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THE UNIQUE CHALLENGE OF MANAGING AN UNDERGRADUATE GET-AWAY-SPECIAL EXPERIMENT

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ABSTRACT

A group of Brigham Young University (BYU) undergraduate students has undertaken an experiment to design and build a normal incidence soft x-ray robotics telescope for solar observations. The design phase of this, GOLDHELOX project, has now been completed and final construction and modifications are in progress.

The GOLDHELOX project was conceived by a group of undergraduate students in 1988. It has proceeded since then with only a minimal input from faculty and graduate students.

The project is under the direction of a four part administration consisting of a faculty advisor, cabinet, administrative assistants, and team leaders. The faculty advisor is the principle investigator and is ultimately responsible for grant money and setting and maintaining a schedule. The de facto program management is the responsibility of the cabinet and administrative assistants. The design and manufacture of the payload is under the direction of the team leaders and a system's integrator.

A goal of this project is educating and furnishing experiences in space engineering and physics for undergraduate students. Well over a dozen former project members have gone on to graduate school in engineering or physics.

Our main source of funding is NASA and the BYU Colleges of Physical and Mathematical Sciences and Engineering and Technology. Other sources of funding have come through advertising and voluntary professional services.

This project is possible because of the NASA Get-Away Special (GAS) program. The only feasible alternative is using an expensive sounding rocket. We estimate the sun tracking and guidance package alone would cost upwards of a million dollars -- at least ten times our entire budget. Because of the GAS program, we simplified the construction, operation, and programming of the instruments with resulting savings in weight, cost, and time spent.

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INTRODUCTION

A group of Brigham Young University (BYU) undergraduate students has undertaken an experiment, The GOLDHELOX[b] Project, to design and build a normal incidence soft x-ray robotically controlled telescope for solar observations. GOLDHELOX, identified by NASA as space shuttle payload number G-133, will fly above the earth's atmosphere to make unobstructed observations of the sun in the 171-181 Å wavelength region. The telescope will make these observations by utilizing the Get-Away Special (GAS) can with a Motorized Door Assembly (MDA).

The design phase of the GOLDHELOX project has now been completed. Final modifications and construction are in progress (a more detailed discussion of this project is found in another paper in this publication[1]). Under the supervision of Dr. J. Ward Moody the project is operated and administered by undergraduate students.

Undergraduate students are a resource in research which is both under-utilized and underestimated, primarily because of the many difficulties associated with operating a large undergraduate student project. High student turnover creates a continually evolving leadership void. Limited student knowledge and experience make progress on a complicated experiment slow and difficult. Also, a volunteer research project such as ours competes with the already limited time available to undergraduate students.

In this paper we discuss our approach to overcoming each of these problems while emphasizing areas in which we have been particularly successful. We highlight how to motivate students to get involved in undergraduate research for reasons other than the need for a part time job, and how appropriate incentives can make participation a beneficial endeavor for students.

We also discuss project administration, funding, and the organization of our project into various interactive teams and sub-teams. Finally, we discuss our interaction with the NASA GAS program, the ways in which the GAS program has been most helpful to our project, and how collaboration with other groups doing similar research has helped our undergraduate team overcome difficult problems.

PROJECT ADMINISTRATION AND ORGANIZATION

As in all organized projects, we required a strong administration to oversee the design and construction of the payload. Our administration is divided into four main groups: the principle investigator, cabinet, administrative assistants, and team leaders (see figure 1).

Dr. J. Ward Moody, of the physics and astronomy department, is the project's Principle Investigator (PI) and faculty advisor. Under his supervision the project is operated and administered by undergraduate students. His role is to monitor progress and expenditures, and see that deadlines are made and kept.

The Cabinet coordinates the operation of the project and is ultimately responsible in practical terms for its success. The Cabinet consists of a Project Coordinator (PC), Assistant Project Coordinator

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[b]GOLD for the color of the sun and HELOX for HELiocentric Observations in X-rays.

(APC), Systems Integrator (SI), and Payload Manager (PM).

The main responsibility of the PC and the APC is to oversee the project and its administration. Some of their duties include organizing and conducting project meetings to coordinate the efforts of the different teams, obtaining weekly status reports, helping team leaders establish goals and deadlines, and recruiting and integrating new members.

One of the difficulties encountered by our project is a continually evolving leadership void created by a high student turnover. Most of the undergraduates participating in our project are upperclassmen. They usually enter the project sometime in their junior year, spending a year on the project as a team member, and then functioning for another year in some leadership position. Since leaders only act in their capacity on the average of a year, keeping an experienced administration is difficult.

Our solution to this problem is to keep the administration aware of future leadership vacancies. The PC and APC are responsible for finding replacements three to six months before someone leaves the project, so that a new leader can be trained properly and completely by the retiring leader.

The SI is responsible for the preparation of the requirements[c] and specifications[d] documents. The SI's duties include approving any specification changes, preparing a project schedule, and overseeing the construction and assembly of the instrument.

The PM acts as sole interface between the GOLDHELOX team and NASA. The PM is also responsible for preparing all documentation required by NASA, informing each team of the safety concerns which relate to them, and helping each team prepare the safety reports required by NASA.

The administrative assistants consist of a Librarian, an Accountant, and a Quartermaster. The Librarian's responsibilities are obtaining and cataloguing materials and documentation to be used as reference material. The Accountant monitors the project budget and informs the Cabinet of monthly expenditures. The Quartermaster acts as an assistant to the SI and organizes, maintains, and issues all project equipment.

The payload design and construction are handled by four independent teams: the Electrical, Mechanical, Optical, and Science teams. Each team has a Team Leader (TL) whose responsibilities include coordinating their team members efforts by holding regular meetings and reporting weekly to the PC. All teams also have a faculty advisor who works closely with the TL and provides assistance for the students on the team.[e]

The Electrical Team, mainly consisting of electrical engineers, is responsible for specifying, designing, and assembling the electrical components. This includes all the motors, heaters, power supply, computer circuitry, programming, etc.

The Mechanical Team, primarily comprised of mechanical engineers, is responsible for specifying, designing, and building the physical and

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[c]The requirements document consists of NASA requirements, spacial limitations, functional and power requirements, mission parameters, etc.

[d]The specifications document includes the specifications of every mechanical and electrical component, and every other device that will be a part of the instrument.

[e]GOLDHELOX Project Charter, January 1992.

structural components of the payload.

The Optical Team, composed mostly of physicists, is responsible for designing and aligning the mirror, filters, and other optical elements.

The Science Team is responsible for establishing the mission parameters and procedures. They are responsible for defining the scientific purposes of the mission and for making certain that the ultimate design and construction can meet these purposes.

The overall organization is essentially a pyramidal structure comprising no more than four levels from the team member to the PC. Because each team consists of one or more sub-teams containing three to five members, and there are four different teams; there is room for a lot of student involvement without becoming top-heavy with management. The result is a lean structure that is flexible enough to adjust to changing requirements quickly and yet remain in control of the project. It allows, and requires, that each student have ample decision making opportunities to incorporate their ideas into the final design. We value the unique abilities and experiences that each student brings into the project and endeavor to ensure that no suggestion that a student makes is treated lightly.

MOTIVATING STUDENTS

Essentially one hundred percent of the work on the GOLDHELOX project, in the last four years, has been initiated or completed by over a hundred undergraduate students. Nearly all of this work has been on a volunteer basis. However, we have learned that before students will volunteer, they must be interested in the nature of the project itself. Of course no one will volunteer unless they know the projects exists and that participation is welcome. Large displays in the lobbies of the physical science, engineering, and technologies buildings advertise the existence of this project to a large number of students. These advertisements detail the project's progress and invite students of all majors and in all class levels to participate. Occasional articles in the student newspaper[2] and flyers posted around campus also serve to recruit interested students.

Even though students may be interested, they still need to devote the majority of their waking hours to their course work. As a result, progress was slow and painful in the early stages of the project. Although the students involved were interested in the project's success, their priorities rightfully rested on their homework and classes. As a result, the project was frequently neglected. It was only after we organized a research class in which progress was demanded and grades were given that the project really started to advance.

Since the project personnel are mainly physics, electrical engineering, and mechanical engineering students, the research class was set up by using a course option already available in each of these majors, whereby students would ordinarily help professors with their individual research in exchange for credit.

A large work force is recruited each year. Each recruit is evaluated and given assignment that are matched to the capability, experience, and the number of research credit hours for which that student has registered. In lieu of class attendance, all project members meet weekly with their team leader who is familiar with the students' assignment as well as the project's construction. Weekly and semester progress reports are required from the students and graded by professors in their individual departments. The advice of the professors is critical to the success of the project, but the students must first formulate their own solutions to problems. After doing this, they may then seek counsel on the feasibility of their solution. This approach encourages the students to exercise their own creativity.

The research course is a catalyst that encourages participating students to work longer and become more experienced and useful with time. In the beginning stages of the project monetary incentives were generally used to obtain results. With the research class, the grade is sufficient motivation for most students.

Another point of this project that makes it attractive to student volunteers is that it is entirely student run and administered. There is a lot of pride in this. The students feel that they are working for themselves, have a say in the progress and performance of the project, and are an integral part of the project administration. Because they have assumed responsibility for the project, it has become in a very real way "their project" and it will rise or fall based on their efforts alone. The faculty does not manage or administer the day to day aspects of the project.

Most of the students involved in GOLDHELOX are interested in space and space exploration and have used it to gain actual hands on experience with practical problems in space exploration. Several students have been invited to present papers about the project to various professional groups. Well over a dozen former GOLDHELOX project members have gone on to graduate schools such as Arizona, Cal Tech, Colorado, Illinois, and BYU.

OBTAINING FUNDING

Most of our funding was obtained as a result of writing three proposals: one to the BYU College of Physics and Mathematical Sciences, one to the BYU College of Engineering, and one to NASA.

Our project received some publicity when a local magazine[3] and newspaper[4] published our efforts. National recognition came when news of our project was picked up by the Associated Press[5] and published throughout the country. As a result of this publicity, we received several small contributions.

We have also received several significant voluntary professional services from different companies and individuals that would have otherwise cost us thousands of dollars. These voluntary private contributions have helped keep us under our budget of approximately $100,000.

THE NASA GAS PROGRAM

This project is possible only through the NASA GAS program. The only feasible alternative to using a GAS can is a sounding rocket. Using a sounding rocket would have required the telescope to have a sophisticated tracking, guidance, control, and recovery or telemetry system. If telemetry was used, arrangements would have to be made for ground based tracking of the payload. If recovery was selected, a tracking and recovery crew would be necessary, and the use of a testing area would have to be arranged so that the descending package would not endanger human life or property. The cost of all of this would be enormous. We estimate that the sun tracking and guidance package alone would cost upwards of a million dollars -- at least ten times as much as our entire budget.

Using a GAS can in the Space Shuttle allows us to worry only about the control of our package. NASA provides the launch vehicle, a stable tracking platform, recovery services, and six astronaut "operations" which we have used to control the warm-up, activation, and deactivation of our instrument. NASA has verbally stated at least twenty minutes of solar facing time, with the solar disk within thirty degrees of the instruments zenith. Because of the six astronaut operations, we simplified the construction, operation, and programming of the instrument considerably with resulting savings in weight, cost, and time spent in development, programming, and testing.

NASA has also been helpful with suggestions, advice, and financing. They have provided us with specifications for various materials and tests, working drawings of the MDA to ensure our camera can "see" adequately and to localize blind spots. NASA seems to be doing all it can to ensure the success of this experiment. We are grateful to them for the timely assistance they have given us.

COLLABORATION

Collaborating with other research groups, who have worked on similar projects, is beneficial. Many of the groups we work with, including those participating in the NASA GAS program, have already solved many of the problems we are encountering.

The Utah State University GAS group has utilized several NASA GAS cans and has been invaluable in helping prepare our project for launch. Stanford University, who conducted an experiment similar to ours[6], and Lockheed have offered indispensable technical advice. Without the cooperation of these groups we would have spent much more time and money on problem solving.

SUMMARY

We have undertaken a complex project using undergraduate students as the primary engineers and technicians. We have found that undergraduate students are useful in research but must be administered properly. Working on GOLDHELOX is worthwhile to the students in terms of educational experiences and to the University in terms of finances. Although using undergraduates requires more time and patience, it prepares them better for careers in space exploration and science.

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[f]. An "operation" is defined as an astronaut throwing a switch from off to on, or from on to off. We need one operation each to warm up the instrument, open the MDA, turn on the camera, turn off the camera, close the MDA, and shut down the instrument. Hence six operations.

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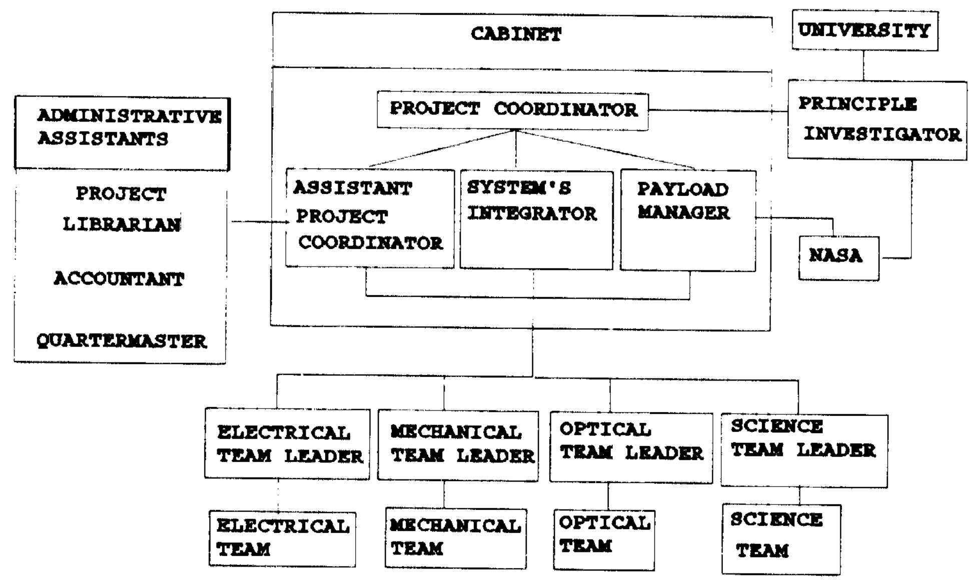

Figure 1: GOLDHELOX Project Organization.