N93-13174

G254 UNDERGRADUATE EXPERIMENT

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ABSTRACT

This paper describes the experiments on payload G254. Each experiment is accommodated in a spacepak and six experiments fly in a full canister. One of the experiments will be housed in a new Isospacepak structure, which will be described briefly. Five of the six experiments have dedicated controllers. The objective of each experiment is discussed. In addition, the operational scenario is provided.

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 utilize the "spacepak" concept similar to G-008, G-004, G-525 and G-006. The sixth uses the new "Isospacepak" concept. The external shape and dimensions of each experiment is standardized and each experiment is independently controlled so that experiments can be easily interchanged within the canister.

One of the experiments in this GAS canister has been mounted on a new Isospacepak structure that has been machined by Utah State University GAS investigator Tina Hubble and Industrial Technology and Education Department graduate student Joe Greathouse, utilizing Isogrid manufacturing techniques. The Isogrid method consists of milling a series of equilateral triangles out of solid plate stock to produce a structure which is six times as strong as a solid plate of equal weight. In addition, the nodes of the machined structure provide convenient attachment points for experiment components. Each of the nodes has been drilled and tapped, so that a regular, repeating attachment pattern is available to the experimenter. Following its demonstration in this canister, the Isospacepak will be employed in all future Utah State University GAS experiments and will be made available to other organizations desiring to adopt this concept.

The remaining "spacepaks" are a hexagonal structure made of fiberglass/polyurethane composite trays. Each tray has three aluminum mounting plates. The trays are mounted on top of each other and are held together by means of supporting struts which attach to the canister endplate. Five of the six experiments will have dedicated controllers. The sixth experiment will be controlled by a simple temperature sensitive switch.

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

The USU GAS program is heavily biased towards developing student skills associated with conducting individual experiments. Currently, G254 is in the integration stage. It has undergone the vibration test, and safety reviews are in progress. The experiments are targeted for delivery by December 1992.

CONTROLLERS

There are two types of controllers that are being used on this payload. One controller uses 24K bytes of user memory divided into 8K RAM and 16K ROM, 32K bytes data storage (EPROM), 16 analog inputs, 8 high current outputs, 8-bit digital input in parallel, a special energy-saving sleep circuit, and a real time clock. There are no external data storage devices and the programs are stored in the EPROM.

The other controller has 64K of internal RAM, functionally divided into 5 areas. Three of these areas are used in processing and storing measurement values. There are 6 differential channels used for analog inputs. They can also be used for single ended measurements. There are 8 digital I/O lines and a serial I/O port. It has two pulse counter inputs which are user programmable. It runs on a 12V power supply.

SPACEPAK 1

The purpose of this experiment is to examine the damping of a tetrahedral truss in a microgravity environment. An area of concern for the design of large space structures is predicting the amount of structural damping which will be present to damp out vibrations caused by orientation or docking operations. The joints used to assemble a large light weight structure like the Space Station will provide some damping. However, an accepted methodology for predicting joint damping is yet to be established. A Get Away Special experiment was assembled to investigate methods for predicting joint damping in large space structures. A miniature tetrahedral aluminum truss will be attached to the wall of a vacuum chamber, and a tip mass attached to the free end. Oscillations will be induced in the truss structure with a solenoid and the rate of decay of the vibration modes will be recorded. The tip mass will be secured using solenoids during both launch and reentry maneuvers. The truss chamber will be evacuated through a vent to the shuttle bay.

Leak testing was conducted on the vacuum cell housing for the tetrahedral truss experiment. A vacuum pump was used to reduce the pressure down to approximately 10^{-6} Torr inside the vacuum cell and a helium leak detector was used to determine if outside air was leaking through any of the seals. A successful leak test was obtained which confirms that a high vacuum can be maintained inside the vacuum cell.

The goal of this experiment is to record the decay of the truss while it is vibrating in its fundamental vibration mode. The controller operates the experiment and measures the data. The controller pulses the solenoid at the resonant frequency of the truss for about 10 seconds. Next the resulting decay of the truss is recorded from either output of a displacement transducer or a strain gage attached to one of the truss members. The controller will excite the truss and record the decay a total of ten times. Since it is desired to measure the decay in microgravity, the experiment will be conducted during the first sleep period. A steel tip mass is attached to the truss to produce a resonant frequency of approximately 15 Hz. Additional structural support is provided to the truss tip mass during launch and reentry by the truss locking mechanism. The locking mechanism is in place during launch. Shortly after launch the stepper motor is activated to unlock the truss. After the testing is complete the truss is locked again for reentry. In the event the locker mechanism fails to relock the truss, the vacuum cell is designed to limit the deflection of the truss. The structural diagram for this experiment is shown in fig. 1.

SPACEPAK 2

The objective of this experiment is to examine the behavior of an isolated water droplet suspended in an electromagnetic field. Theory suggests that when a droplet is polarized under a very strong field (of the order of 10-20 kV) it elongates into a prolate spheroid. The forces exerted on the water droplet are the normal stress from the electric field, the surface tension from the water droplet, and the constant internal and external pressures exerted on the droplet (1,2). Although the internal and external pressures of the droplet are constant they are not constant over the surface of the droplet (1). To balance this inconsistency there must be an induced flow arising from the viscous stress of the droplet (2). This flow is shown to be both inside and outside of the droplet. These forces are believed to be the mechanics of the deformation of these water droplets.

At some point the droplet will become unstable. This point is labeled as the critical field strength. The critical field strength for a conducting incompressible (liquid) droplet is an inverse function of the original radius of the spheroid. After the critical field strength is reached, some droplets would expand until they disintegrate while others expand until they form sharp points from which jets of liquid form. The droplet can expand to an oblate or a prolate spheroid depending on the ratios of three physical parameters of the medium of the droplet. The parameters are electrical conductivity, viscosity and permittivity. These ratios determine the shape of the droplet (1,2).

The water polarization experiment depends upon 13 lead-acid batteries for all its electrical needs. Each battery delivers 2 V and 5 amp-hrs. Four batteries are needed just to power the controller. The main component of the experiment is the water chamber. It consists of two parallel plates with a separation distance of about 4 cm. The plates are made of aluminum and are 5 cm square in area. The volume inside allows a water droplet of radius 1 cm. A needle of nylon will be used to produce the water droplet. A high voltage supply which requires 15 V and delivers about 18kV output is required. A super 8mm movie camera will be used to photograph the water droplet during the experiment.

The aim in this experiment is to confirm a relationship between the eccentricity of the ellipsoid and the applied voltage across the plates. The experiment configuration is shown in fig. 2.

SPACEPAK 3

This experiment is called Project Panchamama. Project Panchamama is a biological experiment designed to study the effects of microgravity on photosynthesis. Physiological data of this nature will be useful in elucidating the effects of microgravity on the performance of plants. Microgravity may affect photosynthesis in one of two ways: (i) by altering the diffusion of gases (i.e.. CO_2) into cells or (ii) by altering cell function due to redistribution of water or altering hydrostatic forces. The experiment has been designed to study photosynthesis by using chlorophyll fluorescence measurements. Chlorophyll fluorescence is a sensitive indicator of the efficiency of photosynthetic reactions and has been used extensively to monitor plant stress.

Biological experiments are inherently more complex than non-biological ones, because measurements must be obtained from a living organism. The GAS CAN environment is extremely harsh for living organisms because of the pre-flight dormancy period (30-90 days), exposure to high g-forces during liftoff, and followed by approximately 7 days of a potentially harmful thermal environment. Furthermore, the atmosphere of the GAS CAN is composed of nitrogen, and the experiment will be unable to provide life support during the pre-flight dormancy period. GAS payload temperatures were found to reach minimums close to -20°C. The sample temperature during the experiment must be maintained between a maximum of 30°C and a minimum of 5°C, so as to avoid thermal damage of the samples. Fluctuating temperatures also affect the thermal drift of electronic components and the heating rate experienced by the organism.

The experiment will rehydrate a lichen in orbit, and fluorescence measurements will be recorded using a simple fluorometer. A lichen, a symbiotic poikilohydric organism composed of algae and fungus, was chosen because it can remain dormant for many months without the loss of viability. The organisms will be housed within a compact life support system composed of an airtight chamber, and a water reservoir. The chamber is made of aluminum and is sealed by a static o-ring. The chamber atmosphere will be air containing 21% O_2 and 600-1200 ppm of CO_2 at 1 atm of pressure. A nylon sample holder assembly is located inside the chamber. It consists of two aluminum sample holders, six incandescent glow lights, and a sensor arm. The two sample holders are independently connected to a water reservoir. Water is pumped into each sample holder with a peristaltic pump. Sample holder temperature is controlled with a feedback circuit composed of a peltier heater. All electrical connections into the gas tight chamber are made through three 20 pin feedthrough connectors.

Water is passed into the chamber through an o-ring sealed water feedthrough connector. The reservoir consists of a 10cm long, 5cm diameter solid PVC pipe and holds 150 ml of distilled water. The reservoir will be insulated and heated by a thermofoil heater. Water flow is regulated by two individually operated, normally closed solenoid valves.

The experiment will be activated by a baroswitch, which will power up the control system. Data acquisition is accomplished through 16 single-ended input channels. Control is accomplished through a memory mapped multiplexer and switching board. The control system will heat the water reservoir to 10°C, and then each sample holder will be rehydrated. The glow lights will then be turned on to start photosynthesis to allow for a period of normal growth and recovery from the long pre-launch dormancy period.

The data acquisition portion of the experiment will begin after a suitable time for rehydration. The data acquisition consists of a sensor arm shaped like an X, that holds a pair of photometric sensors in each leg of the X. Each leg contains a chlorophyll meter and a fluorometer. The sensor arm is moved directly over the samples during the measurement sequence by a linear actuator. Measurements will be made at five different temperatures in order to characterize the temperature response of the organism.

The power required to provide a controlled temperature regime was estimated from the expected power use of both the water reservoir and the sample holders. The water reservoir will require 2 watts of continuous power to maintain the water temperature at 10°C if the GAS CAN temperature is 5°C, and 10 watts if the GAS CAN temperature drops to -10°C. Each sample holder will require 0.88 Watts continuously to heat the sample at a heating rate of 2°C/min. The second sample holder will be rehydrated only if the payload temperature is above -5°C. This arrangement allows both redundancy and economy of power in the event of encountering an extremely harsh temperature environment.

The life support system presently being developed allows certain biological experiments to be performed in the GAS CAN. The nature of these experiments was found to be limited by the reduced capability for life support during the pre-launch phase, and thus dictated by the choice of test organism. Furthermore, the use of photometric probes for measuring physiological parameters allows simplicity of design, in-flight data acquisition, and low mass and power requirements.

SPACEPAK 4

The bubble micro-gravity experiment is designed to study the characteristics of a small three-dimensional bubble structure inside a NASA GAS canister. It is completely self-contained and requires a signal to initiate the experiment operation. The primary goals of the experiment are to: (i) observe the formation process of the bubble, (ii) look for evidence of drainage in the bubble after it has been formed, (iii) look for interference bands due to bubble wall thickness gradients, and (iv) observe surface tension induced motions on the bubble surface. The bubble experiment data will be gathered by an 8 mm movie camera. Supplemental data will be measured in analog form and stored in a memory module. The bubble itself will be formed using a fluid which is 85% (by volume) Dow Silicon diffusion pump oil and 15% 3M FC430 surfactant.

The experiment consists of 5 major subsystems: command and control, a bubble blower, camera and lighting, power and heaters.

The command and control subsystem is run by a controller. The controller has 8 digital output lines. The controller is electrically isolated from the experiment apparatus through the use of optical isolators and a separate power source.

The bubble blower is the crux of the experiment. It consists of an aluminum block onto which other parts are attached. The block serves as a bubble material reservoir. A blower aperture is affixed to this block. The bubble is formed at the blower aperture. Two linear actuators are also attached to this block, as are the DC stirring motor, two thermofoil heaters, and two thermistors. The stirring motor is used to mix the bubble material prior to the bubble formation sequence. One of the linear actuators is used to unseat a spring-loaded check valve. This valve normally keeps the bubble material inside the reservoir. The second linear actuator is used to force the bubble material to flow to the top of the bubble aperture. The thermofoil heaters are used to keep the bubble material at a temperature above 15°C. One of the two thermistors is used in a closed-looped heater subsystem. The second thermistor is used to monitor the bubble blower temperature.

An 8 mm movie camera is used to record all of the bubble formation activity. A fluorescent lamp is used to provide lighting during the filming sequences. The light is mounted directly behind the blower block, on the other side of the camera. A small incandescent lamp is used to heat the bubble surface. The heating is not uniform, which causes a gradient in the surface tension. The induced surface tension gradient will cause movement of the material on the bubble surface. This movement will be filmed by the camera.

All energy for operation of the experiment comes from several sets of lead-acid batteries. One set of 6 cells is devoted to the controller, while a second set of 12 cells is devoted to the experiment power. This was done, in part, to completely electrically isolate the controller from the experiment.

Thermofoil heaters are attached to the base of the blower block for temperature control purposes. Once powered up, the heater subsystem does not require attention from the controller. Power is supplied to the thermofoils whenever the temperature of the blower block falls below 15°C.

SPACEPAK 5

This project was proposed by Kinkaid High School. Since USU began supporting this project, various students have assisted in its development. Since the delays that resulted from the Challenger accident, the USU GAS program has taken the initiative to complete this project. The controller has been completed and tested.

The objective of this experiment is to distill a mixture of two fluids in microgravity using a temperature differential. The fluids intended for the experiment are trichlorotrifluoroethane and carbon tetrachloride. Significant properties of these fluids that require examination include boiling point, vapor pressure, and toxicity and flammability characteristics.

This experiment is contained within a composite hexagonal spacepak. Lead-acid batteries supply four power sources of 35V, 5V, 10V, and 5V. These batteries are contained within a support structure. The fluid containment system includes one solenoid valve, two aluminum containers with a fluid capacity of 13.7 ml each, and brass fittings. A thermofoil heating element wraps around one container. It requires a 35V power supply. The controlling system consists of a mechanical relay, one USU GAS switch, two voltage regulators for each of the 5V power supplies, a printed circuit board, and Teflon coated wires. A voltage regulator stand, fluid chamber stand and two aluminum base plates secure the experiment structurally.

The experiment starts when the NASA signal is received by the USU GAS switch. The USU GAS switch activates the relay that connects all power sources to the controller. The controller receives the power and regulates all power output and operation. A thermistor is attached to the bottom of the aluminum container which has the heating element. The thermistor, in combination with another resistor, makes a variable voltage divider that provides input for a Schmitt trigger. Resistor selection controls the operating temperature and the fluctuation of temperature during feedback about the desired operating temperature. The heater turns on with the power up of the controller. When the operating temperature is reached a binary counter turns on. The valve that separates the two fluid chambers also opens up as the controller receives power. The binary counter runs for approximately three hours. During this time the Schmitt trigger of the controller powers the heater according to the resistance of the thermistor so that a temperature level may be maintained. Three J-K flip flops aid in system operation. When the counter returns to zero, the valve is closed, the controller shuts down, and the project remains dormant. Completion of this experiment involves analyses of the chemical composition of the fluid in each container and comparison with results of distillation experiments in the earth's gravitational field. A figure of the fluid containers and the solenoid valve is shown in fig. 3.

SPACEPAK 6

Float Zone Instability Experiment (FiZIE) aims 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. This will be accomplished by creating four independent liquid wax bridges with varying lengths and radii. In addition, by allowing the liquid wax to resolidify under "non-quiescent" conditions, a sensitive test of background g-levels can be qualitatively measured by the common distortion in the resolidified float zones.

Four columns of solid parowax with radii ranging from 0.5 to 0.7cm and lengths ranging from 3 to 6 cm are suspended in an array between two copper supports. At one end of each of the wax columns is connected a heater which will be used to melt the wax. The four heaters will be operated by eight lead-acid batteries. The heaters operate at 10 watts. To melt the wax, the heaters need to reach about a temperature of $70^{o}C$. A circuit known as a Schmitt trigger will be used to reach and maintain this temperature for 30 minutes. A programmable controller will be used to control the experiment, switches and time-variables. The controller will receive its power from 4 lead-acid batteries. Upon the end of the mission, the resulting shapes of the resolidified float zones will be qualitatively analyzed.

References

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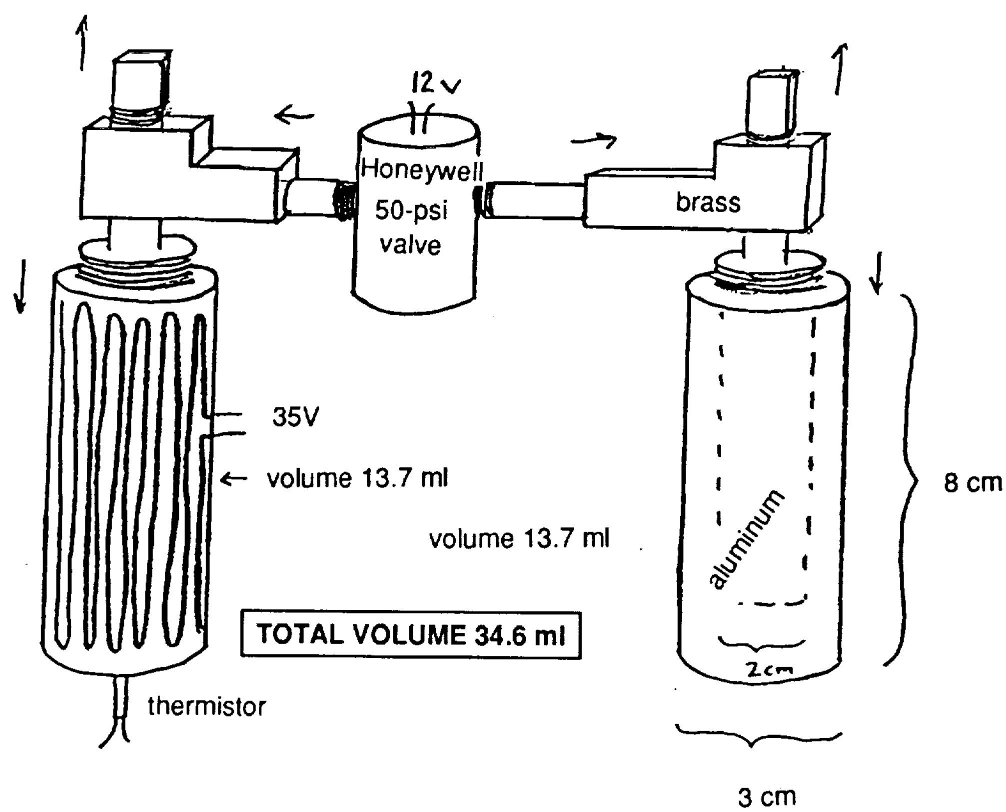

Fig. 3 Fluid containers and Solenoid valve (Spacepak 5)

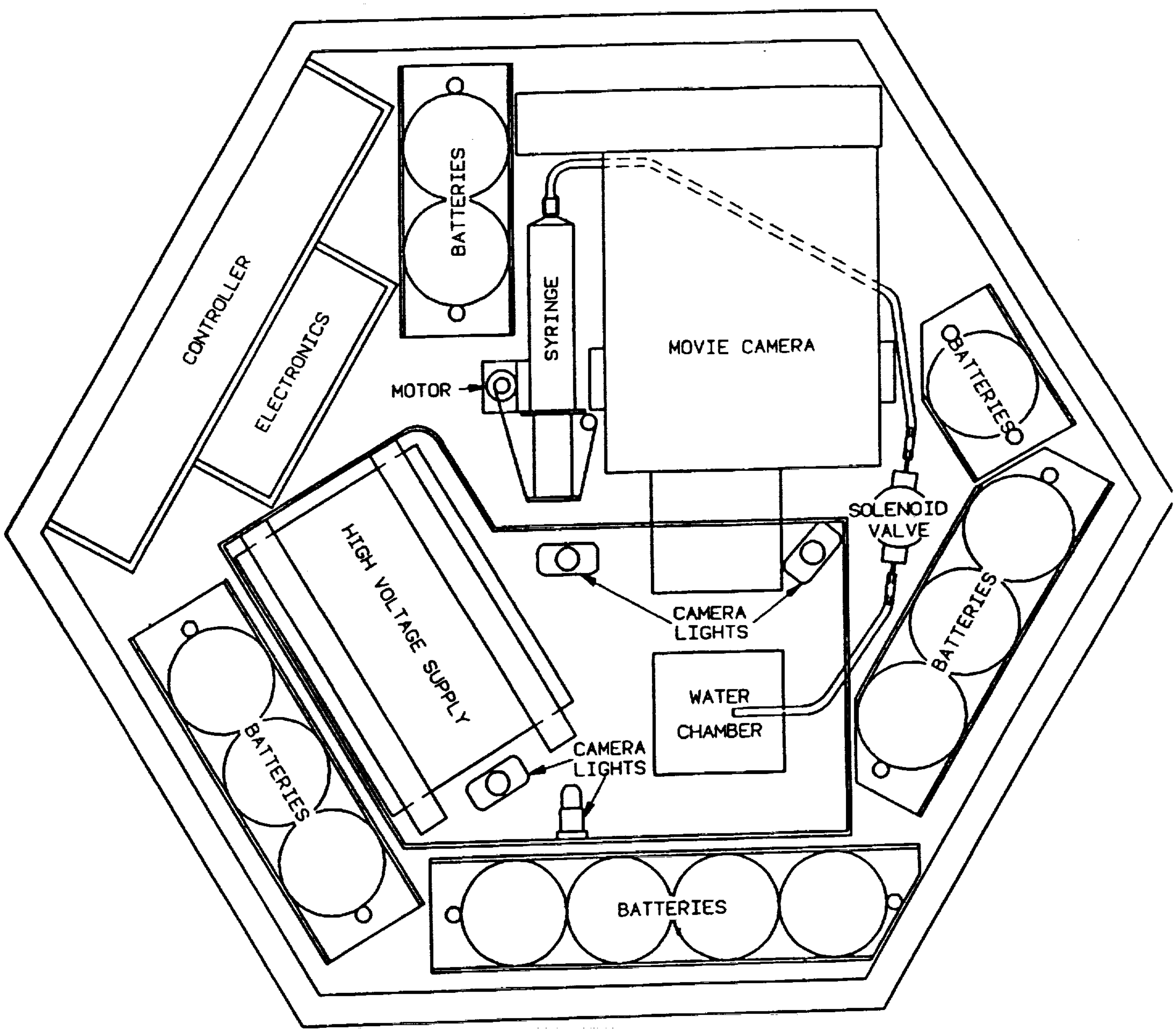

Fig. 2 Water polarization experiment configuration (Spacepak 2)

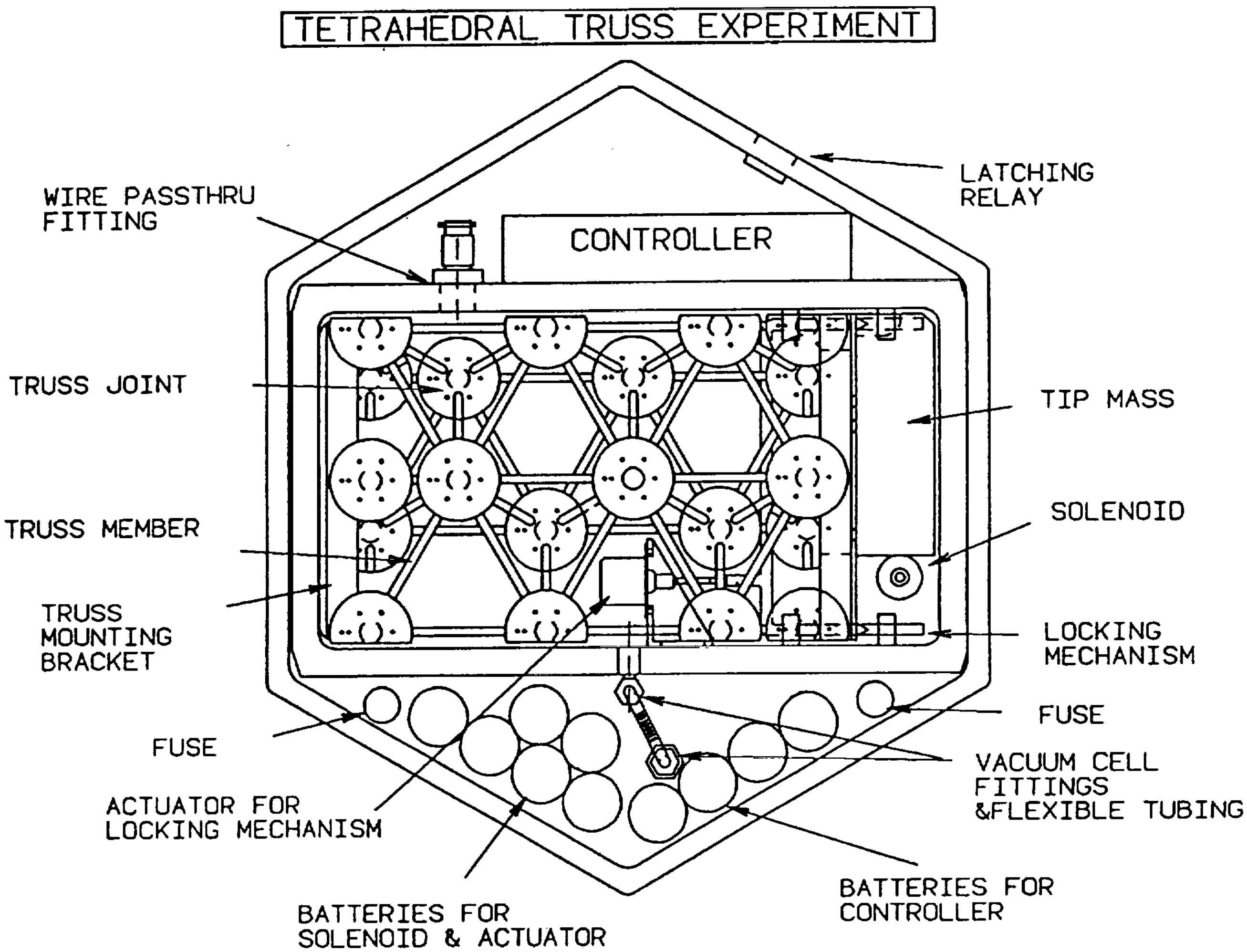

Fig. 1 Structural diagram of Spacepak 1