

# Delivery of a Complete Undergraduate Engineering Degree by Distance Learning Using a Mobile Laboratory

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## Abstract

Described here is the development of a program to deliver a complete undergraduate mechanical engineering degree by distance learning to remote, non-traditional students. A chronology of one community's efforts to gain access to an engineering degree program is presented. Electronic means of remote delivery of conventional lecture material are well documented, but efforts to provide *complete* engineering (or science) degrees by distance learning are in their infancy. The major impediment to offering a complete degree by distance learning is the need to deliver hands-on laboratory experiences. Although virtual laboratories and similar methods are under development, they will serve to complement rather than replace actual hands-on experiences in the near term. This paper documents the development of a system that provides remote students access to a mechanical engineering degree using a mobile laboratory. New methods to enhance faculty interactions with remote students will also be needed. This novel activity should serve as a model for other efforts to meet the educational needs of students in locations where traditional engineering programs are unavailable.

## General Background

Demand for education for remote students has increased considerably in recent years. This demand is fueled by the movement of industry to smaller towns, the decline of state support for higher education, and the growing appreciation of the importance of lifelong learning for maintaining employability. Accelerated job displacement due to technological advances and employers' desire to focus more on core activities and to outsource training activities has increased demand for engineering education programs for non-traditional students. Distance learning provides an opportunity for the delivery of degree programs to industry located far from a university that offers engineering. Distance learning also offers a viable option to a traditional education for "college-aged" students who remain and work in their home communities because they cannot afford to attend a full-time residential college.

"Distance learning" designates programs that provide education to students who are remote from traditional col-

leges and universities. Common delivery technologies, in order of oldest to newest, are: (1) correspondence courses delivered by mail, (2) videotaped lectures, (3) one- or two-way live television broadcast of lectures, and (4) World Wide Web (WWW) based delivery methods. Although each delivery method offers advantages, the more recent methods offer greater ease in delivering graphical material and higher levels of student-faculty interaction.

Judging from the attention it has received in the popular media and the proclamations of experts, distance learning is a rapid growth area in higher education. Distance learning should be popular in engineering education, a discipline that emphasizes technology. The prominence of distance learning as a subject in journals of engineering education and as a topic for NSF funding supports this. Most of the present successful distance learning programs in engineering provide graduate education (e.g., NTU), teach a few courses for a traditional curriculum, or provide specialized industrial training. Few, if any, universities offer complete undergraduate engineering degree programs by distance learning.

A complete undergraduate engineering degree is difficult to provide by distance learning because laboratory courses must also be delivered. Virginia Commonwealth University has developed an engineering technology program that utilizes a traveling laboratory as part of its distance learning program (Verma and Crossman, 1995). The laboratory/hands-on elements of engineering have received research attention in the form of efforts to develop virtual laboratory and multimedia experiences that demonstrate physical phenomena (e.g., Aktan et al., 1996; Mosterman et al., 1994; Mosterman et al., 1996). Although much has been invested in these lab experience simulations, surely the future will see these virtual experiences complementing, not replacing, actual experiences in the real world in which engineers and their creations must function. Just as no one would trust their life to a jet pilot whose only training was on a simulator, engineers also need actual hands-on learning experiences in real laboratories. Although many predict that distance learning will rapidly supplant traditional, on-campus education, the need to provide real lab experiences poses a major roadblock to educational delivery via the information superhighway.

## A "Real World" Problem

The customer to be served by the activity described here is the Dothan, Alabama area, which is 210 miles from the University of Alabama (UA) campus in Tuscaloosa. About a quarter of a million people live within a half-hour commute of Dothan. Local industries include the Farley Nuclear Plant operated by Southern Nuclear Co., Sony, Michelin, General Electric, GTE, Polyengineering, Gates Rubber, and the U.S. Army-operated Fort Rucker helicopter training school. Local industry and community leaders in Dothan have campaigned for years for a local engineering education program for their employees. These employees are non-traditional college students who typically are older and have family responsibilities and demanding jobs. Their employers view them as highly competent and experienced, but they need an engineering degree to be promoted into technology management positions. Troy State University at Dothan (TSUD) and Wallace State Community College are located in Dothan, but neither offers engineering. The state government of Alabama already supports seven engineering colleges at state universities, and the political climate does not favor the establishment of new programs.

Recognizing that they needed to work with an existing engineering program in the state, Dothan industries surveyed their employees to gauge student interest and preparedness, and to determine which areas of engineering were in greatest demand. Mechanical engineering emerged as the most popular option—over 160 potential ME students were identified. At this point, some industries evaluated a pre-recorded videotape-based course program offered by another university, but these tapes were recorded years earlier and were determined to be stale and unacceptable. Representatives of Dothan then approached UA through its Dothan Regional Office to discuss the possibility of providing an engineering program for the Dothan area.

## Working Toward a Solution

Beginning in mid-1995, ME and College of Engineering representatives, including one of the authors, visited Dothan several times to explore program possibilities. One of the larger companies had a prior negative experience with a non-ABET-accredited engineering technology program offered by a for-profit institution at another of its facilities in a nearby southeastern state. Dothan was interested only in an accredited BS degree in engineering, not technology. UA first planned to deliver engineering lecture courses through an existing UA videotape program, but move as quickly as possible to two-way interactive television. Several meetings with many prospective working students revealed that live IITS classes were undesirable because of swing-shift schedules. Students would be un-

able to attend IITS lectures at some point every semester no matter when the lectures were scheduled. Videotape delivery of lectures appeared to be the most feasible.

From the beginning, delivering lab classes to Dothan was viewed as a major problem. Naively, UA assumed that the Dothan students would be willing to make periodic trips to the Tuscaloosa campus to participate in labs. Interviews of prospective students and their employers quickly revealed that having to make the eight-hour round-trip journey to UA to meet labs would be greatest deterrent to participation. These employees, many with families and substantial work responsibilities, could not afford the time needed to travel to Tuscaloosa for laboratories.

This strong objection to travel left three potential solutions to the laboratory delivery problem. First, labs could be set up at a Dothan industry, and partly supplied by existing industrial equipment. Second, labs could be operated at one or both of the two area colleges. Third, UA could construct and operate a mobile laboratory to deliver laboratory classes.

The first option appeared to be the most cost effective. It was explored in discussions with representatives of local industry. Although it seemed possible to put labs together in a somewhat ad-hoc manner, the organizational effort required would be horrendous. Several other negative issues also arose. All of the industries were concerned with liability. Scheduling the use of facilities and equipment to meet both the teaching schedule and the needs of the industry would be difficult and subject to last minute breakdown. The industries had concerns that an experiment or student might cause damage at their site.

The second option was not feasible for political and regulatory reasons. The Alabama Commission on Higher Education (ACHE) controls which colleges and universities are allowed to offer which programs. Because the state is overbuilt in terms of institutions of higher education, each institution guards its sanctioned programs vigorously. If one of the local colleges began offering engineering laboratories, complaints to ACHE would arise from other institutions, which would likely disallow the activity. It soon became clear that the mobile lab option was the only feasible means of delivering hands-on experiences.

## The Basic Plan

After deciding that a mobile laboratory was needed to deliver a complete BSME degree to the Dothan area, a working plan for the program was formulated. Students will take preliminary courses in the sciences, math, social sciences and humanities at local Dothan colleges, then complete their BSME by taking engineering courses from

UA by distance learning. The BSME degree that will be delivered to Dothan is ABET-accredited and identical to that offered to on-campus students, except that the engineering courses will be taken by distance learning. UA offers a high-quality distance learning program (QUEST) using videotapes of current on-campus classes. Delivery of QUEST courses is a well-established program and is sanctioned by ACHE. The QUEST program delivers traditional lecture classes well, but it is not designed for the delivery of laboratories and other hands-on activities. Laboratories will be delivered using a mobile laboratory.

### **Courses Delivered by Mobile Laboratory**

The Department of Mechanical Engineering has recently implemented a major curriculum overhaul (Midkiff et al., 1997; Parker and Ferguson, 1997). Laboratory courses in chemistry and physics (each a two-semester sequence) are required, but these are offered by the Dothan-area colleges. There are four courses with extensive laboratory content required in the new BSME curriculum. No lab electives are required. The following subsection provides thumbnail descriptions of these four laboratory courses.

*ESM 251 - Mechanics of Materials Laboratory:* (1 semester hour, accompanies ESM 250 - Mechanics of Materials; existing course) Mechanical tests of metallic and nonmetallic materials in the elastic and inelastic ranges; use of materials testing for acceptance tests, for the determination of properties of materials, and for illustration of the validity of assumptions made in mechanics of materials.

*ME 283 - Modern Manufacturing Laboratory:* (1 semester hour, accompanies ME 383 - Modern Manufacturing Practices; existing course) Operational experience with manual and computer-controlled machining operations. Interaction with machining technology students in the design and fabrication of a machined part. (This class is currently taught at a community college machining technology laboratory in Tuscaloosa. It is planned to use a similar arrangement at the local community college in Dothan.)

*ME 360 - Control & Instrumentation Components:* (3 semester hours; new course in revised curriculum) Selection and use of electrical, pneumatic, and other components found in mechanical system instrumentation and control. Demonstrations and both pre-assembled and open-ended experiments will provide significant "hands-on" opportunities for learning. Includes signal conditioning, force and torque measurement, proximity sensors, AC and DC motors, pneumatic system components and programmable logic controllers. Strong emphasis on written reports.

*ME 460 - Thermal Systems Instrumentation:* (3 semester hours; new course in revised curriculum) Selection and use of instrumentation for thermal/fluids measurements. Topics include pressure, fluid flow, temperature, and environmental parameter measurement. Tests of fluid movement systems, heat exchangers, refrigeration devices, and heat engines. Introduction to statistical design of experiments. Strong emphasis on written reports.

### **Operation of the Mobile Laboratory**

The basis for the mobile lab will be a 12 ft  $\times$  40 ft trailer such as is used for construction site offices. It is significantly wider than the 8-ft wide trailers pulled as part of an 18-wheeled, over-the-road, tractor-trailer rig. The mobile lab will be a self-contained unit complete with its own heating, cooling and ventilation equipment, electrical wiring, compressed air, water supply and sewage. A conceptual schematic for the laboratory is shown in Figure 1. The mobile laboratory will be centrally located in Dothan, probably at TSUD, where utility connections can be made

The mobile laboratory will be outfitted in Tuscaloosa for the lab to be taught prior to its first use each semester. This will require removing experimental equipment used during the previous semester, and installing and testing the equipment to be used in the upcoming semester. After the lab is outfitted, it will be towed from Tuscaloosa to Dothan and set up. Because of the width of the trailer it will be treated as a "wide load" on the highway, so the lab will be towed to and from Dothan only once per semester.

Classes will be taught in four or five "doubleheader" sessions on Saturday morning and afternoon. Laboratories will be taught by experienced graduate teaching assistants, just as they are for on-campus labs. The GTA will drive to Dothan on Friday (a four-hour drive), supervise the laboratories on Saturday, and return Saturday night or Sunday. Small, valuable equipment items and replacement supplies can be carried to the site by the GTA on each visit. At the end of the semester, the mobile laboratory will be towed back to Tuscaloosa and outfitted for the laboratory offered by remote delivery the following semester. It is anticipated that the four lab courses will be taught one at a time on a two-year rotating schedule. Because only three of the four classes use the mobile lab itself (ME 283 will be taught at a local community college), it would be idle for several months every two years for repairs and renovations.

### **Financing the Plan**

#### **Paying for the Mobile Laboratory**

An estimate of the mobile laboratory first cost was made by considering the costs of the trailer and the equip-

ment for the three labs to be taught in it. Assuming that much of the finish casework, wiring, plumbing, etc., is accomplished by College of Engineering technicians, the cost of the mobile lab and equipment is estimated at \$200,000. The cost of operating a single laboratory course per semester, including GTA salary and travel costs, supplies, and lab-hauling costs, is \$25,000 to \$30,000 per year. These costs are significant, and the relatively small tuition to be collected for these lab courses will never cover the cost of building and operating the lab. Consequently, a major hurdle to implementation of the BSME by distance learning program was covering these costs.

At this point, the University of Alabama faculty reached an understanding with Dothan industry: if Dothan could provide \$200,000 for the first cost of the mobile lab plus approximately \$25,000 per year for operating costs, the University would agree to offer the BSME degree by distance learning. The University incorporated this offer into a formal memorandum of agreement signed by the President and the Deans of the Colleges of Engineering and Continuing Studies. The agreement was transmitted to Dothan representatives early in the Fall 1996 semester.

This proposal precipitated a fund raising effort in Dothan, although it proceeded at a discouragingly slow pace from the viewpoint of UA faculty. Late in Fall 1996, after two meetings with management of the largest industrial player in the Dothan area, a substantial pledge toward the cost of the lab was received. A couple of significant, but considerably smaller gifts followed in Spring 1997. As time passed it began to appear that fund raising efforts would fall short. The Dothan Chamber of Commerce sponsored a luncheon to promote the cause in late Spring 1997, but few additional funds were pledged through the summer. Finally, in early Fall 1997, through a lobbying effort of Dothan representatives, the State Legislature appropriated about \$55,000 toward the mobile lab, which put the total pledge very near the required \$200,000. In early October 1997 the President of the University and the Deans of the Colleges of Engineering and Continuing Studies visited Dothan and agreed that the University would offer the BSME degree by distance learning. It was promised that the mobile laboratory would be ready to operate for the Fall 1998 semester.

#### **Paying for Course and Lab Design and Development**

In parallel with the fundraising effort in Dothan to pay for the mobile laboratory, College of Engineering faculty have attempted to procure funding for laboratory and experiment design and curriculum development for distance learning lab courses. A proposal was submitted to the NSF Leadership in Laboratory Development (LLD) activity of the Instrumentation and Laboratory Improvement (ILI)

program in the Division of Undergraduate Education (DUE) in October 1996. This proposal was declined, but the proposal was strengthened and submitted to the NSF Course and Curriculum Development (CCD) program of DUE in June 1997. The proposed goal is to provide engineering lab courses to remote students that are of the same pedagogical quality as traditional on-campus lab courses. The activities for which funding is requested are to:

1. modify curricula to facilitate parallel instruction of remote and on-campus students,
2. design a mobile laboratory and develop experiments that are compatible with the mobile lab,
3. develop tools and techniques to enable interaction between on-campus faculty and remote students, including student mentoring and advising,
4. assess the effectiveness of the remote laboratory activities and improve equipment and teaching methods where warranted, and
5. disseminate the results to the engineering education community.

NSF funds (along with institutional cost sharing) are requested only to cover time for the development activities. This proposal is still under review by NSF.

### **Implementation Tasks**

The University of Alabama has agreed to provide its BSME degree by distance learning to the Dothan area. More than 70 Dothan-area students have already submitted informal transcripts as an initial application to the program. About 20 students have enrolled at Troy State University at Dothan or at Wallace State Community College taking freshman and sophomore level courses in anticipation that this program would be launched. A handful of students has been taking lower level engineering courses at UA by QUEST (videotape-based). To implement the laboratory class delivery, the following tasks must be completed.

#### **Design and Build Mobile Laboratory and Experiments**

The mobile lab must be designed with environmental controls, facilities, and utilities to support a different set of lab equipment for each course that will use the laboratory. Experiments must be designed to operate within the constraints of the mobile lab and to be readily installed, removed and stored. Equipment for each course must be selected to satisfy physical and pedagogical requirements. Experimental setups need not be identical to those used in the traditional laboratory on campus, but they must be similar enough that the (videotaped) lectures are applicable. Design of the lab and experiments will be performed by UA faculty and graduate students, with or without NSF funding. College of Engineering technicians will build the equipment and finish the mobile lab's interior.

## **Modify Curricula for Instruction by Distance Learning**

Lectures and demonstrations must be compatible with videotape or WWW delivery. Currently, lectures for lab classes frequently use equipment and phenomena demonstrations, and some labs require pre-lab activities for students. Many of these demonstrations and pre-lab activities can be delivered to remote students using a virtual lab or other multimedia tools. Existing virtual and multimedia lab-related tools must be identified and incorporated into curricula, and some new tools may need to be developed.

## **Mentor and Advise Remote Students**

Infrastructure must be developed to facilitate communication between Dothan students and UA faculty for instruction, advising, and mentoring. Good lecture and laboratory experiences are critical to the success of a course, but being able to handle students' questions and problems away from the lecture or lab are also important. Prior experience with teaching in a distance learning environment (Todd, 1997) has shown that e-mail is a good means of handling student questions in conventional lecture/problem courses, but more visual and interactive tools are also needed to teach lab courses. Development of WWW-based visual aids demonstrating lecture and laboratory concepts would benefit both conventional and distance learning students. These demonstrations will be put together using a high-resolution scanner and a digital camera in conjunction with Web-site authoring tools. The Web and Internet will also be used to post homework and lecture notes, to allow student team interactions, and to handle student questions. As greater Web bandwidth becomes available, technologies such as "see you/see me" interactive cameras will render the Web ideal for interacting with students.

## **Assess Effectiveness of Distance Learning**

In keeping with ABET requirements and with the Department of Mechanical Engineering's philosophy of continuous improvement, the effectiveness of distance learning instruction will be assessed regularly, and the results will be used to improve the program. Assessment of the effectiveness of distance learning courses and laboratories will be performed several ways. Information will be gathered from students (both on-campus and off-campus), laboratory GTA's, employers of off-campus students, and faculty in follow-on courses. Ultimately, the success of any degree program is determined by the performance of its graduates throughout their careers (Schmitt, 1996). The use of standardized exams, such as the FE exam, provides a consistent way to compare groups of graduates. Senior exit interviews allow faculty to obtain feedback from students on their overall perspective of their education. Due to their part-time enrollment, the progress of the off-campus stu-

dents toward completion of their degree will be slow, nevertheless assessment of the program will be carried out to provide evidence for ABET accreditation.

The performance of remote students and on-campus students in the same courses will be compared. While studies show that there is no statistically significant difference between on-campus and remote students, the subjects tend to be graduate students from a traditional undergraduate education. In those cases, on-campus and remote students have very similar backgrounds (Mines, 1997; Davis, 1996). Because most of the remote students in this program will be older part-time students with full-time jobs, their differences in life experience may lead to different strengths and weaknesses compared to the more traditional on-campus students. By tracking the students' performances in all of their classes and using pre-tests, help can be provided to students (on campus or off) who demonstrate an unacceptable level of performance in a particular area.

Students' suggestions for course improvements will be obtained through end-of-semester student evaluation forms. During the semester, remote lab course students will be given the opportunity to provide anonymous feedback on the remote lab experience. This will be particularly important when the first course, ESM 251, is taught. As input from students enrolled in the early lab courses accumulates, adjustments to the laboratory and virtual activities will be made. This feedback loop will allow improvements to be made to the delivery of future courses. GTA lab instructors will have experience teaching the same labs to on-campus students. If they notice appreciable differences between the two groups of students, they can alert the faculty so that appropriate corrective action can be taken.

Opinions of the remote students' employers will also be collected by means of questionnaires. Depending on a particular student's job, i.e. if they actually do some type of laboratory work, this is likely to provide more information about the success of the entire remote delivery BSME program than the material in any particular course. Faculty in follow-on courses, and in particular the capstone design courses, will be asked to give their feedback on the concepts that need reinforcement.

## **Potential Impact on Engineering Education**

The BSME by distance learning program is designed primarily for employees of Dothan industry, but all area residents may participate. This activity affords students in Dothan access to a full engineering degree without establishing expensive new local programs. Several other urbanized industrial areas in Alabama, e.g., the Gadsden, Anniston and the Florence/Muscle Shoals areas, are also

sufficiently distant from existing engineering education programs that working students have no access to engineering. The Dothan program could serve as a model for similar programs for these Alabama areas as well as the engineering education community nationwide. This activity is also relevant to the science and technology education communities. Since the organization of this distance learning program began, one large technical employer in the Dothan area has already expressed interest in utilizing a similar program at its other locations. Leaders in the Gadsden, Alabama area have also expressed interest in a program for their community. The demand for engineering education in areas distant from existing programs is large and growing, and only practical solutions such as those described here can meet this demand.

### Conclusions

This paper provides a real-world example of what is required to make distance learning live up to its highly touted role as an alternative to the traditional engineering program. The critical element in delivering a complete degree to a remote site is the mobile laboratory. The financial and organizational cost of providing hands-on experiences to remote sites, as described herein, is considerable. Possibly an electronic substitute for laboratory experiences will be developed in the future using virtual reality technologies. In the near term, however, engineering and science distance learning programs that deliver actual laboratory experiences will have no choice but to use methods similar to those described here. This paper shows that strong support for distance learning at both the "supplier" and "customer" ends are crucial to its success.

This distance learning program will provide an excellent test of the ability of new communications technologies to enhance and increase the availability of engineering education. Challenges that must be met include facilitating faculty interaction with remote students and the design of a mobile lab equipped with modular, portable experiments. This paper is an interim progress report on this distance learning project. Future dissemination of knowledge gained from this novel activity should aid in the propagation of distance learning activities elsewhere.

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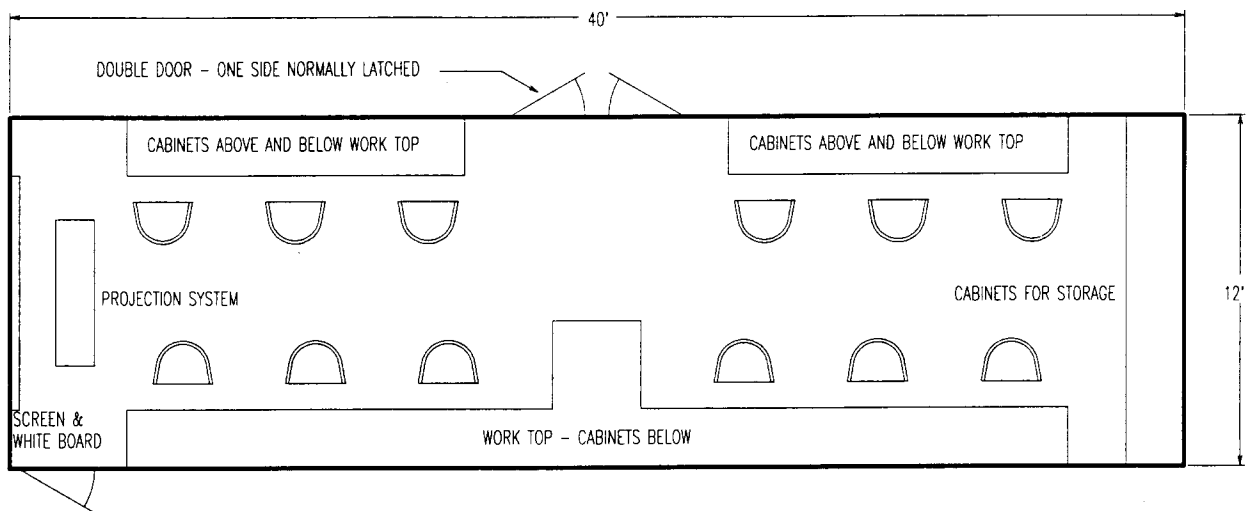


Figure 1. Possible Layout for Mobile Laboratory

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Clark Midkiff graduated from Yale University with a BA in economics in 1974. He received the BS, MS and Ph.D. (1986) degrees in mechanical engineering from the University of Kentucky. Dr. Midkiff joined the Department of Mechanical Engineering at The University of Alabama as an assistant professor in 1986 and is presently an associate professor there. Dr. Midkiff performs research in combustion, internal combustion engines, thermal energy storage and energy management. He teaches courses in thermodynamics, heat transfer, instrumentation, powerplant technology and energy management. Dr. Midkiff is presently coordinating the BSME by distance learning for the Dothan, Alabama area. He has served six years as an officer in the Mechanical Engineering Division of the Southeastern Section of ASEE.

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Dr. Todd graduated from Penn State University in 1981. Before attending graduate school, she worked in nuclear reactor core performance at Bettis Atomic Power Laboratory. She earned an MS degree in applied mechanics in 1986 and a Ph.D. in mechanical and aerospace engineering in 1992 from the University of Virginia. She is interested in applying mechanical analysis to problems of the human body. She has completed biomechanics research projects for NASA and the US Air Force. Prior to her current position as an Assistant Professor in Mechanical Engineering at the University of Alabama, Dr. Todd was an instructor at GMI Engineering & Management Institute (now Kettering University) in Flint, Michigan.

### **JOEY PARKER**

Joey Parker is currently an Associate Professor of Mechanical Engineering at The University of Alabama, where his teaching responsibilities include control systems, instrumentation, and senior capstone design. He has been involved with the Foundation Coalition effort at Alabama since 1993, and currently serves as coordinator of the upper division. He 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. Dr. Parker's experience includes three years with the Badische Corporation (now BASF) as an R&D engineer and three terms as a NASA/ASEE Summer Faculty Fellow at Marshall Space Flight Center. His research interests include microcomputer applications, industrial automation, electro-mechanical actuators, and I.C. engine control.



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