AC 2008-1102: ADDRESSING AEROSPACE WORKFORCE NEEDS: THE IMPACT OF HANDS-ON SPACE SYSTEMS PROJECT EXPERIENCES ON CAREER CHOICES

Sven Bilen, Pennsylvania State University
SVEN G. BILÉN is an Associate Professor of Engineering Design, Electrical Engineering, and Aerospace Engineering at Penn State. He is the Chief Technologist for Penn State's Center for Space Research Programs and Director of the Student Space Programs Lab. He is member of IEEE, AIAA, AGU, ASEE, URSI, and Sigma Xi.

Mieke Schuurman, Pennsylvania State University
MIEKE SCHUURMAN is an engineering education research associate with the Leonhard Center for the Enhancement of Engineering Education in the College of Engineering at The Pennsylvania State University. She has a Ph.D. in Social Psychology from The University of Groningen in The Netherlands.

Lisa Brown, Pennsylvania State University
LISA BROWN is the Director of the Pennsylvania Space Grant Consortium and an Instructor in the College of Earth and Mineral Sciences at Penn State.

Timothy Wheeler, Pennsylvania State University
TIMOTHY F. WHEELER is a Research Assistant in the Electrical Engineering Department at Penn State University, where he leads long-term project-based programs based on sounding rockets and community service.

Julio Urbina, Pennsylvania State University
JULIO URBINA received his B.S. degree from Universidad Nacional de Ingenieria, Lima, Peru, and M.S. and Ph.D degrees from University of Illinois at Urbana-Champaign. He is an Assistant Professor in the Department of Electrical Engineering at Penn State.

Abstract

Several reports have recently been released on the looming workforce issues within the aerospace industry. To address these workforce needs, a number of universities have developed projects, laboratories, and/or courses that target the fundamental education and training of university students in the space systems field. Although a fair bit of anecdotal evidence exists that these types of space systems projects are strong motivators for students to enter space-related fields, at Penn State we have sought to measure this effect via a series of exit surveys for graduating seniors in electrical and aerospace engineering. Although we have specific interest in the aerospace field, we are also interested in assessing how students’ participation in design projects and other hands-on activities affects students’ career choices. We believe that these experiences can have a great impact. We chose the aerospace field for our pilot study because it is of particular interest to us, but also because the aerospace field is reasonably well defined and space-related programs and activities are fairly easy to identify, as are companies in the space field. Our initial data confirm that space systems-related activities indeed increased students’ interest in space-related careers.

Introduction

There are a number of reports that have recently been released on the looming workforce issues within the aerospace industry as the “Apollo generation” reaches retirement. Universities have been searching for the role they are to play in addressing this issue—indeed, the past three Universities Space Research Association (USRA) Annual Symposia have addressed aerospace workforce issues with members of its Council of Institutions. While the need for a trained workforce is growing, opportunities for students to obtain hands-on experience with spaceflight hardware have been steadily declining. Indeed, the “Aldridge Report” states:

“At present, there are insufficient methods for students to acquire hands-on experience in the scientific and technical disciplines necessary for space commerce and exploration.”

There have been a number of proposals for addressing this workforce-development issue, as well as a number of high profile space-systems project efforts—such as the University Nanosatellite program and CubeSats, to name but two—to encourage students to enter the aerospace field by developing their skill set via hands-on projects. To address the Vision for Space Exploration, NASA will need many new engineers to fill its workforce. Indeed, a National Research Council committee recently released a report that states:

“The [NRC] committee believes that training students to design and build satellites and satellite instruments, gain hands-on experience with the unique demands of satellite and spacecraft systems environments and operations, and acquire early knowledge of systems engineering techniques is an extremely important investment for NASA to make.”
At Penn State, the Student Space Programs Lab (SSPL)\textsuperscript{12,13} is providing for the fundamental education and training of university students in the space systems field—beginning in the first year of college—that we hope will help to address these workforce needs. Although we have had a fair bit of anecdotal evidence that these types of space systems projects are strong motivators for students to enter space-related fields, we have sought to measure this effect. Samples of the types of projects at Penn State include sounding rockets, balloon payloads, small satellites, and reduced-gravity experiments.

This paper discusses the data collected to examine the impact of aerospace projects on student interest level in entering the aerospace field and preliminary analysis of those results. We also discuss how these results mirror those of a larger nationwide effort by Space Grant to measure the effects that activities have on the students participating in them. While providing access to such projects is important, our experience with these projects indicated the need to establish a course that helps encourage students into these projects. We discuss this and some data collected to help design the course to better meet the needs of students and of the SSPL. Finally, we end with a summary of our findings and some implications of the results.

**Impact of Aerospace Projects on Student Interest Levels**

**Data Collection**

The College of Engineering at Penn State administers a Senior Exit Survey at the end of each semester for graduating seniors. In the spring and summer semesters of 2007, in the graduating classes of Aerospace, Electrical, and Mechanical Engineering we added questions about students' involvement in aerospace-related projects and their interest in a career in the aerospace field. As this is an existing survey that already has many questions, we sought to limit the length of the additional questions. The Departments of Aerospace and Electrical Engineering agreed to add the following questions related to the field of aerospace:

1) Indicate in which aerospace project(s) you were involved in which year(s) of your study [here students chose from a list of existing projects and had the option to fill in projects not listed].
2) Indicate your level of interest in working in the aerospace field upon graduation at each of the following times [these results were on a Likert scale with answer options: Not Interested at All – 0, Slightly Interested – 1, Interested – 2, and Very Interested – 3]:
   - Right before I went to college
   - Currently [at graduation]

We aimed to answer the research following questions:

1) Did the interest of students who graduated in the fields of aerospace and electrical engineering change between the moment they went to college and when they graduated?
2) If students’ interest changed, what was the impact of their involvement in aerospace activities?

As mentioned, the data described in this paper are from seniors who graduated in spring 2007 and summer 2007. The response rates were as follows for the questions related to aerospace:
Aerospace 47% (36 out of 76 graduates), Electrical 54% (56 out of 104), and Mechanical 6% (10 out of 173). The student responses from mechanical engineering were extremely limited, which reflects the fact that there are far fewer mechanical engineering students in these projects. Hence, for the paper we will report only on the aerospace and electrical engineering students. Because students were not required to complete each question, these numbers can vary below.

Results
The first questions asked for involvement in aerospace activities. Table 1 shows that 39% of the aerospace engineering students in the graduating cohorts were involved in one or more aerospace activities during their time in college, whereas in electrical engineering the percentage was 28%. The majority of the students were involved in a single activity, but a number of the students were involved in more than one activity. Additionally, as would be expected, a higher number of students in aerospace engineering were involved with space-related projects, and higher numbers have been involved in more than one.

<table>
<thead>
<tr>
<th>Involvement in Aerospace Activities</th>
<th>Aerospace Engineering Students</th>
<th>Electrical Engineering Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>No activities</td>
<td>22 (61%)</td>
<td>40 (72%)</td>
</tr>
<tr>
<td>1 activity</td>
<td>8 (22%)</td>
<td>9 (16%)</td>
</tr>
<tr>
<td>2 activities</td>
<td>2 (6%)</td>
<td>3 (5%)</td>
</tr>
<tr>
<td>3 or more activities</td>
<td>4 (11%)</td>
<td>4 (7%)</td>
</tr>
<tr>
<td>Total</td>
<td>36 (100%)</td>
<td>56 (100%)</td>
</tr>
</tbody>
</table>

Table 2 indicates that both aerospace and electrical engineering graduating seniors reported an increased interest in working in the aerospace field.

<table>
<thead>
<tr>
<th>Interest Level</th>
<th>Aerospace Engineering Students (N = 36)</th>
<th>Electrical Engineering Students (N = 56)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right before College</td>
<td>Upon Graduation</td>
</tr>
<tr>
<td>Not interested</td>
<td>1 (3%)</td>
<td>2 (5%)</td>
</tr>
<tr>
<td>Slightly interested</td>
<td>6 (17%)</td>
<td>6 (17%)</td>
</tr>
<tr>
<td>Interested</td>
<td>10 (28%)</td>
<td>5 (14%)</td>
</tr>
<tr>
<td>Very interested</td>
<td>19 (52%)</td>
<td>23 (64%)</td>
</tr>
<tr>
<td>No data</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
</tbody>
</table>

To explore the influence of students’ involvement in space-systems project activities on their changed interest, we calculated a score for each student that indicated the difference between their interest right before they went to college compared to their interest upon graduation. Table 3 shows that the interest level of 53% of the aerospace students and 59% of the electrical Engineering students did not change from right before college to when they graduated; 28% of the aerospace students and 23% of the electrical engineering students showed an increased interest and 20% and 12% showed a decreased interest, respectively.
It is important to keep the following in mind when comparing the changed levels of interest of aerospace and electrical engineering students. A vast majority of aerospace engineering students were already “interested” or “very interested” in the field of aerospace right before they went to college, compared to only 25% of the electrical engineering students (see Table 2), as might be expected. Therefore, the latter group had much more room to increase their interest. Despite a possible “ceiling effect”, 12% of the aerospace students still showed a change from “interested” to “very interested”. Electrical engineering students showed the largest shift at the other end of the scale: 7% of the students changed from “not interested” to “slightly interested”.

Table 3: Student level of interest upon graduation compared to right before college

<table>
<thead>
<tr>
<th>Change in Interest Level: Upon Graduation – Right before College</th>
<th>Aerospace Engineering Students</th>
<th>Electrical Engineering Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>−3</td>
<td>1 (3%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>−2</td>
<td>3 (8%)</td>
<td>3 (5%)</td>
</tr>
<tr>
<td>−1</td>
<td>3 (8%)</td>
<td>4 (7%)</td>
</tr>
<tr>
<td>0</td>
<td>19 (53%)</td>
<td>33 (59%)</td>
</tr>
<tr>
<td>+1</td>
<td>6 (17%)</td>
<td>9 (16%)</td>
</tr>
<tr>
<td>+2</td>
<td>4 (11%)</td>
<td>3 (5%)</td>
</tr>
<tr>
<td>+3</td>
<td>0 (0%)</td>
<td>1 (2%)</td>
</tr>
<tr>
<td>No data</td>
<td>0 (0%)</td>
<td>3 (5%)</td>
</tr>
</tbody>
</table>

To answer the question how students’ changed interest was related to their involvement in aerospace activities, we calculated how their individual difference scores correlated with the number of activities they were involved in by calculating Spearman’s rho. The results showed no statistically significant correlation between the number of activities in which students were involved and their change in interest level for both aerospace and electrical engineering students; the Spearman’s rho was −0.18 ($p = 0.28$) for aerospace and 0.11 ($p = 0.42$) for electrical engineering students. Since only 17 aerospace and 20 electrical engineering students showed a change in their level of interest, these low numbers might have been the reason no statistically significant difference was found. We will need to collect data from more students in order to test this.

Space Grant Tracking Efforts

Established by U.S. Congress in 1988 and implemented by the National Aeronautics and Space Administration, the National Space Grant College and Fellowship Program (also known as Space Grant) works to prepare students for careers in aerospace science and technology by funding research, education, and public service projects through a national network of 52 university-based Space Grant consortia. These consortia administer programs in all 50 states, the District of Columbia, and the Commonwealth of Puerto Rico. The consortia’s 820 affiliates include 531 academic institutions and 80 businesses. Other partners include state and local government agencies, other federal agencies, and nonprofit organizations.
As many of the programs at Penn State are funded in whole or part by the Pennsylvania Space Grant Consortium\textsuperscript{16}, there is also interest in tracking what effect these programs have on the career choices of the students involved. The results are broader in that they do not focus exclusively on the aerospace field, but STEM (science, technology, engineering, and math) in general.

Space Grant has been evaluating the impact of their efforts on students’ educational progress since the program’s inception. Beginning in the 2005 program year, these evaluations are now endeavoring to track the movement of students beyond graduation from their Space Grant institutions toward either the pursuit of advanced degrees or employment. Many state consortia are establishing mechanisms by which students can continually report their status within the aerospace or greater STEM workforce. Data has been collected\textsuperscript{16} from participants of the 2005 program year (417 graduating students reporting) and the 2006 program year (219 graduating students reporting). This data is presented in Table 4 below.

<table>
<thead>
<tr>
<th>Employment Status</th>
<th>2005 Program Year</th>
<th>2006 Program Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>NASA</td>
<td>7%</td>
<td>7%</td>
</tr>
<tr>
<td>STEM Industry</td>
<td>61%</td>
<td>55%</td>
</tr>
<tr>
<td>STEM Academia</td>
<td>27%</td>
<td>16%</td>
</tr>
<tr>
<td>Other (non STEM)</td>
<td>5%</td>
<td>22%</td>
</tr>
</tbody>
</table>

These results clearly show the impact that Space Grant programs have on the students who are part of them. However, as currently formulated, the survey does not capture which specific STEM field they enter. Therefore, our study adds value in that it gives more specific information about the fields in which graduates are going to work.

**First-Year Seminar**

In our discussions with students, it has become clear that there is a need to “on ramp” students to aerospace project activities. To this end, we developed a first-year seminar (FYS) called This is Rocket Science. At Penn State, FYSs are first-year courses with no prerequisites, designed to engage students in learning and facilitate their transition to college life, and limited to 20 students to ensure close student–faculty interaction. The course is open to any student who wants to learn about space systems and how space instruments work. Therefore, the course serves several important purposes: (1) it serves as the introduction to space systems and instrumentation, (2) it provides an overview of systems engineering, (3) it serves as a recruiting function for aerospace, electrical, and mechanical engineering majors (among others), and (4) as a FYS, it was designed also to expose students with non-technical majors, including prospective K–12 teachers, to an important technology field and the engineering process (although the first offering of this FYS contained only engineering majors).

The goal of this course is to produce a conceptual design for an entry to the CanSat competition\textsuperscript{17} that takes place each summer. This space-related competition involves students with the beginning-to-end lifecycle of a complex engineering project: from conceptual design through
integration and test, and the actual operation of the system, which is the final launch. Therefore, the pedagogical approach of the course follows the Learning-by-Design (LBD) technique of constructionism. 18 Constructionism postulates that new ideas are generated when learners are actively engaged in building some type of external artifact that they can reflect upon and share with others. 18, 19, 20 The first portion of the course focuses on small team-oriented projects to introduce fundamental concepts in electrical, mechanical, and aerospace engineering topics related to space projects and the design of a CanSat payload. The remainder part of the semester (about 2 weeks) is devoted to design and build a payload—which we have dubbed ClassSat—that carries three raw eggs to an altitude of ~1800 feet and then returns the eggs to the ground unbroken, which is a modified version of the Team America Rocketry Challenge. 21, 22

For the purpose of course assessment, an initial survey, a mid-term, and an end-of-term questionnaire were administered. This feedback was intended for course improvement and to register which of the elements of the class were found most meaningful by the students. The goals that had been set for the course were:

1) Provide a low-key supportive learning environment to ease the transition to a big University
2) Recruit a high quality cohort of new students for SSPL
3) Introduce those students to the Systems Engineering approach
4) Provide a hands-on experience
5) Form a team for CanSat

In the initial survey, we received 20 responses with the following results: 37.5% of the students stated that they had chosen the course in order to help them choose a departmental major; 37.5% cited an existing interest in rockets and space; 12.5% were looking for a hands-on experience; and 12.5% said the course sounded like fun.

The mid-term questionnaire was intended to provide some assurance that the course was meeting its goals. We were gratified by a decidedly positive response. 80% of the 20 respondents gave a positive response, compared to 15% negatives. Students were asked to register their satisfaction with elements of the course plan. 75% of the responses were positive, while 7% were negative; the rest were neutral. The students made a strong statement that they appreciated the student assistants and faculty who were there to help them. More than half of the responses to the open question of “What has been most helpful?” included responses, such as “The vast amount of experience available to us” and “Good interaction with other students and professors.” Thus, our determination to provide a high level of faculty and upper-class student contact was noticed and appreciated by these students. Students consistently suggested that more time should be provided in class to do project work. This request was met during the second half of the course.

The semester-end evaluation was almost as positive as the mid-term questionnaire. 73% of the possible responses were positive, versus 8.6% negative and 18.3% neutral. 82% of the class suggested that the course had helped them to be confident in selecting an engineering major. 65% reported that it “increased my interest” in pursuing a space-related engineering career (29% were neutral). This confirmed that this goal of the course was being met.
We asked the students to rate eleven features of the course. The CanSat payload concept exercise was rated positively by 100% of the students. Systems Engineering received the most negative/neutral ratings, though just over half the students still rated it positively. The class lectures were also rated “worthwhile” by about half of the students.

From these data, we conclude that the goals of providing a welcoming transition to Penn State and encouraging first-year students to consider engineering as a major were met. Observations by the faculty and students who ran the course seemed to support these conclusions. Close to half the class subsequently became involved in SSPL projects, including CanSat, indicating to us that this FYS was an effective tool for attracting entering first-year students to space-related student projects. If we are to increase the flow of quality engineers to space careers, this strong recruitment record is an important first step. We will need to follow the students involved in this FYS to determine the longer-term effects on their interest in the aerospace field.

Summary and Implications

In this work we sought to quantitatively measure anecdotal evidence that space systems projects are strong motivators for students to enter space-related fields. We measured this effect via a series of exit surveys in the spring and summer semesters of 2007 for graduating seniors in electrical, mechanical, and aerospace engineering. Our data confirmed that space systems-related activities indeed increased students’ interest in space-related careers. Future work will focus on determining what aspects of the projects had the most effect in increasing this interest. Additionally, we would like to identify ways that these projects might better attract women and underrepresented minorities to the field.

These space-systems projects equip students with many of the abilities that the aerospace industry—and other industries—desires in the new engineering graduate. These projects provide the student with hands-on experience in real-world aerospace systems that are not possible through courses alone. In general, for design experiences ABET desires that the design experience should:

- include a variety of realistic constraints, such as economic factors, safety, reliability, aesthetics, ethics, and social impact;
- be a meaningful, major engineering design experience that builds upon the fundamental concepts of mathematics, basic sciences, the humanities and social sciences, engineering topics, and communication skills;
- be taught in section sizes that are small enough to allow interaction between teacher and student;
- be an experience that must grow with the student’s development; and
- focus the student’s attention on professional practice and be drawn from past course work.

Clearly, space-systems projects are excellent design experiences that match up well to the formal educational, rather than just the experiential, aspects of the design experience.

The research work presented here was specifically targeted at the aerospace field. The field of aerospace is well-defined, and space related programs and activities are fairly easy to identify, as
are companies in the space field. There is interest in the more general question as well, i.e., how students’ participation in design projects and other hands-on activities affects students’ career choices; we believe that these experiences can have a great impact.

Bibliography