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GAS-007: FIRST STEP IN A SERIES OF EXPLORER PAYLOADS

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ABSTRACT

To date the Alabama Space and Rocket Center (ASRC) in Huntsville has undertaken the sponsorship of three Get Away Specials as part of its Project Explorer program for promotion of space flight and student participation in current space activities. The purpose of this paper is to review the history of Project Explorer, present preliminary experimental results, and describe future ASRC plans for Shuttle Get Away Special payloads, including GAS-105 and GAS-608. The involvement of youth attending the ASRC's SPACE CAMP is also briefly described.

GAS-007: FIRST STEP IN A SERIES OF EXPLORER PAYLOADS

As part of the NASA Get Away Special program for flying small, self-contained payloads onboard the Space Shuttle, the Alabama Space and Rocket Center (ASRC) in Huntsville has sponsored three of these payloads for its Project Explorer. One of these is GAS-007, which was carried originally on STS mission 41-G in early October 1984. Due to an operational error it was not turned on and was, therefore, subsequently rescheduled and flown on mission 61-C. This paper will review Explorer's history, outline its experiments, present some preliminary experimental results, and describe future ASRC plans for Get Away Special activities, including follow-on Explorers GAS-105 and GAS-608. Additional details on GAS-007 may be found in other papers prepared for this symposium by Chris Rupp, Ed Stluka, Arthur Henderson, and Frank Wessling and also in two earlier symposium proceedings (3,4,5,6).

BACKGROUND

Under the direction of Edward O. Buckbee, ASRC, as the official sponsor, has provided funds for purchase of the GAS-007 payload cannister. From the beginning it has cooperated with two local educational institutions, the University of Alabama in Huntsville (UAH) and Alabama A & M University, in the design, development, assembly, testing, and flight operation of the "can." The Alabama-Mississippi Section of the American Institute of Aeronautics and Astronautics (AIAA) and the Marshall Amateur Radio Club (MARC) have supplied technical support. The universities have furnished laboratory and research facilities. As Explorer has progressed, its manager, Konrad Dannenberg, has interfaced with NASA's Goddard Space Flight Center at major project milestones. Al Orillion has served as liaison to and from AIAA. In addition to these personnel, a number of specialist consultants have provided volunteer-expertise in various subject areas to support the project from its inception through completion of the flight.

As with other Get Away Specials, the Project Explorer payload was conceived and developed around a desire for simplicity and standardization. The container in which it is housed represents the largest of three choices of volume-weight cannisters. Physically it is a cylinder 28.25 inches high and 19.75 inches in diameter which contains a working volume of five cubic feet. GAS-007 met the NASA overall weight requirement for this size can, being under 200 pounds, including experiments and mounting pieces, at the time of shipment.

DESCRIPTION OF PAYLOAD

Explorer carried four experiments in its cannister which were originally formulated by its principal investigators as high school students. Experiment #1 is an investigation in microgravity of solidification of samples of two different alloys. Experiment #2 is a study of the germination and growth of radish seeds in the reduced-gravity environment. The third experiment is an arrangement for electrochemical growth of a complex inorganic crystal. The fourth part of the payload is designated MARCE, as it was prepared by the Marshall Amateur Radio Club (MARC). It represents the first-ever transmission of signals from the Shuttle for reception real-time by amateur radio operators worldwide. Some details of these experiments and their results from STS 61-C are given below.

PROJECT HISTORY

Conceived in 1978, GAS-007 navigated a long road of technical preparation and revision which included a number of changes in its flight schedule. It was subjected to and successfully completed its functional testing phase in the period March 3-16, 1984. In this operation all activities were performed in a laboratory exactly as planned to occur in the actual mission. A SPAR (Space Processing Applications Rocket) battery was utilized. A second major milestone, the system thermal test, was conducted April 7-13, 1984, to simulate the thermal environment expected and to determine any adverse effects on the design configuration. For this test a laboratory power supply was used. The chief result was the discovery that a nutrient pump in the radish growth experiment would freeze at -15 degrees C, and adjustments were consequently made to the heater power outputs for this experiment and for the crystal growth experiment.

The EMI (electromagnetic interference) checkout, conducted June 13, 1984, constituted a third significant test. With MIL-STD-462A as the applicable standard, the assembly was exposed to electromagnetic field radiation over a wide range of frequencies. No problems were found. The final major test barrier, a vibration test, was successfully completed during the period July 18-26, 1984. In this operation the whole assembly was mounted on a large shake table capable of supplying a range of vibration forces. The entire assembly, with its electric power applied for normal transmitter operation, was shaken in three dimensions over a range of acceleration forces. No loose connections were found and the results showed that GAS-007 met the required structural safety margins. Technical data from the vibration and EMI tests and a related stress analysis are given in an earlier paper (5).

The Explorer package was shipped to the Kennedy Space Center in late August 1984. Its checkout and integration into the Shuttle orbiter's bay followed. GAS-007 was carried on the STS 41-G mission by Space Shuttle Columbia, with launch on October 5 and landing at Edwards Air Force Base on October 13, 1984. It was determined, however, only late in the mission that because of an operational error the assembly was not activated as scheduled. Consequently no experimental data were acquired. A careful postflight analysis revealed no evidence of anomalies within the cannister and plans were developed for a reflight on a subsequent Shuttle mission.

A few minor actions were required for preparation for a new mission. Chief of these was the necessity to replace the main battery due to aging. Of the two SPAR battery spares, one developed a casing leak and the second exhibited low voltage in one cell. Because of the battery difficulties, assignment to mission STS 51-G was abandoned and an SRB (Solid Rocket Booster) battery was selected as a replacement. The new power source had a capacity of 50 amp-hours at 28 volts dc at the the time and therefore provided a greater reserve overall for GAS-007. Fortunately, also, this battery fit into the existing space occupied by its SPAR predecessor. Beside the battery replacement, a change in the MARCE transmitter was made when approval was received to upgrade its radio frequency power from 0.5 to 5.0 watts. Some minor modifications in MARCE software were also made.

On October 20, 1985, GAS-007 was shipped to the Kennedy Space Center for its reflight on STS mission 61-C. Following a period of checkout and integration similar to that for the previous 41-C mission, the 170-pound Explorer was launched on January 12, 1986. Carrying a crew of seven astronaut-pilots, payload specialists, and mission specialists, the Shuttle Columbia placed GAS-007 and ten other cannisters into an orbit 160 nautical miles high of 28.5 degrees inclination.

ORBITAL ACTIVITIES

GAS-007 was turned on, as scheduled by the Crew Activity Plan, at 11:50 (i.e., eleven hours fifty minutes) hours after liftoff. This action was accomplished by a crew member's keying numerical codes into the Autonomous Payload Controller (APC) inside the orbiter, activating two MARCE relays in quick succession and beginning a period of automatic operation. Because other papers planned for this symposium are devoted to some of the experiments on Explorer, the reader is referred to these for more detail.

Experiment #1, involving the solidification of two alloys in reduced gravity, was prepared by Arthur Henderson, a former graduate engineering student at Clarkson College of Technology who received an undergraduate degree at Alabama A & M University and is now a NASA-Marshall employee. In Henderson's experiment small samples of lead-antimony (Pb-Sb) and aluminum-copper (Al-Cu) hypereutectic alloys were heated, in separate furnaces, from ambient temperature to temperatures above the respective eutectic points, temperature-controlled briefly, and then allowed to solidify. A dedicated electronics package provided the appropriate timing, data management, and interfaces with MARCE.

Henderson's general objective was primarily to determine what differences in alloy structure and properties are produced with cooling under microgravity as compared with the Earth-based condition. He also sought to find out (1)whether any nitrides might be formed by leakage of gas into the samples and (2)the special surface effects applicable during solidification. Preliminary results indicate that the experimental design worked quite well, with both samples being heated as planned. The samples cooled, from the end of the temperature-regulation period to the phase-transition point (solid-liquid equilibrium line), at a rate of approximately 11-12 degrees C per minute. Analysis of the data was still underway at the time this paper was being prepared.

Experiment #2 was prepared under the direction of Guy Smith, who took his undergraduate degree at UAH and is currently Research Associate with the Johnson Research Center at the University. His experiment sought to investigate the germination and growth in space of a specie of radish seeds known as Raphanus sativus. Smith's experiment began as planned, with a small pump supplying a nutrient solution to the growth chamber. The chamber was equipped with a heater intended to sustain 20 degrees C. The plant rooting process was initiated and continued for some 79 hours instead of the anticipated 120 hours. The reduction in growth time was caused by a change in mission planning whereby an earlier-than-normal reentry was elected. When the decision to attempt the early landing had been made, a relay command from the APC signaled a second small pump to discharge a buffered formaldehyde solution into the chamber. This action terminated plant growth and preserved the products for analysis on the ground.

The major purpose of this experiment was to evaluate differences in tissue orientation and organization as they occur under microgravity conditions. After the mission had ended and the cannister opened for inspection, it was learned that the seeds had grown normally, producing plants with an outward appearance that resembles those grown on earth. The roots produced average one centimeter in length. Although the chamber was determined to have been significantly cooler than anticipated, this amount of growth is about as would have been expected for that range of temperatures under earth-based conditions. The plants have been sent to a professional laboratory for full analysis, including "embedding" and "sectioning," but data from those examinations have not yet been returned.

Jonathan Lee, an engineer at the BDM Corporation who received undergraduate and graduate engineering degrees from UAH, has been responsible for Experiment #3. His investigation was concerned with the electrochemical growth of single crystals of potassium tetracyanoplatinate hydrate (KCN) in an aqueous solution under the action of a small (1.3-volt dc) potential. Flash photographs were taken as planned every 40 minutes to document the growth process. Lee's chamber was also equipped with an electric-resistance heater, with its control point intended to be 10 degrees C.

The objectives of Experiment #3 were to produce single crystals of KCN; to investigate the governing reaction mechanism, which had is thought to be one involving electron transfer; and hopefully to evaluate the electrical properties of the product as a "linear chain conductor." A postflight inspection revealed that indeed the process performed quite successfully: four fine crystals, averaging about 2 millimeters in length, were formed as a result of the electrochemical action. These products actually represent two periods of growth, the first corresponding to the planned period of 24 hours, and a second, "bonus" period of 10 hours which arose after the first attempt at landing was waved off. Although the crystals are very much smaller than what would be expected for earth-like conditions, the growth process was demonstrated. This position is confirmed with the high quality photographs taken during the mission. The orbital environment was distinctly colder than that anticipated in advance, and this factor is most likely the major cause of the smaller size of the product. The on-off thermal cycling may also have influenced the results. Analysis of the experimental operation is not yet complete but the crystals seem to be too small to permit detailed examination.

The fourth experiment aboard GAS-007 is MARCE, prepared for the Project Explorer by Ed Stluka, an engineer employed with Teledyne Brown Engineering. As briefly mentioned above, MARCE is the first Get Away Special activity to conduct transmission of signals on an amateur radio frequency for reception around the world. Since details about MARCE were scheduled to be presented at this symposium by its principal investigator, only a summary will be given here.

As the electronic hub and lifeblood of the entire payload, MARCE consisted of four major components: an NSC 800 microprocessor, with its central processing unit and associated memory; a transmitter, with its accompanying dipole antenna; an analog-to-digital converter for voice synthesis; and the SRB battery, which served as the centralized payload energy source. Working in conjunction with the other components of GAS-007, MARCE (1)furnished electrical power, (2)provided timing and sequencing control, (3)acquired sensor data (cannister temperature and pressure) and experimental measurements for storage in memory, and (4)downlinked, i.e., transmitted, its data to earth-based "ham" radio operators.

The objectives of MARCE were essentially two-fold: to ensure, as best possible, the successful operation of the other three experiments and also to transmit the status of each to earth-based receivers in a real-time fashion. Operating at a frequency of 435.033 MHz, MARCE transmitted directly to Earth as planned with an effective radiated power of approximately 5.5 watts during three downlink cycles. In the first downlink the transmitter came on once every minute for a duration of 30 seconds; in the second and third downlinks, once every minute for 45 seconds. In some instances it was also possible to transmit the signals initially to the Oscar 10 satellite, which then relayed them to Earth at 145.972 MHz.

All the objectives of MARCE were achieved with great success. As Stluka reports at this symposium, "A total of 1,440 transmissions were programmed...485 messages have been received to date..." Altogether data for some 110 hours of payload operation were acquired and stored into the MARCE memory. Compared to the goal of a minimum of 120 hours, this total represents a 91% success.

When a decision had been made to attempt an early landing, GAS-007 was turned off by an APC relay command. Because of adverse weather at the landing site, the attempt was waved off. MARC then requested a second power-up of GAS-007, which was approved but which, it was later learned, did not lead to an additional (fourth) 8-hour MARCE downlink cycle of data. When a second attempt at landing was made, bad weather again forced a wave-off. As before, another (fifth) 8-hour downlink was requested and granted, leading to actual transmitter operation. A third landing attempt was likewise aborted, but no additional Explorer operation followed. Mission 61-C finally ended with reentry and landing at Edwards Air Force Base on January 18, 1986, after a bit over 6 days 2 hours of flight. After a short delay, the payload was picked up at the Kennedy Space Center and brought back to Huntsville for postflight analyses.

CONCLUSIONS AND RECOMMENDATIONS

All experiments on GAS-007 worked as designed. Only because of an orbiter environment which was substantially colder than planned were the results not more satisfactory in the cases of Experiments #2 and #3. It is not possible to be exactly certain as to how much better growth would have been achieved, but the experimenters for these investigatins strongly believe that better quality products would have been obtained if additional chamber insulation, more powerful heaters, and/or different Earth-orbiter orientations had been available. It is recommended that this experience be incorporated into future experimenter mission thermal requirements, i.e., planning for an environment of, say, 10-30 degrees C instead of 0-20 degrees C. Cooling provisions to control temperature excursions above 30 degrees C are felt to be unnecessary.

FUTURE EXPLORER GAS PAYLOAD

For several years ASRC has been operating the very successful SPACE CAMP program, which updates high school students on space activities, especially Space Shuttle operations, and the purpose of space missions. The Explorer program is intended to provide continued involvement in space activities for interested campers who have graduated from SPACE CAMP and are now back in school. It was decided that creating an opportunity for students to propose, and eventually fly, their own experiment ideas in space would be the best way to accomplish this goal.

It is of great benefit that ASRC has had a long-time working relationship with UAH relating to Get Away Special missions and their preparation. The University has provided invaluable assistance in the design, construction, and testing of the successful GAS-007.

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GAS-105

UAH was recently awarded a "Consortium for Materials Development in Space" agreement from NASA. Since no student proposals by SPACE CAMP attendees were ready for construction and installation at that time, ASRC offered UAH the next cannister, GAS-105, in return for previous cooperation on GAS-007. It was hoped that early flight opportunities for GAS-105 would greatly contribute to the basic knowledge in the area of microgravity sciences which would be made available to future SPACE CAMPers for new proposals.

The Consortium is now designing a series of microgravity experiments for GAS-105 in cooperation with scientists at such industrial organizations as GTE Research Laboratories, Celanese Research Corporation, and McDonnell Douglas Astronautics Corporation--Huntsville Operations. The payload is, therefore, of a commercial nature, but the experimental results will be used in SPACE CAMP classes. Some SPACE CAMP proposers will also have an opportunity to work on these experiments at UAH during their summer vacations and will thus acquire valuable experience for flying their own proposals.

These experiments are of particular interest to ASRC since they examine and test physical and chemical phenomena in space. They are, therefore, in contrast to the life sciences-oriented proposals normally submitted by SPACE CAMPers as a result of their high school backgrounds. The GAS-105 proposals are very difficult to perform in the highly restricted cannister . This payload demonstrates that many different space experiments are possible in the fields of physics and chemistry. ASRC expects that some of the equipment being developed will be useful, with slight modification as appropriate, for follow-on experiments by SPACE CAMPers.

GAS-608

This package consists of experiments proposed by SPACE CAMPers. Most will utilize space microgravity for the study of biological specimens but one will be devoted to crystal growth. Experiment #1, by Bryan D. Agran, will carry fertilized insect eggs for study on orbit. Comparison tests with identical life forms will be conducted on the ground under conditions as nearly similar as possible to those of space. Insect eggs have been chosen because of their availability, ruggedness, and small size. Experiment #2, by Jay S. Andrews, was originally planned to study the germination of bean seeds in microgravity. He is considering a change to radish seeds due to their faster response to the proper growth conditions.

Experiment #3, developed by Greg T. DeLory will investigate the effect of low gravity on the growth of yeast. One half of his test tubes will contain samples of yeast that grow mitotically (i.e., by budding); the other half, samples that grow meiotically

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(i.e., by producing spores). The test tubes will contain a fiber optic light source probe and photocell so that the concentration of yeast cells in solution can be determined in flight. The tubes will also carry small carbon dioxide, oxygen, and pH sensors. Experiment #4, by Tom P. Malone, is a study of the morphology of a species of phototropic bacteria grown in microgravity. Flight results will be compared with a control sample grown in full Earth gravity. Colonial morphology will be observed and recorded directly in space by means of a 35-mm camera. Individual and small-group morphology will be observed and recorded under the microscope once the bacteria have been brought back to Earth.

Experiment #5, prepared by Jawahar Nayak, will produce the antibiotic streptomycin. Incubation of the organism will occur in liquid media for 48 hours. A sterile environment and a temperature of 25 degrees C will be maintained for optimum growth. The output of streptomycin is to be compared with that for samples grown similarly on the ground. Experiment #6, by Seth A. Watkins will study the growth of silicon and/or gallium arsenide crystals in space and their production potential.

Consideration is also being given to a reflight of Jonathan Lee's GAS-007 crystal growth experiment in order to obtain results under more a closely controlled thermal environment. Several minor changes would be incorporated toward this end by Raymond Cronise in cooperation with Lee.

The Marshall Amateur Radio Club will again provide an SR2 battery as a power source for all experiments and will arrange for all data acquisition and management functions. All experimental requirements will be integrated with MARC-furnished equipment by local members of the L-5 Society. This support to ASRC is provided under the technical direction of Jan Bijvoet, formerly a representative of the European Space Agency and now employed by UAH and working for the Consortium. This activity is an excellent example of broad citizen involvement in future space developments and will lead to better understanding of associated problems as well as potential benefits to all mankind.

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