of the box was fully closed. Since the push-button switches are not rated for the cold temperatures that the experiment encountered during its flight, a sensor failure is possible. We also speculate that the switches may have slipped down the rods on which they were mounted, possibly as a result of thermal contractions and expansions. Each lid of the box is sealed with an o-ring which lies in a groove cut into the rim of the box. It is possible that one or both of these o-rings were displaced during the flight and prevented the box from closing properly. Throughout the flight, the experiment successfully down-linked data from three temperature sensors, the lid status sensors, and a current sensor. One of the temperature sensors failed partway through the flight and began generating meaningless data. We do not know the cause of this failure. The lid status sensors also experienced intermittent problems. The other sensors functioned properly for the duration of the flight.

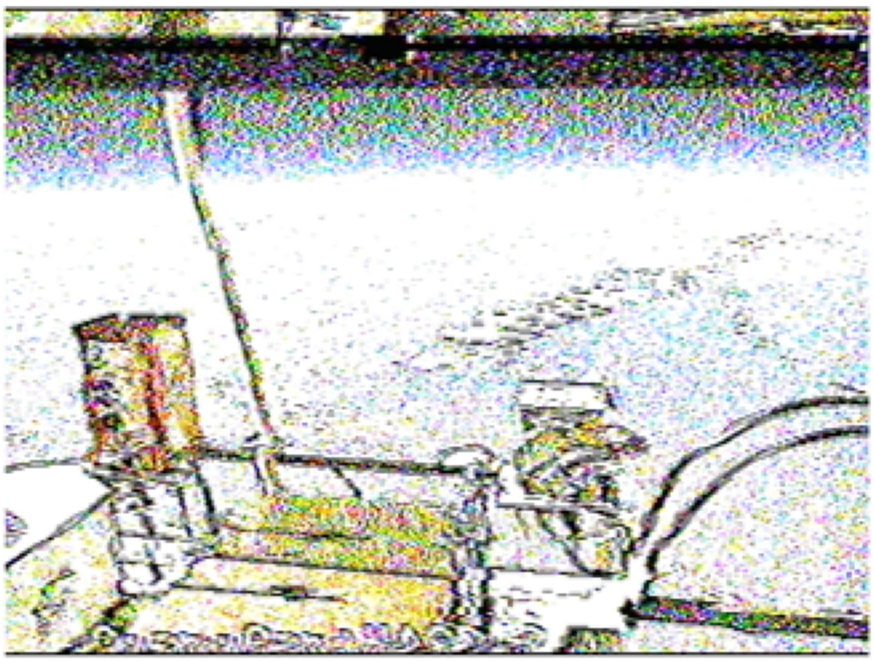


Figure 2. CosmoCAM image of the experiment after closing.

In-Flight Data

The plots below summarize a portion of the data which was down-linked by our experiment's sensors during the flight. The top panel is a plot of altitude vs. time; the center panel is a plot of the temperature of the DC/DC converter vs. time; and the bottom panel is a plot of the temperature of one of the servos vs. time. (The bottom panel is a plot of the data from the servo whose sensor functioned properly throughout the flight.) Spikes on the servo temperature vs. time plot mark the times at which the servos were being heated. The two spikes which are not followed by an opening/closing sequence indicate heating cycles which were performed in anticipation of closing; however, in each case, the decision to terminate the flight was postponed and the box was not closed. The brief period of "Lid opening" indicated near the end of the flight is present because after the box was closed for the first time, we decided to open it slightly and attempt to close it again. This action was the result of our concerns over whether the box was fully closed.

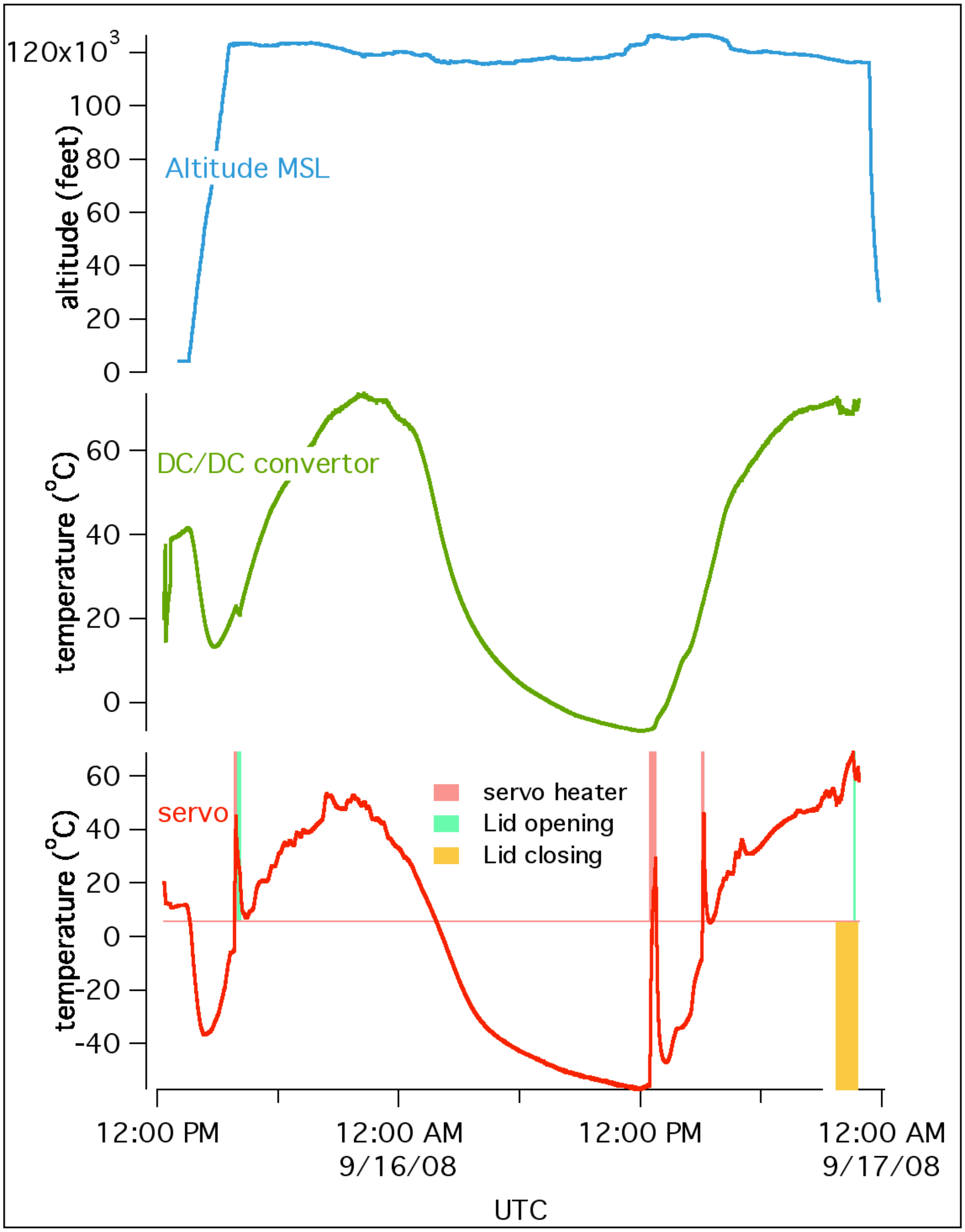


Figure 3. Plots of data down-linked by the experiment during flight.

Post-Flight Analysis

Upon landing, the HASP rolled onto our experiment, opening the box and exposing the collection plates to high levels of contamination. Grass and dirt were found embedded in some of the box's components, leading to the conclusion that HASP partially rolled on top of it. The photos below indicate the level of contamination of the plates and the damage to the experiment.

Figure 4. Our experiment after the crash landing.

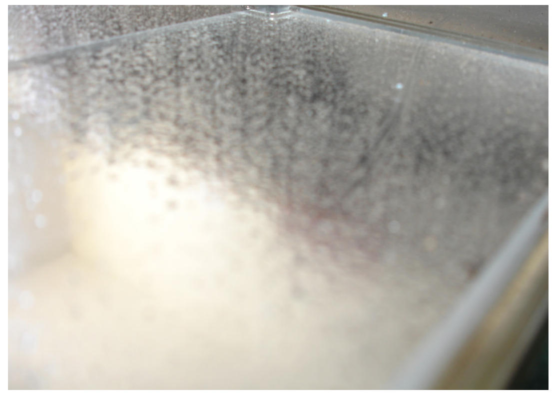


Figure 5. Close-up of the contaminated collection plates.

Analysis of the plates has been conducted using an optical microscope at 15X zoom to determine whether layering the silicon oil on the optically clear plates is a viable system. The oil provides an advantage of surrounding the particles in a halo, which makes them very easy to detect and could speed the process of analyzing the plates greatly. However, due to the high levels of terrestrial contamination, no identification of particles of interest has been attempted.

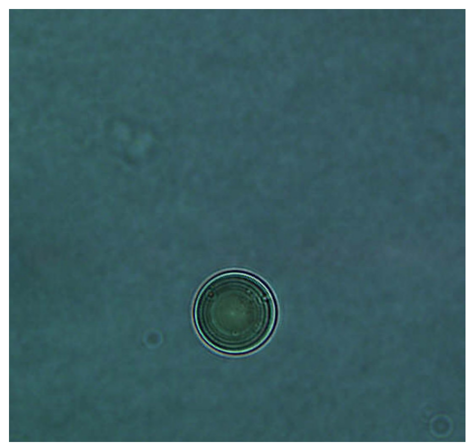


Figure 6. Optical image of a particle on one of the Plexiglas capture plates.

Conclusions and Lessons Learned

In light of our experiment's performance and the events upon landing, we believe our device would benefit from three upgrades. First, a latching mechanism should be incorporated, with a design criteria of keeping the box closed in a situation similar to the landing of HASP 2008. Second, the position indicators for the box lids need to be improved. Third, a system needs to be incorporated to secure the o-rings in the grooves, preventing them from fouling the box closure.

HASP 2007—Analysis Update

While preparing for HASP 2008, the BOREALIS team has continued the analysis of the results obtained from our HASP 2007 experiment. More than 400 particles have now been imaged, analyzed and catalogued. The particles were prepared by dissolving the silicone fluid from our capture box in hexane, then passing the fluid through filters. One of these filters was prepared for us by Jack Warren of NASA's Cosmic Dust Lab at Johnson Space Center, and will hereinafter be referred to as the JSC filter. Additional filters were prepared in an onsite clean room by members of BOREALIS. So far only one of these filters has been searched for particles; it will be designated filter B3. All particles were imaged and analyzed using a field emission scanning electron microscope (FEM). This microscope is housed in the Imaging and Chemical Analysis Laboratory (ICAL) at Montana State University.

We have developed a classification system to help us organize our particles. Each particle is given a two-part designation, based on its chemical composition and morphology. The chemical categories are as follows: AlO (Aluminum and Oxygen), ZnS (Zinc and Sulfur), Silicate, Metal-rich, and Other. The ZnS category will be discussed in more detail below. The morphological categories are as follows: Spherical, Granular, Rounded, Flattened, and Irregular. Granular particles are those which possess a porous or crystalline structure or surface texture, as if formed of multiple tiny mineral grains cemented together. Rounded particles are roughly spherical or oblong and have smooth edges. Flattened particles take the form of discs or pancakes. The charts below reveal how the particles we have analyzed so far are distributed among the various categories. Note that these distributions are not necessarily representative of all the particles on the filter, since there is some selection bias in the particles we choose to analyze.

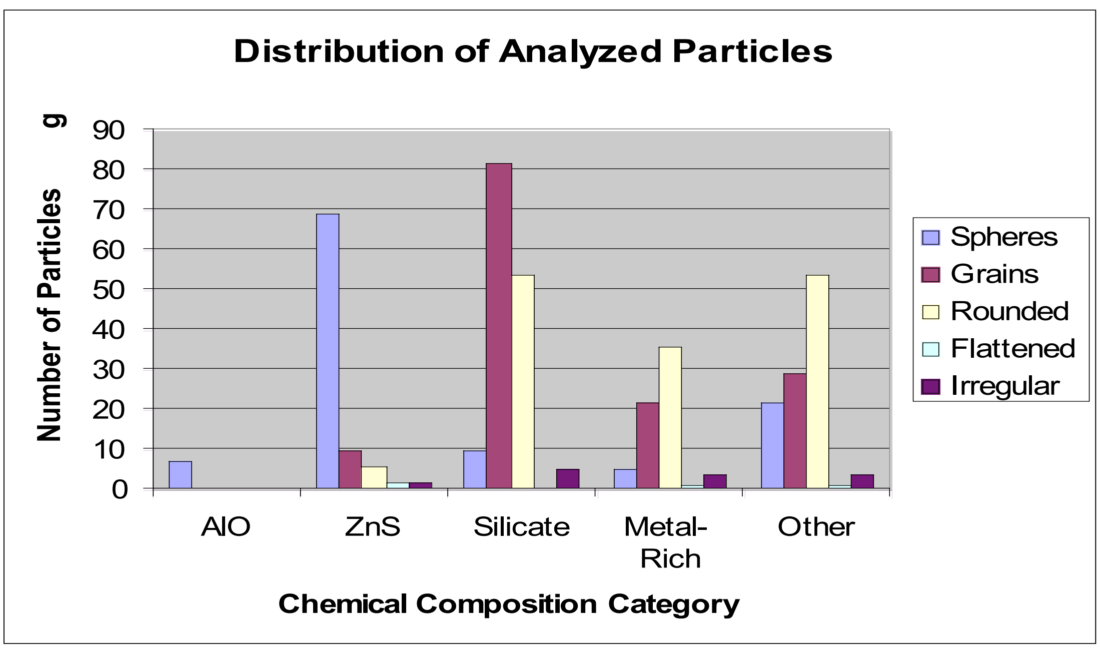


Figure 7. Distribution of all analyzed particles by category.

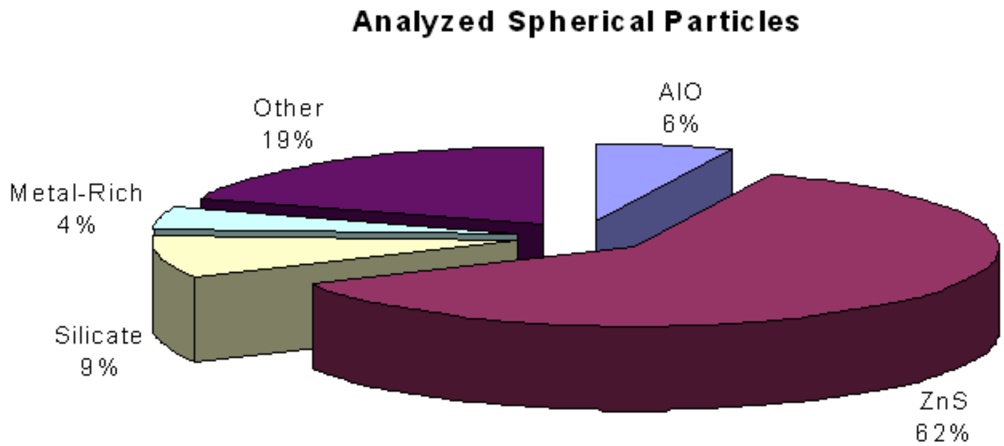
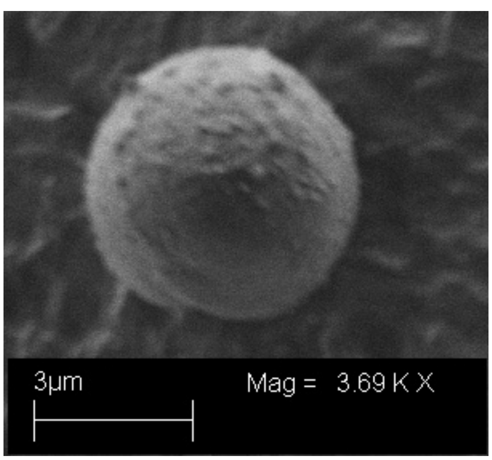


Figure 8. Breakdown of the analyzed spherical particles by chemical composition.

We have identified several interesting types of particles among our collection. The first consists of those particles belonging to the spherical AlO category. We believe these to be Al_2O_3 (aluminum oxide) spheres, which are a common product of solid-fuel rocket exhaust. We have identified seven of these particles so far. Although aluminum oxide spheres are common in the stratosphere, we would be unlikely to find one in a sample of dust collected at ground level. Therefore, these spheres serve as an indicator that our box successfully collected dust at the target altitude during HASP 2007. An image and chemical spectrum of one of these spheres are presented below.



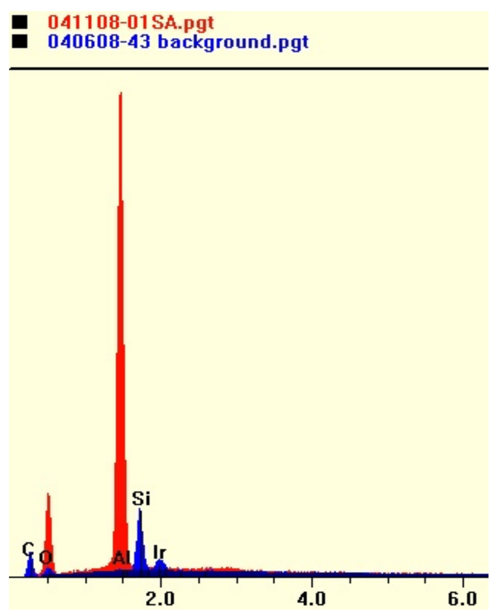


Figure 9. Particle 041108-SA, an aluminum oxide sphere from the JSC filter.

The next important particle group consists of the spherical, rounded, and flattened particles in the ZnS category. These particles take the form of spheres, mounds, or globules which share similar morphological characteristics. They often have glassy-smooth surfaces, possibly punctuated by dimples, wrinkles, or other irregularities.

Chemically, the one thing they have in common is the presence of zinc and sulfur in their spectra. They may also contain a wide variety of other elements, including silicon, titanium, calcium, iron, and chlorine. Their sheer numbers and the fact that they only appear on the JSC filter have led us to conclude that they are some form of contamination, which must have been introduced as a result of the way the JSC filter was prepared. An image and chemical spectrum of one of these particles are presented below.

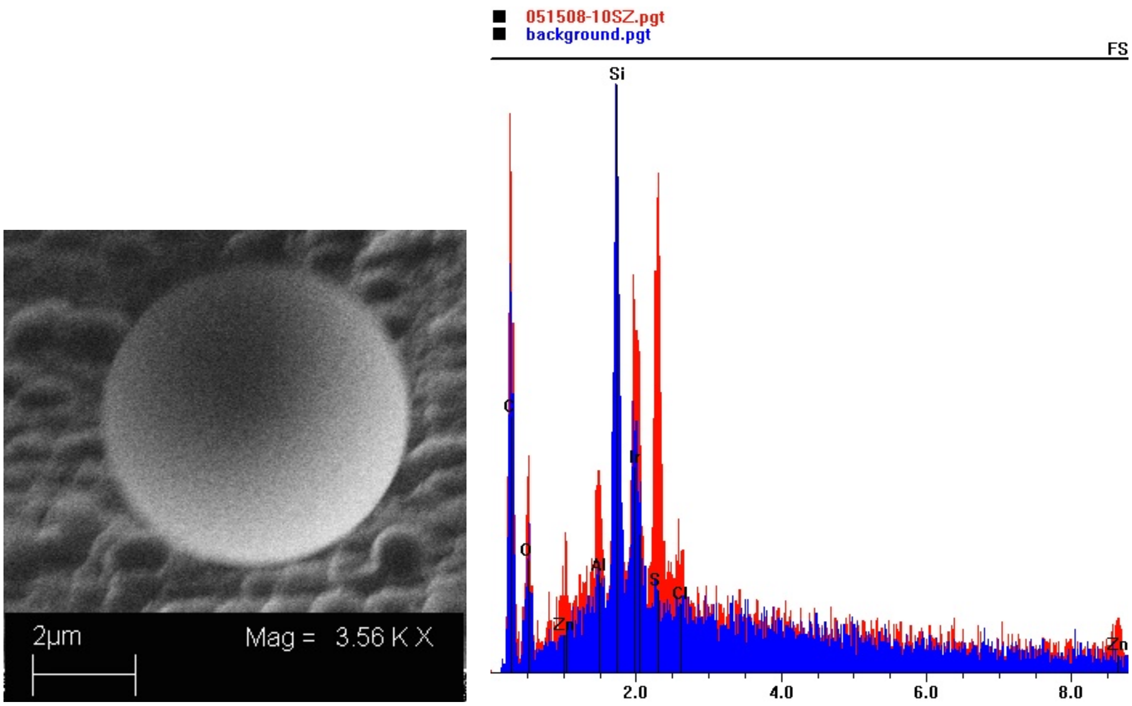


Figure 10. Particle 051508-10SZ, a spherical contaminant from the JSC filter.

The last important group does not have its own category in the classification system; instead, it is a subgroup of the granular silicate category. This group consists of loosely constituted, highly porous grains, principally composed of the elements O, Si, Al, Na, and K. Particles of this type have only been identified on filter B3. This fact and their abundance on this filter lead us to believe that they, too, are contaminants. An image and chemical spectrum of one of these particles are presented below.

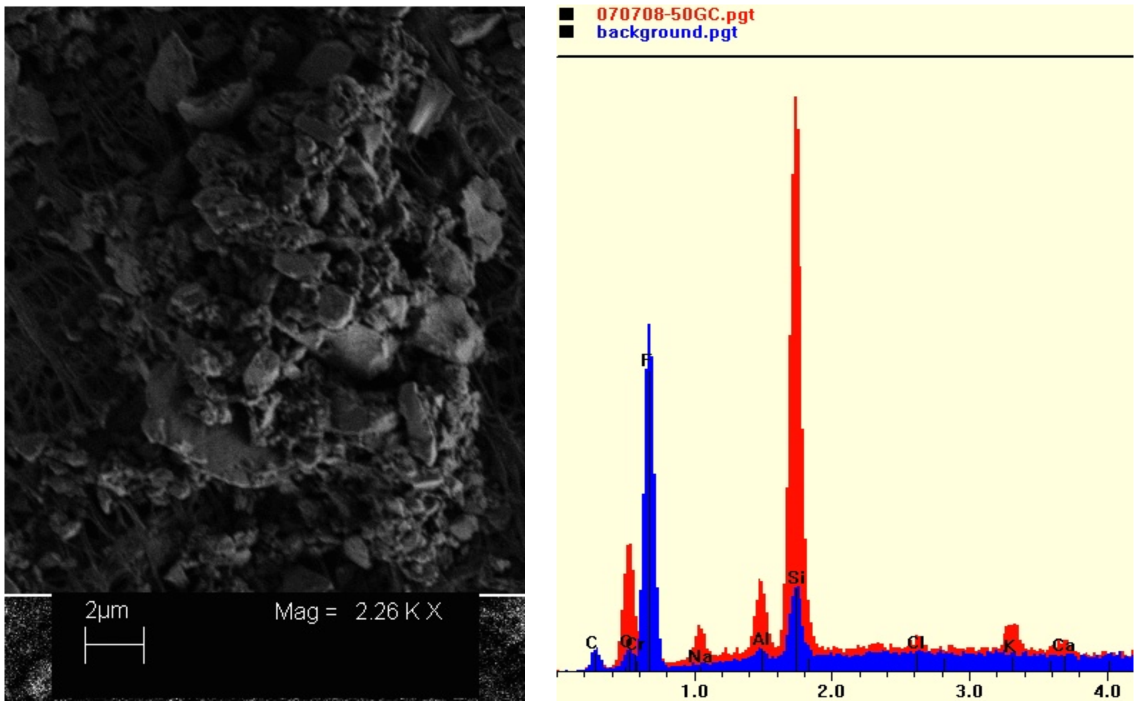


Figure 11. Particle 070708-50GC, a granular contaminant from filter B3.

We have also identified a number of intriguing particles, of whose origins we are not certain, on our filters. Eventually, we hope to seek expert advice that will help us determine the nature of these particles. Two examples are showcased below.

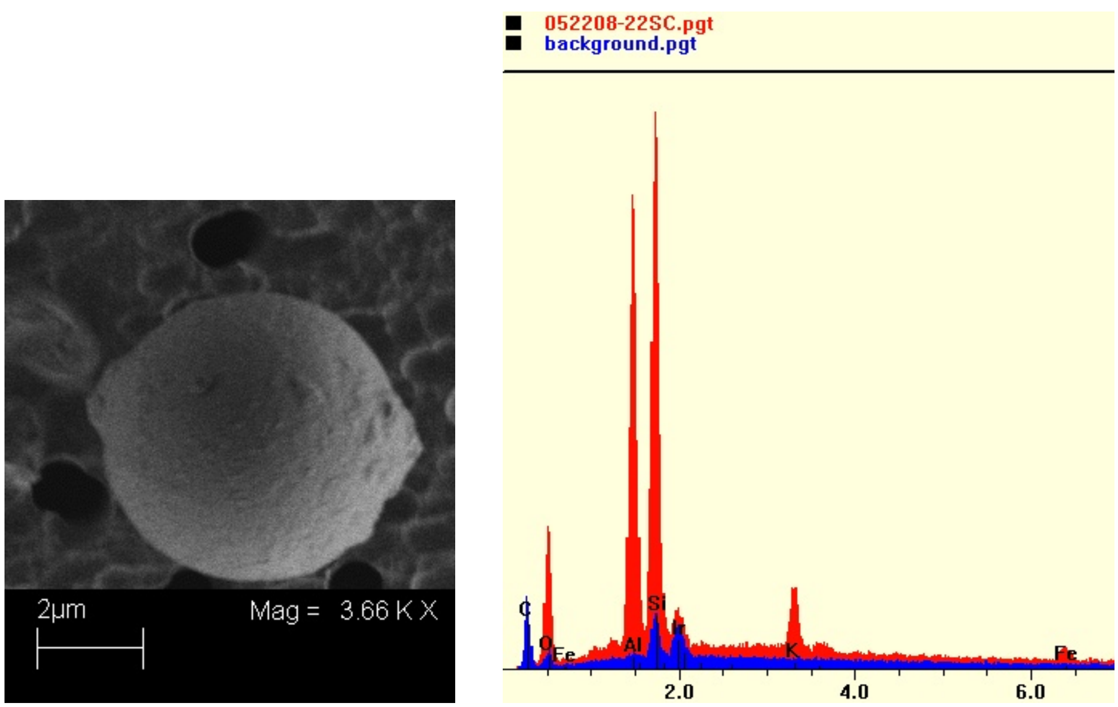
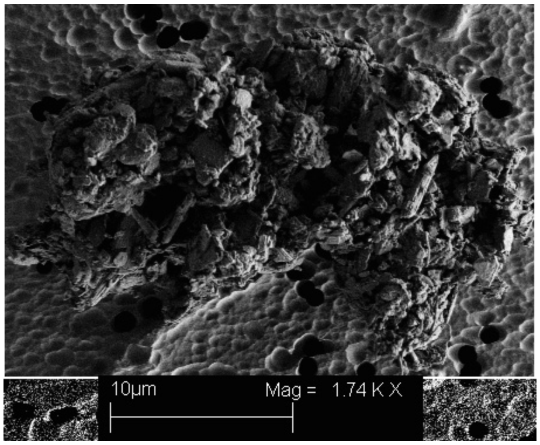


Figure 12. Particle 052208-22SC, from the JSC filter. David Mogk has identified the spectrum as a match for the mineral muscovite; it may be of volcanic origin.



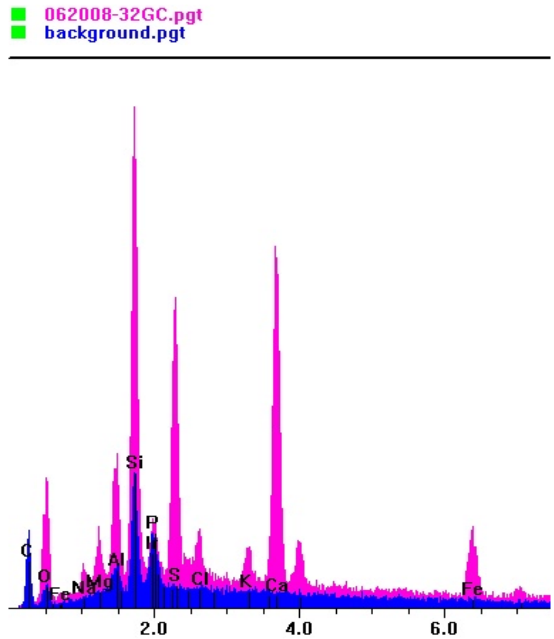


Figure 13. Particle 062008-32GC, a granular silicate from the JSC filter. Strong S and Fe peaks suggest a possible cosmic origin, but the presence of K and Na calls that into question.

The complete particle catalog may be viewed on the Internet at spacegrant.montana.edu/borealis/HASPWeb/HASP.html.

In conclusion, our analysis of the results of HASP 2007 has shown that we have collected particles from the stratosphere. We have identified seven aluminum oxide spheres and a number of other well-formed spheres, which could be other types of space debris or volcanic material from the stratosphere. We have a number of particles which have a chance of being extraterrestrial, but we have yet to analyze a stereotypical cosmic dust particle. (We are deriving our notion of "stereotypical" from the chemical spectra provided in the online version of NASA's Cosmic Dust Catalog. Such a particle would have strong iron and sulfur peaks, and most likely a small nickel peak, in its spectrum. It would contain no potassium.) We have identified two major types of contaminant particles in our samples, namely, the ZnS globules and the grains bearing Si, Al, Na, and K.

Analysis of the material on filter B3 is ongoing, and we have three more filters to examine. We also plan to analyze some mineral standards using the FEM, so that we can get a better idea of how sensitive it is to various elements and learn to recognize the chemical signatures of these minerals.