Results of the Purdue University
GAS-I Payload
by
Rigoberto Perez

Abstract

This paper summarizes the results of Purdue University GAS-I payload and describes their implications from an engineering design standpoint. The payload consisted of one biological and two physical science experiments, along with the supporting subsystems. Some of these subsystems included, the structure, power supply, electronic controller and thermal control system. Data was obtained from one of the experiments, but electrical and mechanical malfunctions prevented the operation of the other two. The thermal control design maintained the desired temperatures and the structure successfully supported all components. The microprocessor collected and stored temperature readings and other data during the flight. A series of recommendations based on these results and our experiences are included in this report.

1. *Introduction*

The Purdue University GAS-I was housed inside a standard 2.5 cubic foot, 100 pound canister donated by an alumni in 1977. In 1978 experiment proposals were solicited by a faculty committee from the Purdue University community. Three experiments were selected for the project. The completed payload was flown on STS-7 in June, 1983.

The space science experiment is entitled "The Nuclear Particle Detection Experiment". The purpose of this experiment was the detection of nuclear particles that are encountered in the near earth space environment, and to study their subsequent paths after the particles penetrated a stack of sensitive sheets. The second experiment was a biological project entitled "The Seed Germination Experiment". A study of the effect of microgravity on the germination of sunflower seeds was the objective here. "The Fluid Dynamics Experiment" was intended to investigate the motion in low gravity conditions of a drop of mercury immersed in a clear liquid.

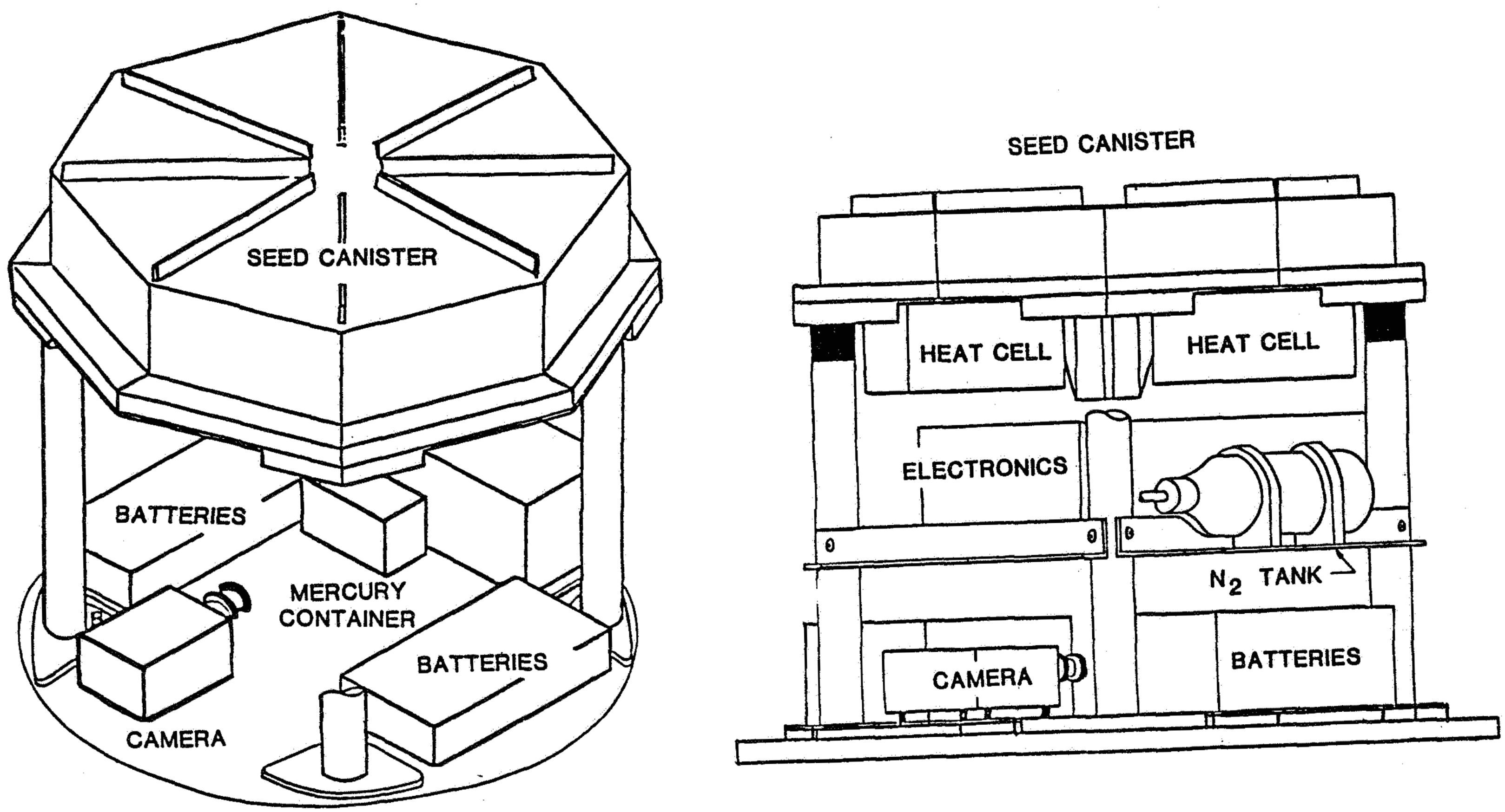
In addition to the primary experiments, other important subsystems included the batteries, temperature control system and the electronic control package which included a Radio Corporation of America CDP1802 microprocessor [1]. All the units were held together by a structural fram Schematics of the payload are shown in Fig. 1.

2. Structural Design

Ascent and landing loads were supported by a structure composed of four cantilever beams fixed to the mounting plate and connected at the free end to the seed experiment canister. Crossbeams connect the cantilever beams and served to carry the experiment subsystems (see Fig. 1). The entire structure is made of 6061-T6 aluminum with a total mass of 7 pounds. With a factor of safety of 1.5 used in the stress analysis, it was found that the structure could support the payload mass of 100 pounds up to 16.3 in a direction perpendicular to the major axis of the Get Away Special container. Vibration tests simulating the space shuttle flight were also performed, and showed that the structure could survive the flight [2]. Inspection of the payload after the flight determined that the frame successfully carried all the components and confirmed the preflight tests and analyses.

3. Thermal Control System

A temperature control system had to be designed to satisfy the thermal requirements of various subsystems. The seed germination experiment was to be kept between 15 and 27^{o}C, and the battery packs needed to be within 15 and 50^{o}C. The microprocessor was allowed a slightly larger range.



a. Perspective view.

b. Side view.

Fig. 1 Schematic of the Purdue University payload.

The final temperature control design was based on thermal models and heat transfer simulations of the environment before and during flight. Outer thermal protection provided by NASA consisted of POMEX felt insulation around the sides and on the bottom of the canister. The upper surface was coated with white paint. In addition to these external blankets, various internal methods were used to maintain the required temperatures. A completely passive control system was chosen, because of the excessive weight and power requirements of other options. The primary component of the system consisted of three custom-built "heat cells" (mfg. TEXXOR, Inc., Omaha, NE). These cells contain a mixture of calcium chloride hexahydrate and Bisol II™ (Δh_{fg} = 221 kJ/kg) that melts at 27^{o}C and have a total heat capacity of 1585 kJ. They act as heat sources and sinks during liquid-solid phase changes. Surfaces of other components were covered with aluminum foil to inhibit or enhance the local radiation exchange. The battery packs, for example had aluminum foil on the outer sides to reduce radiation to the canister wall. A radiation shield consisting of a thin fiberglass shell covered with foil surrounded the seed experiment, heat cells and fluid containers. This shield minimized the radiation to the GAS canister wall, the primary cause of heat loss.

Microprocessor records analyzed after flight showed that both the seed experiment and mounting plate were between 294 and 299^{o}K (21-26^{o}C) from 94 to 145 hours after launch [3]. Note that due to a malfunction, the seed experiment did not operate and was not a source of heat. This differs from the preflight simulation which had assumed an operating seed experiment. Nevertheless, the passive thermal system used in this payload maintained the required temperature range.

4. Particle Detection Experiment

The main component of the particle detection experiment consisted of a stack of 78 sensitive CR-39 plastic sheets stored inside an aluminum container. Each sheet measured 2 x 3 x .025 inches. The sheets on the top and bottom of the stack and the inside walls of the container were coated with a boron paint so that as neutrons entered the container they were converted to alpha particles by the boron. The alpha particles then would penetrate the subsequent sensitive sheets and leave tracks to be detected. Postflight analysis and investigations showed that tracks of particles were indeed present in the sheets [4].

5. Failure Analysis

Inspection of the payload after flight revealed that two of the three experiments (seed germination and fluid dynamics experiments) did not operate as planned. An investigation was performed to find the cause(s) of the problems. Failure of the seed germination experiment to start was traced to an electrical short which occurred when the payload structure was accidentally placed over a wire from the battery pack. This incident happened during final assembly at NASA and appeared at the time to have caused no damage. The inspection made after the flight showed that the heat generated by the short damaged the protection diodes used in the main power supply. During take-off these diodes eventually fractured, and formed an open circuit that prevented electricity from reaching the seed experiment [1].

The reason behind the failure of the fluid dynamics experiment to operate was independent from the problems described above since this system used a separate battery set. A mechanical malfunction of the camera used in this experiment was ruled out as a failure cause since this camera operated before and after flight. Although there is no concrete evidence, a possible source of problems is the film cartridge used by the camera. This cartridge model had several moving parts that could have jammed and prevented the camera from running.

6. Conclusions and Recommendations

Successful designs in the Purdue University GAS-I payload included a structure which was able to support the components during ascent and landing, and a microprocessor which recorded flight data. The thermal control system maintained the required temperatures and data was collected in one experiment. An electrical short which occurred during final installation and possible mechanical problems prevented the operation of the other two experiments.

Based on these experiences and post-flight observations, several recommendations are made here. Systems must be kept simple with as few moving parts as possible. Passive systems are highly recommended. The electronic package should be protected against possible damage and redundant components should be included to serve as backups to important parts. Repeated simulations of the assembly, preflight and flight environments must be performed. These should include vibration tests followed by full scale operation under as realistic conditions (i.e. thermal) as possible. A task group in charge of anticipating possible problem and failure sources should be formed.

7. Acknowledgements

With the exception of some fabrication tasks the entire project was developed by Purdue University students. The author gratefully acknowledges the help provided by the project faculty advisor, Professor John T. Snow (Department of Geosciences), and wishes to thank the donor of the payload reservation, Dr. Harold Ritchey.

REFERENCES

[1] Kark, D., "Design of the Get-Away Special Payload Controller", Purdue University (an unpublished paper, 1983).

[2] Perez, R., "The Development of the Purdue University Small Self-Contained Shuttle Payload", AIAA Midwest Regional Student Paper Conference, March 1983.

[3] Stark, J.A., "Thermal Control System of the Purdue University Space Shuttle Payload". Submitted to Jour. AIAA, 1984.

[4] Weber, D. and M. Weber, Nuclear Particle Detection Using a Track Recording Solid. See this volume, 1984.