Science Report
High Altitude Student Platform – 2007

Passive High Altitude Particle Capture Experiment

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By
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Overview

The BOREALIS team from Montana State University designed, constructed and deployed their Passive High Altitude Particle Collection Experiment as part of the 2007 High Altitude Student Platform (HASP) balloon 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 design, construction, integration and flight of the particle collection device and includes preliminary data on some of the captured particles. The BOREALIS team consisted of 11 student members and these individuals are recognized here: Jayson Nissen (Senior, Physics), Nathan Martin (Sophomore, Physics), Jennifer Susan Hane (Freshman, Electrical Engineering), Kyle Crawford (Freshman, Mechanical Engineering), Teresa Lannen (Senior, Mathematics), Dylan Larson (Sophomore, Civil Engineering), Clark Kogan (University of Montana, Senior, Mathematics and Physics), Michael Lenander (Junior, Physics), Gordon Nelson (Sophomore, Computer Engineering), David Wax (Senior, Computer Science) and Andrew Marx (Freshman, Computer Engineering).

Design and Construction

Conceptually the particle capture box is simple. It is an aluminum box possessing lids that are opened at altitude to expose a silicone oil capture fluid contained in two trays. 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. One major design change was implemented during the construction phase of this project. It involved switching our capture box opening/closing system from a pneumatic system to an electrical servo motor system, which is shown in Figure 1. This change was motivated by several factors. The greatest of these factors was our discovery that we would not have power to our payload during descent. Our pneumatic system required that there be power available to our payload throughout descent and landing. Without power to the payload we would not have been able to hold the capture box lids closed to prevent contamination. A secondary motivation for this change was the difficulty we were having in matching materials for the air line connections in our pneumatic system. We had hoped to keep the materials in our plumbing as homogeneous as possible but found this unachievable because the necessary parts were not available. The servo motors were also chosen over the pneumatic system because we believed they would be much simpler to operate. Finally, we chose the servo system because of its lighter weight. The pneumatic system would have brought our payload's weight very close to the limit. Switching to the servo based lid control system added several parts to our box design. The new system lead to a redesign of the control arms being used for opening and closing

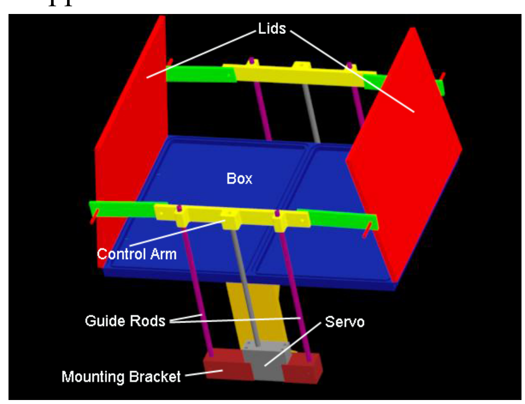

Figure 1. Drawing of the particle capture box showing major components.

the box lids, an additional aluminum base plate, and new mounting brackets to house and support the servo motors.

Integration

Two team members, Nathan Martin and Kyle Crawford, traveled to the Columbia Scientific Balloon Facility (CSBF) in Palestine, Texas to integrate the particle capture experiment onto the HASP platform. During integration several problems were found with our payload that had not been encountered during the construction and testing phase of the project. The first major lesson we learned during integration concerned our power system. We had chosen to use simple IC voltage regulators to step the power down from 28V to the voltages required by our subsystems. During integration we found that the fully charged battery system supplied a voltage of 32 V and that the step from 32V to the 5 and 6 Volts that we used in our subsystems was too large for the voltage regulators to handle. The voltage regulator for the servo motors failed to operate when the servos were triggered to operate. The LSU staff was able to loan us a DC-DC converter to handle our power needs. Dropping the supply voltage to 5V using a device that could handle the initial current draw through the servos greatly improved the servos' performance. We were also able to use the BEMCO environmental test chamber while we were at CSBF. This chamber allowed us to test our payload under flight-like conditions to monitor our system performance while opening and closing the lids of the capture box. The BEMCO test helped us to refine and adjust our operating procedure for heating the servo motors during flight. This test also showed that our electronics box could stay above minimum operating temperature without an external heating system during a flight. Temperature sensors were added to monitor the temperatures of the servo motors, the DC-DC converter, and the bottom surface of the aluminum capture box. These temperatures were monitored via the HASP platform. In future flights we intend to incorporate this function into our own payload. Figure 3 shows a picture of our experiment successfully integrated onto the HASP platform.

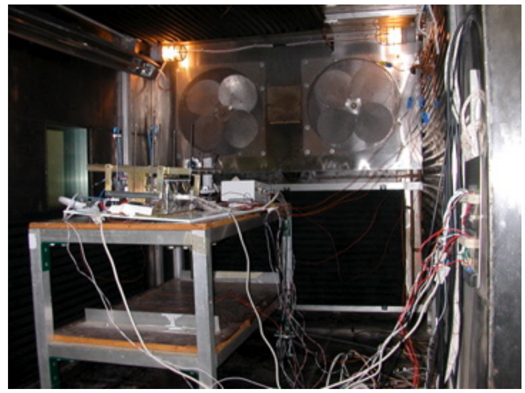

Figure 2. Preparing particle capture box in the BEMCO chamber.

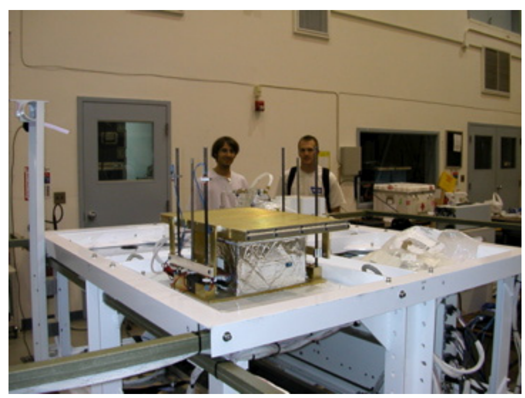

Figure 3. Successful integration of the particle capture experiment onto the HASP

Flight Line

Two students, Teresa Lannen and Kyle Crawford, traveled to the NASA balloon facility at Fort Sumner, New Mexico to clean the box and add the silicone capture fluid prior to the launch of the HASP payload. The flight line experience taught us a major

Figure 4. Preparing the particle capture experiment on the flight line.

Figure 5. Loading the silicone fluid into the particle capture box.

lesson regarding the preflight preparation of the capture box and enclosed fluid. The method of using a glove bag as a clean environment was inadequate to minimize contamination and hampered preparation of the capture box. Figures 4 and 5 show pictures of the BOREALIS team members preparing the particle capture experiment. Contrast these pictures to the clean room facility pictures shown later in this report. To correct our previous oversights, this year we will be utilizing the clean room at the Cosmic Dust Laboratory at the Johnson Space Center for our preflight preparation of the capture box and capture matrix.

Flight

The HASP platform was launched at 13:12 on September 2, 2007 and reached float altitude (~124,000 feet) at 15:20. The on-board microprocessor reported the status of the lids of the capture box and any up-linked commands approximately every 12 seconds. This data was then down-linked via the HASP platform to a series of data files that are archived on the LSU website http://laspace.lsu.edu/hasp/data/payload_10.htm. Examples of the data files containing the time periods where commands were up-linked to the on-board microprocessor are included in the appendix of this report. The temperatures of the underside of

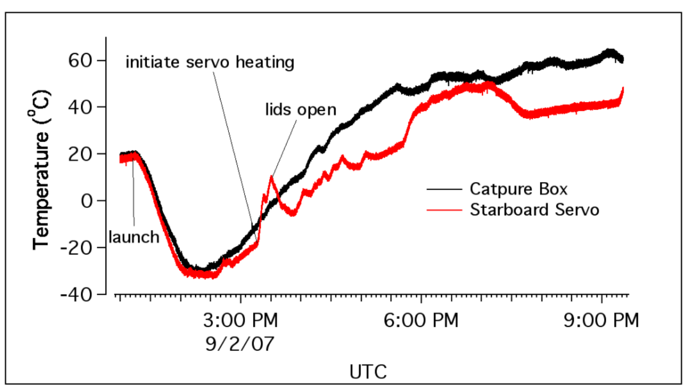

Figure 6. Temperature profiles of the starboard servo motor housing and the underside of the capture box.

the capture box, the DC-DC converter and the two electrical servo motors were monitored continuously as part of HASP flight environment readings. This data is available on the LSU website http://laspace.lsu.edu/hasp/data/adc.htm. The temperature profiles of the starboard servo motor and the underside of the capture box are shown in Figure 6 for the first 8 hours of the flight. Figure 6 has been annotated to indicate when the servo motors were heated and when the box lids were opened. The servo motor heaters were commanded to turn on at 15:16 UTC for a 5 minute heating cycle that increased the servo motor temperature from -18 °C to -2 °C. A second heating cycle was initiated at 15:25 UTC, which brought the servo motors above their minimum operational temperature of 0 °C. At 15:30 UTC the open box command was sent. The down-linked data indicated that the lids were not fully opened (see appendix), but real-time video from Cosmo Cam indicated that the lids were fully opened. Figure 7 shows a Cosmo Cam image of the particle capture box with its lids fully open. It was later determined that one of the lid-open sensors had failed. Except for the one lid-open sensor all of the components remained functional and within their operational limits during the flight. Table 1 provides a summary of the minimum and maximum temperatures for the first 8 flight hours. We have not been able to locate the data logs for the remaining flight data. Shortly before sunset it became uncertain as to whether the lights on Cosmo Cam were operational. We wanted to use the Cosmo Cam video to confirm that the lids were closed so the decision was made to terminate our experiment early before it became too dark to see our payload. At 02:10 UTC September 3, 2007, we issued the command to close the box. Cosmo Cam and our lid-closed sensors both indicated that the lids were successfully closed. The HASP platform remained at float altitude for approximately 6 more hours until the flight was terminated at 7:52 UTC September 3, 2007. While we are disappointed that we lost the additional capture time, we believe that we made the prudent decision to terminate our experiment early. The particle capture box was opened for approximately 12 hours. Upon retrieval and inspection of the payload we were happy to see that the mechanical seal between the box lids and the silicon O-ring had been attained.

Figure 7. Cosmo Cam picture of our experiment with the lids open.

Table 1. Temperature limits of the major components of the particle capture box experiments.

Device	Minimum Temperature (^oC)	Maximum Temperature (^oC)
Port Servo Motor	**-30**	**61**
Starboard Servo Motor	**-33**	**51**
DC-DC converter	**-34**	**68**
Capture Box (bottom)	**-32**	**65**

Analysis

Extraction of fluid from one half of the capture box

We began by detaching the capture box from the rest of the collection apparatus. We cleaned the capture box with lint free wipes and alcohol before taking it into the clean room. Once inside the clean room, we found that the lids had formed a good vacuum seal. We carefully pried open one side of the box with a screwdriver to break the vacuum seal. To remove the fluid we poured hexane solvent into that side of the box, a small amount at a time, in order to dissolve the silicone fluid. When the fluid had softened sufficiently, we picked up the box and began pouring the silicone fluid out one of the box's corners into a glass vacuum bottle. Since the fluid was difficult to dissolve, we periodically added more hexane to the box, and used a lint-free swab to push the silicone fluid along. In this manner, we collected almost all of the fluid that remained in that side of the box in our vacuum bottle. However, some of the fluid from that side of the box had crept onto the underside of the lid and into the O-ring groove during storage. We did not attempt to remove this fluid; instead, we replaced the O-ring and lid and clamped that side of the box shut. We plan to attempt to dissolve and remove the fluid on the lid and O-ring at a later time. All together, we believe we removed approximately three fourths of the fluid that was originally contained in the side of the box that we opened. In future flights, it will not be necessary for us to remove fluid from the box in this manner due to the addition of a new and improved system involving Plexiglas collection plates. Two Plexiglas plates will be mounted within the capture box. The Plexiglas plates will be coated with a thin layer of capture matrix using a hexane dilution technique adopted from the CDL. These plates will ease particle retrieval and identification as the particles can be directly imaged from the plates after their removal from the capture box.

Visit to Johnson Space Center

The fluid that was collected in the vacuum bottle was shipped to Johnson Space Center in Houston. Two BOREALS team members, Jayson Nissen and Jeniffer Susan

Figure 8. BOREALIS team members receive instructions from CDL senior particle analyst, Jack Warren.

Figure 9. BOREALIS team member, Jayson Nissen examines a sample of the capture fluid for cosmic dust particles.

Hane, traveled there at the invitation of Jack Warren, the head analyst of the Cosmic Dust Laboratory. We were given a tour of the CDL and were instructed on the systems and procedures they use to collect, examine, mount and analyze particles. While at the CDL, we examined approximately one quarter of our fluid under an optical microscope. Small amounts of fluid were poured into two glass petri dishes, which were then placed on the microscope stand. Using a camera attached to the microscope's eyepiece, we were able to photograph an assortment of particles. Some of these appeared to be aluminum oxide spheres (see Figure 10), which are a component of rocket engine exhaust and are somewhat common in the stratosphere. A particle which shows some promise of being extraterrestrial origin, a dark brown aggregate, is shown in Figure 11. We also discovered terrestrial contamination in levels high enough to complicate the analysis of our sample. This contamination is a primary motivator of our design and procedural changes.

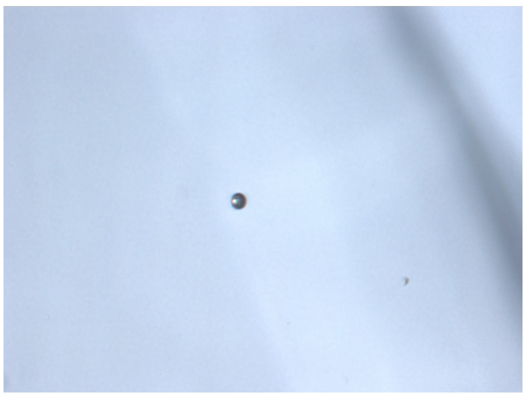

Figure 10. Aluminum oxide sphere, 20 microns, rocket exhaust particle (tentative).

Figure 11. Potential cosmic dust particle. Dark color. 18x25 microns.

Particle Analysis

During the CDL trip we successfully isolated three particles that we suspected were collected at altitude. Unfortunately, two of these particles were lost during the imaging process in the ICAL facility at MSU. One particle was lost due to a static charge build-up resulting from our attempt to image the particle directly from a non-conductive glass microscope slide. The other particle was lost while we were attempting to remove the silicon oil from it using a hexane rinsing procedure. Because we have not yet developed the skill to rinse the silicone oil off the particles we will be using Teflon filter paper to isolate the remaining particles. We intend to process the remaining portion of the fluid by dissolving the silicone in hexane and then filtering the mixture through a 2.5-micron pore size Teflon filter paper. This procedure will allow us to easily and effectively remove any silicone oil from the particles. The BOREALIS team is currently working with terrestrial particles to develop methods for imaging and isolating the particles that have been processed using the filter paper method. Jack Warren of the CDL has isolated and mounted approximately 20 particles on glass slides. He also processed the remainder of the silicone oil that was shipped to JSC through a filter paper. These particles will be analyzed once the BOREALIS team has developed reliable techniques for handling them and has been trained in the use of the ICAL equipment.

One particle was successfully imaged using both an optical microscope and an FEM. The optical microscope revealed it as the 40-micron translucent spheroid leading us to believe it was an abnormally large aluminum oxide sphere from rocket exhaust. Further analysis using the FEM, which gave a superior resolution (see Figure 12), revealed a topological surface indicative of pollen. Using the FEM for chemical analysis supported our conclusion that the particle was pollen because only the carbon and calcium signals were enhanced relative to the background spectrum of the glass slide and silicone oil. The FEM spectral analysis of this particle is shown in Figure 13.

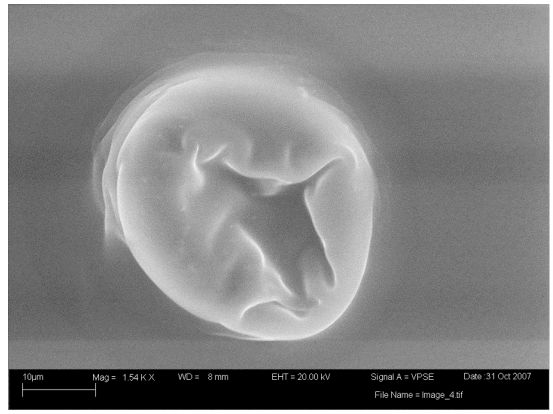

Figure 12. FEM image of a pollen particle extracted from silicone oil capture fluid.

Princeton Gamma-Tech, Inc.
Spectrum Report
Wednesday, October 31, 2007

File:	Z:\HASP\20kV_sphere_1.pgt				
Collected:	October 31, 2007 10:21:41				
Live Time:	60.31	Count Rate:	588	Dead Time:	59.59 %
Beam Voltage:	18.72	Beam Current:	2.00	Takeoff Angle:	38.88

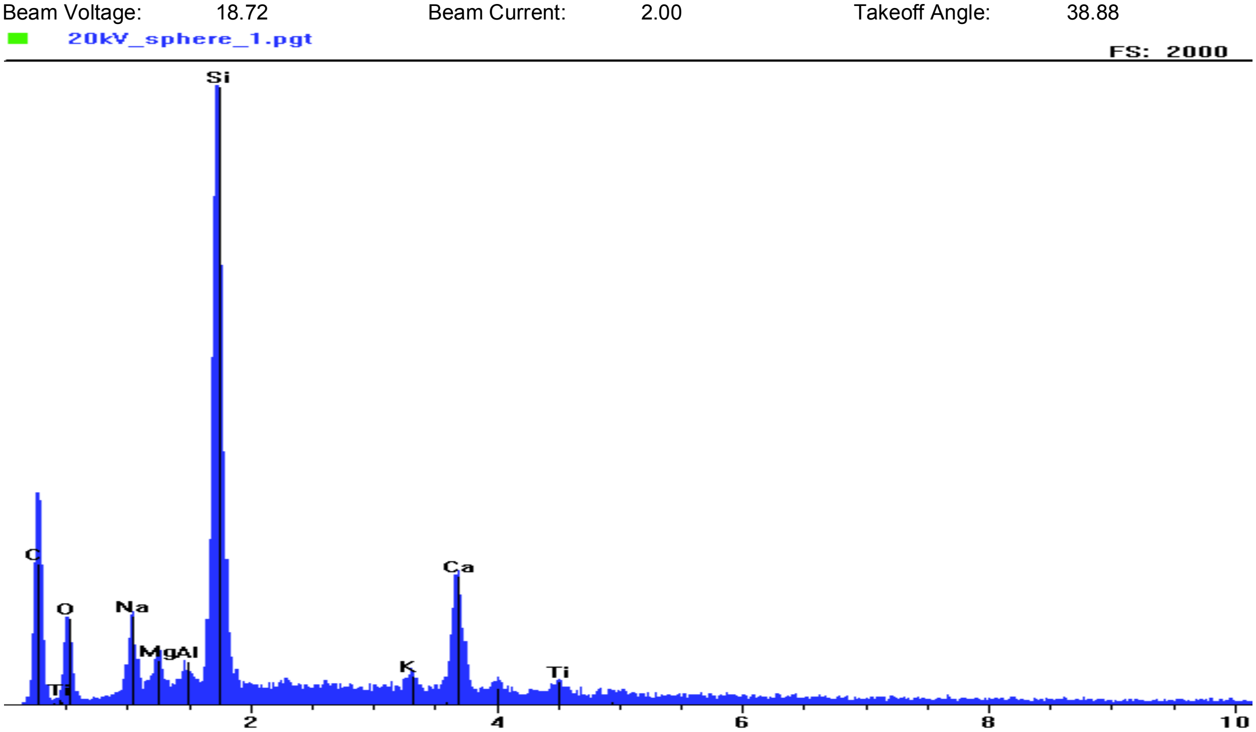

Figure 13. FEM spectrum of the particle shown in Figure 11. The major peaks are from the silicone oil capture fluid. Background subtraction revealed only significant intensity in the carbon (C) and calcium (Ca) lines indicating that the particle is a grain of pollen.

Lessons Learned

Based on our observations of procedures at the CDL, and on our personal experience with this project, we have a number of improvements that we intend to implement for future flights. Firstly, we now understand that our previous attempts to keep our sample free of terrestrial contamination were not sufficient. In the future we plan to filter our solvents and the silicone fluid prior to use and we plan to perform the final assembly of the box in a clean room. Integration will be conducted at the LSU specified location. Upon completion of integration the containment box will be removed from the platform and shipped to the CDL at JSC. In the CDL clean room, final cleaning, preparation and sealing of the box and Plexiglas collection plates will be performed.

To simplify particle identification and analysis two polished heat-treated Plexiglas plates will be mounted inside our capture box. A very thin layer of the silicone fluid will be applied to these plates. After the capture box is recovered, the plates can be removed and placed directly under an optical microscope where preliminary imaging and visual identification will take place. Particles may then be removed with a glass needle and further processed for imaging and chemical analysis with the FEM. This procedure will prevent cluster particles, which consist of a number of small fragments that originated from one particle shattering on impact, from being dispersed, as occurs if the fluid is filtered. Cluster particles are generally extraterrestrial in origin, and being able to keep their fragments together would greatly enhance our ability to identify them.

Future Work

The BOREALIS team plans to continue developing procedures for identifying and isolating the particles collected on the first flight. Particle manipulation tools are being designed that should ultimately allow us to pick up and transfer single particles imaged under the optical microscope to electron microscopy grids for final imaging and chemical analysis. Several students are presently in training to use the optical microscope and the FEM instrument in our ICAL surface science facility. If we are successful at isolating one of our particles and identifying it as being cosmic dust, we intend to submit our finding to a professional journal through collaboration with the CDL.

Appendix

Files 245-15-21-42.raw;245-15-32-28.raw
DDDDDDDDDDDDDDDDDDDDDDDDD
The box is CLOSED
command open = 0
command close = 0
DDDDDDDDDDDDDDDDDDDDDDDDD
The box is CLOSED
command open = 0
command close = 0
DDDDDDDDDDDDDDDDDDDDDDDDD
The box is CLOSED
HEATER has turned on
Heat loop 1out of 9
Heat loop 2out of 9
Heat loop 3out of 9
Heat loop 4out of 9
Heat loop 5out of 9
Heat loop 6out of 9
Heat loop 7out of 9
Heat loop 8out of 9
Heat loop 9out of 9
Heat loop is done
command open = 0
command close = 0
DDDDDDDDDDDDDDDDDDDDDDDDD
The box is CLOSED
command open = 0
command close = 0
DDDDDDDDDDDDDDDDDDDDDDDDD

DDDDDDDDDDDDDDDDDDDDDDDDD
The box is CLOSED
command open = 0
command close = 0
DDDDDDDDDDDDDDDDDDDDDDDDD
The box is CLOSED
command open = 0
command close = 0
DDDDDDDDDDDDDDDDDDDDDDDDD
The box is CLOSED
Command Open
command open = 1
command close = 0
Starting open box loop
left open = 0
time counter = 1

Starting open box loop
left open = 1
time counter = 42
Open box loop is finished
DDDDDDDDDDDDDDDDDDDDDDDDD
The box is NEITHER
command open = 0
command close = 0
DDDDDDDDDDDDDDDDDDDDDDDDD

File 246-02-03-48.raw
DDDDDDDDDDDDDDDDDDDDDDDDD
The box is NEITHER
command open = 0
command close = 0
DDDDDDDDDDDDDDDDDDDDDDDDD
The box is NEITHER
command open = 0
command close = 0
DDDDDDDDDDDDDDDDDDDDDDDDD
The box is NEITHER
command open = 0
command close = 0
DDDDDDDDDDDDDDDDDDDDDDDDD
The box is NEITHER
Command Closed
command open = 0
command close = 1
Starting close box loop
left closed = 0
time counter = 1
Starting close box loop
left closed = 0
time counter = 2

Starting close box loop
left closed = 0
time counter = 41
Starting close box loop
left closed = 1
time counter = 42
Close box loop is finished
DDDDDDDDDDDDDDDDDDDDDDDDD
The box is CLOSED
command open = 0
command close = 0
DDDDDDDDDDDDDDDDDDDDDDDDD

Sample data down-linked from our experiment showing the servo heating and lid opening and closing commands being initiated and completed. Note that the one of the open lid sensor was not functioning and so a lid state of "NEITHER" was reported. The data files are identified at the top of each sample and can located on LSU HASP website http://laspace.lsu.edu/hasp/data/payload_10.htm.