PENN STATE GET AWAY SPECIAL

G-62

Mike Thames Penn State
Dave Moul Penn State
Bob Birman General Electric Space Division

June 1, 1984

INTRODUCTION

The Get Away Special program at Penn State has become a major factor in the education of a large number of engineering students. The Penn State GAS program started in the winter of 1981 with the donation of a 2.5 cubic foot canister by the General Electric Space Division, which is located in Valley Forge, Pa. With the full support of the Space Division's Vice President Al Rosenberg and the Military Payloads Division Manager Bill Phucas, the Penn State GAS program was able to utilize the GE satellite testing facilities to insure the payload's success. Bob Birman, the GE program Manager, has been instrumental in obtaining exotic space rated materials and much needed technical advice. Although Mr. Birman's job is in the Military Division, his expertise with the Space Division and its' personnel has been crucial.

In addition to some monetary funding, GE has donated the services of its' thermal vacuum and vibration testing personnel and facilities. Full scale testing was accomplished in November of 1983 during a period of two weeks. The tests represented state of the art spacecraft testing available to only major aerospace corporations. The testing is believed to have surpassed all previous GAS program testing, including that done by NASA.

The canister was donated to Penn State's College of Engineering through the assistance of Dean Wilbur Meier. The Administrative duties at Penn State are being handled by the Associate Dean of Research, Dr. Edward Klevans. Dean Klevans, in addition to the GAS program, handles many high tech research programs at Penn State, and is adept at cutting through bureaucratic red tape. An open call for experiments was made by Dean Klevans to the undergraduate engineering students in December of 1981. The tentative ideas were presented and a feasability analysis of each idea was conducted by the students themselves. The three experiments chosen were selected by the junior students and their faculty advisors. The experiments investigate critical problems whose solution requires a micro-G environment. Groups of students volunteered to work on the experiments on their own time, and a few turned their work into undergraduate theses. Initially this was to be a one-year project with few credit-hours and little funding offered. Two and a half years and twelve thousand dollars later, the full scope of such an undertaking has been realized.

The major funding for this project has come from the Penn State Engineering Society which is composed of the PSU engineering alumni. The alumni have been very understanding about the monetary needs of a program of this scope. Minor funds were solicited from some of the engineering departments and their professional societies. The project was housed in a small room in the basement of an old engineering building, acquired with the help Bob Houtz of the College of Engineering.

EXPERIMENT DESCRIPTIONS

The three experiments to be flown are unique in that they address problems currently under parallel investigation by major corporations. The experiments have been designed, constructed and tested by the students without professional aid. The Convection experiment was designed and fabricated by one student, Mark Kedzierski. This experiment will isolate the effect of convection in heat transfer. There are three modes of heat transfer: radiation, conduction, and convection. These three modes are inherently linked in the one-G environment of Earth and it is empirically difficult to separate their individual effects. The convective effects may be determined by comparing the results of this experiment performed in space and on Earth.

The experiment consists of three concentric cylinders. The inner cylinder contains a resistive heat source that will heat oil between the inner and middle cylinders. There will exist a partial vacuum between the middle and outer cylinders. The temperature measurements will be spatially recorded by 16 high sensitivity thermobeads. Heat transfer will be measured, and after comparison to one-G results, the effect of convection in heat transfer will be determined.

The Terminal Velocity experiment headed by Jeff Rice and Brett Kline will determine the effect that a micro-gravity environment will have on a liquid's surface tension. One method of finding a liquid's surface tension is to measure its' terminal velocity, which is the highest speed a liquid particle can strike a hard surface without breaking apart. Surface tension is directly proportional to the liquid's terminal velocity.

This experiment will determine the terminal velocity and hence the surface tension of two liquids in space by injecting droplets into the path of a moving piston, which will strike the droplets and send them to a special retaining foam donated by Scott Foam, Chester, Pa. This procedure will be repeated in its' sealed pressure vessel with the piston moving slightly faster each time, until the droplets begin to break up upon impact (i.e. when the terminal velocity has been reached). The impacts will be recorded photographically by a 35mm Nikon camera. This will yield the piston's speed at time of impact. By comparing the results with the results from a one-G simulation, with all other factors constant, the effect of gravity on surface tension may be determined and hence help quantify surface tension formulae.

The remaining experiment investigates the problem of liquid slosh in spin stabilized satellites. Group leader Joe Bieber and his team of Aerospace engineers hope to measure the slosh forces and observe photographically the slosh motion resulting from a perturbation in a model satellite propellant tank. Propellant slosh in spacecraft dissipates energy, thus resulting in spacecraft nutation. Nutation is a wobbling motion about the spacecraft's spin axis. This, if left uncorrected, can render a spinning satellite useless. For example, a spinning satellite used for a communication relay requires very precise pointing accuracy, and liquid slosh can hinder this. The prototype system for this experiment is the COMSAT INTELSAT IV communication satellite. COMSAT has experienced and investigated this problem but it still remains unresolved. Hughes Aerospace and Ford Aerospace have expressed interest in the results.

The liquid slosh experiment will simulate the INTELSAT IV satellite undergoing an attitude maneuver. Two conispherical tanks, manufactured from clear acrylic and filled with an aqueous solution, will be mounted on a spin table rotating at about 180 rpm (a spin rate which will provide dynamic similitude between the model and prototype systems). The table will then be impulsively tilted and the resulting slosh motion will analyzed and recorded. Two modified World War II vintage 16mm gun cameras will visually record the slosh motion at a rate of 16 frames/sec. The lighting will be provided by an array of LED's, which will necessitate the use of KODAK's extended red sensitivity Tech-pan 2415 film. This film, which was selected and donated by Bob Anwyl of KODAK's scientific and technical department, has an ESTAR polyester base to survive vacuum exposure and will be an unique test in itself of photography in space.

High resolution piezoelectric force transducers being used to measure the resulting slosh forces (and yet withstand a high-G launch), were acquired through the invaluable assistance of Paul Bussman of Kistler Instrument Corp. of Amherst NY. The simulation will be repeated for three different fill ratios at three different spin rates. This will provide a photographic record of the acutal slosh motion and an analog record of the associated forces for nine attitude conditions. This experiment will do much to help assess and quantify a very important problem in spacecraft dynamics.

ELECTRONICS

The electronics involved in the operation of these experiments are the concern of Steve Herr and his team of Electrical engineers. They have developed the power, sequencing and data recording systems for the three experiments. These systems will have to withstand a high-G launch, vacuum, temperature variations and incident radiation.

The electrical power will be supplied by an array of Gates Lead-Acid cells. These cells were chosen due to their consistent safety characteristics in space, a prime concern of NASA. NASA has imposed a three month waiting period prior to launch, which seriously affects the power capacity at launch . Due to these and other factors, low power CMOS circuitry was used throughout the design. Many state-of-the-art CMOS components were donated by INTEL, National SemiConductor, and Harris Corp.

Because the astronauts' control of the experiments is limited to three on-off switches, the experiments must be internally controlled and sequenced. This will be accomplished by the recently developed NSC800 low power microprocessor, which requires the newly released 74HC CMOS support chips. This entire system will be unique in that it has the low power characteristics of CMOS and the high speed characteristics of 74LS Schottky. Using these chips, the power dissipation for the entire mother board averages only 200 milliwatts. This eliminates the need for extensive heat-sinking. This system also has the advantage of having an access time of 200 nanoseconds, rather than the 450 nanoseconds common to standard CMOS. It is believed that these characteristics will increase the reliability and survivability of the electronics package.

The data storage will be accomplished through the use of an INTEL 1 MEG magnetic bubble memory. This device will record the data physically rather than electrically; this is necessary due to the inevitable battery discharge. Harris Semiconductor Corp. has donated 256K CMOS RAM for the scratchpad memory that will be loaded into the bubble. The data storage for the convection experiment will use two EEPROMs recently developed and donated by INTEL. These are exceptional in that they only need 5 volts to write into PROM. This data is then permanently stored until purged.

The electronics have to survive extreme environmental conditions, which has mandated the use of high technology components. It is believed that the system designed is far superior to any flown in previous GAS payloads. This will be a unique test of whether undergraduate engineers can assemble a state-of-the-art microprocessor and bubble memory recorder that outperforms the best 'ready-made' systems available today. This attempt would not have been possible without the donation of prototype components that are not on the market as of yet. Thanks to many individual and corporate contributions, this GAS project is utilizing the cutting edge of technology.

TESTING

The extensive testing of this payload would not have been possible without the donation of a test canister by the PSU College of Engineering. This canister was built to NASA specifications and was vibration tested, along with the student built support structure, at HRB Singer in State College. The fundamental resonant frequency of the canister with a simulated payload was determined. This was done to insure the simulation canister's survival through actual testing and to recognize the canister's contribution to the payload's fundamental frequency. The individual experiment components were vibration tested at the PSU Mechanical Engineering Dynamic Structures lab. The payload construction materials were mechanically tested to insure their structural margins of safety. Various epoxies and fasteners were also mechanically tested to determine their suitability in payload construction and environment.

When the actual payload was finished, full scale testing was scheduled at GE when their facilities were not in use. Three axis vibration testing was completed to NASA specifications. Full spacecraft vibration testing was found to be more complicated than implied in NASA literature. The initial testing procedure was designed wholly by the students, but during actual testing it was found that, through lack of experience and information, the procedure was in need of modification. This was accomplished through consultation with GE's helpful technicians. The testing period was originally scheduled for two days, in reality it took a week. An important lesson was learned about the realities of scheduling.

The thermal-vacuum testing followed the vibration testing and was originally scheduled for three days. However, it also took a week. The test canister was equipped with a student-sewn thermal blanket made to NASA specifications. It was composed of five layers of dacron felt, two layers of aluminized mylar spaced with nylon netting and a covering of beta-cloth. In addition to the blanket, a thermal shroud was student fabricated to simulate deep space conditions. This was an aluminum canister that uniformly surrounded the simulation canister; resistive heating pads on the outer canister radiated heat to simulate the hot case environment (+90 C). The cold case (-60 C) was achieved through the circulation of liquid nitrogen through the vacuum chamber. The test canister and payload were cycled through hot and cold worst -case temperature extremes in a vacuum of 10(-6) torr. The cycles simulated orbiter hot and cold cycles as documented by the Flight Verification Payload (FVP) flown on STS-3. Internal payload components were operated during the hot cycles to insure worst case heat dissipation effects. At no time during the testing did the internal payload temperature exceed +30 C or drop below + 15 C. It is hoped that the NASA built insulation will perform as well as the student built insulation.

One of the more interesting setbacks in the PSU GAS program occurred several weeks before a scheduled delivery date for the payload at the Cape. The Gates batteries installed in the payload were found to be of a different size than those tested by NASA. It had previously been assumed that all Gate´s cells were flight qualified on the basis of tests conducted by NASA for the Utah State payload. The PSU canister utilized a larger version of the same batteries, but this specific size had not been flight qualified. NASA then required either replacement of the cells with approved sized cells, or flight qualification testing by Penn State. Penn State opted to test the batteries themselves, rather than settle for a smaller capacity power supply. Another purpose of the test was to prove the cells could be safely sealed witin the battery box. GE ,on short notice, supplied a 1960´s vintage gas chromatograph out of their salvage warehouse. This unit had to be recalibrated and rejuvenated by the students due to its long period of disuse. The Aerospace engineers working on the project then had to effectively become chemical engineers to properly operate and evaluate the chromatograph. The batteries completed tests under various conditions of loading, shorting and standing; the gasses generated had to analyzed quantitatively and qualitatively. It was found that a minimal amount of hydrogen was generated under the worst case shorting conditions. Despite this, the battery expert at Goddard recommended that all battery boxes be vented into the cargo bay. This resulted in a last minute structural redesign to accomodate the plumbing and filters and also the dropping of a fourth PSU experiment that had originally been planned. It was learned here that the individual experimenters must conduct their own safety analysis and not rely upon outside sources to find all existing hazards.

CONCLUSION

The Get Away Special program is important in that it provides actual engineering experience. General Electric's donation of the canister to Penn State has done much for the education of the many engineering students who worked to place the experiments in orbit. Without GE's support in many uncountable areas, this project could not have achieved the level of confidence it now holds. It is obvious to PSU GAS members that to properly complete any type of GAS project an aerospace sponsor is necessary to fully understand the various problems encountered in space. The technical level of this payload far exceeded Penn State's and GE's initial estimations. Many of the problems encountered could only be solved by the experts at GE's Space Division, who were often surprised at the level of the questions. The technical level was only made possible by the sponsorship of an outstanding aerospace corporation, like GE.