# Capstone Design with a Distributed Team

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**Abstract –** The Department of Mechanical Engineering at the University of Alabama offers its Bachelors of Science degree through a distance education program to non-traditional students located in an industrial region in southeast Alabama. The degree program includes the challenge of delivering Capstone Design, a team-based engineering project, to these off-campus students. In fall 2004 three distance education students, one in Montgomery and two in Dothan, Alabama, were combined with four on-campus students into a design team. For their design-build experience, the instructor provided this team with a larger budget (approximately $1000) and more access to machine shop time than other teams consisting solely of on-campus students. The local group set up a webpage, bulletin board, and group email account to foster communication amongst all group members. The paper discusses the way that the group dealt with the extra challenges it faced and also describes the resulting design project.

*Keywords:* Distance education, capstone design, teams

## INTRODUCTION

Alabama currently has seven ABET accredited undergraduate engineering programs located across the state. The Dothan, Alabama area, which is located in southeastern Alabama, is a center of industrial activity [7]. It has a population of approximately a quarter million people within a half-hour commute. Local industry includes the Farley Nuclear Plant operated by Southern Company, Sony, Michelin, General Electric, GTE, Polyengineering, Gates Rubber, and the U.S. Army-operated Fort Rucker helicopter training school. Although Troy State University at Dothan and Wallace State Community College serve some of the higher education needs of this area, neither of these institutions has an accredited engineering program and none of the existing engineering programs is within commuting distance for an employee to take traditional evening courses. The current political climate in the state does not favor the creation of an additional engineering degree program.

Distance learning programs have provided a new opportunity to reach out to these non-traditional students and their employers. However, unlike many other programs, undergraduate engineering has a few special requirements, such as the need for laboratories and the need for team experiences. Virginia Commonwealth University offers an engineering technology program with a traveling laboratory [13], and several instructors have been creating virtual laboratories which might some day go hand in hand with a distance BS engineering degree [3,8,9]. Nevertheless, no other complete undergraduate engineering degree programs are offered through distance education. Despite potential obstacles, in the mid-'90's, Dothan industry began negotiating with the University of Alabama to offer its BSME degree program via distance learning.

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As a result, a program was created to meet the challenges of delivering an ABET-accredited BSME degree through distance education. Since ABET requires laboratory and teaming experiences, plans were developed to handle these issues with the same course content as received by on-campus students [1]. In the resulting agreement, as many general and social science courses as possible, such as English composition, chemistry, physics, and mathematics, are taken by the distance education students at the universities in Dothan. Then the engineering courses will be completed via distance education from the University of Alabama.

Four engineering lab courses were identified as being unavailable except through an ABET accredited program. A mobile lab was purchased and stocked to deliver these laboratories on weekends in the Dothan area. More discussion of these courses is presented by Midkiff et al [7].

In the initial development of the distance education degree, the plan for providing teaming experiences was based upon having a critical number of Dothan students that would go through the curriculum together. Then in the senior design courses, these students could work together on local design projects. In the initial planning of the degree program, employees in the Dothan area were surveyed and approximately 160 non-traditional prospective mechanical engineering students were identified. It was believed that adequate sized cohorts of students would be going through the program to make it work.

**Reality of Distance BSME Degree**

While a number of non-traditional students have enrolled in the lower-level engineering courses, such as thermodynamics and statics, it has become clear that this program requires a lot of dedication from the students. After a semester or two, many of them have not maintained their studies, and we found ourselves confronted with having only one or two distance education students in the senior-level classes. Several students have at least considered the option of spending a year in residence to complete the BSME program. Of the three students who have completed a BSME degree using a significant number of distance courses, only one has finished all of his work as a distance education student [12].

Currently there are three distance education students in senior-level courses, and they were enrolled in ME 489--Mechanical Engineering Design I, the first semester of capstone design, during fall 2004. This is the first course in a two-course sequence in capstone design in the mechanical engineering curriculum at the University of Alabama. In ME 489, students in the class are divided into teams, and each team works on the same design/build project. Each team is given a budget and as part of the final evaluation, students must present and demonstrate a working prototype.

Typically the teams for this course consist of three students, depending on how many students are in the class, but sometimes logistical issues require smaller or, usually, larger teams. Unfortunately this was the case in the fall of 2004 due to the large size of the class and the impact of their projects on the College of Engineering Machine Shop. Therefore teams of seven students were created, and the distance students had to be integrated into a team with on-campus students.

## FALL 2004, MECHANICAL ENGINEERING DESIGN I

The project for the fall semester of 2004 was to design, build, and test a vehicle for the Great Moonbuggy Race [10,11]. The Great Moonbuggy Race has been held each April for over 10 years at the US Space and Rocket Center in Huntsville, Alabama. A 'moonbuggy' is a human powered vehicle that can carry two students, one female and one male, over a half-mile simulated lunar terrain course. One added twist for the ME 489 class was that the drivers of the moonbuggies had to be pre-college students. Each team was required to contact a group of pre-college students and work with them in the design and testing phases of the project.

The Great Moonbuggy Race uses a rugged off-road course containing several obstacles, and component failure is a problem typically experienced by a majority of teams on race day. To be successful, students need to understand design issues related to braking, steering, suspension, drive trains, gearing, and other issues of creating a vehicle. In addition to individual component design, creating a moonbuggy also involves system integration since these components must be able to work simultaneously without interfering with each other.

Specific design constraints for the Great Moonbuggy Race include

- The male and female drivers must be able to carry the vehicle for at least 20 feet
- The vehicle must have a maximum of 15 ft turning radius
- The vehicle must fit into a 4 ft x 4 ft x 4 ft cube and be reassembled in less than 2 minutes
- No passenger body part may come closer than 15 inches to the ground

In ME 489, each on-campus team of students was given an additional economic constraint, i.e. a budget of $750. The distance team had a slightly higher budget of $1000. The additional money was primarily for shipping, travel, and other discretionary costs associated with contact between the on-campus and distance team members. Each team was also allowed to scavenge parts from previous student design projects which included vehicles from the ASME Human Powered Vehicle competition [2]. Each team was also given 10 hours of professional machinist time for working on their moonbuggy. The College of Engineering at the University of Alabama maintains a machine shop housing several professional machinists and woodworkers to provide support for student and research projects. In addition there is a new student machine shop where students can do some machining and fabrication under supervision.

As mentioned previously, originally the class was divided into ten teams of three or four students each. Due to the limited availability of the machine shop, the teams had to be combined, and the distance team consisted of three distance students and four on-campus students. The teams worked independently on their designs for the first four weeks of the semester and had an additional six weeks to complete their design, build their design, and demonstrate their completed moonbuggy after the teams were combined.

## Issues Faced by Virtual Teams

In our global economy, there are more and more occurrences in industry where teams are formed from individuals in multiple locations. These teams are used to leverage intellectual capital and include participants with multiple functions and a variety of perspectives [6]. They are often referred to as "distributed teams" or "virtual teams" [5]. Virtual teams have an even greater need for communication and collaboration than single location teams [6], and there is a greater and greater need to study their function.

Some educational programs even provide the opportunity for their students to develop virtual teaming skills [5]. These teams are typically self-selected by students who value the virtual teaming skills that they are exposed to. David and Lloyd identify power issues, cultural issues, and telecommunication issues as the three major obstacles faced by virtual teams. Power issues occur when the belief develops that some subset of the team has an advantage over another, such as more direct access to a client. Note that power issues can become more troubling when dealing with large teams. Cultural issues are significant for, although not exclusive to, multi-national teams where members have different traditions and societal norms. Telecommunication issues occur when team members do not have the same access to technology or the same training in its use.

### Power Issues

These issues are based around the perception of inequity or unfairness in the relationships among team members and clients (instructors and moonbuggy riders in this case) [5]. Instructors have noted that power issues occur frequently on capstone design teams where all members are located on campus, and they have great potential to be exacerbated when one or more team members are at a second location. However, there are several qualities of our distance education students that have the potential to either enhance or mitigate the power issues of a combined team.

Distance education classes for the distance education program are delivered to off campus students by videotape. (Distance students receive videotapes on a 3 to 7-day delay basis.) To facilitate high quality production, classes are held in special classrooms which, until recently, were only located on the other side of campus. Thus the on-campus students in these courses often had their routines disrupted when they had to walk across campus so that the course lecture could be videotaped. When added to the anonymity of the distance students, there is often initial mistrust and even enmity between on-campus students and students in the distance education program.

Recall that the remaining group of three distance students started out in a larger group of students who attempted the BSME distance program. These remaining students have been taking 1-2 classes per semester for a while and they are very dedicated to the idea of completing their degree. They are familiar with the same courses and instructors as the on-campus students, and they have to be very disciplined so that they can complete their coursework while working at full time jobs and often raising families. On-campus students soon appreciate the work ethic of the distance students and become more comfortable with them and the amount of work that they are willing to do. Although the on-campus students are more conveniently located physically to their course instructors, the distance students have developed effective strategies for contacting the faculty for their other classes, so this issue did not appear to have a negative effect on the team.

**Cultural Issues**

On campus and distance education students tend to have similar cultural backgrounds. As a public university, the vast majority of our students have grown up in Alabama. The biggest cultural difference between students in the two groups is due to the age difference. Dothan students have been 10-15 years older than our traditional on campus students.

**Communication Issues**

Due to the nature of the team, students were given more access to phone and fax than our typical students have. While there have been some strategies attempted in the past to enhance communication between on-campus and distance students, the teams actually developed several effective strategies on their own. One of the most significant ideas was the creation of a website for this team – separate from the course website – that could host information such as photos, calculations, drawings, a message board, and memos, so that all members of the group could be aware of the activities of the other members.

Responsibilities for the project were divided between the seven team members. One of the first decisions was to have a team coordinator whose primary responsibilities were to maintain the website and to check that all members were receiving access to necessary information. The only student with web site experience was an on-campus student, and he became team coordinator. The two students from Dothan were given the responsibility of the front and rear suspension based on the idea that they could work easily together due to their geographic proximity. The Montgomery distance student's company allowed access to their in-house machine shop for construction of the moonbuggy, so he was given the task of frame design and fabrication. The rest of the responsibilities (drivetrain, steering, braking, wheels/tires, and 3D drafting) were delegated to the remaining on-campus students.

The webspace for creation of the website has up to 3 gigabytes of storage space. A large storage space was necessary, since numerous pictures, videos, AutoCAD drawings, and PowerPoint presentations were stored and accessed from this webspace. A private bulletin board was obtained from a free bulletin board service (http://www.ezboard.com) so that the members could 'talk' to each other as a group without the need for a speakerphone or a teleconference setup. The website can be accessed at http://unix.eng.ua.edu/~jsheffield.

During each significant step of the design process, pictures, calculations, and drawings were taken and stored on the webspace, for each member to view and analyze. The team coordinator spoke at length with each team member nearly every day, to keep all members abreast of each others activities and the stage of the project as a whole. Several posts were made on the bulletin board to discuss design ideas and possible resolutions to design issues.

Also, the website served as an easy way to outreach to pre-college students interested in the project, since it housed information about the current stage of the project in great detail and in real time.

The final days of the project saw less activity on the website and bulletin board, since the coordinator and the team members were more focused on accomplishing their individual tasks and the moonbuggy wasn't changing significantly as it was in the earlier design stages. Communication by the final days was primarily through cell phone use, since quick decisions and information were needed to finish the project. Upon completion of the project the website served as a storage space for pictures of the final moonbuggy and competition; it also contains the formal project presentation given on the project due date.

## RESULTING DESIGN

Details of the design can be found on the project web site. A brief description of the final design is provided below.

The team set the following objectives for their design:

- Braking distance less than 10 ft from maximum speed
- Ground clearance no less than 17 inches
- Use recyclable, interchangeable parts
- Top speed of 10 mph on flat, paved ground
- Safety factor > 1.5

The team's preliminary design was a four-wheeled vehicle with drivers sitting side-by-side. It was constructed from 6063-T6 square aluminum tubing, 6061-T6 aluminum plate, and 1018 cold rolled steel with a resulting factor of safety of 1.4. The selected suspension had a stiffness of 69 lb/in. The resulting turning radius was 8.4 ft. A picture of the final design is shown in Figure 1.

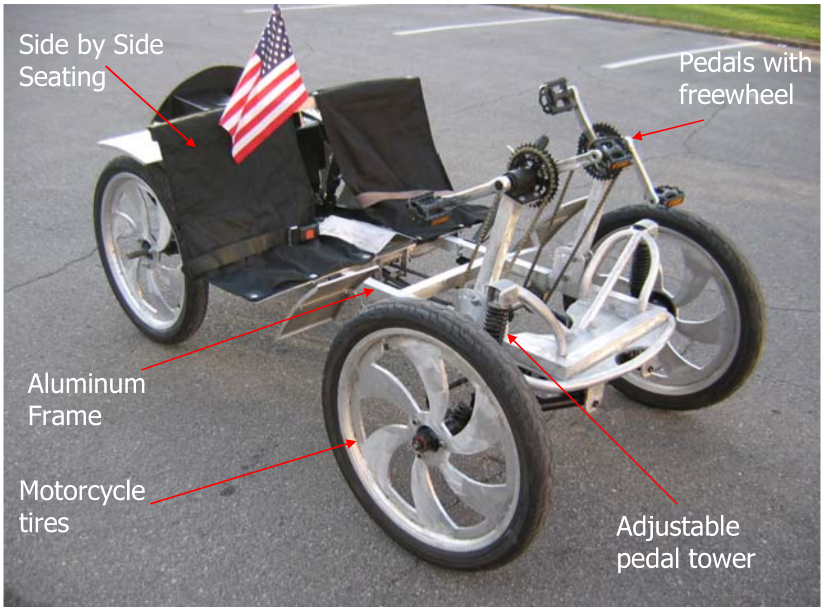


Figure 1. Completed moonbuggy.

The vehicle was designed with a hinged frame, and it fit into the 4 ft cube when folded. The braking system consisted of band brakes, and the team met their braking goal. The team also met its ground clearance goal. The rear swing arms were taken from an old moonbuggy. They were made from 1018 cold rolled steel which disproportionately added to the weight of the project. The resulting moonbuggy weighed 220 lbs, and the pre-college students working with the team were not able to carry it 20 ft.

In retrospect, the team would have reduced the weight of the vehicle and used a shorter pedal tower to make it easier to ride. They would also like to modify the steering.

## Faculty Perspective

On-campus students were initially cautious and somewhat skeptical about being teamed with off-campus students. Their perception was that significant travel would be involved and that perhaps the off-campus students would not contribute equally to the team effort. After discussing these issues, the on-campus student group was less concerned, but still not uniformly enthusiastic about the collaboration. The off-campus students did not share any concerns about working with the on-campus group.

The on- and off-campus students paired to form subgroups around different aspects of the Moonbuggy design. One group handled the frame, one group the front suspension and drivetrain, and the third group the rear suspension and seating. The off-campus students were primarily responsible for design and construction, while the on-campus students were responsible for design calculations and documentation. The remaining on-campus student (the first author of this paper) was responsible for team coordination and communication. The frame subgroup had the most successful collaboration and remained in close contact throughout the remainder of the project. The two other subgroups did not communicate nearly as effectively. The lack of face-to-face meeting time and pressure from other courses were the likely causes.

Several lessons were learned from this experience of teaming on- and off-campus students. Preparing the on-campus students from the beginning with the possibility of working with off-campus students would have been beneficial. Acknowledging the difficulties while emphasizing the unique learning opportunities would have smoothed the beginning of the project. Creating subgroups with students from both groups was a good idea. However, the interaction between the students in these subgroups should be monitored carefully and regularly. Including the course instructor as a recipient of all emails and intermediate documentation (such as drawings and design calculations) would be another good idea.

## Conclusions

Typically in capstone design experiences, students reach the end of the project with modifications that they would like to make to the design, particularly if they had more time and resources. This project was no different. From a pedagogical standpoint, the team members had a successful design and teaming experience. In particular, their idea of creating a web site and their efforts to communicate with one another were important to the success of the project.

In retrospect the instructor would have liked to have seen more team members involved in the manufacture and associated design modifications that went with that process. The process by which we involve the distance education students will continue to evolve in future semesters as communication technology continues to advance and the we gain more experience.

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**Joey Parker**

Joey Parker is currently an Associate Professor of Mechanical Engineering at The University of Alabama, where his teaching responsibilities include instrumentation, dynamics, and senior capstone design. He has been involved with the SAE Mini-Baja design competition for several years, and will be assisting the Formula SAE design team this year. Dr. Parker received his B.S.M.E. degree from Tennessee Technological University in 1978, and his Master's and Ph.D. in Mechanical Engineering from Clemson University in 1981 and 1985, respectively. His research interests include electromechanical systems, hybrid-electric vehicles, and industrial automation.