2006-1791: ARLISS: A MULTIDISCIPLINARY EXTRACURRICULAR DESIGN PROJECT FOR UNDERGRADUATES

Joshua Vaughan, Georgia Institute of Technology

Joshua is a Ph.D. student at the Georgia Institute of Technology. He received his M.S. in Mechanical Engineering in May of 2004. He received a B.S. from Hampden-Sydney College in 2002, double majoring in Physics and Applied Mathematics. Josh was a 2004-2005 NSF STEP Fellow, where he worked at Cedar Grove High School. His Ph.D. research focuses on command generation for flexible machines.

William Singhose, Georgia Institute of Technology

Dr. William Singhose is an Associate Professor in the Woodruff School of Mechanical Engineering at Georgia Institute of Technology. He received a Ph.D. from the Massachusetts Institute of Technology. His primary research interests are spacecraft control, sway reduction in cranes, control of flexible structures, and active seat technology.

ARLISS: A Multidisciplinary Extracurricular Design Project for Undergraduates

Abstract

Design projects that require students to build working prototypes are an invaluable supplement to traditional lectures and laboratory exercises. Additionally, allowing students to participate in challenging design projects outside of any official coursework can greatly improve their educational experience. This paper will discuss three years of such extracurricular projects at the Georgia Institute of Technology for competition in ARLISS - A Rocket Launch for International Student Satellites. Students build small "satellites" that are launched to approximately 10,000 feet. The most popular competition at ARLISS is the "Comeback" competition, where the student satellites must autonomously navigate to a target location. The project requires knowledge of numerous engineering disciplines and is a leap in complexity over the projects in which the typical student gets involved. The majority of students have come from the mechanical engineering department, but several have also been from the aerospace engineering and computer science departments. The ARLISS project has great potential to provide students with experience in multidisciplinary design, expanding upon knowledge gained in the classroom. The nature of the project provides a fun and entertaining venue for education without the constraints of a required course.

1 Introduction

It is commonly accepted that hands-on experience leads to the great educational gains. These gains are further increased if the hands-on projects build upon previous experiences in an interesting and exciting way[1]. Unfortunately, design projects that require students to work on teams to build working prototypes are often difficult to grade. Furthermore, students worry about their grade and have conflicts with team members who do not fully contribute to the project. These uncomfortable group dynamics stifle creativity and degrade enjoyment. Therefore, allowing students to participate in challenging design projects outside of any official coursework can greatly improve their educational experience. This can prove to be a difficult proposition, as student experiences and interests vary. In addition, the priorities of the students will change throughout their educational careers, often making it difficult to retain students during multi-year projects. In order to attract and retain student participants, projects must be both scalable in difficultly and complexity and offer a variety of engineering challenges.

One project that fulfills these criteria is ARLISS - A Rocket Launch for International Student Satellites. The goal of this initiative is to provide students with hands-on experience in the design, construction, and launch of space systems. ARLISS was established in 1999 as a collaboration between the Stanford University Space Systems Development Program and rocket enthusiasts from Northern California[2]. Held on the Black Rock Playa (a dry lake bed) in Nevada in late September, the members of the AERO-PAC rocket club provide

Figure 1: An AERO-PAC Rocket

rockets like that shown in Figure 1 to launch the student satellites. The student projects are not actually launched into space, but rather to approximately 10,000 feet. ARLISS has become an international event, where Japanese participants far outnumber American. The international nature of the competition provides the additional benefit of preparing students for the ever increasing global nature of the workplace by allowing them to interact with the Japanese participants during the three-day ARLISS competition.

There are two main classes of competition at ARLISS. CanSat class devices must be the size and weight of a twelve-ounce beverage can. The Open class devices must fit inside a cylinder of approximately six inches in diameter and ten inches in length and must have a mass less than 1050 grams, as shown in Figure 2. Within each class, there are a number of launch objectives that serve as the basis for competition. Georgia Tech entries have competed in the "Comeback" competition of each class, where the devices must autonomously navigate to a predetermined target location, simulating landing a spacecraft on other planets. In order to win the contest, the device must stop within 100 meters of the target and be closer than other competitors. Furthermore, the team must be able to prove that the device was under control and not just falling out of the sky. This last requirement proves to be very challenging.

The ARLISS competition offers both scalable difficulty and complexity in its various engineering challenges. For both the CanSat and Open classes, there are electrical and mechanical design challenges, as well as control system programming issues. Providing additional challenges, and opportunities for learning, is the fact the project is multi-disciplinary, en-

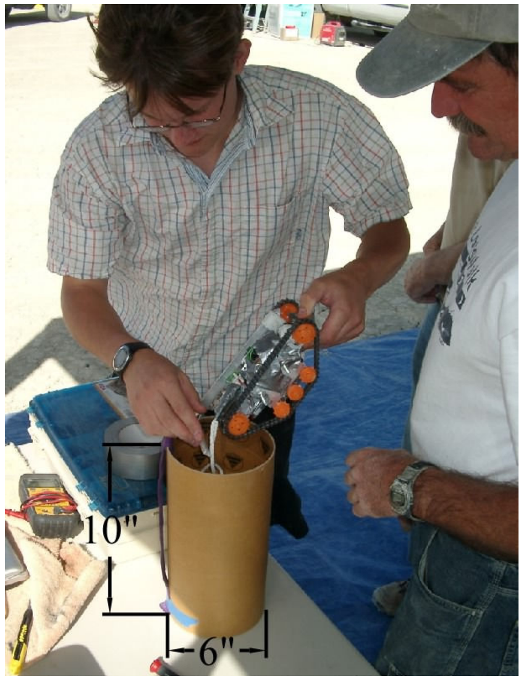

Figure 2: Loading an Open Class Entry

compassing elements of computer science, aerospace, electrical, and mechanical engineering.

In the following section, the activities of the Georgia Tech ARLISS team for each of the past three years will be discussed. In Section 3, the challenges of the project, for both the students and the administration, will be outlined. The main lessons learned and some proposed solutions to the project challenges are highlighted. Finally, Section 4 summarizes the educational impact of the project and suggests ways to increase its impact.

2 Georgia Tech ARLISS Design Projects

Georgia Tech began its involvement in the ARLISS competition three years ago. Since then, the project has evolved substantially and the quality of entries from Georgia Tech has improved greatly. This section will outline the main activities during each of the three years, highlighting the differences between the years. Additional information may be found at the project website[3].

2.1 Year One

The Georgia Tech involvement in ARLISS began as extracurricular activity in the spring of 2003. The initial group of students were the top students in Georgia Tech's introductory mechanical design course during the fall of 2002. This course uses mechatronics as a vehicle to teach mechanical design and ends in a competition between student built mechatronic

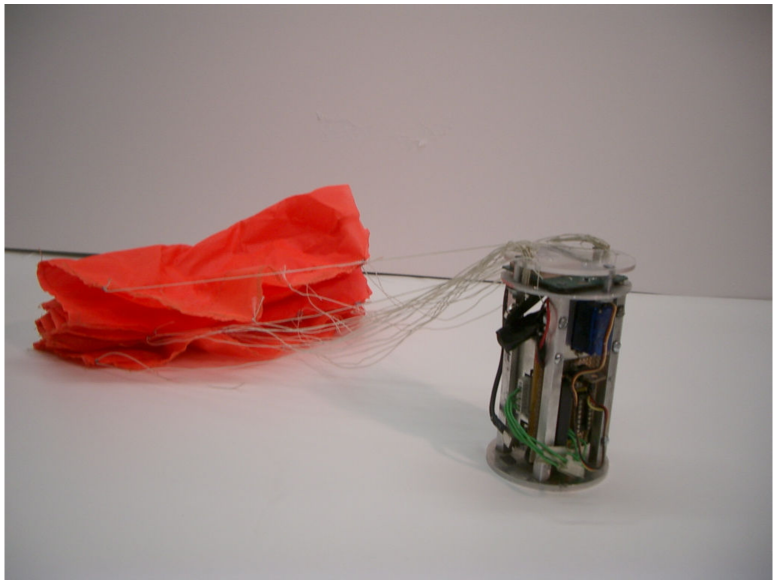

Figure 3: The Year One CanSat Class Entry

devices[4]. As a result, the students are exposed to basic mechatronic concepts. During the spring term, the students worked on developing design specifications and preliminary design embodiments. The project was then used in the summer session as a senior, capstone design project. The senior design students did much of the initial prototyping on the project, and several remained active in the project through the fall semester. The project also involved a high school student during the summer as part of the NASA sponsored SHARP program.

During this first year, the Georgia Tech team competed in the CanSat class of the ARLISS competition. The entry is shown in Figure 3. The device was equipped with a steerable parachute to glide it down to the target location. A Microchip PIC16F876 was used to interface with a Thales Navigation A12 GPS unit and control the actions of the CanSat. Communication with the GPS unit proved to be the largest hurdle for the team. The Hi-Tech C18 compiler allowed the chip to be programmed using C++, a language that the students had experience with during the Georgia Tech engineering curriculum. The Georgia Tech entry landed 1350 meters from the target location, closer than any other competitors. However, because the CanSat was outside the 100 meter limit and the team was unable to prove the CanSat was under control, the team was not officially declared the winner.

During this first year, there were approximately twenty students involved in the project, including the senior design group. Five of these members attended the ARLISS competition in Nevada. Additionally, two of these students attended the University Space Systems Symposium (USSS) in Hawaii. This conference is a sponsored by the Japan-US Science, Technology and Space Applications Program (JUSTSAP), which promotes collaborations between US and Japanese researchers. A large number of the Japanese ARLISS competitors attend the conference annually.

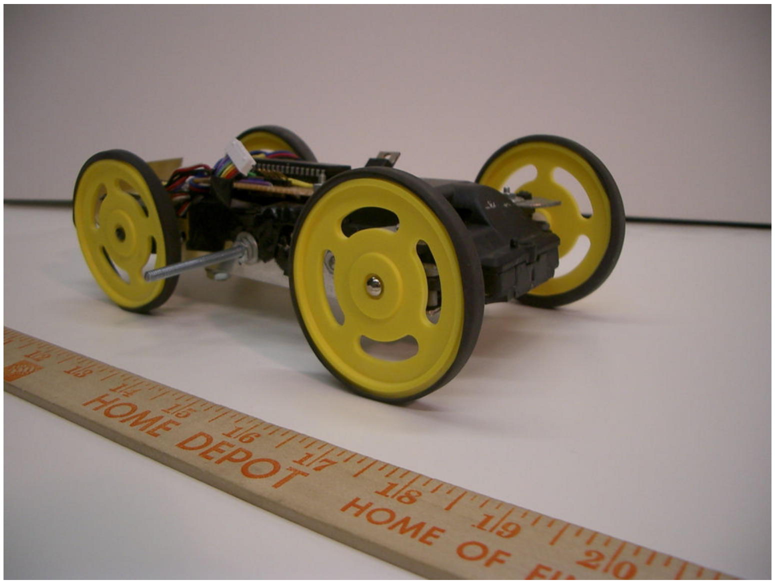

Figure 4: The Second Year Open Class, “Rover” Entry

2.2 Year Two

Many of the first year participants were graduating seniors; therefore, the second year team consisted entirely of rookie members. Because of this, the team was largely starting from scratch. While several aerospace engineering students participated, most of the students during this second year were recruited after completing the sophomore level mechanical design course mentioned previously. The course does provide an excellent foundation for the ARLISS project. However, the ARLISS project is much more complex than the device the students build during the introductory course. The relationship between the required design course and the extracurricular ARLISS design project will be further discussed in Section 4.

During the second year, the Georgia Tech team entered both the CanSat and Open class competitions at ARLISS. The Open class seemed to attract a larger number of team members for several reasons. Perhaps the main reason is that the Open class offers a greater opportunity for mechanical design than the CanSat class. Because the rules are fairly open, the Open class entries can be “rover” type designs, which land and drive to the target location. The team decided to pursue such a “rover” design, and, as a result, a greater percentage of project challenges became mechanical in nature. The final “rover” design is shown in Figure 4. Second, the students indicated that they were more confident in their understanding of what was necessary to build a successful rover than they were in their ability to build a successful CanSat entry that would need to autonomously fly back to the target location. The CanSat entry remained nearly the same as the first year design, but programming duties were shifted to the Microchip MCC18 compiler, which also allows the compilation of the C++ programming language for the PIC16F876. The shift to the Microchip compiler was due to the use of the PIC18F452 chip in the Open class entry; the MCC18 compiler offers support for both microchips. Achieving reliable communication with the GPS again proved difficult for the team, but other functions were relatively easy.

The CanSat entry landed 2600 meters and second closest to target. The Open class entry landed 2100 meters from the target and did not move, due to electrical failure upon crash landing.

During the second year, approximately fifteen students participated in the project. Four of these members traveled to Nevada for the ARLISS competition, and two attended the USSS conference in Hawaii.

2.3 Year Three

During the third year of Georgia Tech involvement in the ARLISS, a large percentage of the second year students remained members of the team, including all the members that attended the competition during the second year. This proved to be a great advantage to the team, as design requirements were able to be more clearly defined and team members were more experienced in both design and construction. In addition to the returning members, several new members were recruited, including a computer science major and an aerospace engineering major. The aerospace engineering major was actually the high school, SHARP student that was a member of the team during the first year of the project.

One major change to the project was the conversion to BASIC Stamps for the microcontroller architecture. This was largely an administrative decision and done for several reasons. The introductory mechanical design course from which many of the team members were recruited uses a BASIC Stamp as part of a kit given to the students to build a mechatronic device. As a result, the students are comfortable and experienced with the BASIC Stamp and are able to more directly leverage knowledge gained during the course into the ARLISS project. The switch to the BASIC stamp was rewarded with numerous improvements to the project including more consistent GPS communication and more rapid prototyping.

For the third year of Georgia Tech involvement in ARLISS, the team again completed CanSat and Open class entries. While the mechanics of the CanSat entry again remained nearly the same, the team decided upon a tracked rover for Open class. The final rover is shown on the Black Rock Playa in Figure 5. The rover finished 2151 meters from the target. The rocket carrying the CanSat entry failed during launch, destroying the CanSat entry. More specifically, the rocket stages seperated prematurely, ejecting the CanSat during a period of high acceleration and shredding its parachute lines. The rocket and CanSat are shown in Figure 6, with the damage to the rocket clearly visible.

3 Challenges and Lessons Learned

The ARLISS design project presents several challenges for both the students and faculty administration. These include the timing of the contest, funding issues, and project complexity.

Figure 5: Third Year Tracked Rover on the Black Rock Playa

Figure 6: Damaged Rocket and CanSat from Year Three

One major challenge of the project, for both team members and team administration, is the timing of the contest. It is typically held in late September. Because it occurs early in the fall semester, much of the work must be done during the summer term, when many students are away from campus. This not only causes problems for those already involved in the project, but also makes recruiting and retaining new members more difficult. Efforts must be made to recruit new members and begin work during the spring semester in order to build a vested interest in the project among the team members. This effort falls largely on the project administration, but can also be made a responsibility of the current members.

A second major challenge, and a challenge for nearly all projects similar to this one, is funding. While the Open and CanSat class entries can be built for a few hundred dollars, team travel to the Black Rock playa for the competition becomes a fairly large expense. To this point, the Georgia Tech team has been fortunate to receive funding from the Georgia Space Grant Consortium and, most recently, from the student government at Georgia Tech as an official Georgia Tech club. This project does present itself as a good candidate for funding, due to its multidisciplinary nature. Additionally, the participation of the numerous Japanese schools provides a unique opportunity for international collaboration and related funding.

In addition to the administrative challenges above, there are several additional challenges facing the team. Perhaps the greatest is that the ARLISS project offers a leap in complexity over the systems to which average undergraduate students have been exposed. This leap makes the project challenging for the students and also presents excellent opportunities for teaching outside the classroom. To date, several efforts have been made to ease the transition for the students and to promote learning during the project. Several lessons covering the basic operations of programming microchips, controlling servo motors, DC motor control, and serial communication have been developed. The lessons developed build upon the knowledge the students gained during the mechatronics course, but can also serve as stand-alone lessons for those who have not taken an introductory mechatronics course.

4 Educational Impact

The ARLISS project presents a unique opportunity to build upon previous knowledge in an exciting and interesting way without the need to evaluate and grade the student. One main educational impact of the ARLISS project is building upon the mechatronics knowledge that the students gained during their course work. By adopting the BASIC Stamp as the primary micro-controller architecture for the project, a direct connection is made to the introductory mechanical design course that many of the students have taken. Because the students are already familiar with the BASIC Stamp and its programming, the advanced concepts needed for the ARLISS project are more easily grasped.

A second major educational impact stems from the multidisciplinary nature of the project. In order to build a successful device the students must understand basic mechanical, electrical, and aerospace engineering concepts. Because the project is multidisciplinary in nature, it has attracted members from various departments at Georgia Tech. As a result, the students are exposed to teammates with varying backgrounds and technical proficiencies. This serves to reinforce the necessity of teamwork skills and provides experience in a multidisciplinary, collaborative design environment.

Efforts have been made to further the impact of this project on student learning. As stated in the previous section, lessons have been developed that cover many of the aspects of the project, including programming microchips, controlling servo motors, DC motor control, and serial communication. These lessons were developed to both ease the transition into the fairly complex project and leverage knowledge gained during required coursework. Also, the development of a basic starter kit is underway. The kit will contain the basic electrical components needed for a CanSat or Open class entry, including a Basic Stamp micro-controller, DC motor drivers, and serial communication, all on a printed circuit board. This kit should also serve to ease the transition into the project and aid in linking the project to the students' prior knowledge.

The assessment of this project has been largely informal and very positive. Students have indicated that they have been able to apply ideas and concepts learned during the project to later, required coursework and projects. Courses on which the students have indicated large impact include a junior level electrical engineering course that is a required course in the mechanical engineering curriculum and later mechanical engineering courses such as machine design and mechatronics.

5 Conclusion

In order to maximize the impact on student learning, extracurricular projects must build upon prior knowledge in an interesting and exciting way. One project that offers this is ARLISS - A Rocket Launch for International Student Satellites. Students build "satellites" that are launched to approximately 10,000 feet and must navigate to a predetermined target location. In the three years that Georgia Tech has been involved in the ARLISS competition, the quality of student entries has improved greatly and efforts have been made to further increase the educational impact of the project. Lessons have been developed covering the basic concepts needed to design and build an ARLISS device and the development of an electronics kit for use in the contest is underway. Additionally, the project provides a platform for students to gain experience in a collaborative, multidisciplinary design environment without the limitations or pressures of a required course.

6 Acknowledgements

We would like to thank the Georgia Space Grant Consortium and the Georgia Tech student government for their financial support for this project.

References

[1] John Bransford. *How people learn : brain, mind, experience, and school.* Washington, D.C. : National Academy Press, 2000.

[2] ARLISS - A Rocket Launch for International Student Satellites, http://www.arliss.org/.

[3] Georgia Tech CanSat Project, http://singhose.marc.gatech.edu/CanSat/.

[4] Thomas Kurfess, William Singhose, and Joel Fortgang. Genesis and evolution of an undergraduate mechatronics course. In *Second IFAC Conf. of Mechatronic Systems*, Berkeley, CA, 2002.