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Lessons Learned by the Aerospace Engineering Department at Texas A&M University Following Its First Summer Camp for High School Students

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A native Texan, David Kanipe was born in Corpus Christi and attended Texas A&M University beginning in September 1966. He received a Bachelor of Science degree in Aerospace Engineering in May 1970, followed by a Master of Science degree in Aerospace Engineering in August 1971. He suspended work on a Ph.D. to accept a position with NASA at the what was then called the Manned Spacecraft Center in Houston in November 1972. After holding successively responsible positions, he was selected as chief of the Aeroscience and Flight Mechanics Division in the Engineering Directorate at the Johnson Space Center in January 2001 and served in that position until retirement on December 31, 2010. A month after his arrival at NASA, the last Apollo mission, Apollo 17, was launched. Obviously, that was exciting, but in terms of his career, the commencement of the Space Shuttle Program in November 1972 was to have far more impact. As a result, Kanipe was able to begin his career working on what he says was the most interesting and exciting project he could possibly imagine: the Space Shuttle. Kanipe moved into management in May 1990 when he became the Deputy Branch Chief of the Aerodynamics Branch in the Aeroscience and Flight Mechanics Division. In March 1996 he was appointed chief of the GN&C Analysis and Design Branch. Subsequently, he became the deputy chief of the Aeroscience and Flight Mechanics Division in December 1998 and was selected as Chief of the Aeroscience and Flight Mechanics Division in the Engineering Directorate at the Johnson Space Center in January 2001. Kanipe retired from NASA at the end of 2010 after more than 38 years of service in the US Space Program. His career spanned numerous projects and programs, including both crewed and robotic spacecraft. Kanipe was also an enthusiastic promoter of collaborations between universities and NASA. After retiring from NASA, the Head of the Aerospace Engineering Department at Texas A&M University asked him to come to A&M and teach a Senior Capstone Design course focused on Spacecraft Design. He began his second year of teaching at Texas A&M in August 2012.

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Abstract

In an effort to improve outreach to high schools and encourage interest in aerospace engineering, the Aerospace Engineering Department at Texas A&M University recently held its first summer camp for high school juniors and seniors in July 2012. Most engineering summer programs for high school students administered at the college-level have the common purposes of exciting high school students about engineering and serving as a means to attract talented students into their program. Often, the activities are designed more for fun than for educational purposes, and the appropriate age level is not always considered. One of the goals of this camp was to find a balance between these competing priorities. Since this was the first attempt at a summer camp by the Aerospace Engineering Department, the staff and student workers gathered information and advice from experienced sources to maximize the probability of success. The camp structure and activities were intended to address the following fundamental questions:

- Is this an effective method of communicating the fundamentals of aerospace engineering to high school students?
- Is this activity sufficiently interesting and instructive to maintain the attention of high school students without either boring or overwhelming them?

These questions were used as guidelines during development of the camp structure. All ideas and potential activities were assessed relative to these guidelines.

Introduction

This was the first attempt by the Aerospace Engineering (AE) Department at Texas A&M University to hold a summer camp for high school students who had both an interest in aerospace studies as well as the potential to attend the university. The camp structure ultimately developed by the AE Department at Institution was a week-long summer program designed to teach high school juniors and seniors the basic scientific principles of rockets or aircraft, depending on the track selected by the participant. Entitled Camp SOAR (Summer Opportunities in Aerospace Research), the camp was designed to provide a mixture of hands-on projects reinforced by a minimum level of basic physics instruction, coupled with engaging and challenging demonstrations of basic fundamental laws as well as tours of Texas A&M's aerospace research facilities. Since the camp was intended to recruit the best students possible, and realizing that students are more sophisticated than ever, it was important to strike a balance between classroom instruction, facility tours, and the hands-on activities, which of course the students enjoyed most of all. In the end, that balance was achieved for most aspects of the camp. Valuable lessons were learned, however, that will be applied to next summer's camp. It is anticipated that aerospace engineering departments with current high school summer programs or those considering starting a program will discover practical information in this paper that can be adapted to their circumstances and will recognize pitfalls that should be avoided. In addition, high school programs seeking to use rocket launches to teach basic physical laws will also find useful project ideas and strategies herein.

This paper will provide a review of the camp activities related to the rocket track: details on what worked and was not well received, as well as feedback from both students and mentors. The authors will discuss the development of the camp blueprint, how students were selected, how the project builds moved from paper models to powered flying models, and the unexpected role of social media. Student feedback and plans for future iterations of the camp will also be discussed.

Developing a Blueprint

In the early stages of camp development, several meetings were held with the Electrical and Computer Engineering (E&C) Department, which had held summer camps for several years and had learned from experience things that generally worked and those that were most likely to cause problems. Some of the most valuable advice provided was to avoid large, extended projects and utilize hands-on projects that involved a finished product the students could take home from camp. The danger of large projects is the ever present possibility of an unforeseen problem that stops the activity and results in unplanned down time. AE's plan had always been to provide hands-on projects, but the scope had been fairly broad. After this input, the projects were re-planned and reduced to smaller work units with achievable milestones along the way.

As mentioned previously, it was always intended to provide a basic understanding of the physics behind rocket and aircraft flight. While it was felt that a moderate amount of instruction was necessary, the aim was to keep traditional lectures to a minimum and to season them with interesting and instructive demonstrations to maintain student attention. Once again, this could be a delicate balance that to a certain extent depended on the knowledge of the individual students in the room. In fact, even though the selection process would narrow the range of knowledge and experience, there could possibly still be a wide spectrum of awareness and interest among the students, complicating the issue. The game plan for Camp SOAR was to err on the side of less time spent lecturing.

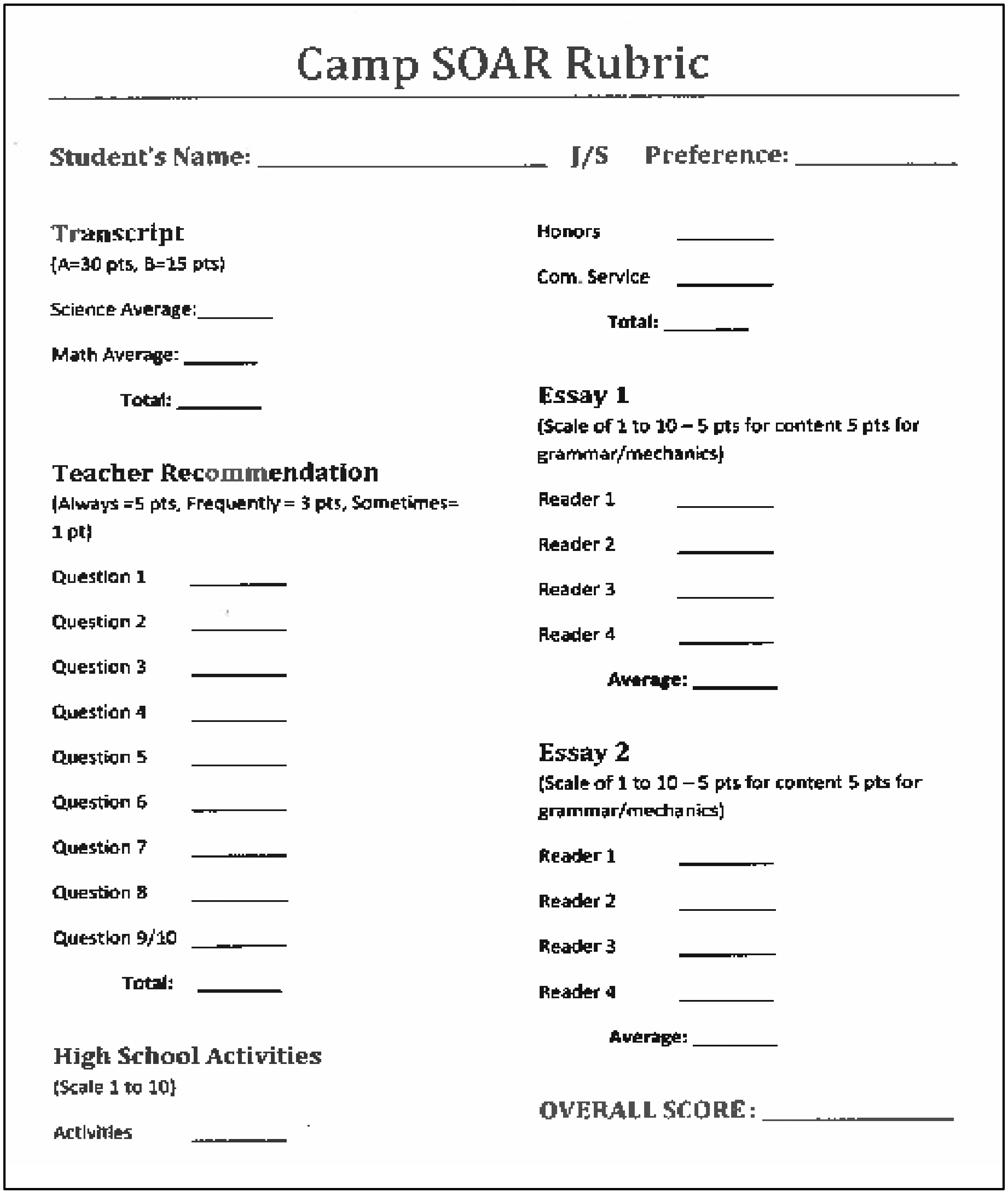
For the time spent not working on the projects, part of the camp was devoted to tours of aerospace research facilities to provide students a view into the research aspect of Texas A&M University. Activities were also planned completely separate from the daily immersion in aerospace projects and research facilities. The summer camp held by the E&C Department occurred simultaneously with that of the AE Department, so the plan was for the two groups to stay in the same dorm and socialize during evening activities.

Student Selection Process

From the beginning it was understood that the process used to select the camp participants was of fundamental importance to the success of the camp. Consequently, significant up-front effort was devoted to the development of a selection rubric that would be fair to all applicants while providing camp organizers with a clear indication of those students with comparable skills, education, and interests. As a first step, the team responsible for developing the selection protocol studied the rubric of the E&C Department at Texas A&M that had significant experience conducting successful summer camps. While not adopted in its entirety, this example was crucial to the development of the selection process.

Each student desiring to attend Camp SOAR was required to submit an application package consisting of the following: 1) transcript, 2) teacher recommendation, 3) honors and activities, 4) essay 1, and 5) essay 2. Applicants were evaluated only on the basis of the information contained in the application. Aspects, such as gender, race, and ethnicity, were not considered during the evaluation of the application. The first essay asked the student to explain interest in AE, and the second essay asked for a description of the biggest obstacle in life and how it had been overcome. The essays were especially important in gauging the maturity level of a prospective student as well as the authenticity of the interest in AE. Applicants were also required to include a high school transcript and a recommendation form and letter of recommendation written by a math or science teacher. While the transcript was an important part of the overall assessment, it should be noted that the extent of an applicant's math background was not a factor in the selection process. It was, however, used subsequently in making team assignments. Each applicant was also asked to select a preference for the aircraft track, the space track, or no preference.

Each application was reviewed and scored by four different reviewers. The rubric score sheet used by the reviewers is shown in Figure 1. The five separate parts of the application were evaluated and scored separately and were then added to produce a total score. No weighting factors were applied; the five sub-scores were linearly combined to produce the total score. Finally, the total scores from all reviewers for each applicant were added, and the applicants were sorted from highest to lowest score. Since the capacity of the AE summer camp at Institution was 30 students, the 30 applicants with the highest scores were chosen and notified. Of course, if an applicant decided not to attend, an alternate applicant was notified. Of particular interest was the fact that the 30 applicants chosen for the first camp were composed of 15 males and 15 females, although gender parity was not a goal. Selecting a group that was most likely to be interested and motivated was the objective. The use of the selection protocol described above as well as an impartial review process provided a straightforward means of attaining that objective.



Camp SOAR Rubric

Student's Name: ______________ **J/S** **Preference:** __________

Transcript
(A=30 pts, B=15 pts)

Science Average: ________

Math Average: ________

Total: ________

Teacher Recommendation
(Always =5 pts, Frequently = 3 pts, Sometimes= 1 pt)

Question 1 ________

Question 2 ________

Question 3 ________

Question 4 ________

Question 5 ________

Question 6 ________

Question 7 ________

Question 8 ________

Question 9/10 ________

Total: ________

High School Activities
(Scale 1 to 10)

Activities ________

Honors ________

Com. Service ________

Total: ________

Essay 1
(Scale of 1 to 10 – 5 pts for content 5 pts for grammar/mechanics)

Reader 1 ________

Reader 2 ________

Reader 3 ________

Reader 4 ________

Average: ________

Essay 2
(Scale of 1 to 10 – 5 pts for content 5 pts for grammar/mechanics)

Reader 1 ________

Reader 2 ________

Reader 3 ________

Reader 4 ________

Average: ________

OVERALL SCORE: ____________

Figure 1. Camp SOAR student selection rubric.

Camp SOAR Program

The week of Camp SOAR began at noon on Sunday and continued through Friday afternoon when the students checked out of the dorms. On Sunday, the families and students met with the faculty and camp counselors who would be working with the campers and had lunch together to begin the familiarization process. As expected, the students were initially reticent, but it did not take long before the participants began to relax and enjoy the new experience. The rest of Sunday involved ice-breakers, a lab safety review, and an entertaining design project using pizza boxes to create a hovercraft as shown in Figures 2a and 2b.

Figure 2a. Students get to know each other.

Figure 2b. Pizza box hovercraft.

Each day was organized a little differently but typically involved facility tours and a limited amount of instruction with the majority of the day spent with hands-on activities. By design, hands-on activities were preceded by instruction in the relevant laws of physics that would be demonstrated by the activity as shown in Figure 3a. It was important to continually be conscious of the fact that the participants were high school students (including juniors) who could possibly be easily overwhelmed.

At the same time, the notion that first rate universities conduct exciting, on-going research activities available to undergraduate students was intentionally showcased. The caveat, however, was that the representatives of the labs must deliver their presentation with energy, enthusiasm, and at the appropriate level in order to be effective and enjoyable by high school students. Figure 3b shows a student participant obtaining hands-on experience during the Materials Laboratory tour.

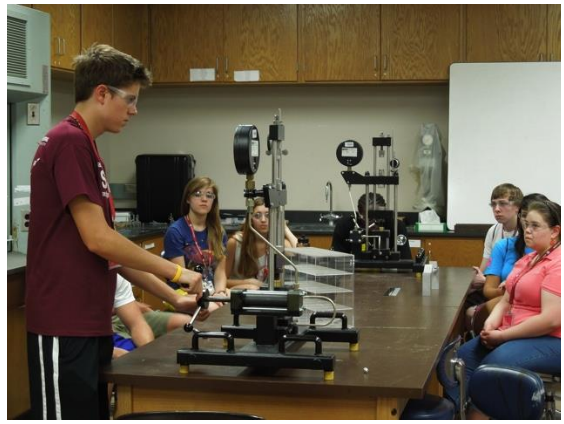


Figure 3a. Lecture: Application of physical laws. Figure 3b.Students in the Materials Lab.

Even though the students were split into two separate groups, a conscious decision was made to occasionally switch the Aircraft and Rocket tracks in order to give each group a taste of what the other half was experiencing. There was some uncertainty concerning whether this would be welcome or not, but in the end, it turned out to be a popular feature. Each group was able to appreciate what the other group was doing and in the process, learn something about that aspect of AE.

Beginning on Monday, the first full day of camp, various demonstrations of Newton's laws as well as the principle of momentum exchange, critical to how a rocket works, were conducted[1]. A very basic demonstration used a small, four wheeled cart on a tabletop equipped with a slingshot mechanism that launched a steel ball bearing in one direction such that it moved in the opposite direction. Using larger or more ball bearings showed that the cart moved further, depending on the amount of mass ejected. This relates directly to the importance of the rocket fuel properties (e.g., mass, chemistry, exit velocity). The principle was demonstrated in a more personal and entertaining way by having two people sit on a chair with caster type wheels on a hard floor. One of the persons is situated, so that it is easy for them to jump off the chair, thus propelling the other person in the opposite direction. This provided an excellent visual demonstration as students could see how smaller students riding the chair would be propelled quite far when a larger person jumped off, but the smaller person's effect was much less if leaving first.

There were a total of 15 students in the Rocket track, which were divided into five teams of three. With the exception of the paper rockets' launch mechanism, these teams built the hands-on projects. The teams were formed prior to the start of the camp based on what was provided in the applications by the students. The intent was to avoid having one dominant team composed of three students experienced in model rocketry. In addition, there was a conscious effort to have gender mixed teams. While it was not an issue here, this could have been a tricky endeavor depending on the number of females who apply and are accepted.

The hands-on activities began with paper rockets propelled by compressed air[1,2]. These were simple to build and provided a good introduction to the physics of rockets. The equipment and setup for these rockets can be seen in Figure 4. Due to the fact that the "engine" that propelled the rocket was compressed air and that as soon as it cleared the end of the PVC pipe the rocket was no longer accelerating but coasting, it was relatively easy to predict the resulting trajectory. Depending on the supply pressure, these simple rockets were surprisingly dynamic.

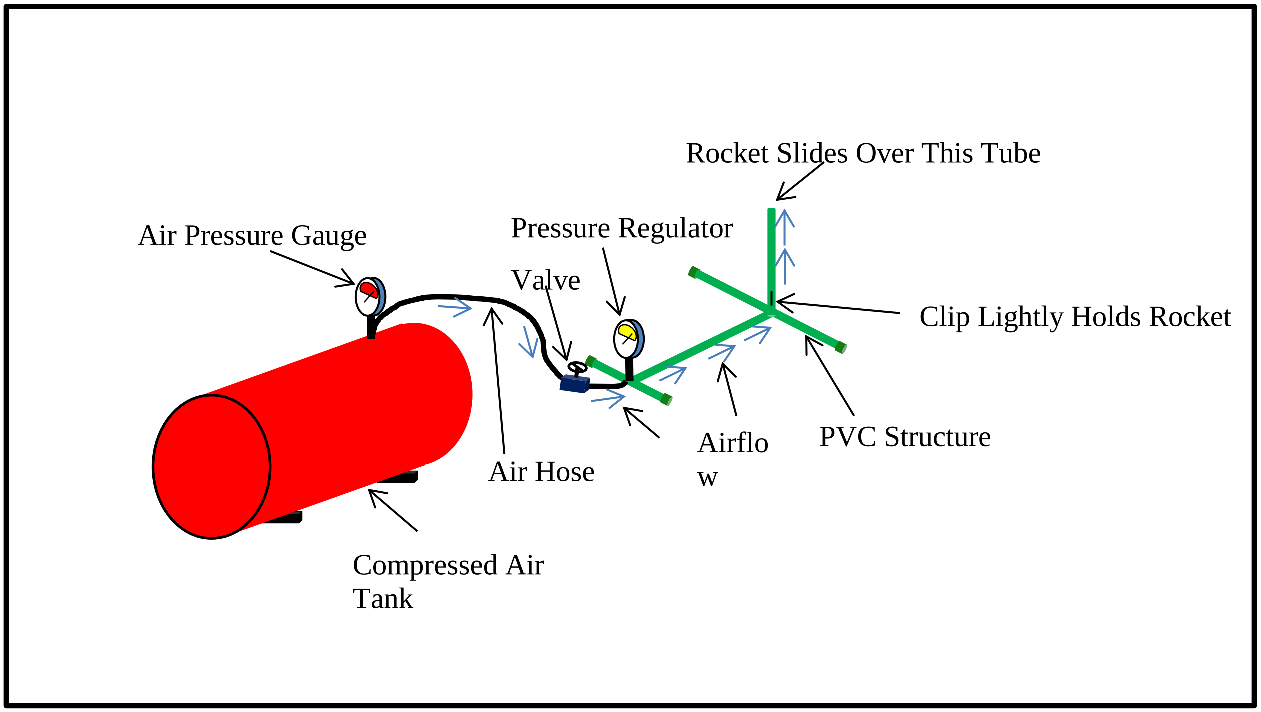


Figure 4. Compressed air system used for the paper rocket project.

After basic laws of physics had been demonstrated with the paper rockets, the students in the Rocket track then received hands-on experience in building an Estes Rocket model, as shown in Figure 5. Since it was unlikely that every student had previous experience building and flying model rockets, a relatively simple rocket was built first to establish a common foundation. Originally, there were three separate powered model rocket builds planned, but during the camp it became obvious there was not enough time for all three, so the second model build was eliminated. The second rocket project was designed to be a slightly more complicated medium sized rocket. Cancelling the second project turned out to be a good decision since it allowed more time to be spent on the third and most exciting rocket project of the camp which allowed the students to utilize what had been learned and exercise creativity.

Figure 5. Building the first powered rocket.

After building the first Estes rocket, the teams analyzed the rocket trajectories in light of the physical concepts of momentum exchange discussed the first day. For these analyses, each student constructed a personalized model of the rocket using an Open Source Java Applet developed for Estes rocket analyses called OpenRocket[3]. This applet provided accurate results for the trajectory and apogee of the rockets due to its ability to accurately model individual rocket configurations as well as characteristics of the engines used. By performing these analyses, students were able to predict trajectories and obtain estimates of apogee comparable to what was observed.

The final rocket project, and the most popular, provided the opportunity for students to build upon previous designs and explore their creativity as displayed in Figures 6a and 6b. The teams were given a simple box of parts (tubes, engine mounts, balsa wood, nose cones, etc.) and allowed to design their own rocket that would provide an opportunity for the students to experiment with some of the basic variables of rocket flight. Students attacked this project with great delight and produced quite a collection of unusual and exotic rockets. In some cases, creativity outran practicality; in turn, those rockets were typically less successful. Even then, however, there was something to be learned from failure. This was the most popular activity of the camp and will be further refined and included in the design of future camps. Figure 7 depicts launch preparations for the final rocket projects.

Figure 6a. Designing the final rocket.

Figure 6b. Examples of final rocket design.

Figure 7. Preparing to launch final rocket designs.

Observations and Feedback

To aid in the evaluation of Camp SOAR, participants completed surveys, which rated various aspects of the camp and allowed for suggestions to be provided. Since the camp counselors interacted closely with the students during the week, there was a different survey version to obtain this perspective. These data proved to be both revealing and valuable and will definitely influence the design of the next summer camp. As shown in Figure 8, overall students had a good impression of Camp SOAR. Survey results were obtained using a Likert scale. This type of qualitative survey is used to score responses along a range, in this case from Strongly Agree to Strongly Disagree. Students were mainly interested in AE before the camp with 76% of participants selecting strongly agree or agree. Most importantly, participants were still interested in AE after the camp with almost the same percentage, 73% in this case, strongly agreeing. For comparison, 90% selected strongly agree or agree on their interest in AE after the camp. Overwhelming, students felt participating in the camp provided encouragement to pursue a career in AE and excitement about AE with 84% and 90% of the students strongly agreeing or agreeing with this statement, respectively. Students surveyed did not disagree with any of the above statements. To obtain a different perspective and ensure students were reading the survey questions, the next question turned it around a little bit by asking if participating in camp caused nervousness. The majority of students, 57%, disagreed or strongly disagreed with this statement. As of the last day of camp when the survey was administered, 70% of the students intended to apply to the AE Department at Texas A&M University with another 27% being unsure at that time.

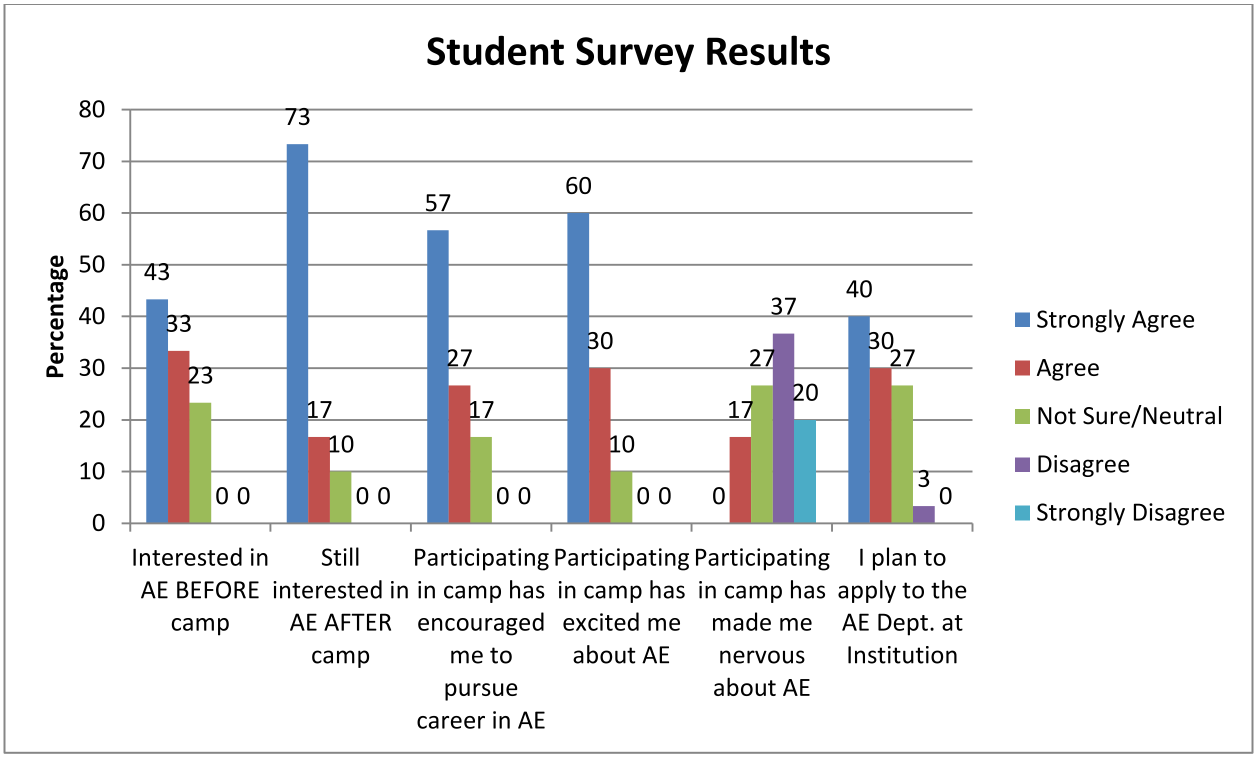


Figure 8. Final survey results received by students in Camp SOAR.

Information related to the reason students decided to attend Camp SOAR was collected as shown in Figure 9 with a large majority of students wanting to become more knowledgeable about the AE field. The number listed next to each of the responses was the actual number of times that response was denoted. It was an open-ended question where students listed one or more reasons for deciding to attend Camp SOAR. Other popular reasons included wanting to gain experience and seeing what Texas A&M University was like.

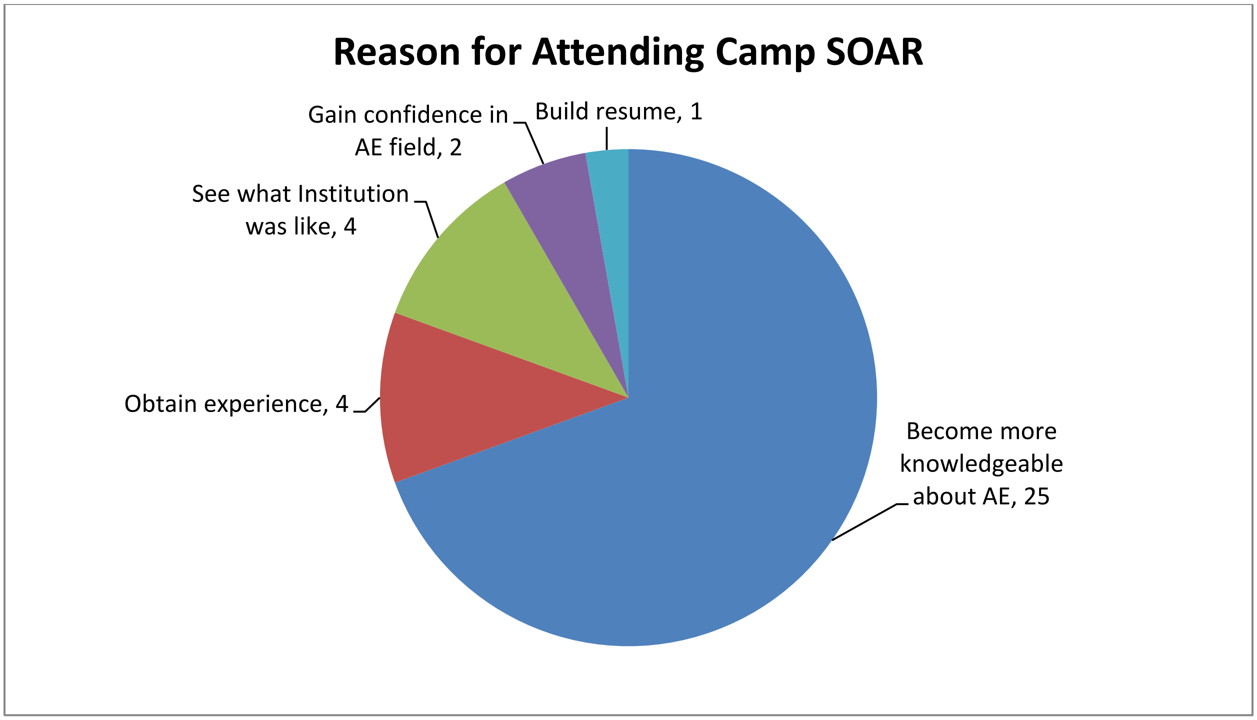


Figure 9. Student reasons for attending Camp SOAR.

Additional information included in the survey related to favorite and least favorite labs visited, feedback on each of the projects completed, overall experience in the camp, and suggestions for improvement. Providing the students exposure to unique world-class research laboratories was deemed important in the initial planning of the camp. Laboratory tours with high interaction and less repetition were easily the most popular tours. While the feedback received on some labs was negative, it was not interpreted as a sign that the particular lab tour should be discontinued but rather that it needed to be retooled. An example would be having the students observe robots moving in one of the labs versus the excitement generated when students were able to control the robots. On the other hand, the lab where students were allowed to handle research materials seemed to make more of an impression. Visiting wind tunnels was exciting, but it was much less memorable than it could have been due to an experiment not being tested at that time. Needless to say, flying a plane in the flight simulator was a favorite as it provided high interaction and hands-on experience. It was important for not only the lab to be interactive but also to have the speaker being energetic and talking on the level of the high school students.

The students were unanimous in the approval of the hands-on projects but repeatedly commented on wanting more time to work on the projects as some of the students felt rushed. Having the opportunity to be creative was also a positive experience for camp participants. Students even suggested projects that involved problem solving or goal attainment and repeatedly asked for more involved challenges. This was seen very positively as students wanted to solve a problem and find a solution with their projects. In addition, the students wanted more competition. There was a certain level of competitiveness built into the camp but, apparently, not nearly enough. The students also reported enjoying working in teams. This was encouraging since teamwork has become an important part of the engineering education of college-level students and of an engineer's working life.

Camp counselors for the program were current students in the AE Department at Texas A&M. While they have the technical AE background, this did not automatically translate into complete knowledge about each of the projects while under the microscope of helping a room full of high school students. While very brief introductions to the projects were done prior to camp, counselors did not receive hands-on experience or instruction. It cannot be stressed enough that camp counselors needed to be able to perform the activity, project, or construction the students were attempting without any hesitation. Camp counselors provided valuable insight into the appropriateness of an activity, which can be helpful at all stages especially during planning.

Providing each of the Aircraft and Rocket tracks a sampling of the other respective activities and technology turned out to be very successful. Each group was able to appreciate what the other group was doing and, in the process, learned something about that aspect of aerospace engineering.

Overall, students responded positively about the experience at Camp SOAR. Survey responses indicated a rate of 90% that students felt the camp fulfilled or exceeded their expectations. The other 10% responded that it mostly fulfilled their expectations. Students enthusiastically suggested that Camp SOAR continue, and comments were provided for ways to improve the experience.

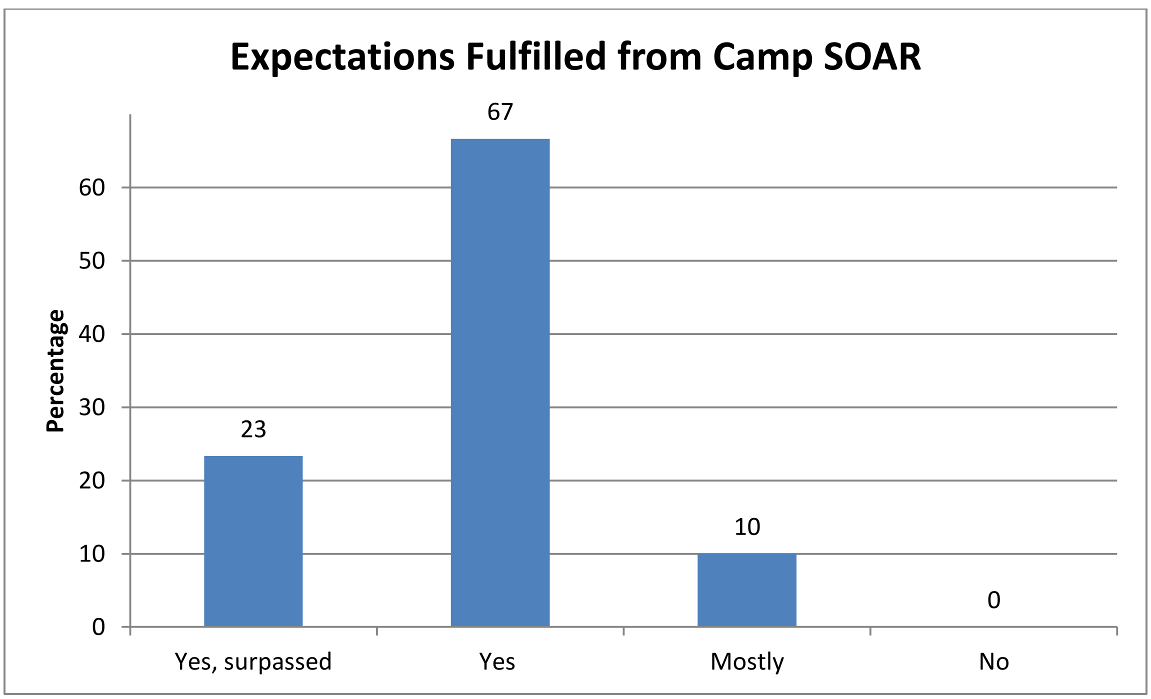


Figure 10. Student responses to overall expectations fulfilled from Camp SOAR.

In addition to the student survey, another mechanism used in tracking success of the camp was the use of the social media tool, Facebook. A Facebook page was created once students were accepted into the camp in early summer. Camp coordinators used the page to post information about the camp and encouraged students to meet each other prior to camp. Looking at posts prior to camp starting, however, the only posts recorded were from the camp coordinators with the exception of one student asking a question about the camp schedule the day before the camp started. The dramatic impact in the social media tool occurred once camp had commenced. In a one-week timeframe after camp concluded, there were 72 posts from participants and 77 posts from camp counselors. This does not include the amount of 'likes' that students added to the various posts. It was refreshing to see the back and forth exchange of comments between camp participants and then between the camp counselors and participants. Feedback received was overwhelmingly positive with students showing their appreciation for all of the work that went into the camp and continuing the friendships started during the program. Through the months, these conversations have continued with students asking questions quite often on the Facebook page related to various items, such as application inquiries, best dorms on campus, orientation dates, best time to visit again, and even on scheduling a reunion for the camp participants and counselors. This social media tool was quite effective in keeping the students plugged into the AE Department at Texas A&M University.

Conclusions

Overall, the AE Department at Texas A&M University is very pleased with the outcome of the initial edition of Camp SOAR. As previously discussed, valuable lessons were learned regarding what worked well and what did not have as much of a positive impact. As stated earlier, the primary purpose of Camp SOAR was to attract talented students to the Department. Therefore, the effectiveness of the camp will be measured by the number of students from Camp SOAR who ultimately attend Texas A&M as students in the Aerospace Engineering Department or even in other engineering and science majors.

While data is only available relative to the first edition of Camp SOAR, the following metrics would appear to be very positive. Of the 30 students who attended Camp SOAR in the summer of 2012, 20 were rising high school seniors, and ten were rising juniors. As shown in Figure 11, 19 of the high school seniors have applied to Texas A&M. As of January 2013, 17 have been accepted and two are currently in further review. Of the 19 applicants, 11 students intend to major in AE. The remaining eight seniors have been accepted into either other engineering majors, science majors, or one in a non-engineering major.

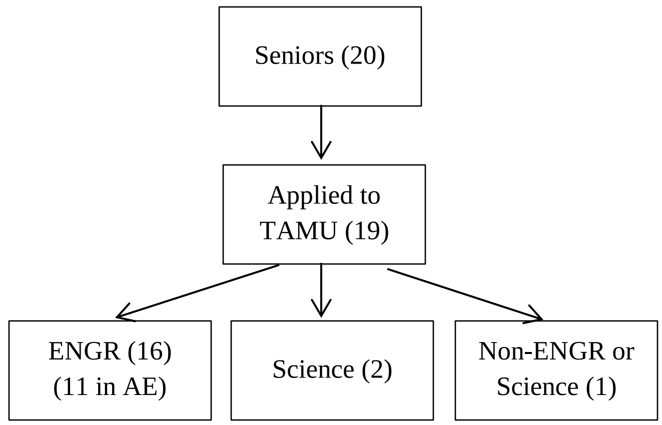


Figure 11. Departments at Texas A&M University where Camp SOAR seniors applied.

Both the AE Department and Texas A&M University benefitted from Camp SOAR. Of course, the argument could be made that the students would have decided to attend Texas A&M and declare the same majors without the benefit of Camp SOAR, but survey feedback and detailed feedback from Facebook indicate that the camp had a major effect on the perception of engineering in general by the student and AE in particular with comments, such as "…I wanted to thank everyone who made Camp SOAR such an awesome experience! I had a blast, but more importantly I now truly feel like Texas A&M is where I belong! Hope to see everyone back in Aggie Land next year as aerospace engineers!...". Finally, it is anticipated that these students will bring an elevated level of enthusiasm to Texas A&M due to their experiences at Camp SOAR. The next edition of Camp SOAR, scheduled for the summer of 2013, will incorporate the lessons learned from the first camp and will also provide new lessons and more metrics to use as guidance for future camps.

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