Presenting Science and Engineering Careers in a Unique and Appealing Way

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An original summer camp activity in the areas of aerospace/aeronautical engineering and aviation has been developed. A pilot version of the program was completed successfully in June 2007 at Minnesota State University, Mankato. The main objective of the program was to increase the awareness and interest among high school students for science and engineering careers. Through a series of short lectures and extensive hands-on demonstrations the attending students have been familiarized with the fundamental concepts and relationships of science and engineering in general, and of aerospace engineering and aviation, in particular. Two major team projects have been completed and tested. The activities have culminated in an FAA approved flight simulator sessions and the students' flights aboard Piper Seminole twin-engine airplanes. The participating students have provided extensive positive feedback on the program. To the teaching faculty, this has been a very pleasant and rewarding experience. The outcomes of the two-week Camp have been discussed in detail and some very useful guidelines for successful outreach efforts have been presented.

Introduction

The state of Minnesota has been among the regions of the country where the interest on the part of its high school students in science and engineering careers in recent years has been alarmingly low. Typical surveys taken among tenth-graders have repeatedly indicated that only about ten percent of them have any interest in pursuing science or engineering career paths. This fact, coupled with the opposite trend witnessed in some major foreign countries, like China, India and Russia, clearly signals the hardship which the Minnesota workforce in the twenty-first century is going to face if it wants to remain competitive, nationally and, particularly, on the global level.

To remedy this situation, various federal, state, and local initiatives have originated in recent years to improve this situation. Significant human and material resources have been devoted to overcoming this adverse imbalance. The Project "Lead

the Way" is an example of a nationwide initiative undertaken to address this situation. On the state level, the Governor of Minnesota has also earmarked significant funds in an attempt to address this adverse climate. In particular, several centers for excellence in various areas of engineering have been formed throughout the state. Their primary objective has been to improve the competitiveness of the Minnesota workforce through better preparing the state graduates for careers in engineering, then through forming stronger links between the Minnesota colleges and universities and its industry, and finally by addressing the low level of interest among HS students in these professions. Minnesota State University (MSU), Mankato, has been a partner in one such center, the Minnesota Center for Engineering and Manufacturing Excellence (MNCEME).

Realizing the need to increase the student enrollment and retention in science and engineering programs in the state of Minnesota and MSU in particular the authors have decided to explore the possibility of designing and setting up an outreach program in the areas of aerospace/aeronautical engineering and aviation. It was felt that the climate for such an undertaking was rather right. Also, the combined experience and educational and professional background of the two authors seemed to provide an excellent opportunity. Namely, Dr. Daidzic brings to the camp an exciting blend of excellent engineering and science background together with his professional flying skills. He has worked as a scientist/researcher on European Space Agency (ESA) projects since 1989 as well as within NASA since 1995 on deep-space, long-duration manned space missions. Some among the projects involve the optimization and redesign of the European rocket launcher ARIANE third-stage rocket engine for MBB and SEP. Dr. Daidzic is also an Airline Transport Pilot and an FAA certified Flight Instructor for airplanes and gliders and has flown a variety of airplanes and gliders. He also has performed many experiments onboard the NASA's reduced-gravity parabolic platform KC-135. On the other hand, Dr. Nikolic has worked for thirteen years in aircraft design and has been involved in the design and development of six aircraft, five overseas and one in this country. He has worked on aircraft design teams and aircraft factory floors and was involved with a variety of aircraft ranging from a remotely piloted vehicle to a supersonic fighter. Dr. Nikolic has cooperated closely with the design teams from British Aerospace

of the UK and Avions Marcel Dassault of France. Both authors have built quite impressive records of accomplishments and publications and thus felt confident with their qualifications for this undertaking.

Pilot Program of MSU Aerospace Engineering Summer Camp "Reaching for the Stars"

The authors developed an initial proposal which called for a two week, four hours each day, program, in which through brief lectures, extensive experimental exercises, and two major hands-on team projects, a number of the most significant concepts from various areas of engineering, in general, and from aerospace sciences/engineering and aviation in particular were introduced and explained. Also, the plan was for the students to have an opportunity to tour several MSU engineering laboratories and Mankato Airport, fly in a flight simulator and in an airplane. A series of guest speakers, one each day, involving a number of administrators and faculty members from the MNCEME and MSU have also been contacted and agreed to address the Camp participants during lunch. A detailed plan for the Pilot Program Camp is given in Appendix. It is pointed out that the main idea of the camp has been to show to the participating students that engineering is much more than just solving equations, crunching numbers and generating complex designs; it is also exciting, creative, and a lot of fun. The program is intended for the high school juniors who had little interest in engineering but who also have not made up their minds as to the future career yet. In other words it is intended to those students who under certain circumstances may consider engineering as a distant career possibility only. The program staff included the two authors, three teaching assistants (MSU students, two from the Aviation Department and one from the Department of Mechanical and Civil Engineering) and the necessary clerical support by one person on a part time basis.

The 2007 Pilot Program enrolled seventeen students from four area high schools and ran from June 11 to June 22, 2007. Due to some previously made time commitments three students did not attend, thus fourteen students regularly participated in the Camp activities and successfully completed the program. The Camp has been named "Reaching

for the Stars" with the intention to suggest that the hope by its organizers that some participating students may work on the problems related to space travel, as well as to point out that some of them may well be the future stars in the areas of aerospace sciences and engineering.

The original plan called for transporting the students to the MSU campus and back and for providing lunch there. This worked quite well. The students and staff were given specially designed T-shirts displaying the Camp logo and the names of the sponsors, MSU and MNCEME.

Program Progression - An Overview

Given below are brief comments on various Program activities in the order in which they have been conducted. Exact timings of the various activities can be found in Appendix, 2007 Pilot Program of MSU Aerospace Engineering Sumer Camp.

- *Opening, Introductory remarks, Careers in engineering and science*. After welcoming the participating students and briefly reviewing the two week program, the instructors discussed various career options in the areas of sciences and engineering. About two dozen of these professions were outlined. Additional information to be delivered by the Program guest speakers was announced.

- *Introduction/Review of fundamental concepts from science and engineering. Demonstration of physical principles. Four forces of flight.* In order to get everyone "on the same page", some basic concepts from science and engineering were reviewed first. To better explain to the students why these particular concepts needed reviewing, this section was opened with the famous "Four Forces of Flight". Thus, it became clear that, in order to fully understand flight, both atmospheric and space, which are the main themes of the program, a discussion of the ideas such as mass, weight, force, pressure, velocity, and acceleration was necessary. These concepts were introduced, the differences between them clearly

pointed out, and the appropriate units in both the SI and USCS systems explained. This section was concluded with several demonstrations which were deemed helpful in facilitating better understanding.

- *Newton's laws, introduction and demonstrations*. Next, the Newton's laws of mechanics were presented. While the analytical/mathematical expressions and formulations were kept to a minimum, the emphasis was on the physical meanings and the consequences of these important relationships. To further strengthen the students' understanding, several hands-on demonstrations and computer animations were shown.

- *Introduction to aerodynamics. Bernoulli's law, introduction and demonstrations.* In preparation for the major activities of the first week, an overview of the basic principles of aerodynamics was presented. Once again, the emphasis was placed on the physical phenomena involved while using only the necessary minimum of the analytical/mathematical expressions. In particular, several demonstrations of the Bernoulli principle were presented. Examples included cases from nature, real life, human and animal, as well as various engineering applications. The functions of the most important aircraft components were explained. Both fixed-wing and helicopters were discussed.

- *Introducing powerful engineering software*. To give the students a flavor of typical engineering tasks, they were presented with an opportunity to try, hands-on, two powerful software packages for computer aided engineering, the Pro/ENGINEER and Pro/MECHANICA which are used widely by many industrial companies for computer aided design (CAD) and computer aided finite element analysis (FEA), respectively. It is noted that the Pro/ENGINEER software suite belongs into the high-end category and is one among the world's most powerful systems. Nevertheless, all students were able to successfully first create a model of a structural element, then apply forces, constraints and material

properties, and then analyze the state of stresses and deformations throughout the model.

- *Touring mechanical and civil engineering laboratories. Touring electrical and computer engineering and technology laboratories.* The thermal-fluids and materials testing laboratories were toured. During that time the students were able to see and understand to a good degree in what types of testing structural engineers as well as those engineers dealing with the systems involving thermodynamics/heat transfer/fluid mechanics engage. About a dozen of different setups have been shown and discussed. Following this, the students were given a tour of the laboratories which support the curricula of the electrical and computer engineering and technology department. At the same time various career paths pursued by the EE/CE&T graduates were discussed.

- *Wind tunnel demonstration.* Due to the themes of the Program, the wind tunnel laboratory had a special place in the laboratory tour. To help the students better understand the concepts of aerodynamic lift and drag, which had been previously discussed in the Introduction to Aerodynamic presentation, an actual test for measuring the lift and drag of a finite-span wing was demonstrated. Also, various other phenomena like, for example, wing stall, critical angle of attack, and the shedding of trailing vortices into the wing wake were demonstrated and explained.

- *Airplane model project guidelines*. The instructors have devoted significant care to selecting the optimal airplane model which the students would build. Seven design teams, comprising of two students each, were formed and the students completed the two projects – airplane and rocket - staying in the same teams. The teams were given flying/aviation/space related code names: *Thunderbirds, Blue Angels, Falcons, Sky Walkers, Young Eagles, Sea Bees and Sky Knights*. Next, the students were advised on how to proceed in building their airplanes. The instructors discussed in detail the possible favorable or adverse effects of various

design decisions and how those choices may affect one or more among the four forces of flight, lift, drag, weight and thrust and thus the airplane performance. Specific guidelines applicable to the model at hand were provided and the students embarked upon the first of the two major projects of the Program.

- *Building airplane models*. Next the students began actually building their airplanes. It appeared that they greatly enjoyed this activity. As an anecdotal aside, it is noted that when at the end of the first forty-five minutes the students were reminded by one of the instructors that it was the time for a break, that not one among the fourteen students took the break - they were so utterly immersed into the task at hand. Figure 1 shows a student team diligently working on their airplane.

Figure 1: Aerospace Summer Camp students building airplane model.

Each team did their best intending to create a successful airplane deserving one of the two awards in this Airplane Category, the Best Performance or the Best Design. Figure 2 shows the seven completed airplanes.

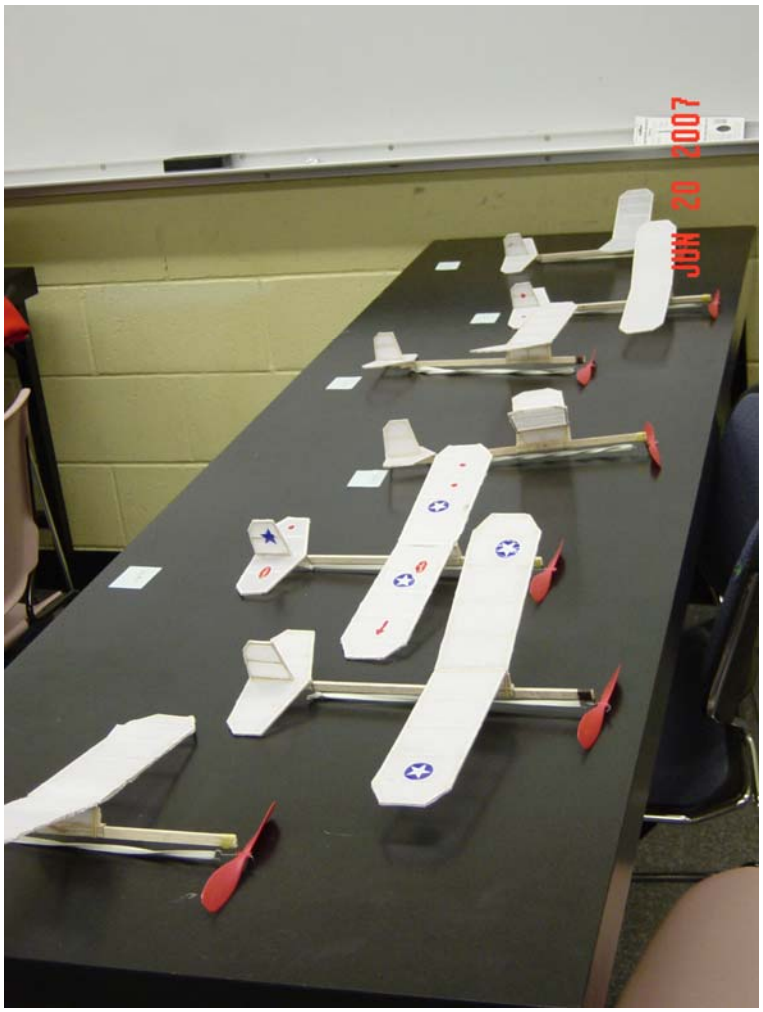

Figure 2: Aerospace Summer Camp airplane models lined up for "takeoff".

It is noted that throughout this process the students continued working very attentively and patiently.

- *First day at Mankato Airport. Viewing North Star airplanes on static display. Flying in flight simulators.* The first day at the Mankato Airport was filled with various activities. The students were first introduced to the weather monitoring

capabilities at the airport. Then they were given a tour of the facilities. They viewed a total of ten airplanes with the greatest attention. After lunch, the students flew "the left seat" in two flight simulators owned by MSU and used by the North Star Aviation for actual pilot training. Dr. Daidzic and a teaching assistant - an MSU aviation student were the instructors on two different flight training devices. The students enjoyed this experience tremendously.

- *Introduction to principles of rocket propulsion and space flight.* A thorough introduction of the principles of rocket propulsion was given next. The students listened carefully as they were aware that what was being discussed would have a direct impact on the success of their next major project – building a two stage rocket model. The phases of acceleration, coasting and descend with parachute were explained in detail as were rocket engine characteristics (solid propellants, specific impulse, thrust, exhaust velocity, etc.). This presentation was supplemented by a series of videos depicting actual rocket launches and flight, both full scale and model rockets.

- *Rocket model project guidelines and remarks.* Next the students were given very specific guidelines pertaining to their particular rocket models. They were properly cautioned of various pitfalls in the rocket building process.

- *Building rocket models*. Next the student design teams began building their rockets. This was another example of utmost enthusiasm – rarely a student ever left the room while this worked was being completed. The teams spared no effort attempting to generate the best design possible, again with the expectation to win one of the awards - the Best Performance or the Best Design. Figure 3 shows a camp student with his team's rocket model. Stability and height a model rocket reaches is a strong function of the good assembly, minimizing skin-friction and form drag. This degree of freedom and understanding of rocket model stability and performance gave students opportunity to compete and show creativity.

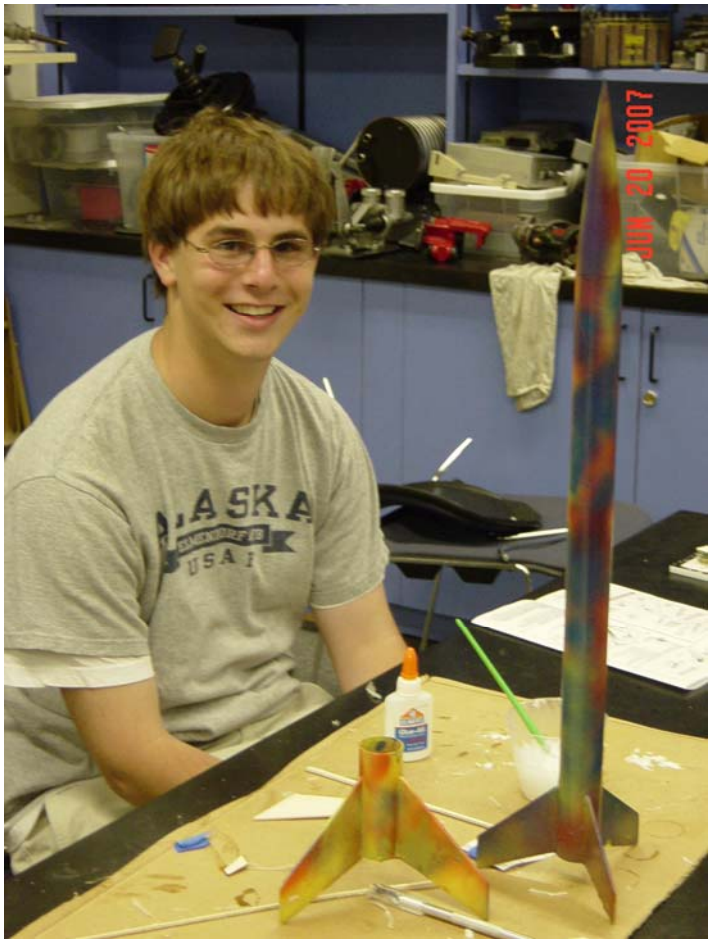

Figure 3: An Aerospace Summer Camp student with his almost finished two-stage rocket model.

- *Launching rocket models*. This was the first major competition in the Program. Due to a fairly compressed timetable and because the safety was given the paramount importance, the instructors decided to conduct only one launch per team, i.e., going with the first rocket stage only. The launches went flawlessly. All the rocket models flew quite successfully and reached and exceeded nominal altitudes of 800 feet using single stages only. NAR (National Association of Rocketry) safety guidelines were strictly followed. Additional seven people together with Dr. Nikolic were responsible for tracking, data measurements, and safety of students and spectators. Altitudes obtained were calculated from angle measurements at different locations and the use of goniometers/protractors.

Trigonometric relationships were used to derive accurate apogee altitude formula. Stop watches and binoculars were used by trackers and launch officers to determine apogee and take measurements consistently.

- *Second day at Mankato Airport. Flying in Piper Seminole twin-engine airplanes. Airplane model competition.* The students formed groups of three each and the groups flew simultaneously with Dr. Daidzic and Professor Ruedy in two reciprocating/propeller twin-engine Piper Seminole airplanes. Each flight lasted 35-40 minutes including taxiing, take-off and landing. FAA procedures were implemented to assure maximum safety of flights. This was a highly memorable experience for the participating students and they enthusiastically exchanged their impressions upon landing. In Figure 4, the students and the instructors in front of one of the two twins in which the students flew are shown.

Figure 4: Aerospace Summer Camp students at the airport with instructors (Drs. Nikolic and Daidzic on the very right end). The twin engine airplane Piper Seminole (PA-44-180) is behind.

While some students were flying the others tested their airplane models in a competition for the best performing airplane. The criterion was maximum range in a straight line. Each design team made three flights and the longest range was chosen. Out of the seven airplanes six flew well to very well, while one airplane experienced a "hard landing" on a test flight immediately before the competition.

- *Touring astronomy observatory*. Accepting a kind invitation by an astronomy Professor, the instructors decided to slightly modify the plan for the last day and thus the students toured the MSU Astronomy Observatory. There they watched a video on space explorations and toured the facility.

- *Student survey. Closing ceremony and remarks. Certificates of participation. Presentation of awards.* On the last day of the Camp, the students were asked to complete a survey providing their feedback on the Pilot Program. The students took this task very seriously and offered detailed responses, of both quantitative and qualitative nature. The most important among these results are discussed in a separate section below. Following lunch, a closing ceremony was held during which time Dr. Takamura, Director of MNCEME and the Program instructors handed Certificates of Participation and MNCEME pens to all participating students. Next, four awards were presented to the student teams, for Best Performance and Best Design, in the Airplane and Rocket categories. The students making up the winning teams received Certificates of Award and MSU T-shirts.

- *Daily guest speakers*. Throughout the Program seven guest speakers joined the participating students and the Program instructors for lunch. These speakers included: Dr. Kuma Takamura, Director, MNCEME; Dr. Michael Miller, Dean, College of Education; Ms. Tracey Hammell, Academic Advisor, Advising Center, College of Science, Engineering and Technology; Professor Craig Ruedy, Chair, Aviation Department; Dr. Charles Johnson, Chair, Department of Mechanical and

Civil Engineering; Dr. James Wilde, Associate Professor of Civil Engineering; and Professor Ann Goebel, Chair, Department of Automotive and Manufacturing Technology. Figure 5 shows the lunch at the Mankato Airport while Professor Ruedy (aviation chair) was addressing the students.

Figure 5: Aerospace Summer Camp students at the lunch during the visit to the Mankato regional airport and MSU Aviation Department and North Star Aviation training facilities.

In 15-20 minute speeches, the speakers offered remarks on science and engineering career choices and the necessary preparation. The department chairs stressed the possibilities in their respective areas. All presentations were very well received with students asking questions.

Gaging the Success of the Pilot Program, Students' Feedback

In order to gain the necessary feedback on the Pilot Program an extensive survey was conducted on the last day. Twelve students participated since the remaining two

could not attend on that day. The students' responses to the nine questions which were seen by the Program instructors as the most important ones have been prepared in the form of 'pie' charts and are shown here as Figures 6 through 14. The legends for the charts shown in Figures 6 through 12 are as follows.

SA	Strongly Agree
A	Agree
M	Mixed feelings
D	Disagree
SD	Strongly disagree

Those of Figure 13 are:

VF	Very fast
RF	Rather fast
JR	Just right
S	Slow
VS	Very slow

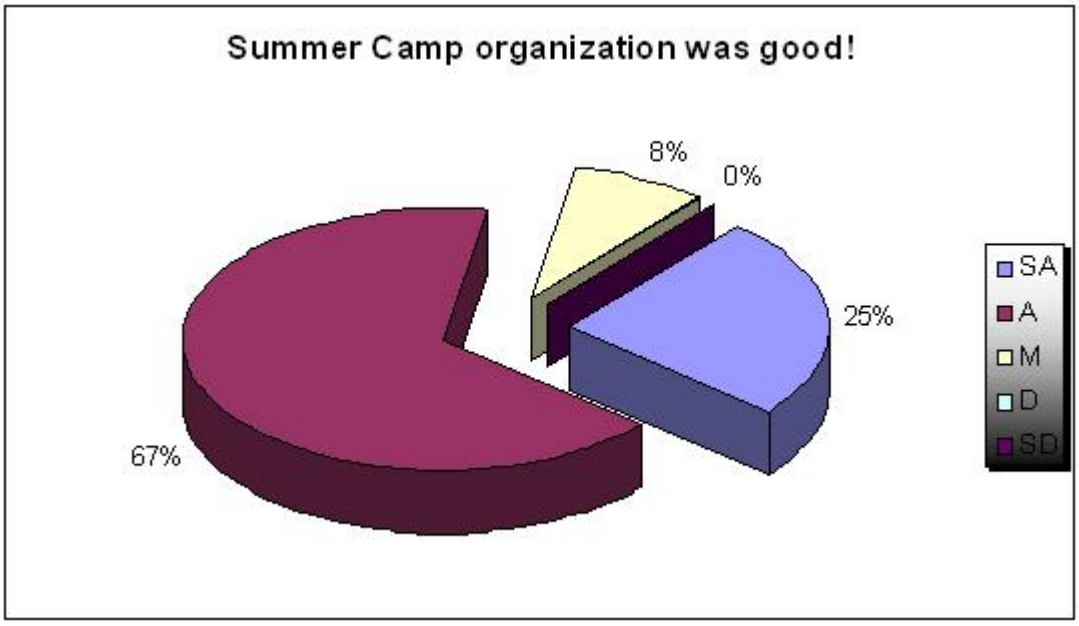

Figure 6: Survey Q&A - Aerospace summer camp organization was good!

Figure 7: Survey Q&A - Aerospace summer camp met my expectations!

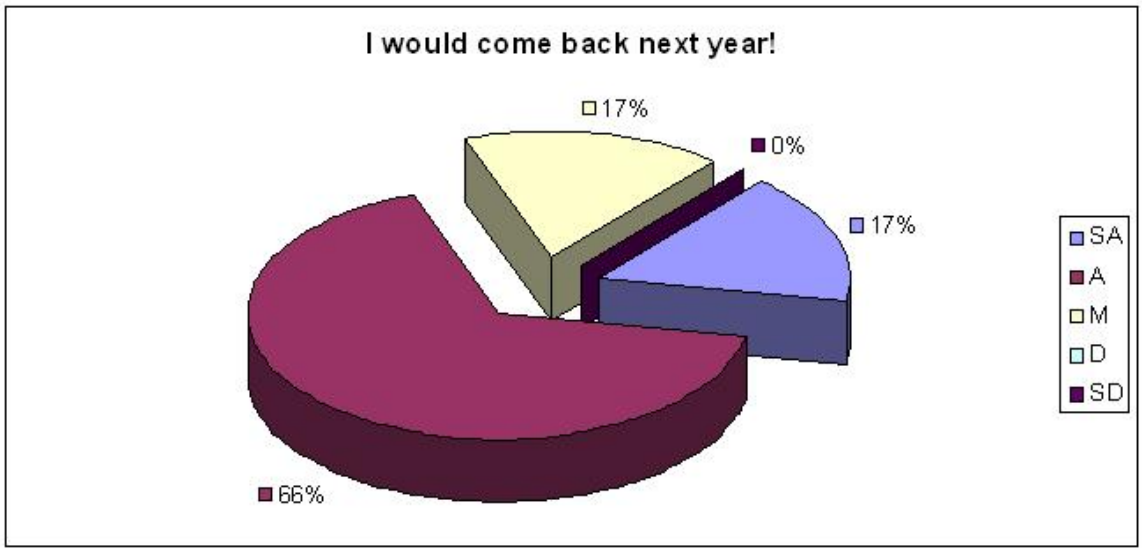

Figure 8: Survey Q&A - I would come back next year!

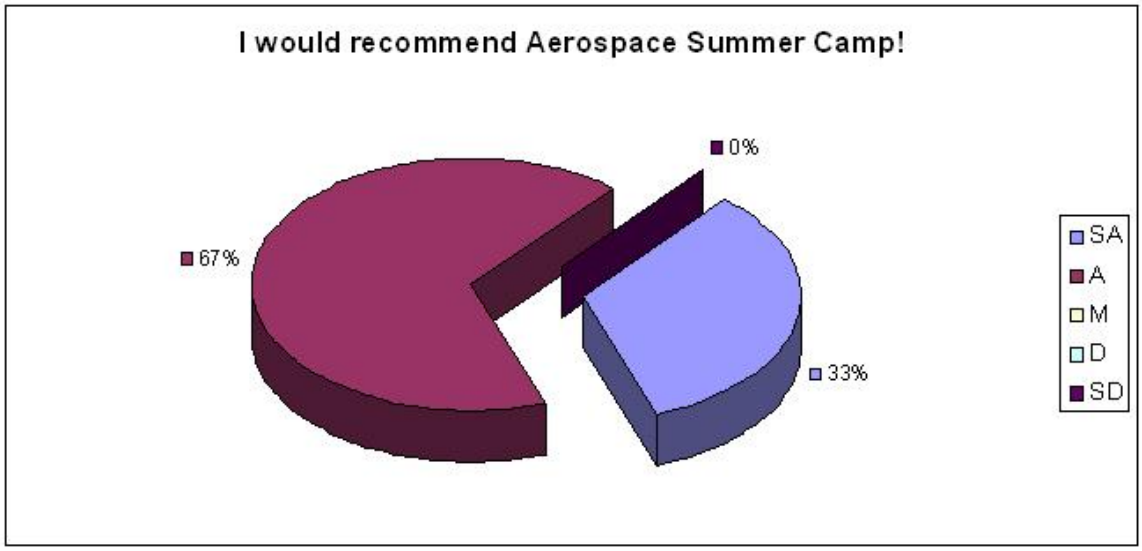

Figure 9: Survey Q&A – I would recommend Aerospace summer camp to my peers and friends.

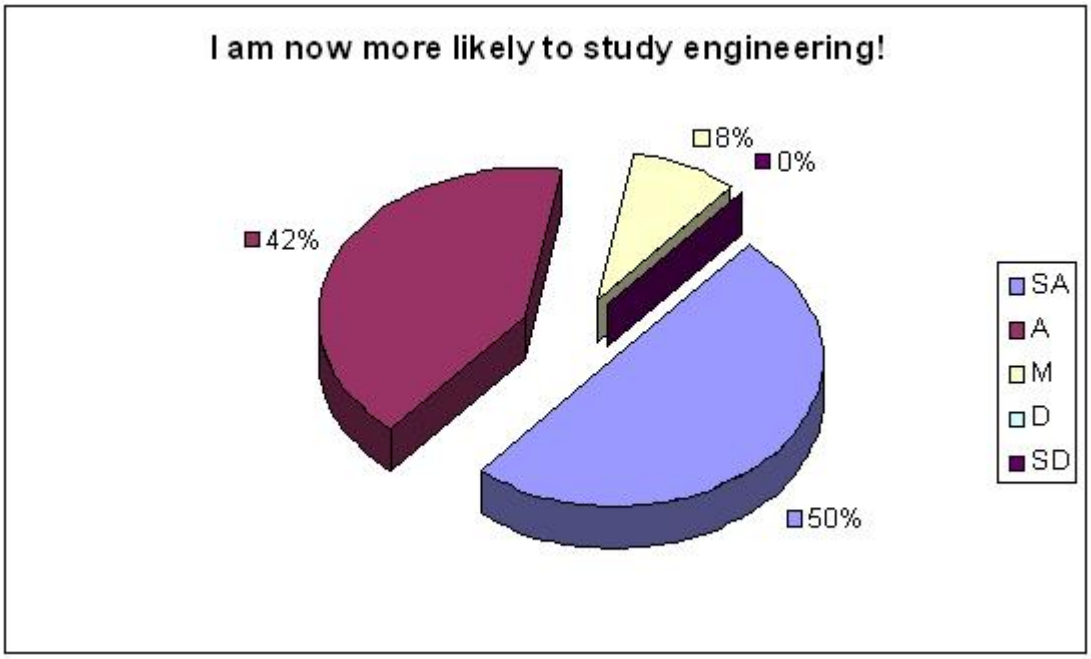

Figure 10: Survey Q&A – I am now more likely to study engineering!

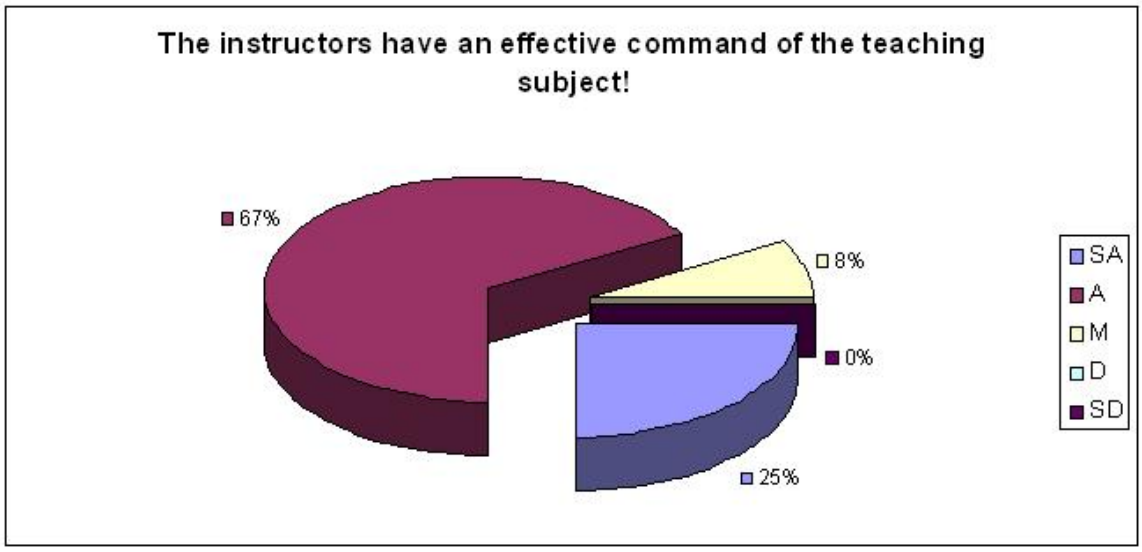

Figure 11: Survey Q&A – The instructors (Drs. Daidzic and Nikolic) had an effective command of the teaching subject.

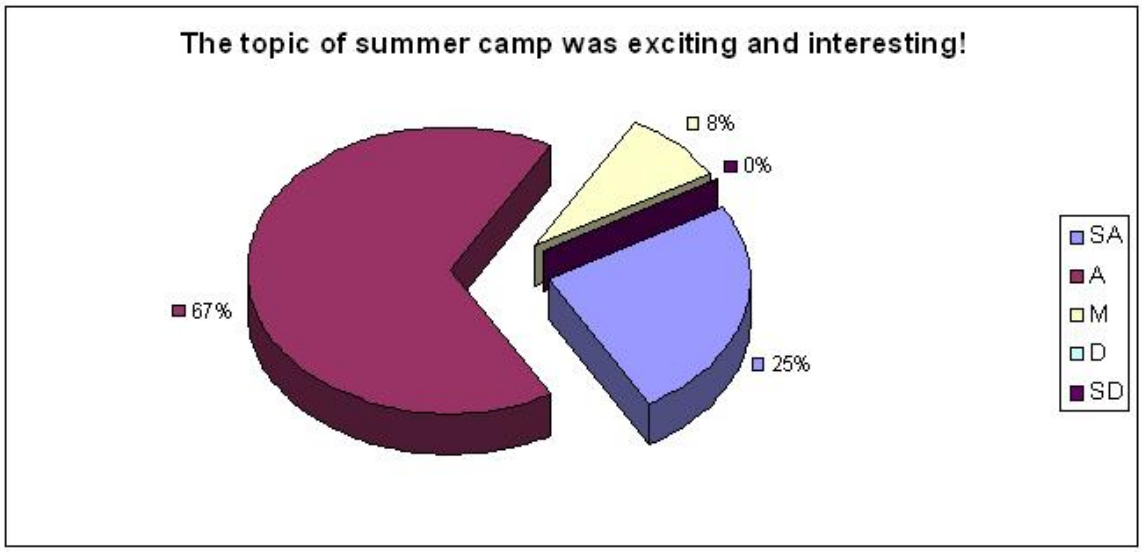

Figure 12: Survey Q&A – The topic of the Aerospace Summer Camp was exciting and interesting!

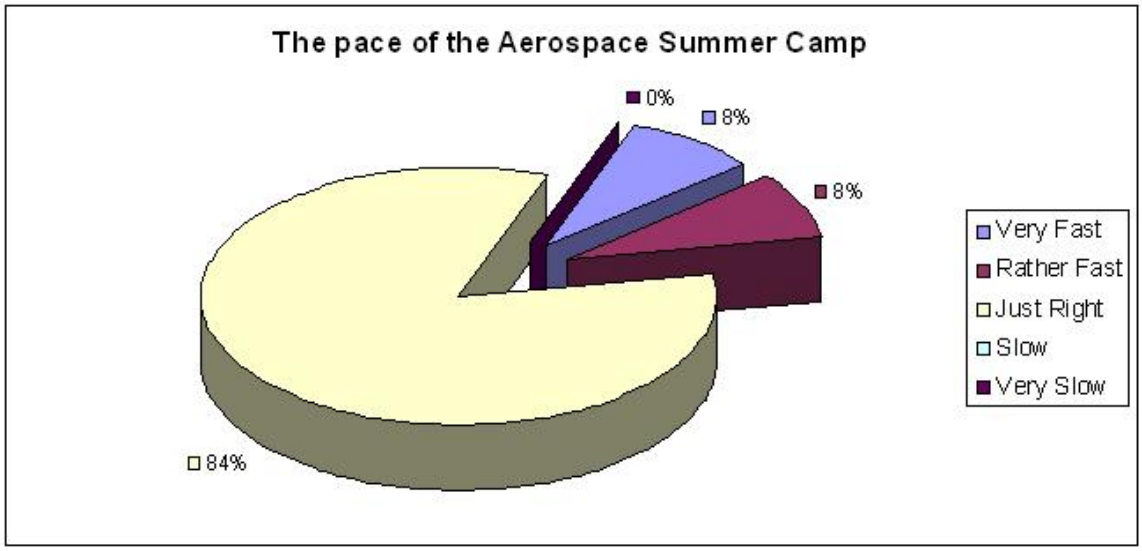

Figure 13: Survey Q&A – The pace of the Aerospace Summer Camp was just right!

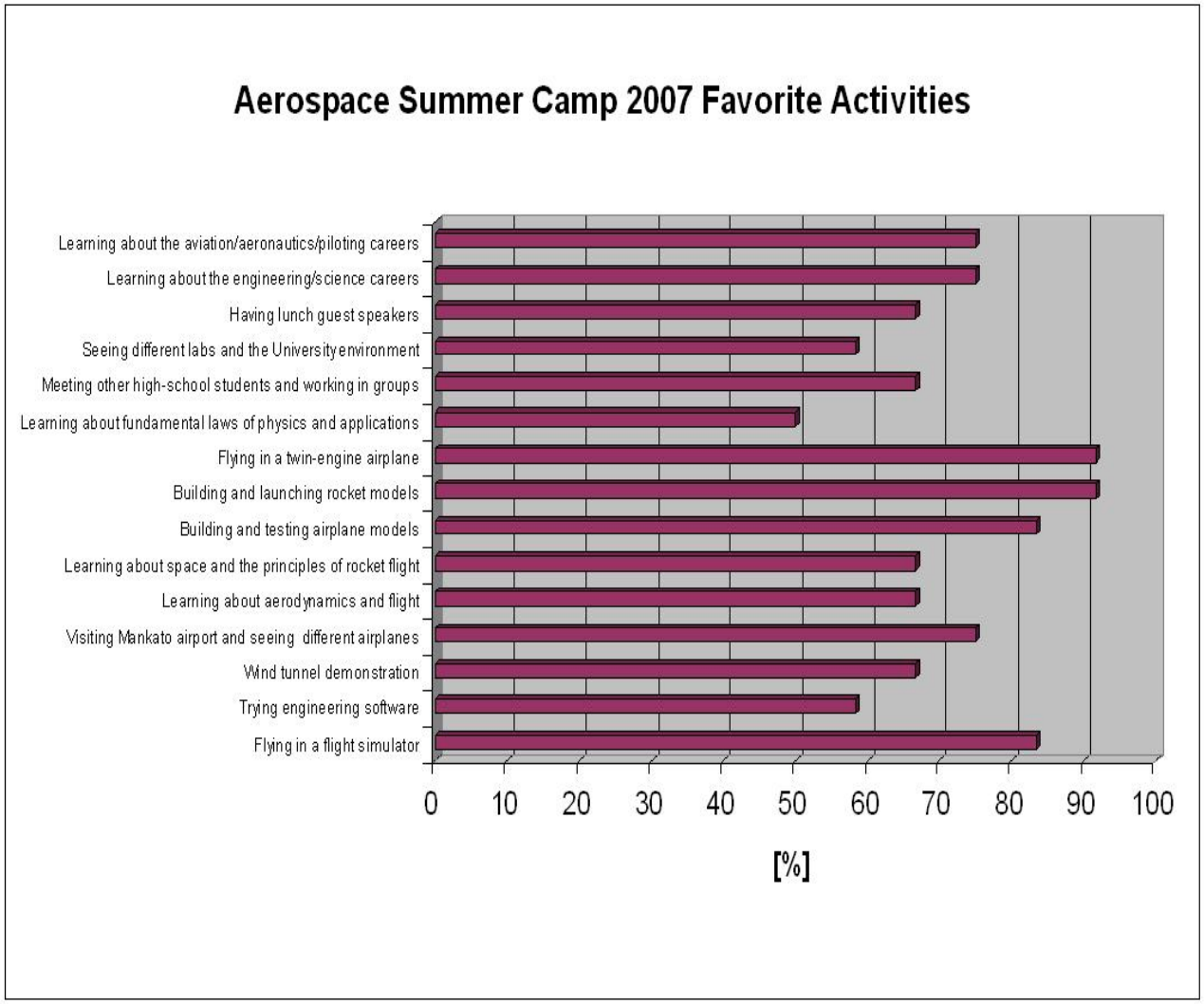

Figure 14: Survey Q&A – Aerospace Summer Camp favorite activities.

It is noted that the students apparently enjoyed the experience of being part of the Pilot Program. They expressed themselves very favorably when responding to all of these important questions. Of particular interest is that they in most cases were very eager to come back and that they would recommend the Program to their friends and peers. Figure 10 summarizes the overall effect that the camp had on the participating students. Thus, it is the single most important result of the Program: It says that ninety-two percent among the participating students are now, after having been in the Program, more likely to study engineering than what they were before. It shows the definite impact that this carefully planned and well conducted program have had on these young people.

Equally, significant is Figure 14; it illustrates that most of the students truly enjoyed most of the Program contents. The highest number of activities that a student enjoyed was 15/15; this outcome was recorded five times among the twelve students who completed the survey. The low was three, the mean was 10.8, or 72 percent; the median was 12.5/15, or 83 percent. These results suggest that the selection of the activities was rather good. We believe, however, that further improvements are possible. These include the addition of a hands-on aerospace/mechanical engineering optimization project using the wind tunnel, as well as possible inclusion of gliding/soaring flights with the students.

It is important to note that the atmosphere throughout the Program remained very positive, susceptible to working diligently and meeting various deadlines, yet having a lot of fun, which was one of the most significant 'ingredients' of the Program.

It was noted that the Pilot Program "Reaching for the Stars" has also impacted the public awareness of the MNCEME and MSU and their activities in a very positive and definite way. A fairly extensive coverage was featured by the Mankato daily "The Free Press." Dr. Nikolic, Dr. Daidzic, and several students featured in a KMSU interview about the summer camp preparations, building airplane models and during rocket launches. Local TV station, KEYC, broadcasted footages that were taken during rocket launches and the program was aired twice. Program students have been featured and interviewed.

Conclusions and Recommendations

A pilot version of an outreach program in aerospace sciences/engineering and aviation "Reaching for the Stars" has been developed and conducted at Minnesota State University, Mankato, thanks to the support by the Minnesota Center for Engineering and Manufacturing Excellence. A very effective program based on hands-on activities and team projects has been developed. The fun element of the program has been very present throughout its duration and culminating in the participating students flying in twin-engine airplanes. The Pilot Program has been an unqualified success; all participating students

have completed all the activities with very good to excellent results. In the end-of-program evaluations the students provided extensive feedback, predominantly very positive in nature, as well as numerous highly complimentary comments. The foremost conclusion found has been that the attitude toward science and engineering can be positively impacted to a large extent even by modest means when intended activities are well planned and carefully conducted. At the end of the Program ninety-two percent among the students (agree and strongly agree) said that they were more likely to study engineering now then they were before entering the Program. The Pilot Camp has also showed several avenues for further improvement of this outreach Program in the future. Examples include adding a hands-on optimization project in mechanical/aerospace engineering involving use of wind tunnel, as well as gliding/soaring flights with each individual student.

Acknowledgement

The Pilot Program of the Aerospace Engineering Summer Camp Reaching for the Stars has been made possible by the generous support of the Minnesota Center for Engineering and Manufacturing Excellence (MNCEME). Also, the Center's Director, Dr. Kuma Takamura has provided invaluable input before, during and after the Camp. Also the support by Dr. John Frey, Dean, College of Science, Engineering and Technology and Dr. Michael Miller, Dean, College of Education is greatly appreciated. The authors would also like to thank the following individuals for their participation in the Pilot Program: Professor Craig Ruedy, Chair, Aviation Department; Dr. Charles Johnson, Chair, Department of Mechanical and Civil Engineering; Professor Ann Goebel, Chair, Department of Automotive and Manufacturing Technology; Dr. William Hudson, Chair, Department of Electrical and Computer Engineering and Technology; Dr. James Wilde, Associate Professor of Civil Engineering; Ms. Tracey Hammell, Academic Advisor, Advising Center, College of Science, Engineering and Technology; and Dr. Steven Kipp, Professor of Astronomy.

Appendix

Actual daily Schedule of 2007 MSU Aerospace Engineering Summer Camp "Reaching for the Stars"

Week I (June 11 - June 15)

Monday	Tuesday	Wednesday	Thursday	Friday
Welcome, introductory remarks (15), Engineering/Science careers (15), Student Interview (15)	Hands-on introduction to Pro-E CAD by PTC (45)	Airplane project guidelines, remarks (20) Building airplane Models (25)	Building airplane Models (45)	Tour of Airport MKT (45)
Introductory Lectures: Review of Basic Physical Quantities. Demonstrations of basic physical principles (50)	Hands-on introduction to FEA software Pro-M by PTC (50)	Building airplane Models (50)	Building airplane Models (50)	Tour of Airport MKT (40)
Lunch 11:40-12:30	**Lunch 11:40-12:30**	**Lunch 11:40-12:30**	**Lunch 11:40-12:30**	**Lunch KMKT 11:40-12:30**
Newton's laws introduction and demonstrations (45)	Tour of CSET, Mechanical/Civil Eng, and labs (30). Tour of EECT with labs (15) if applicable	Building airplane Models (45)	Building airplane Models (45)	Flight Simulators (FTD's) KMKT (45)
Introduction to Aerodynamics, Bernoulli's law introduction and demonstrations (40)	Wind Tunnel demonstration (30), NASA airfoil flow simulation (10)	Building airplane Models (40)	Building airplane Models. Finish (40)	Flight Simulators (FTD's) KMKT (40)

Week II (June 18 - June 22)

Monday	Tuesday	Wednesday	Thursday	Friday
Finishing airplane models (45)	Building Rocket models (45)	Building Rocket models (45)	Testing Rocket models at KMKT (45)	Visit to the MSU Astronomical observatory (45)
Finishing airplane models (50)	Building Rocket models (50)	Building Rocket models (50)	Testing Rocket models at KMKT (50)	Visit to the MSU Astronomical observatory (50)
Lunch 11:40-12:30	**Lunch 11:40-12:30**	**Lunch 11:40-12:30**	**Lunch KMKT 11:40-12:30**	**Lunch 11:40-12:30**
Introduction into rocket propulsion and space flight (45)	Building Rocket models (45)	Building Rocket models (45)	Flying at KMKT (45). Testing of Airplane models.	Awards, certificates, interviews, survey, program evaluation (45)
Rocket project guidelines and remarks (40)	Building Rocket models (40)	Building Rocket models. Finish (40)	Flying at KMKT (40). Testing of Airplane models.	Closing ceremony and remarks (40)