G254: USU Student Payload Flown on STS-64 in September, 1994

Tumkur Raghuram (Payload Manager),
Oscar A. Monje, Brett Evans, Matt Droter, Mark Lemon, Kristen Redd, Tina Hubble, Mark Wilkinson, Michael Wilkinson, Dan Tebbs, and Casey Hatch

Student Experimenters, USU GAS Program,
Department of Physics, Utah State University
Logan, UT 84322-4415

Brandon Lobb, Kent Altsuler

ex-students of Kinkaid School,
Houston, Texas

R. Gilbert Moore* Jan J. Sojka

Faculty Advisors, USU GAS Program
Department of Physics, Utah State University
Logan, UT 84322-4415

Prent Klag

Director, Edith Bowen Lab School,
Logan, UT

ABSTRACT

G254 is the culmination of USU Get Away Special (GAS) students' efforts to get back into space. After a hiatus of a decade, the USU GAS program flew its sixth canister on STS-64 in September 1994. Like its predecessor payloads, this one contained a diverse set of experiments, six in all. Each experiment has its own lessons learned, which hopefully can be passed on to the next generation of GAS students. This presentation will give a balanced view of the successes and failures of G254. Emphasis will be placed on describing the stumbling blocks and the many lessons learned that come from experience rather than academic training. G254 has once again taken a team of about fifteen USU students, plus about one hundred fourth and fifth graders, and given them an immeasurable education.

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* Now at US Air Force Academy, Colorado Springs, Colorado.

INTRODUCTION

The Get Away Special (GAS) program is an academic program at Utah State University (USU) which enables students and other educational organizations to participate by designing their own engineering and microgravity science experiments. Five of the experiments on this payload utilized the "spacepak" concept similar to G-008, G-004, and G-518. The sixth used the new "Isospacepak" concept. The external shape and dimensions of each experiment was standardized and each experiment was independently controlled (ref. 1).

The USU GAS program is heavily biased towards developing student skills associated with conducting individual experiments. Currently, the safety review has been completed for our next GAS payload, G200. G200 is a back-up GAS payload on STS-76 due to be launched in March 1996 and primary GAS payload on STS-77 in April 1996.

To start with, we will briefly talk about the experiments on G254 and later talk about the problems faced and the lessons learned on each of them.

BRIEF SUMMARY OF EXPERIMENTS

A detailed description of the G254 experiments were presented at the 1992 Shuttle Small Payloads Symposium (ref. 1). The fully assembled structure is shown in figure 1.

Experiment 1: Distillation Experiment

This experiment was proposed by the students of Kinkaid School in Texas. After working on the experiment for some time, Kinkaid School turned over the reservation to USU with USU completing their experiment in return for the rest of the space in the canister. The objective of this experiment was to distill a mixture of two fluids in microgravity using a temperature differential. The fluids used were trichloro-trifluoroethane and carbon tetrachloride. These fluids were contained in two different aluminum chambers with a solenoid valve in between. The chamber containing the mixture of the two fluids was heated to a temperature in between the boiling points of the two fluids. During the heating operation the solenoid valve was kept open. Since distillation is a gravity dependent process, it was an interesting way to see how the system would behave in microgravity conditions. A cut-out of the experiment is shown in figure 2.

Experiment 2: Float Zone Instability Experiment (FZIE)

This is an experiment which aimed to investigate convective instabilities in float zone geometries. The primary goal of the experiment is to verify the Plateau Instability Limit, which states that in zero gravity a fluid cylinder is unstable when the ratio of length L to radius R exceeds 2π. Three independent liquid wax bridges with varying lengths and radii were held between copper supports and the wax is melted by heating one of the copper supports by means of a heater. The liquid wax would be allowed to resolidify under "non-quiescent" conditions to qualitatively measure the background g-levels by looking at the common distortions in the resolidified float zones. A cut-out of the experiment is shown in figure 3.

Experiment 3: Pachamama

The idea for this experiment was conceived by one of our students, who is from Bolivia and Pachamama means 'Mother Earth' in Bolivian.

The objective of this experiment was to study the effects of microgravity on the photosynthetic ability of a plant lichen with the help of chlorophyll fluorescence measurements. Due to the inherent harsh environment of the GAS can, the lichen was chosen for the experiment. A lichen can stay dormant for a period of time and then be rejuvenated with the help of water and light. The temperature in the sample chamber could be varied using heaters. Once the lichen is sufficiently rehydrated, data acquisition is done through a pair of photometric sensors. Measurements were made at five different temperatures in order to characterize the temperature response of the organism. A cut-out of the experiment is shown in figure 4.

Experiment 4: Bubble Interferometer Experiment

The objectives of this experiment were to: (i) observe the formation of bubbles in a microgravity environment, (ii) look for interference bands due to bubble wall thickness gradients, and (iii) observe surface tension induced motions on the bubble surface.

Bubbles were formed using a mixture of diffusion pump oil and a surfactant. The bubble blowing sequences were recorded on an 8 mm movie camera and the temperature data was stored in an EPROM. The bubbles were blown with the help of two linear actuators and an air pump. A fluorescent lamp with a monochromatic filter served as the source for the interferometer. A small incandescent lamp was used to heat the bubble surface. The heating is not uniform and causes a gradient in the surface tension. This induced surface tension gradient will cause movement of the material on the bubble surface. A cut-out of the experiment is shown in figure 5.

Experiment 5 and 6: Elementary School Experiments

One of the spacepaks contained popcorn kernels and radish seeds, in addition to the regular experiment. An experiment with these were conducted by the Edith Bowen Elementary School. After being flown in space, students popped the popcorn and tasted it. Similarly, the radishes will be grown and sampled. The scientific purpose of this experiment was to foster interest in the space sciences amongst the younger generation.

CHALLENGES ENROUTE

Some of the errors we committed on this payload would seem very trivial and silly to the professional organizations that fly GAS payloads. But these are probably common to an amateur student group with the whole show being run by students. These are the results of inexperience and the education derived from them has proved to be invaluable to the concerned students.

Two years after work started on this payload, things came to a stand-still with the Challenger disaster. In the ensuing two years, it took a lot of ingenuity on the part of the concerned faculty to keep the program alive at USU. By the time the GAS queue was reopened, most of the original students had graduated and new students had come in their places. The tendency of every new student is to redesign things that have been in existence up to that point. As a result, no progress was made for a long time. In addition, no one had a clear picture of the exact paper-work involved with NASA and the new safety regulations that were in place. The general morale was so low and none of the students had any idea about when their experiments would fly or what direction to proceed on the experiments. This was mostly the story till 1992 and was probably the biggest challenge that the program faced.

The item of priority was to pick up the paper work with NASA. A revised Payload Accommodations Requirements (PAR) was sent to NASA. Work was then started on the Safety Review. The Preliminary Safety took a long time to be put together due to lack of experience. With the wrong notion that this had to be the most comprehensive document, a lot of time was lost in pursuing unimportant issues. After all this effort, the first comment during the telecon with NASA was that we had the wrong format for our safety package. It was a pre-Challenger format!

The Final Safety was sent in with the proper format. But at this stage we learnt a few new things about our payload. The entire design for the payload was pre-Challenger. So we had different sets of batteries scattered all through the payload. NASA wanted us to either group all the batteries in one place or to build a box around each set of batteries. The second option was impossible since there was hardly any room in the spacepaks to accommodate separate battery boxes. The boxes had to be liquid-tight only and not air-tight. In order to satisfy NASA's requirement, we had to remove one of the proposed experiments in order to make room for batteries. Inspite of accommodating 67 cells in this spacepak, 30 more cells had to be placed in half of another spacepak. Power was not allocated in a very efficient manner too. There was a lot of power available but the payload could have performed equally well with lesser batteries.

The original design of the payload included a USU GAS switch, which after receiving power from the NASA relays did the switching internal to the payload. But NASA requires that their relays be in direct control of the payload power. This opened up a new problem. The payload had 18 different power supplies and each of them was being turned on at different times. The only relays available to us were the three NASA relays A, B and C. Relays B and C do not handle more than 2 A of current. This necessitated 3 6-pole relays, which would provide us with a total of 18 different switches. With redundancy in mind, 2 sets of 3 relays were included.

With the introduction of two sets of batteries and a set of our own relays, more complications began to creep in. The relays and the half-pak of batteries were at the bottom of the payload. The other spacepak of batteries was located in the middle of the payload. The NASA control lines came into our own relays whose power was coming from the other pak. These relays in turn, switched power from the other pak to the different experiments. In short, this needed a very sophisticated wire harness running across the length of the payload.

Being conservative is useful when dealing with a lot of issues with NASA. But students often tend to get carried away in their quest to be conservative. The following is a prime example. On several circuits in the payload, the current being handled required the use of 12 gauge teflon wire. Students decided to use 10 gauge wire just to be on the safe side. After having committed to 10 gauge wire in the SDP, we were shocked to see what 10 gauge wire really meant. The wire thickness is very large and the wire itself is highly inflexible. Soldering the wire on to the pins of a D-connector turned out to be a nightmare. Soldering a combination of 10 gauge and 16 gauge wire to the set of 6 USU relays was only worse.

A vibration testing of the payload was planned 2 months prior to the shipment date. The shaker table needed repairs and it was finally fixed only 10 days before the payload shipment date. With such a short time to ship, we could either test the payload and break it or ship it without testing and run the risk of it coming loose during launch. We chose the former option. Since the shaker table was operating at less than normal power, we could only test individual paks at a time and not the entire payload. The first payload we tested had been completed well in advance. It was a high precision mechanical truss and the objective of the experiment was to examine the vibration dampening characteristics of the truss-joints. The mounting plate was not bolted to the shaker table perfectly. During the test there were a couple of bad shocks. Upon inspection of the payload after the test, the locking mechanism had come loose and hence the truss had got bent out of shape. Since it was a high-precision mechanical truss, the bending ruled the experiment out of the flight. There was quiet feeling of gloom in the USU GAS lab after this.

The week before the shipping of the payload turned out to be hectic and chaotic. Some students had completed their experiments and were busy testing the different subsystems. But some students were still working on finishing up their experiments. Some were coding the final flight software into their controllers. When the time came for the payload to be put into the shipping container, there was no relief yet for the already exhausted students. The payload and the bumper system refused to fit snugly into the shipping container. Students battled hard trying to shave off material in the hope of getting a good fit. Tired as they were, no one was thinking. Only frustrations set in. Help from a professional machinist was summoned. The problem was fixed and the payload was shipped off to KSC. G254 had left USU on way to space finally after 10 years.

The travails for the USU GAS team were not over yet. They continued to the end till integration. On day 3 of integration, it was discovered the lid of the battery box in spacepak 1 was a little too tall and the pak would not fit into the canister. With the help of the GAS Integration team, this problem was solved and the last and most embarrassing of all mistakes was discovered. We found that instead of leaving the NASA connectors on the payload hanging, we had fixed them to the bottom of the payload. This was not a very serious problem, since NASA offered to give us another set of cables and connectors which would extend the length to reach the interface plate. We discovered to our utter shame we had the wrong connector on our end. So NASA had to cut two different connectors and Big Tom from the GAS Integration team spliced the two cables together with a cheerful smile on his face. The GAS Integration team saved the day for us with their professionalism. It was 11 PM when we left the GAS Facility in KSC after setting up the leak-test on our canister.

POST-FLIGHT RESULTS AND LESSONS LEARNED FROM INDIVIDUAL EXPERIMENTS

Experiment 1

After the flight, there were a few things that had gone wrong and a few others that had worked in ways different from expectations. Of the four circuits that were present in this payload, one of the circuits had been wired carelessly during integration. This resulted in a short and hence a blown fuse. This was the circuit which was doing the temperature control and timing. So the experiment was in a run-away state with just the heaters on and the solenoid open. Upon opening the two chambers, it was found that the liquid was present in both chambers, contrary to expectations. The liquids were carefully extracted from the two containers. These two liquids and a sample of the original mixture have been sent for gas chromatography analysis. Results from this are eagerly awaited and will be presented at the symposium.

The controller on this experiment was a simple Schmitt trigger circuit which maintains the right temperature of the liquid mixture. A simple binary counter times the duration of the heating. During testing, we found that not having a micro-controller made of lot of things inflexible. Unconnected pins on digital chips caused a lot of problems with floating grounds. By tying these to ground, the outputs of the controller were consistent and noise-free. A little more thought in the designing of the chamber fittings would have saved time during the liquid filling and removal operations. The experiment testing procedure was designed without faculty input, often resulting in erroneous tests. Some of the wiring was done too late which resulted in an electrical short. The battery box was never assembled before hand and the problem with the excess height was discovered only during integration.

The hope is to resolve some of these problems and to build a better experiment for reflight sometime in the near future.

Experiment 2

This was the only experiment which had visible indicators to show whether the payload worked while in space. Of the three wax columns, the shortest column had melted completely and formed a ball of wax around the heater. The other two columns had melted partially and resolidified. It is assumed that the power to the experiment was removed earlier than anticipated. The reasons for this have not been determined. No analysis has been done on the experiment results.

The lack of analysis on the part of students could be attributed to the long delay between the conception of the experiment idea and the flight of the experiment. The student who worked on the experiment in the end was not the student who started the experiment. The curiosity for the experiment results was lost and there was satisfaction with merely having the experiment work partially in space.

Experiment 3

On deintegration of the experiment and the experiment memory storage module, it was found that 77 kilobytes of data was collected during flight. Initially this was reason to cheer about since we had a biology experiment that had collected some data. While doing a ground run of the experiment, a serious bug in the flight program was discovered which rendered the acquired data extremely difficult to interpret. Looking back, this does not come as a total surprise since the final flight program was written barely a day before shipment. A lot of time was spent in testing the experiment with power supplies which did not source enough amps and as a result, something always showed up as faulty, when in reality it was not.

The final phase of work on this experiment was started very late and with the complexity of the experiment, there was not enough time to do adequate testing. The complexity of the experiment itself could have been substantially reduced if help was sought from knowledgeable electrical engineers. But on the positive side, the experiment has provided a biology major with a fairly good background in electronics and hardware. A simple lesson learnt from this experiment is that teflon wire is rigid, expensive, heavy and its positioning should be included in the blueprints wherever possible. Perhaps the best of all lessons learnt is as simple as START EARLY.

Experiment 4

The Bubble experiment was probably the most impressive experiment in the entire payload for several reasons. It had a very good experiment idea, the hardware was machined very well and it was the most tested experiment in the entire payload. But the saddest part was that the experiment never saw power turned on to it while in flight. This was the last experiment in the payload to be turned on during the mission. There is good reason to believe that the batteries had failed on the switching relays by this time and hence they failed to turn power on to the experiment. Upon return, when the experiment was powered up using power supplies, the experiment went through its sequences flawlessly. We had either seriously underestimated our power budget on the relays, or the batteries had behaved contrary to expectations while in flight. This experiment is a worthy candidate for reflight on a future GAS payload.

Experiment 5

This was probably the most successful of all experiments in terms of post-flight analysis. In December 1994, fourth and fifth grade students gathered in the school to conduct experiments on the space flown and ground samples of popcorn. A total of 120 students were involved in this massive experiment. The group was divided into 10 specialized research teams. They were:

Event Facilitators, Science Writers, Exhibit Committee, Science Illustrators, Popper personnel, Data Collectors, Data Analyzers, Space Futures Study Group, Seeds in Space Trainers (to educate primary students) and EBTV (school video news reporters).

Two specific trials were held to examine the popcorn which was flown in space and the popcorn which was maintained on earth. A lot of experimentation was done with these two trials. Some of them were the following:

The weight of the popcorn bags before and after popping, width and height of the popped bags, odor of the popcorn after popping, the number of popped kernels and the number of unpopped kernels from each trial, the size, color, odor, kernel weight, ingredients left in the bag, freshness/staleness, crunchiness, chewiness, saltiness and after-taste.

The whole process was carried out for almost two hours. The fourth and fifth graders collected data and worked in a very efficient and effective manner. Following data collection, students compiled their data into a consistent format and included illustrations and drawings that were taken on site. Following this, some data interpretation was held with some most interesting results. Some of them were:

1. Students found a 10 gram difference in the bag weight of the space popcorn as compared with the weight of the earth popcorn. The space popcorn being lighter.

2. Students found that the space popcorn had 779 kernels pop per bag compared to 545 kernels in the earth popcorn.

3. Students found that on a rating scale of 1-5 for crunchiness, the space popcorn rated 4.0 while the earth popcorn rated with 3.0 with 5 being most crunchy.

4. The students found that in terms of after-taste, the earth popcorn rated 5.0 and the space popcorn 3.0 - on a scale of 1-5, with 5 having the most after-taste.

The process had a few scientific deficiencies, but without a doubt, it exposed the fourth and fifth graders to the scientific process. It had a tremendous impact on all who were involved. It most certainly motivated students to become interested in space science and engineering. Students became real life investigators of real-life phenomena. It was an example of a tremendous STS related science experience which were all the primary objectives of this experiment.

Experiment 6

This refers to the experiment pertaining to the space flown radish seeds. At this time, the school has acquired some growth chambers and the details of the experimentation are being worked out. This should also provide the elementary school children with a very unique experience related to space experimentation.

LOOKING INTO THE FUTURE

The overall lessons learned from G254 have been invaluable for the USU GAS team on their subsequent payloads. G254 had stayed in the lab for so long, that students wanted to get it flown at any cost. That the experiments had partial successes on the flight seems like a bonus. But the total educational experience derived from it have more than compensated for the failures of the experiments.

The USU GAS team is currently working on G200 which is slated to fly on STS-77 in April 1996. The safety review for this payload has already been completed. The entire payload has been designed and drawn using CAD software. Materials have been chosen carefully. The structural analysis was completed before any metal was cut. After having been through some embarrassing moments, the students now want to build a professional looking payload which works according to its objectives. With the way things have gone so far, there is every reason to believe that the lessons from G254 were learned well and will be incorporated into G200.

REFERENCES

1. *G-254 Undergraduate Experiment.* NASA Conference Publication 3171, October 1992, pp 151-163.

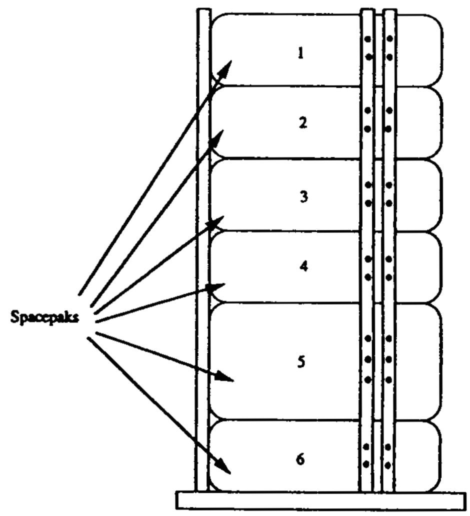


Figure 1 Fully assembled Structure

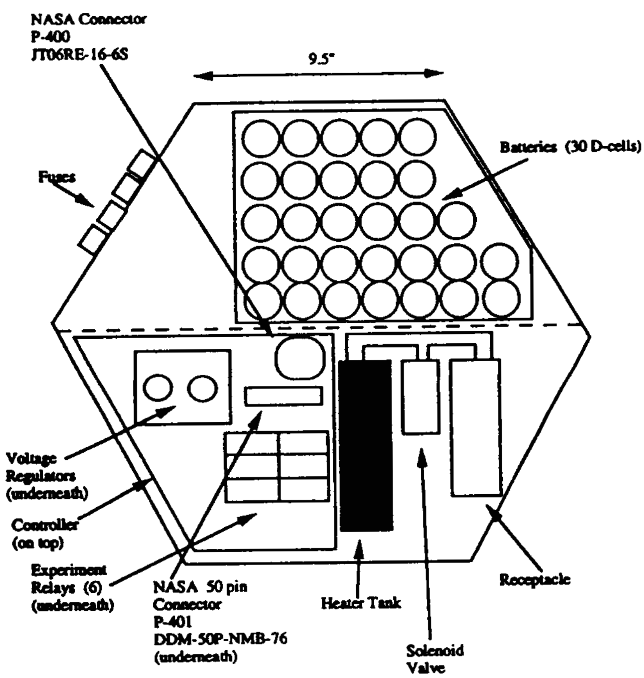


Figure 2 Cut-out of expt. 1

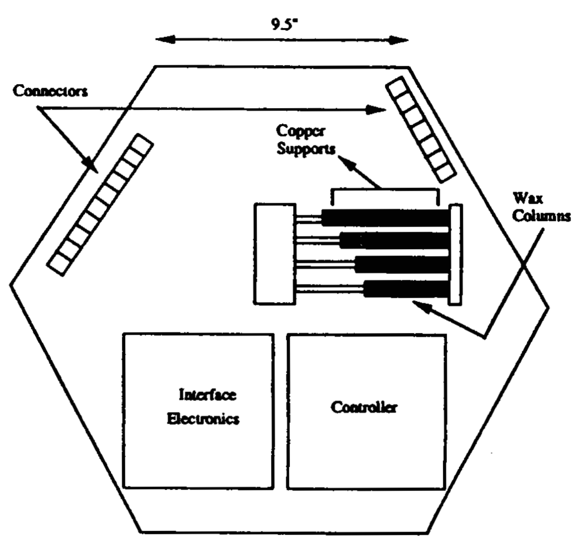


Figure 3 Cut-out of expt. 2

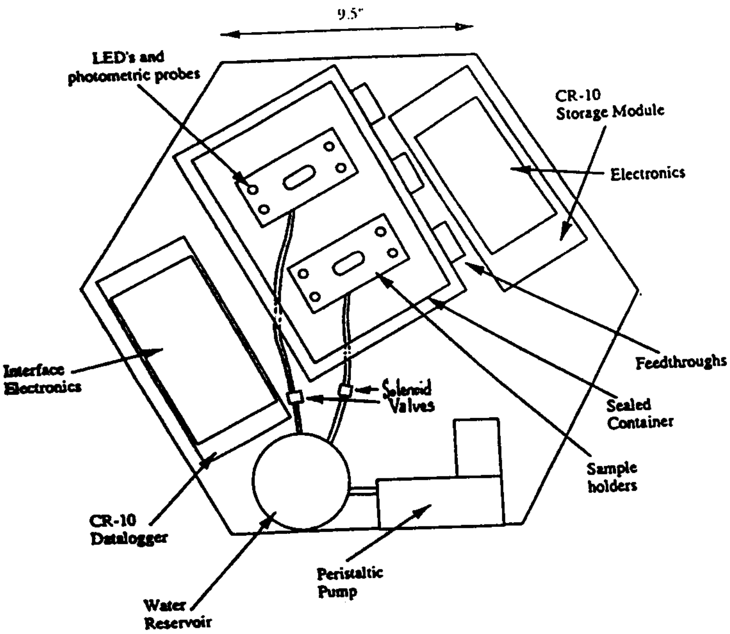
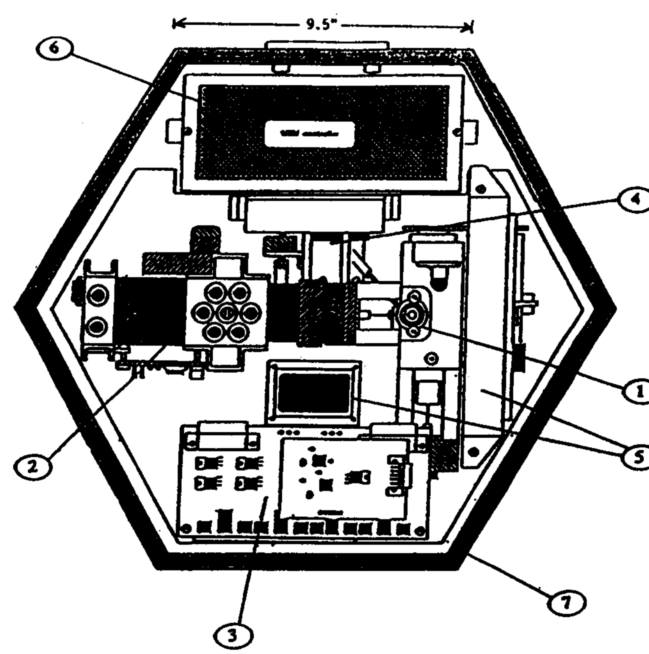


Figure 4 Cut-out of expt. 4



Item	Description
1	Blower Unit
2	Camera Unit
3	Interface Electronics
4	Air Pump
5	Interferometer Light
6	Controller
7	Space Pak

Figure 5 Cut-out of expt. 4