N88-17697

AN UPDATE TO THE MITRE/WPI SPACE SHUTTLE PROGRAM GASCAN G-408

F. J. Looft, Ph.D
Associate Professor
Electrical Engineering

W. D. Durgin, Ph.D
Professor
Mechanical Engineering

Worcester Polytechnic Institute - Worcester, MA 01609

ABSTRACT

The objective of the MITRE/WPI Space Shuttle Program was to develop a set of scientific meaningful experiments that could be flown in a Get Away Special Canister. Currently, the first GASCAN is finished (G-408) and ready to be launched. The program has been so successful that the design and development of a second set of experiments has been started (G-533). This paper will describe and summarize both of these programs.

I. INTRODUCTION

The MITRE/WPI Space Shuttle program was started in December of 1982. At that time, the objective was to have WPI engineering students develop a set of experiments that could be flown as a Get Away Special (GAS) payload during the 1985-86 academic year.

As with any complex program, we were overly optimistic and did not finish our first payload until late 1986. In addition, because of difficulties in performing a finite element analysis of the experiment support structure [4] and the submission of the required NASA safety documents, this payload has only recently been ready for space-flight.

The primary purpose of this paper is to describe certain aspects of our first payload. Because of the success of the first payload development program, we have started the development of a second set of experiments. Consequently, some details of these experiments will be provided. Finally, a brief overview of the organization of our joint university/industry program will be presented.

II. PROGRAM OVERVIEW

In December of 1982, the MITRE Corporation of Bedford MA and Worcester Polytechnic Institute (WPI) of Worcester MA entered into a cooperative agreement of joint sponsorship for the design and implementation of a Get Away Special Canister (GASCAN) payload. For MITRE the agreement was a logical follow-on to a variety of NASA related work conducted by the corporation for the past ten years. MITRE's aim was to use the project as a means to obtain first-hand knowledge and experience with NASA space operations and procedures. For WPI, it was an excellent opportunity to couple the college's project oriented educational philosophy to the real-world problems of system development [3].

The Major Qualifying Project

One of the unique aspects of

the WPI degree program that was particularly amenable to the development of this program was that each undergraduate student was required to successfully complete an intensive, year-long technical project [5]. This project, known as the Major Qualifying Project or simply MQP, typically encompasses four seven-week terms (one academic year).

The MQP was important to our decision to join in a cooperative development program because it was a key factor in the implementation of a multiyear program to develop the experiments. In addition, because of a significant number of prior MQPs that were supported and co-advised by industrial contacts, there was a mechanism in place to manage projects supported, in part, by industry. Thus, the WPI project environment was ideally suited to the Space Shuttle venture.

The multiyear program that was developed was based on a five term (one and one-quarter year) commitment by students and a multiyear commitment by faculty advisors. It was recognized early in the planning stages that the uniqueness of the experiments, the intended environment and the overall complexity of the experiment development process warranted a long-term commitment by both the advisors and students to ensure the program's success.

Project Groups

An average of 40 students a year, primarily representing the disciplines of electrical, mechanical and chemical engineering have been involved with experiment development. These students have generally been divided into teams with from two to six students and with one to three faculty advisors.

Approximately fifteen WPI faculty members and five MITRE engineers/scientists advise the projects on a regular basis. The advisors meet with their student team members 2-3 hours/week. Students are expected to spend approximately 17 hours/week on their project. Overall, the level of a student's activity is equivalent to one-third of a full academic load per term, for each of the four terms during their senior year.

Program Management

The management of the joint program has been in the hands of a Technical Steering Committee (TSC). This committee is composed of four WPI faculty and one or two MITRE engineers/managers. The responsibilities of this committee have been to insure that (a) the GAS canister was filled with experiments, (b) that the experiments were developed in a manner that would result in functional and reliable hardware, (c) that the experiments would comply with all applicable design, safety, scheduling and budgetary requirements and (d) that the experiments were scientifically significant. As with most committees, the day-to-day operations of the program, the generation of the required safety documents (PAR, PSDP, FSDP, P3SDP) and interactions with the GSFC technical liaison were the responsibility of the committee chairperson.

The general organization described above has worked extremely well during the development of our first set of experiments (G-408). As a result, a new TSC has been formed and a new chairman appointed for the development of the second set of GAS experiments (G-533).

III. EXPERIMENT CHOICE

Scientifically, we have attempted to encourage the development of original experiments that have not previously been conducted in the space environment [2]. Although our funding is not commensurate with what one normally expects to spend for long-term space flight and/or complicated space flight experiments, we believe that each of the proposed experiments will provide unique scientific data or prove an original engineering concept.

An interesting aspect of all the experiments is the emphasis on integrating and understanding diverse systems from various fields representing the basic sciences. At a time when many students, particularly at the high school level, are minimizing their involvement in the basic sciences, it has been refreshing to have a program where the fundamental goals of each experiment are embodied in a good understanding of physics, chemistry and earth sciences.

IV. THE FIRST GASCAN (G-408)

Each of the experiments that are part of this package will be described. We will note both the status of the experiment, the concept we wish to test and, very briefly, how we intend to perform the test. Obviously, much more detailed information can be found elsewhere [1-4,6].

Film Sensitivity Experiment

This experiment will test for film fogging as a result of exposure to the radiation encountered during low Earth orbit. Small pieces of black-and-white film are sandwiched between thin, light blocking sheets of a composite material. An optical densitometer has been designed to evaluate the amount of fogging, if any, that occurs. The results from this experiment will have a direct impact on an experiment being developed for our second GASCAN.

Zeolite Crystal Growth Experiment

This experiment will determine whether a low acceleration level environment will promote the growth of large zeolite crystals in a small, heated reactor vessel. A liquid growth solution will be brought to the reaction temperature and stabilized at that temperature for three days. An electronic controller will maintain the required temperature, activating a heater coil wrapped around the autoclave when necessary. The entire unit is contained in a super insulated vacuum canister to minimize heat loss and power consumption.

This experiment is particularly intriguing since it was developed under the auspices of a faculty research project. Subsequent to the development of this experiment, the faculty advisors applied for and received funding to continue research on the growth of zeolite crystals in a low acceleration environment.

Fluid Behavior Experiment

Several methods for measuring the behavior of a two-phase fluid system in a low acceleration environment will be tested. Two identical measurement chambers will be used; one containing a "wetting" solution, the other a "non-wetting" solution. The measurement techniques are based on a thermodynamic properties measurement system and an ultrasonic measurement system.

Micro-Gravity Accelerations Experiment

Three low-level (10^{-4}G) accelerometers in a triaxial arrangement have been integrated with the appropriate instrumentation to capture low G accelerations. The data from this experiment will be recorded by the Environmental Data Acquisition System. It is believed that very low level accelerations experienced by experiments compromise the quality of experimental data for experiments that require exceptionally low environmental acceleration levels.

Environmental Data Acquisition System

This unit is not a formal experiment but rather a completely self-contained data acquisition system for storing data from other experiments and for cataloging the environment internal to the GASCAN from launch to landing. A barometric relay will activate the system during launch. During its operation, data will be stored from the Zeolite experiment, the Micro-Gravity Accelerometer experiment and the Fluid Behavior experiment. Data will also be stored from several temperature transducers, three high level accelerometers, gas pressure and sound pressure level transducers and the battery voltages. All data will be stored on digital cassette tape for post flight analysis.

Experiment Support Structure

Although not officially an experiment, a significant amount of effort went into the development of our Experiment Support Structure (ESS). The resulting structure was composed of a tri-wall frame with the battery pack in a hermetically sealed demountable box on one end and an end-plate holding several experiments on the other end.

During the summer of 1986, a Civil Engineering graduate student performed a complete finite element analysis on the structure to evaluate its overall strength and to determine the fundamental modes and frequencies of oscillation [4]. The ultimate margin of safety for the structure is 0.5 while the fundamental frequency of oscillation is 67 hertz, both well above the respective NASA specifications.

Testing

Probably the most important aspect of any GAS payload is the type of operational and environmental testing that was performed on the unit. We dedicated a significant amount of time to this task. Everything was tested, from individual boards and components to the full integrated system.

Testing included electrical and mechanical functional evaluations, cycle tests, environmental tests (-10 to +40^{o}C), vibration tests (5 G_{rms} for five minutes), storage degradation tests and simulated integration -> storage -> launch -> recover tests. Although we encountered minor problems, there were no obvious areas where reliability was a problem. Indeed, we are extremely confident that if the payload is properly installed in the flight GASCAN, it will function properly.

V. THE SECOND GASCAN (G-583)

Targeted Research Areas

As a result of our success with our first set of GAS experiments, we have decided to emphasize three similar research areas for our second GASCAN. These areas are fluids management, microgravity combustion and atmospheric science.

WPI has a strong research and professional basis for emphasizing these areas. For example, several Mechanical Engineering faculty members are nationally recognized experts in the area of fluid mechanics research concerned with modeling of fluid systems. This expertise stems from research at the Alden Hydraulics Research Laboratory, a well known physical modeling laboratory previously associated with WPI. Their general interests are in the area of the behavior of fluids under low and extremely low acceleration levels.

From a fire safety perspective, WPI has one of the only graduate departments in the nation in Fire Protection Engineering. The faculty members in this department are interested in issues related to fire initiation, detection, propagation and interdiction in an enclosed, low acceleration environment such as presented by the proposed Space Station. Obviously, a GASCAN presents an ideal mechanisms by which various practical engineering aspects of the science of fire protection in a space station can be evaluated.

Faculty at WPI also have substantial expertise in radio frequency propagation in the atmosphere. This expertise has led to the development of an experiment wherein electromagnetic emissions from thunder storms will be monitored and used to trigger UV, IR and visible wavelength spectral recorders. The interest of the faculty is in establishing whether thunder storms strong enough to create wind shear hazards can be detected from orbit.

Regardless of the area of emphasis, our general goal with our second GASCAN is to integrate faculty sponsored research, graduate research and undergraduate senior project work into a cohesive and scientifically meritorious program for the development of space flight experiments. Ultimately, we believe that this type of organization will, like the Zeolite experiment described above, lead to further funding outside of the current program.

<u>Combustion Experiment</u>

The purpose of this experiments is to study how combustion occurs in a low acceleration environment. Several different types of combustible material will be ignited with a focused IR lamp. The gasses and particulate matter that are emitted by the material will be studied as the material begins to burn. This experiment will be particularly interesting to observe because the emitted substances will most likely not dissipate from the vicinity of the host material in the low acceleration environment of the GASCAN.

Fluid Flow Experiment

Fluids in a low or zero acceleration environment will behave distinctly differently than those in a normal one-G environment because of the increased importance of surface tension. To study these differences as the effective gravity goes to zero, we have undertaken the development of a spinning platform that will be housed in a GASCAN. This platform will then be used to study the formation of vortices at acceleration levels from approximately 0.05 to 1.0 G. The platform being developed is being designed so that it can be used for a variety of fluid behavior studies over the course of many flights.

Micro-Gravity Accelerometer Experiment

From the results reported for earlier GASCAN experiments, it is clear that the cargo bay of the Space Shuttle is not a "zero-G" environment. Indeed, the results from some experiments seem to indicate that they were seriously compromised by the non-ideality of the "zero-G" environment. As a result, we are developing a very low level accelerometer to quantify the accelerations that are experienced during a typical GASCAN flight. This accelerometer will be able to sense accelerations on the order of 10^{-5}G.

Atmospheric Event Detector

Several students are interested in the detection of lightening and possible associated IR events during storms. As a result, these students are developing a multi-frequency, multiplexed RF receiver and various optical detection systems that will statistically quantify the occurrence of optical and RF "pulse like" events. The system will operate in two phases. During the first phase of operation, multi-spectral pulse data will be collected and statistically analyzed. During the second phase of experiment operation, events that are considered "statistically significant" will be recorded and photographic pictures will be taken on IR film. During post-flight data processing, the photographic images will be correlated with the recorded events and a profile of the types of multispectral events that can be expected to be encountered during low earth orbit will be developed.

Support Teams

In addition to the experiment teams, we have several students working on the development of a new support structure and a new end-plate. The structure will integrate the experiments, the rotating platform, all of the experiment electronic control systems and the power supply system. The new end-plate will have a window for taking photographic pictures and will have, in some fashion, an integrated antenna for the multispectral pulse detector experiment.

The major efforts of the support teams include the qualification and finite element analysis of the support structure and the safety qualification of the new end-plate.

VI. DISCUSSION

The MITRE/WPI Space Shuttle Program and the associated projects have represented an ambitious and complex undertaking that has required dedication by the students and staff alike. We believe that the educational, engineering and scientific benefits to the joint staffs, and particulary the students, have merited such an undertaking.

Although we are encouraged and delighted with the experiments we have developed for our first GASCAN, and are excited about the experiments we are developing for our second GASCAN, we have grown to appreciate the problems one can encounter. These problems have included the identification and acquisition of engineering design aids, documentation methods, experiment integration coordination and designing for safety. Each of these will be discussed briefly below.

Development Aids

We recognized early in the development of our experiments that the students would benefit from certain engineering design tools. As a result, all of the design teams regularly use two important design tools. When developing their circuits, the schematic drawing package **SCHEMA** (Omation, Inc) is used. The circuits diagrams are easy to read and follow, fewer mistakes are made in testing and wiring boards, and changes are readily incorporated into the documentation.

Printed circuit boards are designed using the **smARTwork** (Wyntek, Inc) design tool. This aid is particularly useful since there are a number of companies that will mask a double sided board directly from a file on a disk. Again, corrections and updates are easily incorporated into the final board design.

Structural analysis is conducted using **ANSYS** implemented on a MicroVax II computer system. Students model the support structure using the wire-frame method and generate three-dimensional views to study the placement and interrelationship of the experimental modules. The model can then be used to identify the vibratory modes and to determine the lowest natural frequency as well as stress levels for prescribed acceleration inputs.

Finally, **ACLS-PC** has recently been acquired and will be used for drive system modeling and payload thermal analysis modeling.

Documentation

In addition to the aids noted above all reports are expected to be written using a word processor (**PC-WRITE**, Quicksoft) and where possible, graphs, charts and figures drawn using appropriate software design aids (**GEMDRAW**, Digital Research). The primary reasons for doing so are that it simplifies the transfer of knowledge from one project group to another over several years of experiment development, and the documentation job for the safety packages (PSDP, FSDP, P3SDP) is greatly simplified.

Coordination

When the individual experiments are "finished" there still remains the work of integrating the experiments onto the structure, cabling them together and testing the final package. To accomplish these tasks for our first payload, we employed an electrical engineering graduate student for the spring and summer of 1986. This student verified that each individual experiment worked, integrated the experiments onto the support structure, cabled the experiments together and tested the final package. Along the way he also designed a power distribution and control box, rewrote the flight software for several of the experiments to account for updated flight and operational scenarios and helped prepare the required NASA safety documentation. From our perspective, probably no single person was more responsible for the final preparation and certification of the flight hardware than this graduate student.

VII. SUMMARY

The first set of experiments, otherwise known as G-408, developed as part of the MITRE/WPI Space Shuttle Program is ready to fly. A second set of experiments is currently being developed as part of a continuing multi-year program to design and build space flight experiments. Because of the care that we have taken in the development and testing of the experiments, we expect that they will function properly and return scientifically useful data upon post-flight data analysis.

ACKNOWLEDGEMENTS

We would like to thank Mr. Dino Roberti for his contributions to the development and integration of the experiments for GASCAN G-408. We would also like to thank Mr. Donald Carson (GSFC) for his continuing support and helpful suggestions. Finally, we are particularly grateful to the technical staff at MITRE and WPI who have been involved with the advising, development and design of the G-408 experiments.

REFERENCES

1. Looft F. J., **The Design of Flight Hardware: Organizational and Technical Ideas from the MITRE/WPI Shuttle Program**, GAS Users Conference, GSFC October (1985)

2. Looft F. J., Labonte' R. C., Lutz F. C., **The NASA Space Shuttle: A Vehicle for Science and Engineering Education**, IEEE Frontiers in Education, Worcester MA, October (1983)

3. Looft F. J., Labonte' R. C., Lutz F. C., **The NASA Space Shuttle - A Vehicle for University/Industry Educational Interaction**, IEEE Transactions on Education, 29:100-104 (1986)

4. Broderick T., Looft F. J., **Modal and Structural Analysis: Experiment Support Structure G-408**, Attachment A, P3SDP for the G-408 GAS Payload, Submitted to GSFC, March (1987)

5. Collins T., **A Radical Experiment in Teaching**, IEEE Spectrum, 15:48-52 (1978)

6. Looft F. J., **Preliminary Safety Data Package: MITRE/WPI Space Shuttle Program - G408**, Submitted to NASA GSFC (1986)