An Investigation of the Phototropic Effect on Seedling Orientation in a Microgravity Environment: a Student Involvement Project

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The prospect of extended space flight and possible space colonization demands that on-board systems be developed to provide a continuing supply of food to spacecraft occupants. A study conducted by Boeing Aerospace for NASA's Controlled Ecological Life Support System (CELSS) looked into the needs of such future space missions and concluded that occupants of future space stations could survive more economically by growing their own food. Astronauts have always carried their own food and oxygen and have stored their waste, but weight penalties for longer missions and larger crews could prohibit storing and resupply. Two examples of missions which would benefit from recycling are earth orbiting scientific space stations and military command posts, both of which, if they could produce fifty percent of their food needs, would become cost effective in five to ten years.[1]

Various systems have been proposed to utilize waste products to grow algae and bacteria which would be useable for human nutrition. However, as a food source, algae has caused gastrointestinal problems.[2] Experience has also shown that even conventional food products in squeeze tubes and reconstitutable form do not provide the psychological satisfaction that accompanies conventional food. Experience with Skylab and the space shuttle has demonstrated that eating can be done in a quite normal way.

Research on cultivation of conventional food plants in a space environment began early in the space program. A flight of wheat seedlings in Biosatellite II, launched September 7, 1967, revealed that short periods of weightlessness do not disorganize the normal process of growing wheat. Only small deviations from normal physiology or behavior were found, which returned to normal after several hours.[3] However, the lack of typical shoot and root system in the wheat plant made it difficult to predict confidently the results of growing plants with more complex organization in the absence of gravitational force.[4] In addition, the seeds began germination before launch and were in orbit only forty-five hours. Either situation could affect the outcome.

A student-designed experiment to test phototropic response and flown in Skylab for twenty-two days resulted in a random growth of rice seedlings and little phototropism. The proposed explanation was that the auxin distribution system of plants depends on gravity and without it the auxins may have been dispersed unevenly, thus causing irregular stem and root growth.[5] More recently, a plant growth unit designed by NASA Ames Research Center to carry experiments by Dr. J. Cowles and Dr. W. Shield to study the effect of hypogravity on plant lignin flew on STS-3. The results demonstrated a more positive phototropic response.[6] Variations in experimental design and conditions have produced conflicting or inconclusive results; therefore, a need for more work in this area is evident. The Getaway Special Program, with its low cost, provides a means by which more experimentation on phototropism may be conducted. In response to this opportunity, teachers and students at Brighton High School have designed a microgravity growth chamber to investigate the phototropic response of radish seedlings.

PURPOSE

The purpose for Brighton High School's involvement in the Getaway Special Program is twofold. First, we want to provide an opportunity for students to learn the scientific process by allowing them to design and conduct an experiment for flight on the shuttle. The experiment does not need to be unique nor the idea of one individual, but can be a team effort. Our emphasis is to stimulate interest in scientific investigation through hands-on involvement. Second, since more information about phototropic response in microgravity is needed, we could make a scientific contribution by designing an experiment which might add to that body of knowledge. We propose to build a functional growth chamber which will provide an environment conducive to germination and growth of plants and to investigate phototropic stimulation to determine if it is adequate to influence directional orientation in the growth of plant seedlings in a microgravity environment.

EXPERIMENTAL DESIGN

Due to their location in the payload bay, Getaway Special cannisters are exposed to extremes of the space environment. Depending on the experimenters' requirements, various options are available. The cannister may be sealed to maintain one atmosphere of pressure or vented to attain the vacuum of space. An opaque or transparent lid may be used at present, and the option of an opening lid is planned. All cannisters are covered with an insulating protective outer layer. For our flight, we chose an opaque lid and a dry nitrogen atmosphere at sea level pressure.

The two and one half cubic feet of space in the cannister was apportioned into three parts. Our share was a space four inches in depth by twenty inches across. The experiment was enclosed in a one-fourth inch thick, hexagonal, fiberglass-foam spacepak nineteen inches across corners. It consists of a growth chamber and germination tray, a water reservoir and solenoid valve, a florescent light, a Minolta X700 camera with programmable back, a 50mm macro lens and flash, a battery pack, and a computer controller. (see figure 1)

The growth chamber and germination tray are constructed from one-fourth inch plexiglass and painted inside with flat black epoxy paint to reduce internal reflection. To maintain one atmosphere of air, the lid seals completely. Its geometry evolved from a need for the camera to see across the entire face of the germination tray. Felt strips were glued to the inside to prevent creeping of excess water toward the transparent camera window. The germination tray contains a diaper liner medium on which seeds germinate. This medium was chosen for its ability to absorb water rapidly and hold it. A mesh placed over the individual seed windows prevents seeds from vibrating out at launch.

Surgical tubing was used as a reservoir for water because it could act as a container and pump to force water into the germination tray. Release of the water is controlled by an electrical solenoid valve. Tests determined the exact amount of water required to saturate the diaper material without leaking any into the growth chamber.

The florescent light apparatus used for photostimulation was obtained from a hand held battery powered light and operates adequately on four volts. Six ten amp Gates X cells provide current to operate the lamp.

Data acquisition and storage is provided primarily by a Minolta X 700 camera which is programmed to shoot a picture every two hours for thirty-six exposures. In addition, two temperature sensors and one light sensor located in the walls of the growth chamber provide temperature and illumination data. A computer-controller designed by Sawat Tantiphanwadi, of Utah State University, provides 8 K command and 34 K data storage capability. All systems were chosen for minimal power requirement due to limited battery capacity. The computer runs on six volts, the solenoid six volts, and the lamp on four.

EXPERIMENTAL PROCEDURE

After construction and trial runs, Getaway Special experiments are taken to Kennedy Space Center to be placed in a Getaway cannister. NASA engineers perform safety and operational checks, the cannisters are purged with dry nitrogen and readied for installation in the orbiter. At a predetermined time during the space flight, depending on shuttle and payload requirements, the astronauts send a signal to the Getaway Special latching relay which actuates the experiments.

When the latching relay actuates the computer-controller in the Brighton High School experiment, the sequence is as follows:

1. The solenoid valve opens to allow water to flow into the germination tray.

2. Seeds germinate in the dark for fifty hours.

3. At fifty hours, commands are given to turn on the camera and light.

4. The camera takes one exposure every two hours.

5. The light operates for forty-six hours.

6. At a total elapsed time of ninety-six hours, the controller shuts the system down.

7. During the entire ninety-six hours, the computer takes a reading of temperature and illumination each thirty minutes and stores it.

8. Within seventy-two hours after landing, we are able to pick up our experiment.

DISCUSSION

When we opened our experiment, we determined that it had not been activated. A malfunctioning latching relay had stuck and caused the battery power level to reduce to a point that, when astronauts gave the signal to start the experiment, it would not function.

Although the experiment did not activate, a major educational goal had been achieved. Students had taken basic concepts of geotropism and phototropism and designed around them a plant growth experiment to determine their effect in a microgravity environment. They further demonstrated a high degree of innovativeness in using off-the-shelf materials to construct a completely self-contained and self-controlled experiment. The experiment was run through its entire cycle many times and worked satisfactorily every time. Each subsystem was designed and tested thoroughly before the final project was integrated. Germination studies gave valuable experience to those students who patiently grew many types of seeds to determine the fastest germinating and most phototropically sensitive variety. Plans are being made and preliminary arrangements made to refly the experiment on STS 19 (51 A) in late October of 1984. The project will fly alone and will be equipped with a new space rated activating relay.

CONCLUSION

The prospect of extended spaceflight calls attention to the necessity for growing food in space. Preliminary experimentation has been conducted to determine growth characteristics of plants in weightlessness and results have been varied. A major conclusion is that more work remains to be done toward understanding the mechanisms of plant orientation in microgravity. Space research, which used to be limited to a few leading scientists, is now accessable to all levels of the educational community through the Getaway Special Program. Students are able to apply basic principles learned in class to exciting, mind expanding research projects.

References

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[5]Schlack, W. and Wordekemper, J. "Plant Growth and Plant Phototropism." Skylab Classroom in Space (NASA SP-801, 1977), p. 67-73.

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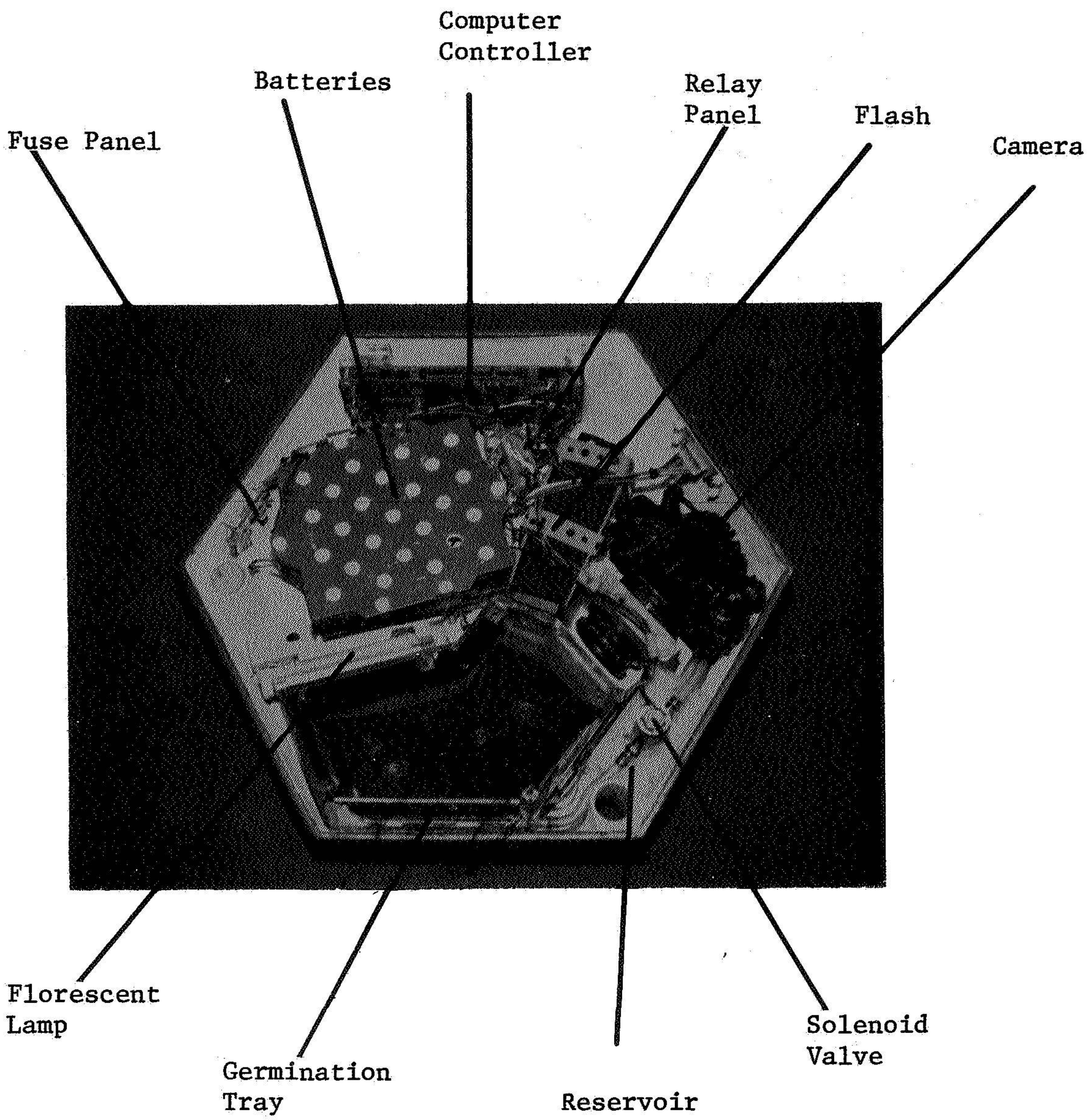
Figure 1



Top view of experiment showing growth chamber without cover. Spacepak construction is fiberglass-foam-fiberglass sandwich producing high strength and rigidity with minimum weight.