NASA's Great Moonbuggy Race - Innovative Student Projects

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Introduction

The Society of Manufacturing Engineers student chapter at Southwest Missouri State University decided to follow the lead of another student group and build a "Moonbuggy" to race in the NASA sponsored "Great Moonbuggy Race" held annually at Marshall Space Flight Center, in Huntsville, Alabama. The first buggy was designed by a small team and constructed as a part of a senior level capstone course. The buggy completed the preliminary qualification run successfully but lost a drive chain on the second run. The second year a portion of the design was completed in an introductory design class. The class, working in teams, was able to develop a successful dual range drive system that allowed high torque for difficult obstacles and high speed for flat stretches. They were able to utilize the mechanics/statics that learned in a previous course.

The race is used as an integral part of courses at other institutions. Pittsburg State University in Pittsburg, Kansas utilizes the race as a central part of their design curriculum. Each team of, from 5 to 6 students in the class, is required to design and build a buggy for the competition. This, plus the sponsorship of are industry, has resulted in some innovative use of materials ranging from titanium to space age composites.

The competition is a two-part event. One part is the race, which depends on durability and speed the second part deals with the documentation of the design and construction phase. This requires that students present a comprehensive review of the design and construction process. The students also become involved in assessing cost and of course in fund raising activities.

The Institutions

Southwest Missouri State University (SMSU) is a multi-campus metropolitan university system. The main campus at Springfield is home to the Department of Technology, which offers a bachelor of science degree in Industrial Management (IM) with concentrations in CADD, Construction, Electronics, and Manufacturing. The IM program enrolls about 300 students. Three courses have participated in this project: TEC 312 - Engineering Drafting Standards, TEC 417 – Computer Aided Design, TEC 530 – Advanced Manufacturing Technology. The Department also offers a Master of Science degree through the College of Natural and Applied Science with emphasis on project management.

Pittsburg State University (PSU) in Pittsburg, Kansas sets the regional standard for higher education in technology. In many of its technology programs, PSU is a recognized national leader.

Pittsburg State has a tradition of offering outstanding educational opportunities in technology programs that have been developed since the University's founding in 1903. In the Fall 1997, the university began offering all its technology programs in the Kansas Technology Center, a 260,000 square-foot building featuring state-of-the-art facilities. The university offers undergraduate and graduate degrees as well as some certificate and associate degrees in more than 12 technology program areas. All PSU technology programs emphasize a practical approach or applied experience.

Marshall Space Flight Center is the world leader in space propulsion and transportation systems. The Center is also making significant contributions to the International Space Station, scheduled for completion in 2004. The Space Station will be used to conduct microgravity and other space sciences research. As NASA's Lead Center for Microgravity Research, Marshall will be at the forefront of that effort. Marshall has also led the way in developing the Chandra X-Ray Observatory. And the space optics center at Marshall is developing advanced optics manufacturing technologies that will enhance future space observatories. The NASA Higher Education team is responsible for involving the higher education community in NASA research and technology activities. Marshall Space Flight Center provides many opportunities for both students and faculty of higher education institutions.

The Great Moonbuggy Race, held annually in April, gives undergraduate and high school students from around the nation an opportunity to apply engineering skills and develop team spirit in an activity that will enhance awareness about human exploration and development of space. Moon buggies are built from the students' own designs, recreating the lunar experience of the Apollo astronauts and looking ahead to further human exploration of the solar system. Two-person crews, one male and one female, assemble their collapsible vehicles, receive a safety inspection, and power their vehicles along a simulated lunar terrain obstacle course. Prizes are awarded for originality of design and quickest traversal of the lunar course. The competition is hosted by the NASA Marshall Space Flight Center and the U.S. Space & Rocket Center. (http://moonbuggy.msfc.nasa.gov/)

The 2001 competition will have been be held on April 6-7 on the grounds of the U.S. Space & Rocket Center. Students are required to design a vehicle that addresses a series of engineering problems that are similar to problems faced by the original Moonbuggy team. Each human powered Moonbuggy will carry two students over a half-mile simulated lunar terrain course including "craters," rocks, "lava" ridges, inclines and "lunar" soil.

Moonbuggy entries are expected to be of "proof-of-concept" and engineering test model nature, rather than final production models. As a part of the competition, and prior to course testing, the un-assembled Moonbuggy entries must be carried to the course starting line, with the unassembled components contained in a volume of 4'x 4'x 4' (dimension requirements similar to those for the original Lunar Roving Vehicle). At the starting line, entries are assembled, readied for course testing and evaluated for safety.

The top three winning teams in each division (one high school division and one college division) will be those having the shortest total times in assembly and traversing the terrain course. Each team is permitted two runs of the terrain course.

Prizes are awarded to the top three winning teams in both the High School Division and College Division. Awards are for the six registered team members and their faculty advisor.

A prize is also awarded to the team whose Moonbuggy design represents the best technical approach toward solving the engineering problems of navigating the lunar surface. This award is based, not on race performance, but upon the technical approach taken by teams in their design. The design competition is optional. A list of 2001 competitors is appended to illustrate the range of institutions that have been involved in the race.

Attendance at a regional Society of Manufacturing Engineers (SME) Chapter Officials Conference got SMSU started in the Moonbuggy competition. Students from PSU were displaying a buggy that they had designed and built as part of a capstone course in their engineering technology program. SMSU students who have an emphasis in management wanted to participate in the Moonbuggy race. Two of the SME members registered for a special problems course and began the development of the first buggy in ProE software with the help of the engineering staffs of their respective employers. Other chapter members then signed up for the Spring semester, lab/lecture, TEC 530 – Advanced Manufacturing Technology class where the instructor agreed to integrate the project into his class. The first buggy was completed with the aid and advice of the student chapter advisor, the 530 instructor and input from SME senior chapter members. Sponsorship was solicited from many area companies and ranged from the boating industry to heavy equipment suspension builders.

Reflections from the SMSU instructor indicated that it was difficult to coordinate the project as a part of a project within a class. That effort was not repeated the second year. The consequence being that it was difficult to coordinate student work on the project. This year, the third in our series, the lack of coordination resulted in cancellation of the project. This is probably influenced by the fact that our student body is largely composed of non-traditionals, who for the most part hold full time jobs.

The second SMSU buggy project had the significant advantage of more advanced planning, experience and a graduate assistant. The Graduate assistant, Mr. Charles Roop had been SME student chapter chairman the year before. Dr. Drake was drafted to teach the TEC 417 design course and integrated part of the project into that course. One of the problems that was noted in the previous race was the need for a range of drive speeds. The course has areas where a higher speed is possible on paved surfaces but there are also areas such as a “sugar sand” obstacle where a high torque is desirable. One of the first projects for the TEC 417 students was to define the drive requirements for the buggy. The length of the course, winning times from the previous year, weight of the vehicle with riders and torque necessary to overcome obstacles and rider stamina were all taken into consideration. Trips were made to the fitness center to develop data from exercise cycles. Bicycle drive systems were analyzed using statics. Human effort to push a pedal was also analyzed in the fitness center. The women in the class were able to develop as much peddle power as the fellows. That came as of a shock to most.

As an ad hoc exercise this project proved very valuable. The students were excited to have a project that had some physical parameters that they could easily measure. They found that they could “search the web” for information on bicycle drive parts and other gear systems. They

found by analysis that bicycle parts alone would not give them the necessary range in torque to win the race. The project offered a nice range of design problems for a one semester course. It allowed the students to utilize knowledge from previous classes. It also gave them an opportunity to meet with the university president, Dr. John Keiser, who, with his administrative assistant took the buggy for a test drive. While our second buggy placed only eighth in the college division we consider we won in several other ways, especially when you consider that many buggies do not even complete the course. From personal observation, all those who get there and complete the course have won. All who participate will take away valuable lessons.

This exercise, which came to SMSU by chance, was the result of earlier work done by our neighbors at Pittsburg State University. PSU Manufacturing and Mechanical Engineering Technology programs have been TAC/ABET accredited since 1979. Part of the curriculum requirements for both programs is a "capstone" experience to "bring together" all of the students' experiences during their senior year. Many universities address this requirement by having students work on industry projects, having industry cooperative or internship experience or taking a class or classes in which such experiences can be achieved.

Pittsburg State has used all the above to address this curriculum requirement. The majority of PSU students take a class called MFGET or MECET 669 "Manufacturing Design Project" to meet this requirement. However, in 1992 the professor who was responsible for the "capstone" class retired. The Engineering Technology Chairman felt it was time to make some changes in how the course was being taught. Instead of one professor in charge of the class, the chairman suggested the three-hour class could be team-taught. Mr. Tim Thomas, coordinator of the mechanical engineering technology program, and Dr. Larry Williamson, coordinator of the manufacturing engineering technology program, were asked to team-teach the course.

Two professors team-teaching one course and both receiving credit for teaching the course was a new concept for the Engineering Technology Department. However, the course would bring together the expertise of both the design and the manufacturing professors into one classroom. The professors met and decided a project completed by the students in a team atmosphere would be best for the two programs. They wanted the project to have all aspects of design, analysis and manufacturing processes involved. Other requirements included quality control, testing of the project, project planning, cost analysis and keeping a budget. In simple terms the professors wanted the students to see the "birth" of the project in the concept stages as well as the testing of the project. In 1993 an adjustable wrench with defined requirements was selected and built by four teams of students. In 1994 four teams of students built a series of can-crushers, again, with defined requirements. Each year the professors were trying to expand the scope and the complexity of the project. This was accomplished in 1995 by having each of the student teams make a pitching machine to meet certain market requirements.

How PSU got involved: The NASA Human Powered "Great Moonbuggy Contest" as a "Learning Tool." In the summer of 1995 a fellow colleague from the manufacturing area spent the summer working at the NASA facility at the Marshal Flight Center at Huntsville, Alabama. He had seen videotape about the first human powered moon buggy contest and talked to some of the contest officials. When he returned to the PSU campus he met with Mr. Thomas and Dr.

Williamson and suggested they might consider building a human power moon buggy for the "capstone" class and enter the contest.

Thomas and Williamson decided to use the NASA Human Powered Moonbuggy as the student learning project for the 1996 spring "capstone" class. Since there were 15 students enrolled in the class, the class was divided into three teams of five students each. Each team built a moon buggy.

The professors have learned through past experiences the ideal number of students in a team project is four or five students. Six students in a group are too many if you expect each student to work effectively on the team project. The students are placed into teams by the professors in based on the known abilities of each student. Both design and manufacturing majors are placed on the each team. The design majors should be able to answer all design issues including stress analysis and the manufacturing majors should be able to address manufacturing issues. Each team should be able to "Design for Manufacture;" A very important learning issue for graduating students in Mechanical and Manufacturing programs.

In 1996 three teams of students started work on their moon buggies. The NASA rules and requirements for the moon buggy contest were used as the "design" concepts for each student group. Each group was given a budget of $300 to build their moon buggy. If additional money was needed, each student group could seek in-kind donations from industry or other firms.

The student teams making the moon buggies created lots of excitement in the spring of 1996. Not only from a classroom perspective, but there was additional interest from other engineering technology programs about what was being done in the class.

Taking one or all teams to Huntsville, Alabama for the contest was not a major consideration in the spring of 1996. The NASA Human Powered Moon Buggy project had been selected solely to give students, working in a team environment, a chance to see a project developed as industry would build it. There would be design requirements, design restraints, a model built, a program plan, and a budget. As design was taking place, considerations as to how the various parts were to be machined, fabricated, tested, as well as issues related to cost and quality control had to be covered.

Each student team elects a team leader. The team leader may rotate from student to student as the semester progresses. Each team creates their own team logo and uses it with all of their class presentations. Each team leader is responsible for a one page, by weekly, report in which each of the team members tells, in a short paragraph, what they have done for the team in the past two weeks. The team leader collected the individual comments from each team member and submitted this report to the professors in charge of the class. Each team leader was also responsible for the evaluation of each of his or her team members based up on three-point scale: 1 for below above average, 2 for average and 3 for above average. The professors evaluated the effectiveness of the team leaders and how well they performed their evaluation of their team members.

There has never been a formal "test" requirement in the traditional sense by the individual teams for this "capstone" class. In place of the traditional test, there are a series of reports the team has to make to management (the professors in charge of the class). Each student is required to present what he or she has accomplished as part of a review. Typical reviews included: design requirements and concepts, a formal design review including analysis and materials needed, a manufacturing review to include process planning, quality control and product testing. A formal report, including all of the above issues is handed in at the end of the semester. All formal reports document individual efforts as well as the team effort. Seventy percent of each grade is based on the team effort and the balance on individual effort. All oral reviews are videotaped for accreditation purposes, as well as to allow students to learn how they might improve their presentations by watching themselves.

Each of the formal reports is presented to members of the Mechanical and Manufacturing Engineering Technology advisory committees when they meet in the spring. These reports are videotaped for accreditation purposes.

As the spring semester of 1996 progressed, it was clear that only two teams would have their moon buggies ready for either our on campus contest or the Great Moonbuggy Race at Huntsville. In March we decided to try to take two human powered moon buggies to Huntsville for the 3rd annual NASA Contest to be held on the third Saturday of April 1996. Our major goal was to go to Huntsville, learn all we could, and have a good time. It would provide an excellent opportunity to test the PSU moon buggies on the simulated moon track set up for the contest. Winning was not the goal nor has it ever been the goal the "capstone" class. However, when the dust had settled, PSU had taken 3rd and 4th place in the contest. This was a remarkable accomplishment considering their $300 budget for each team moon buggy.

In the fall of 1996 the "capstone" three-hour course was divided into two classes called Manufacturing and Design Project I, for one credit hour and Manufacturing and Design Project II, for two credit hours. Thus the students had a whole school year to complete their projects compared to one semester.

Design concepts, analysis, and engineering drawings are completed in the fall semester. Manufacturing and testing of the project is accomplished in the spring semester. The NASA Human Powered Moonbuggy idea has been "the project" used to accomplish the goals set for the "capstone" class since 1996. One of the goals has been to have students work in a team environment and to perform those tasks found by working mechanical and manufacturing engineers. In 1997 PSU took 4 teams to compete in the contest and won nothing. In 1997, each student was required to contribute $100 into his or her team account. The two professors also contributed $100 each to each team. This created a budget between $600 and $700 for materials, etc. Despite increased funding some of the moon buggies never left the starting line.

In 1998 three moon buggies were entered into the contest with a 2nd place finish. In 1999, again, three moon buggies were taken with a 1st place win in the university or college division. Each year, students start with a new concept and cannot use the previously built moon buggies. Parts can be taken from previous year’s moon buggies to save on cost of materials. Never has the goal been to win the contest. The contest is the final test setting for the project.

Results and lessons learned by PSU using the NASA Moon Buggy as a "learning tool"

1. Since 1996, the University President, as well as the Department Chairman and Dean of the College of Technology have been involved in the helping PSU receive as much publicity as possible for the programs in Engineering Technology.

2. Students like the project. The professors in charge treat the student teams as they would be treated in industry. Students will remember the work completed in this class long after graduation. Students have been known to spend entire weekends working on their moon buggy.

3. Industry Advisory Committees like the team project. The experience received from this class has helped students receive many job offers.

4. Each student has had to learn how to work in a team environment in order accomplish the whole task. Some teams have been dysfunctional. There have been occasions where members of a team would nearly come to blows with each other over issues.

5. The frame material for all of the moon buggies built between 1996 and 1999 were made using traditional material such as steel and aluminum. In 2000 PSU decided to use new materials for three new moon buggies. One frame was built using Titanium, one used a composite beam, and one team used fiberglass and the frame material. Since PSU had no means of bending titanium tubing, a network of industry assistance in the area of bending, welding, etc. was required. Total fabrication cost of the titanium frame was over $15,000 by itself. The composite frame cost industry over $6000 to be fabricated. This is long way from the $300 used to build the first PSU moonbuggy. PSU did not place in 2000. Each team in 2000 had a budget of $700.00. Without the help of industry, projects using non-traditional material would be nearly impossible.

6. The Engineering Technology Chairman uses the class as an opportunity for to evaluate the program by meeting with the students without the professors being present. This serves as an exit interview for the class.

7. The moon buggy project is supported by the entire teaching faculty (a total of 8 professors) of the Mechanical and Manufacturing Engineering programs.

8. It has helped with an enrollment increase in the Mechanical and Manufacturing programs.

9. The moon buggies have helped in showing new prospective students what is done at PSU in some of the classes they will take while attending PSU.

10. The ideal size for team projects is four or five students. Six students in a team creates a situation in which some students do not contribute as much as they could if put into a smaller group. Three students can not accomplish the necessary timely fashion.

11. The Mechanical and Manufacturing Engineering programs have had help from the Construction Engineering Technology program in creating a lunar testing track on the Pittsburg State University campus to test their moon buggies before going to Huntsville, Alabama.

12. Funding for travel and lodging for all students in the "capstone" class who participate in the NASA Human Powered Moonbuggy contest in Huntsville, Alabama has come from many sources. One major source of funding has been the Kansas NASA Space Grant. Without their help many of the PSU trips to Huntsville would not have been possible.

Appendix

Names and Email Addresses for 2001 Competitors

School	Email Address
Arizona State University I	Helen.reed@asu.edu
Arizona State University II	Helen.reed@asu.edu
Autauga County Technology Center I	
Autauga County Technology Center II	
Carbondale Community High School	Snotzombie@aol.com
Cameron University	georgef@cameron.edu
Carthage High School (MO)I	christianw@carthage.k12.mo.us
Carthage High School (MO) II	christianw@carthage.k12.mo.us
Christian Brothers University	xcbu2000x@aol.com
Cornell University	bjl16@cornell.edu
Eastlake High School (CA)	edroeters@yahoo.com
Embry-Riddle Aeronautical University I	wellss@db.erau.edu
Embry-Riddle Aeronautical University II	lazersos@db.erau.edu
J. O. Johnson High School	Rciliax@worldnet.att.net
Lafayette Co. C-1 High School	Goodman@huskers.k12.mo.us
Lansing High School (NY)	lfoley@mail.lansingschools.org
New Century Technology High School New	foil41@aol.com
Mexico State University	ahyde@nmsu.edu
Pinewood Preparatory School (SC)	coolchemist@rocketmail.com
Saint Martin's College	esjoblom@stmartin.edu
Southern Illinois University	mrtfehr@aol.com
Southwest Missouri State University	billdrake@smsu.edu
Tennessee Technological University	rcp5542@tntech.edu
The College of New Jersey	sepahpou@tcnj.edu
UniTec Career Center (MO)	bminkel@peoplepc.com

University of New Hampshire	moon.buggy@unh.edu
University of Tennessee, Knoxville I	dki@utk.edu
University of Tennessee, Knoxville II	dki@utk.edu

William H. Drake is an Associate Professor of Technology at Southwest Missouri State University. Dr. Drake received a B.S. in Technology and a Master of Education at the University of Houston in 1976 and 1978 respectively and a Ph.D. in Industrial Education from Texas A&M University in 1983. He is a Certified by the Manufacturing Engineering Certification Institute and is a Distinguished Member of the American Welding Society.

Larry Williamson is a Professor of Manufacturing Engineering Technology at Pittsburg State University. Dr. Williamson received his BS in Industrial Technology and a Master's of Science in Industrial Education in 1965 and 1968 respectively and an Ed.D in Vocational Education from the University of Arkansas in 1981. He is a Certified Manufacturing Technologist by the Manufacturing Engineering Certification Institute.