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PROJECT EXPLORER'S UNIQUE EXPERIMENTS: GET AWAY SPECIAL #007

by

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ABSTRACT

The Project Explorer payload represents the first attempt at broadcasting digitized voice signals via a Space Shuttle flight on amateur radio frequencies. These amateur ham-radio frequencies will be transmitting real time data while the experiments are operating. Experiments 1, 2, and 3 represent the work of students ranging from materials processing to the science of biology. Experiment #1 will study the solidification of two hypereutectic alloys, lead-antimony and aluminum-copper. Experiment #2 will investigate the examination and growth of radish seeds in space. Experiment # 3 will examine the electrochemical growth process of potassium tetrocyonoplatinate hydrate crystals and Experiment #4 involves amateur radio transmissions, monitoring and support of the entire GAS #007 payload.

INTRODUCTION

G #007 was flown in early October, 1984 on Space Shuttle "Challenger," STS-41G. However, there was substantial evidence that this payload was never turned on during the otherwise most successful mission. Because of this procedural error, G #007 did not yield the desired results. Currently, Project Explorer is tentatively rescheduled to fly in November, 1985, on STS-61B. In any event, a unique feature of this GAS payload will be its ability to demonstrate transmitting amateur radio transmissions to global ground stations around the world, real-time and in the English language.

Obviously, where there are new problems, changes in the paperwork must be amended accordingly. The one and only spare battery we had available unfortunately developed a crack in its outer casing which allowed the electrolyte substance to leak out. In addition, the only two battery vent valves we had were damaged during shipment of the GAS flight lid. G #007 was sealed and ready, we thought, for its June 1985 launch date, but last minute problems indicated the need to scrub, repair and replace vital components. The entire group inspected the overall package and found that a new SRB (Solid Rocket Booster) battery would fit into the same space in which the SPAR (Space Applications Rocket) battery was being accommodated. And with this new installation, only two components of the radio experiment had to be relocated. No other apparent problems exist.

This GAS experiment package consists of three micro-gravity experiments and an amateur radio experiment which permits data relay to receiving radio ground stations. The concept of the project is to design, develop and fly selected student experiments in the Space Shuttle's cargo bay and to obtain scientific data on the unique conditions of space flight, especially in the area of low-gravity conditions.

In 1978, the co-sponsoring agencies, the Alabama Space and Rocket Center, the Alabama-Mississippi Section of the American Institute of Aeronautics and Astronautics, Alabama A&M University, and the University of Alabama-Huntsville, from which it has required extensive technical support, undertook this project to encourage high school students to become involved in space-oriented engineering efforts. A brochure was developed and distributed nationwide to high schools throughout the United States soliciting proposals by students. The captivating brochure read: "Students, Can You See Your Ideas in Space?" Over 150 proposals were submitted and only thirteen students were selected. Today, only two of the original thirteen students remain with one other being a research associate, and the other being an invited guest.

Experiment Nos. 1, 2, and 3 use the micro-gravity of space flight to study the solidification of hypereutectic lead-antimony and aluminum-copper alloys, the germination of *Raphanus Sativus* radish seeds, and the growth of potassium-tetracyanoplatinate hydrate crystals in an aqueous solution. Flight results will be carefully compared with earth-based equivalents.

Experiment No. 4 features the amateur radio transmitter. It will also provide timing for the start of all other experiments. A microprocessor will obtain real-time data from all experiments as well as temperature and pressure measurements taken within the canister. These data will be transmitted on previously announced amateur radio frequencies after they have been converted into the "English Language" by a digi-talker for general reception.

OPERATIONAL SCENARIO

The G #007 payload will require a duration of five full days and a "turn-on" signal for the experimental package as early in the Shuttle mission as possible. Other operational requirements of the individual experiments are as follows:

Experiment No. 1: The solidification of alloys experiment will be timed so that solidification will occur under the best available micro-gravity conditions. At that time, a signal from the GAS Operations Panel within the crew compartment will trigger the operation of this experiment, via Experiment No. 4, for the first solidification sequence. Subsequent operations will be started by built-in controls and will not require additional signals from the crew. Another period of low-gravity operations for the second solidification sequence of this experiment will occur about a day later.

Experiment No. 2: The radish seed germination and growth experiment must be initiated as soon as feasible, i.e., at about the time the Shuttle reaches its orbit, to obtain the longest possible growth period for the seeds. Operational control will be provided by Experiment No. 4. Upon the initial G #007 power-up, a relay will activate pump "A" to supply the water-fertilizer solution needed to generate the seed growth. Upon power-down, approximately 120 hours later, another relay will activate pump "B" and freeze any further seed development by the application of a buffered formaldehyde solution to the seeds.

Experiment No. 3: Operational control will be provided by Experiment No. 4. Crystal growth will begin when the best micro-gravity conditions exist. At the beginning of the first available low-gravity period lasting 4 hours or more, Experiment No. 4 will power-up the electrolysis cell by a 1.3 Vdc power supply, and crystals will start to form on the anode. A 35 mm camera and its electronic flash will have been activated at the same time with a built-in time delay to take pictures every 40 minutes for at least 9 hours.

Experiment No. 4: The Marshall Amateur Radio Club Experiment (MARCE) will control all other experiments in accordance with individual requirements. The "ORBITER'S AUTONOMOUS PAYLOAD CONTROLLER (APC)" provides AFT-Flight Deck Control for experiments "toggle-on" and "toggle-off" and can also terminate all GAS operations if SAFETY NEEDS require such premature cessation of the experimentation.

The radio experiment's dipole antenna installed on the NASA-furnished GAS container lid will transmit from the Orbiter Cargo Bay during flight at the frequency of 435.033 MHz which has been obtained from AMSAT. This frequency will also be compatible with the OSCAR-10 (Orbiting Satellite Carrying Amateur Radio) for a possible relay link to the ground. A direct down-link requires the ground station to have an FM receiver with 16 KHz RF bandwidth and a 0.1 microvolt sensitivity. Ground antennas should have right circular polarization with at least 10 dB gain. To relay through the OSCAR-10 satellite, a 145 to 146 MHz two-meter receiving station will be required. After initialization by the Orbiter crew via APC, the transmitter "ON" times will be controlled by the MARCE-CPU for maximum experiment data downlink times and efficient power usage.

Three transmission cycles of eight hours each are planned. However, because of our "new" energy capability (about double the amp-hour of the old battery) it would be good to transmit every minute and also extend the cycle life to 12-16 hours, if possible. A transmission cycle consists of a 30 second transmission every minute. When Experiment No. 1 is active, transmissions will last 45 seconds. The first cycle will be activated by a Shuttle crew member at G #007 initial "toggle-on." The second, third and etc. cycles will be subsequently activated during the second crew "toggle-on" command. Furthermore, we highly recommend that HAM radio operators use a cassette recorder as well as our Data Log Sheets to record these data transmissions.

DESCRIPTION

All experiment packages and/or their components are mounted on a rectangular mounting plate, which is in turn bolted to the rib of a round plate which is bolted directly to the GAS canister top lid.

Experiment No. 1 will be a solidification study of two hypereutectic alloy samples (Lead-Antimony and Aluminum-Copper) melted and solidified inside an internally insulated aluminum cylinder (15 in. long and 6 in. diameter). It will house two small oven cylinders that will encompass two miniature furnaces (4½ in. high and ¾ in. diameter). The wall thickness of the oven cylinders is 1/16 in. thick. The melting furnaces are made of lava cores and are wrapped with Nichrome wire (spring coils). The alloy samples are centrally located in the middle of each furnace core, occupying a total volume of 1.0 cm^3, and can heat up to temperatures as high as 800°C. The heat is generated by a 28 Vdc electric current from a central power supply. Moreover, while the inner most part of the small oven is around 750°C, the outer most surface of the oven cylinder is around 60°C.

These alloys will be molten while contained in high purity alumina crucibles. A microstructural as well as chemical analysis of the obtained alloys will be compared with samples processed under similar environmental conditions on the ground. In addition, comparative mechanical tests will be performed on each specimen to determine the influential parameters that may or may not have altered the solidification process.

The DAQ2-K (Data Acquisitions and Control Unit) exterior is also made of aluminum and it contains the experiment control system which supervises the two separate metallurgical experiments. Its primary functions include measuring temperatures of the two experimental vessels, storing measured values for later recall, operating the two ovens used in the experiment and sending experimental data to the external telemetry equipment in Experiment No. 4. The experiment control system has two modes of operation, normal and test. The normal mode is used during flight to run the experiments solely under control of the internal experiment system (DAQ2-K). The test mode is used in the laboratory to insert and display the experiments' parameters via the DAQ2-Console Control Package (a KAYPRO II portable computer).

During operation of the experiment, data is sent to the external telemetry equipment (located in Experiment No. 4) once a minute via a TTL serial data port in Experiment No. 1. If the system is operating in the test mode, identical data is also routed to the RS232 port. Telemetry data consists of identification modes currently executing the current time as maintained by the system and the measured values from the eight thermocouples. These messages are formatted on a computer as shown below and are terminated by a carriage return and line feed:

AA T=HHMM TC1=RR TC2-RR TC3=RR TC4=RR TC5=RR TC6=RR TC7=RR TC8=RR

Where AA is a two character abbreviation of the current mode, HH is the current hour in 24 hour format, MM is the current minute, and RR is the actual temperature reading – all in hexadecimal notation. This experiment weighs less than 30 lbs.

Experiment No. 2 will be a comparative morphological and anatomical study of the primary root system of radish seeds conducted inside an aluminum rectangular container, about 270 in.^{3} in size. This experiment will demonstrate the ability of rapid germination and subsequent seed structure growth. Differences in tissue orientation and organization will be examined under the microscope after return from the mission and will be compared with normally grown seeds. Intercellular adjustments occurring during best available micro-gravity conditions will thus be determined.

The radish seeds will be held in place by filter paper as the growth substrate. Gear-type pumps will initially deliver a water-fertilizer solution to the seeds, and at the end of the mission supply a buffered solution of 5% formaldehyde in isopropylalcohol to stop any further growth during descent and disassembly after return. The radio experiment will provide control of the radish seed operations as follows: One hour after initial power-up, a control relay will be closed for 30 seconds and thus activate pump "A" which supplies the water/fertilizer solution to the seeds. Prior to GAS power-down (approximately 120 hours later) a second control relay will close for 30 seconds and thus activate pump "B", which supplies the buffered formaldehyde/ alcohol solution.

This experiment will require a temperature of 30°C plus/minus 10°C. Should temperatures inside the growth chamber go below 20°C, a small heater will be activated to maintain required temperatures. There will be no cooling provisions for temperatures above 40°C.

A turn-on signal as early in flight as possible is desired to assure an experiment operations time in orbit as close to five full days as possible, or more. Again, best available micro-gravity levels are desired, but 10^{-3} g's is acceptable. This experiment will weigh not more than 15 lbs.

Experiment No. 3 will be a crystal growth study of metallic appearing needle crystals in an aqueous solution of Potassium Tetracyanoplatinate. This experiment will be conducted in an electrolysis cell of 6 ml in volume. The solution carried is a 0.3M concentration. The cell is made of plexiglass and fitted with two platinum electrodes. The overall experiment volume will occupy 0.5 ft^3. Upon application of an electrical potential, nucleation and crystal growth are effected at the anode. A very minute amount of hydrogen gas is released at the cathode. The optical system consists of a 35 mm NIKON F-2 camera with a 50 mm close-up lens; camera autowinder MD-3, with camera battery pack MB-1; and a small NIKON SB-E electronic flash. The battery pack holds 10 AA size batteries (15 Vdc) and is used to power the camera. The electronic flash holds 4 AAA size (6 Vdc) batteries. This experiment requires a micro-gravity duration of approximately 72 hours for completion. Camera operation will be synchronized with the flash to photograph the crystals at a rate of one exposure per forty minutes.

A thermister is attached to the electrolytic cell to monitor the temperature fluctuations of the experiments' environment. This experiment requires a temperature of 20°C plus/minus 10°C. Should temperature inside the electrolysis cell go below 10°C, several small heaters will be activated to maintain required temperatures. The precision reference supply and a control timer will be furnished by Experiment No. 4. This experiment will weigh less than 10 lbs.

Experiment No. 4 will be an amateur radio experiment that will provide information on the "Project-Explorer-Payload-elapsed-time" and the operational status of experiments (such as measurements in canister) during flight by down-linking data to all amateur radio stations and short-wave listeners (SWL) around the world. The data will be transmitted by voice in English at 435.033 MHz, so that amateur radio operators and SWL's around the globe can participate. The Marshall Amateur Radio Club (MARC) identification signal "WA4NZD" will be included at the beginning and end of each transmission. This experiment will acquire these data for input to analog-to-digital converters through signal (hand-shake) lines. A voice synthesizer Digitalker system will convert the experimental data into "English" and will modulate the transmitter.

A surplus SRB battery will furnish the power at a nominal 28 V and 50 Amp-hours. All measurements will be stored in a microprocessor memory for post-flight analysis. All data will be taken every 10 minutes for a total operation time of 120 hours. Receiving amateur radio stations will record the measurement data and relay the information via High Frequency amateur radio channels to MARC at the Marshall Space Flight Center in Huntsville, Alabama, and other interested parties (to be determined). It may also be possible to utilize an existing OSCAR satellite in orbit for this purpose. In the event of objectional radio interference with Shuttle operations, the radio transmitter can be turned-off to assure safety of Shuttle operations.

The data system uses a CMOS micro-processor central processing unit (CPU) with an 8k byte memory, a 2k byte EPROM program memory, Input/Output/Timer (OT) and a 128 bytes scratch-pad memory for temporary (volatile) storage. A 4 MHz crystal provides the base for a CPU and a timer. A back-up battery (2 D cells) is used to retain memory when the CPU power is removed.

The weight of all equipment for Experiment No. 4 aside from the battery will be about 10 lbs. Total volume this experiment takes up is only 0.8 ft^3. A 45 lb surplus SRB battery will provide the overall power at 28 Vdc and 50 amp-hours. It has a total volume of 0.4 ft^3.

SUPPORT STRUCTURE

The support structure for all G #007 experiments consists of two primary plates and four "bumper" assemblies. One of the primary plates is a round plate which mounts to the GAS canister top lid. This round plate has a machined rib along a diameter, to which the second rectangular plate divides the GAS canister volume into two equal halves along the longitudinal axis. The bottom of the rectangular plate, which supports all experiments, is supported by four "bumpers" contacting the inside of the canister. Two of these "bumpers" are mounted on the lower corners of the rectangular plate. The other two "bumpers" are mounted on "T" mounts perpendicular to the faces of the rectangular plate.

TECHNICAL LESSONS LEARNED

On November 16, 1984, the Explorer Team officially learned from Goddard Space Flight Center that the G #007 payload was never turned on during its scheduled 8 day Shuttle flight October 5-13, 1984, STS-41G. Because of this error, neither of the four experiments obtained the long awaited results. Furthermore, based on the post flight inspections and analysis, the Explorer Team concluded; all four experiments, the structural assembly, and the integration hardware withstood the launch and Shuttle environment in all respects from liftoff to landing. The Principal Investigators, as well as the entire Explorer Team learned a great deal about flying and re-flying a Shuttle GAS payload and are continually learning day by day that things do not always go according to plans. These lessons will be gladly passed on to other interested parties and future GAS payload users.

Moreover, even from the simplest of experimental ideas, there is much, much more than meets the eye. The main lesson learned was the complexity involved in preparing a simple GAS payload – in addition to the reams of paper work. From the initial ideas, design and fabrication, to integrating the four experiments into one functional package, made the whole endeavor invaluable for the Explorer Team.

For Experiment No. 1, the major problem was finding a way to monitor and store the experimental parameters during operation. This problem prompted the development of the DAQ2-K.

For Experiment Nos. 2 and 3, the main problem was maintianing a constant temperature for an extended period of time. Miniature heaters were designed to facilitate this problem. In addition, for Experiment No. 3, recording the KCP crystal's growth was questionable until a modified 35 mm camera was acquired.

Experiment No. 4's major hurdle was obtaining approval to mount an external antenna on the outside of the GAS canister. In addition, damage to the battery vent valves and the battery case cracking developments also presented some unforeseen problems. However, these problems were also reworked and resolved.

Overall, Project Explorer has come a long way from its initial beginning and has accomplished 95% of its original objectives. The real test, "during Flight," is yet to come.

ACKNOWLEDGMENT

The G#007 payload could not have been completed without the dedication and total commitment of the student P.I.'s and the MARC P.I. who also made gallant achievements in preparing their individual experiments. Also, thanks and appreciation to the Co-Director, Project Manager, the Integration Team, and countless others who have contributed immensely in making this payload a success.