An Aerospace Engineering Summer Camp for High School Students

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Abstract

A summer camp for high school students has been held at Embry-Riddle Aeronautical University in Prescott, Arizona for the past six summers as a way to expose students to the concepts and the practice of aerospace engineering. This intensive one-week camp immerses students in aspects of aircraft and spacecraft engineering, where the students alternate between lectures, computer simulations, and hands-on laboratory demonstrations and projects. Topics include aerospace propulsion, astrodynamics, aerodynamics, stability and control of aircraft and spacecraft, structures and materials, and computer-aided design (CAD). Each of these topics includes either computer or traditional laboratory components to keep the students engaged. Some examples of the accompanying hands-on work include the design and construction of balsa wood gliders following the lecture on aerodynamics, and the designing of truss bridges using CAD tools, which are subsequently formed from ABS plastic using a rapid-prototyping printer. These particular activities end with a friendly competition between students using both their balsa glider, flown for maximum glide distance, and the fabricated bridge, tested for maximum strength-to-weight using a hydraulic load frame in the mechanical testing laboratory. This paper provides details of the academics, enrollments, and student evaluations of the Aerospace Engineering Summer Camp.

Introduction

The Prescott, Arizona campus of Embry-Riddle Aeronautical University (ERAU) specializes in undergraduate education, with a current enrollment of close to 1700 students. The College of Engineering houses the largest department at the campus, the Aerospace and Mechanical Engineering Department. The engineering student body is composed exclusively of undergraduate students. The department strives to provide close student-faculty instruction and mentorship, significant design experiences, and a hands-on learning environment.

The Prescott campus has been developed with undergraduate education in mind, and laboratories with extensive space in which students can work are a feature. While some number of summer courses is taught, especially during the first summer term, many classrooms and laboratories are nevertheless underutilized when compared to the regular academic year. Embry-Riddle, therefore, likes to provide summer programs for a wide variety of activities, especially those with an academic flavor (which, of course, serves our university mission). Further, the summer climate in Prescott, which is at an elevation around 5300 feet above sea level, makes ERAU an attractive location for summer activities in the state of Arizona.

There is a desire to provide opportunities to get high school students interested in STEM (science, technology, engineering, and mathematics) fields, which is often not done well in K-12 grades, especially when many school districts have financial challenges to contend with. Embry-Riddle is a small, technically-oriented private university in central Arizona, and is interested in both raising the profile of STEM-related degree programs and, of course, offering attractive summer programs at our campus that help recruit new students. The Aerospace and Mechanical Engineering Department is particularly

supportive of hands-on learning experiences, and has worked to develop extensive laboratory facilities for the undergraduate engineering programs[1].

Prescott Campus Summer Programs

During the 2010 summer, three summer academic programs were offered by Embry-Riddle faculty in aerospace engineering, flight, and computer engineering. Each program is intended for high school students from ages 15 to 18 (14 to 18 for the flight program), is one week in duration, and involves students in classroom, laboratory, and a few evening non-academic activities. Table 1 provides a very brief introduction to the three programs.

Table 1. Summer Programs Overview (from Summer of 2010)

Program	Topics and activities
Aerospace Engineering	Introductory lectures accompanied by hands-on laboratory and design experiences in flight and space sciences, structural design and material properties. Balsa wood glider and bridge design competitions.
Computer Engineering	Introductory lectures on robotics and machine vision. Hand-on programming and machine vision system design.
Flight Exploration	Instruction on weather reports and visual flight rules (VFR), as well as aerodynamics, navigation performance, and safety procedures. Students do fly aircraft during the program!

Outside of the academics, students spend the week staying at the campus in the dorms, eating meals at the cafeteria, and participating in social activities. The sum of all these parts leads to a short one-week introduction to college life, which may have some benefits to the high school students if this is viewed from a student retention aspect. The student registration costs for the Aerospace Engineering and Computer Engineering programs was $1050 for the 2010 summer, which covered meals, lodging, and instructional materials. The registration cost per student for the Flight Exploration program was $1950 for the 2010 summer, and this additionally included flight fees, which is a significant cost. The registration fees for the 2011 summer will remain the same.

A number of Embry-Riddle students are hired for the week to act as mentors and chaperones to the high school students, and they answer questions and make sure the summer camp students get to where they are supposed to be. Faculty and staff serve as the instructors, and lead the summer camp students in classroom discussions and hands-on work. The Aerospace Engineering summer camp was the first summer camp (Summer 2005) to be offered at the Prescott campus of Embry-Riddle, and the others were added in subsequent years.

Aerospace engineering camp

The Aerospace Engineering program has had great success in its current form. The last four summer enrollments for only the Aerospace Engineering program are given in Table 2. During the first four years, just one class of up to 24 seats was offered, and that was increased to two concurrent classes during the last two summers. Each class has been filled to capacity each summer, and is typically held mid-summer in late June or early July. It is further noteworthy that while engineering camps for high school students are held at other universities, it is believed that ERAU holds the only such camp exclusively for aerospace engineering in the country.

Table 2. Enrollments in Aerospace Engineering Summer Program

Summer	Enrollment
2006	24
2007	24
2008	24
2009	48
2010	48

An additional third section was added this past summer (2010) because of the popularity of the program. However, due to a faculty member leaving from the computer engineering department and the small number of students (around 5) enrolled for the Aerospace Engineering program, students from the third section were placed into a more general engineering camp, not reflected in the numbers in Table 2.

Participating instructors in the Aerospace Engineering summer camp are all faculty in the Aerospace and Mechanical Engineering Department at Embry-Riddle. A number of these faculty teach undergraduate engineering courses during the first seven-week summer semester, so there are enough instructors that spend their summers in the Prescott area to make adequate commitments to help teach at the summer camp. These high school student summer camps are typically scheduled to closely follow the early-summer semester for the convenience of faculty scheduling.

The instructors each present topics in their respective disciplines of interest, with a total involvement of five to six instructors. Figures 1 and 2 provide the two schedules from the 2010 summer semester.

Breakfast 7:15am-8:00am	Breakfast 7:15am-8:00am	Breakfast 7:15am-8:00am	Breakfast 7:15am-8:00am	Breakfast 7:15am-8:00am
EagleCard 8:00am	Astrodynamics 8:00am-9:00am	Structures and Materials	Aerodynamics 8:00am-10:30am	
Propulsion				Glider Competition

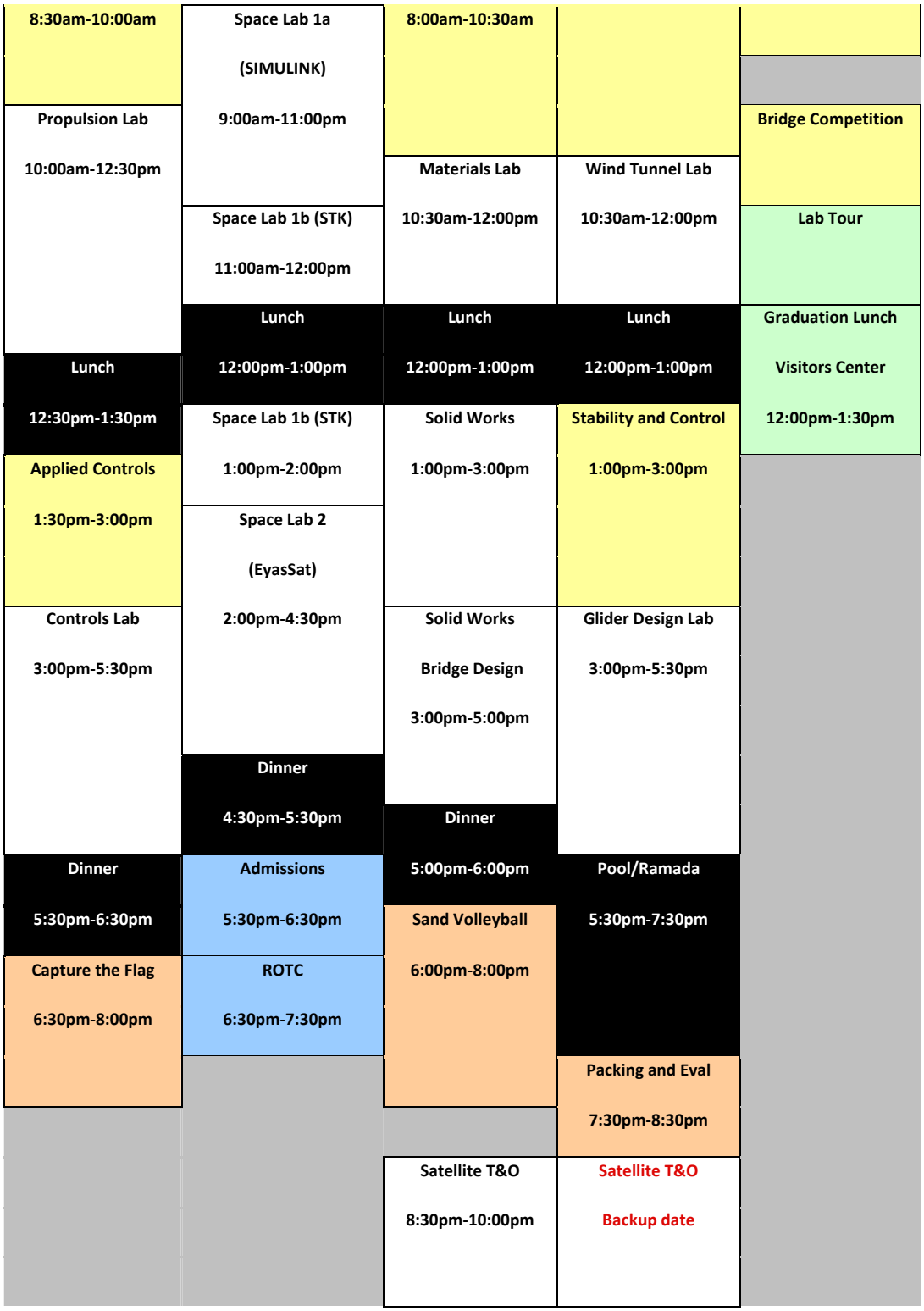

Figure 1. Schedule for students in "Alpha" section of Aerospace Engineering program.

The first schedule was for the student group referred to as "Alpha" group, and the second for the "Bravo" group, and these schedules are typical of the aerospace engineering summer camps from past summers. The schedules are always quite packed to keep the students busy Sunday evening (not shown) through early Friday afternoon. Monday through Thursday, the students are involved in academics with introductions to the topics of propulsion, flight and space controls, astrodynamics, structures and materials, aerodynamics, and aircraft stability and control. Each topic is accompanied by a hands-on activity or laboratory experience to better show the application of theory to engineering practice. The aerodynamics discussion was followed by an opportunity for students to have some involvement with one of the wind tunnels at ERAU. The students built a balsa wood glider, using some of the knowledge obtained from the aircraft stability and control discussion, and this was concluded with a glider competition among the students, who worked in small groups.

Breakfast **7:15am-8:00am**	**Breakfast** **7:15am-8:00am**	**Breakfast** **7:15am-8:00am**	**Breakfast** **7:15am-8:00am**	**Breakfast** **7:15am-8:00am**
EagleCard 8:00am	**Propulsion** **8:30am-10:00am**	**Astrodynamics** **8:00am-9:00am**	**Aerodynamics** **8:00am-10:30am**	
Structures and Materials **8:30am-11:00am**	**Propulsion Lab** **10:00am-12:30pm**	**Space Lab 1a (SIMULINK)** **9:00am-11:00pm**		**Glider Competition**
			Wind Tunnel Lab **10:30am-12:00pm**	**Bridge Competition**
Materials Lab **10:30am-12:00pm**		**Space Lab 1b (STK)** **11:00am-12:00pm**		**Lab Tour**
	Lunch **12:00pm-1:00pm**	**Lunch** **12:00pm-1:00pm**	**Lunch** **12:00pm-1:00pm**	**Graduation Lunch** **Visitors Center** **12:00pm-1:30pm**
Lunch **12:30pm-1:30pm**	**Applied Controls** **1:00pm-2:30pm**	**Space Lab 1b (STK)** **1:00pm-2:00pm**	**Stability and Control** **1:00pm-3:00pm**	
Solid Works **1:30pm-3:30pm**	**Controls Lab** **2:30pm-5:00pm**	**Space Lab 2 (EyasSat)** **2:00pm-4:30pm**	**Glider Design Lab** **3:00pm-5:30pm**	
Solid Works Bridge Design **3:30pm-5:30pm**		**Dinner** **4:30pm-5:30pm**		
	Dinner			

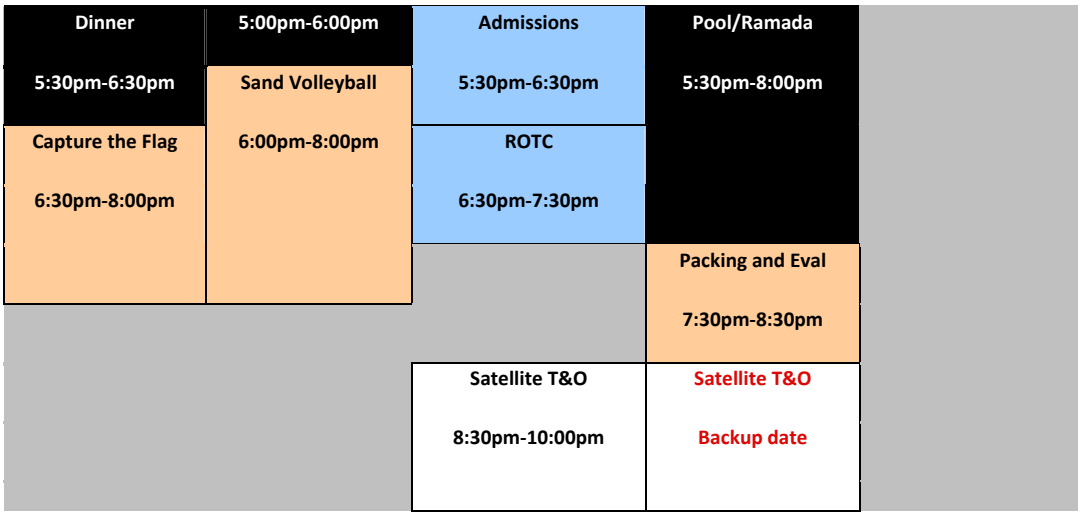

Figure 2. Schedule for students in "Bravo" section of Aerospace Engineering program.

Another opportunity for students to put theory into practice was through a bridge-building competition. Following the discussion on structures, the students participated in a computer lab using SolidWorks, where students learned some three-dimensional modeling techniques, with time to complete a 3-D drawing of a truss bridge. Students performed this final exercise in small groups. The SolidWorks files were then given to an Embry-Riddle student assistant who had the bridges fabricated in ABS plastic using the 3-D printers at Embry-Riddle (Embry-Riddle has two Stratasys Dimension SST 3-D printers). Finally, on a following day, the bridges were tested for structural efficiency (failure strength divided by weight) using an MTS 810 hydraulic load frame in the Embry-Riddle mechanical testing laboratory.

One of the authors first became involved directly in the summer camp through work on an NSF (National Science Foundation) CCLI (Course, Curriculum, and Laboratory Improvement) grant[2]. This grant was for the creation of an undergraduate laboratory-based course in engineering failure (although the grant was not for any direct funding of this summer camp). The author committed to bring a small portion of the topic of materials failure to the summer camp, taught the section on materials, and with one of the other authors, had students perform tension tests on aluminum dogbone samples, section and ultrasonically clean one end of the broken pieces, and then view the fracture surfaces with a scanning electron microscope (SEM). A handout on the SEM was provided to the students, and the digital photographs of the fracture surfaces were made available electronically.

Since the addition of a second section of the Aerospace Engineering program, scheduling has become a little trickier, but was accomplished by staggering the various topics. Viewing Figures 1 and 2, one can see how this staggering was accomplished. One complication is the schedules of the instructors, who may be teaching summer courses. The other noteworthy complication is in scheduling the structures discussion and the ensuing bridge design. The bridge CAD models are all fabricated using the two 3-D printers, and the process is somewhat time consuming. Having either of the Solid Works computer modeling sessions on Thursday would not be an option for this reason, and in case of unforeseen 3-D printing problems, is it perhaps necessary to have these portions of the summer program as early in the

week as possible. Also, in the program's current form, this might easily be a limitation on trying to have three student classes all at the same week (among other possible scheduling difficulties).

Student Evaluation

The office for Summer Programs at the Prescott campus of Embry-Riddle conducts student surveys after each summer camp. The survey questions are fairly general, and encompass both the academics as well as the housing/meals/extracurricular portions of the program. The survey for the 2010 summer camp, performed using SurveyMonkey, included question such as:

1. Please rate your overall satisfaction with the Aerospace Engineering Program. Please provide any additional comments you may have below. This allows us to improve camp in the future.
    a. Overall satisfaction (1-10 satisfaction rating)
    b. Quality of Instruction (1-10 satisfaction rating)
    c. Relevance of Classes (1-10 satisfaction rating)

Such questions were given on the dining and residence hall experiences, with some survey questions on specific extra-curricular activities. Questions on the interest and satisfaction on the specific aerospace topics were included.

Regarding the academics, it was found that students showed slightly more interest in the aerodynamics-type topics (and especially the rocket-launch), and a just little less interest in astrodynamics, structures, and materials. However, student satisfaction was high for all topics. Students were also encouraged to provide written comments, and they indeed provided many, which probably provide more insight that the numerical ratings. While comments ranged widely on all sorts of relevant (and sometimes not especially relevant) topics, one recurring theme was that many students enjoy and would like to see more of the hands-on work and laboratory experiences, compared to the amount of time spent on the classroom lectures and discussions. The amount of time in lectures and discussions can be viewed in Figs. 1 and 2 from the yellow boxes during the first four days (noting that there is often a 15-minute break in the middle of the longer classes), and the hands-on and laboratory sessions are boxed in white. There is somewhat more time devoted to the latter, and the instructors are reluctant to give up much more of the lecture and discussion time. However, one of the authors previously noted that the SolidWorks sessions end up being a little rushed in the completion of the bridge design, because there is certainly a learning curve necessary to end up with workable CAD file, ready for the 3-D printer, and this fact was also reflected in a few comments. An Embry-Riddle student assistant now helps out with this activity, to make sure that students have their files ready to go, and further, this student assistant may also fix the CAD files somewhat if necessary, to ensure proper 3-D printing.

Additional details

The summer camps are advertised nationally by ERAU, and therefore the states of residence claimed by the students vary widely, as shown in Table 3 (only incomplete data for more recent summers were available to the authors at the time of writing, so just 2006 and 2007 are shown). Only a few students come from the immediate Prescott, Arizona area. In the most recent summers, including the upcoming 2011 summer, a few international students have enrolled, which is useful for increasing international exposure for ERAU.

Table 3. Enrollments by state of residence

Summer	Student states of residence
2006	AZ (8), CA (8), FL (2), NV (1), NY (1), OH (1), OR (1), TX (1), VA (1)
2007	AZ (4), CA (6), CO (2), FL (2), HI (1), MA (1), MN (1), NC (1), NJ (1), TN (1), TX (2), WI (1)

The largest fraction of summer camp students, somewhere around half, tend to be high school juniors. The remaining students are of somewhat similar fractions of freshmen, sophomores, and seniors. Table 4 shows additional enrollment information regarding the high school camp students. The number of female students is unfortunately low, with the fraction of female to males remaining about the same from 2006 to 2010. However, the increase in total number of aerospace engineering students at the camp has led to a greater number of females being exposed to this STEM program.

Table 4. Details of enrollments in Aerospace Engineering Summer Program

Summer	Camp Enrollment	Female students	ERAU applicants*	Matriculated to ERAU*
2006	24	5	9	7 (1 at DB)
2007	24	3	15	9 (2 at DB)
2008	24	5	13	5
2009	48	9	16	4 (1 at DB)
2010	48	8	2	2

*as of August 2010

Embry-Riddle is also certainly interested in encouraging summer camp students to consider enrolling at the university as an undergraduate. The number of applications submitted by the aerospace engineering summer camp students is shown in Table 4, as of August 2010. Of course, any high school student who attended the 2010 summer camp and was of junior or earlier standing, would not have submitted an application by the time of this writing. Therefore, the earlier years of the summer camp provide more thorough information on how this program affects students' choice to apply to ERAU. Finally, the number of students matriculating to Embry-Riddle is shown in the last column of Table 4. A few of these students enrolled at the Daytona Beach residential campus of Embry-Riddle, and this number, out of the total number matriculating to ERAU, is noted in this column. At least one of these latter matriculations ended up in a reported no-show when it came time for students to arrive on campus for the beginning of the Autumn 2010 semester, however, illustrating one of the possible difficulties in maintaining accurate statistics. Overall, this summer camp, as well as the others offered by ERAU (statistics not shown), appear to have a positive effect on undergraduate enrollments.

Summary

The summer camps at Embry-Riddle Aeronautical University in Prescott, Arizona have become a strong addition to the growing range of offerings made available to those interested in technical fields of learning. Student satisfaction is high with the current form of the Aerospace Engineering summer camp program, and the instructors are dedicated to bringing a strong, positive experience to the high school students, with the aim of generating interest in STEM-related opportunities. The summer programs also

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Biography

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