TENNESSEE TECHNOLOGICAL UNIVERSITY

CENTER FOR MANUFACTURING RESEARCH

The CMR uses its intellectual capital to solve national problems and meet the needs of small businesses through technology transfer activities.

by Kenneth Currie

What would you think if someone approached you on the street and offered you $2.45 for every dollar you gave them—that they were crazy, or there must be some catch? That's exactly what the Center for Manufacturing Research (CMR), an Accomplished Center of Excellence based at Tennessee Technological University (TTU), has attained by returning more than *$2.45* in additional revenue to the state economy for every state-appropriated dollar. The additional revenue generated by the CMR is ***conservatively*** estimated by calculating the economic impact of external funds generated through research projects, job creation through outreach activities to new and existing businesses, and economic impact as a result of improved manufacturing processes and cost savings. The term *conservatively* has been boldfaced for emphasis since many CMR projects either are proprietary in nature or have financial benefits that are not realized for years.

The "value proposition" for the CMR is far more complex than a simple return on investment calculation. The Centers of Excellence were initially charged with a much broader mission. The 1982 Sub-Committee for Higher Education of the Tennessee Comprehensive Education Study Committee "conceived Centers of Excellence as a mechanism for improving higher education statewide. The method utilized by the Sub-Committee was to request that campuses identify programs which have potential for being nationally recognized."

As a result, the CMR mission statement includes principles that are not as conducive to financial quantification: advancement of manufacturing knowledge, technology transfer, and institutional benefits. The true economic impact is far broader and systemic, both affecting intellectual capital within the state and addressing national needs.

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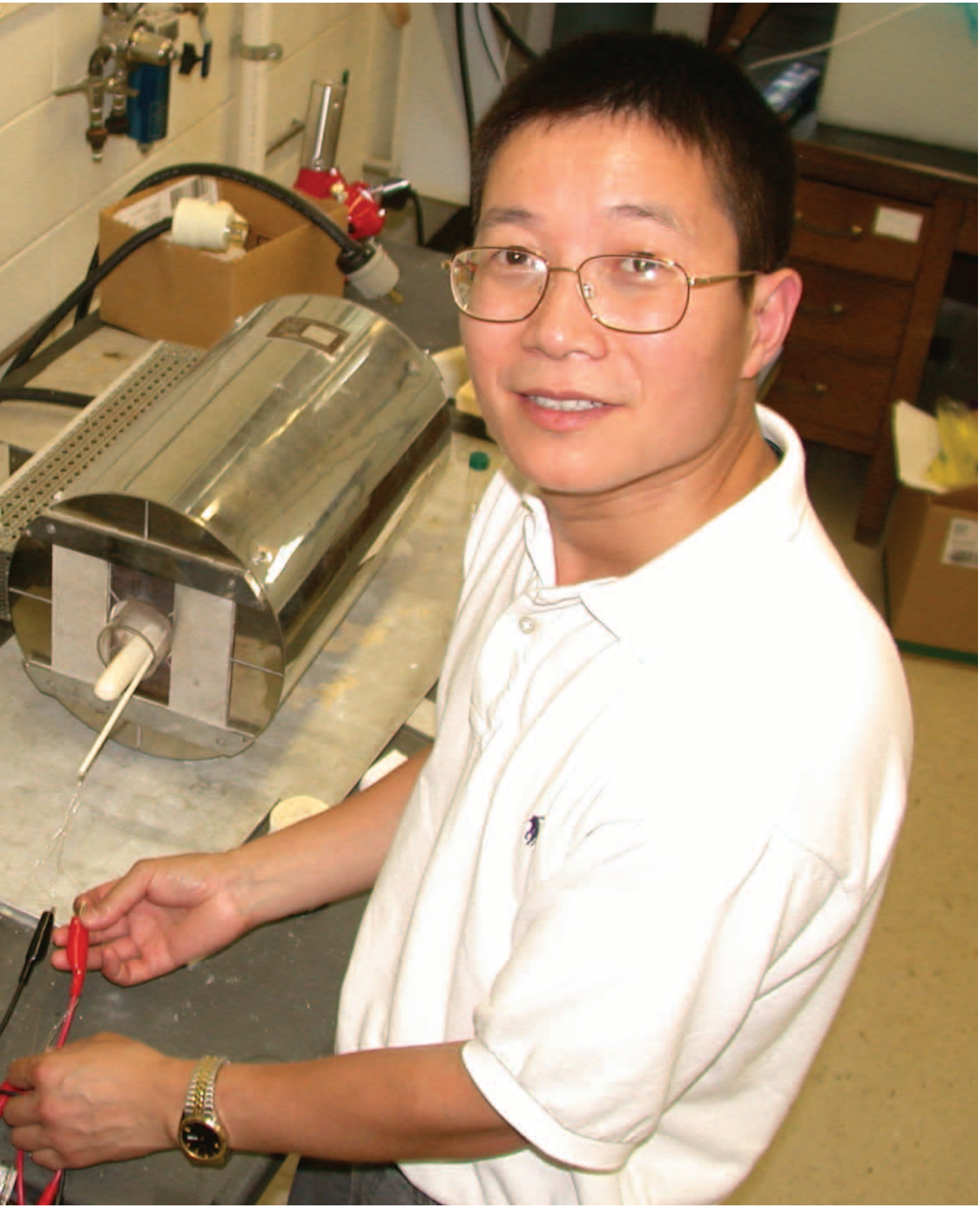
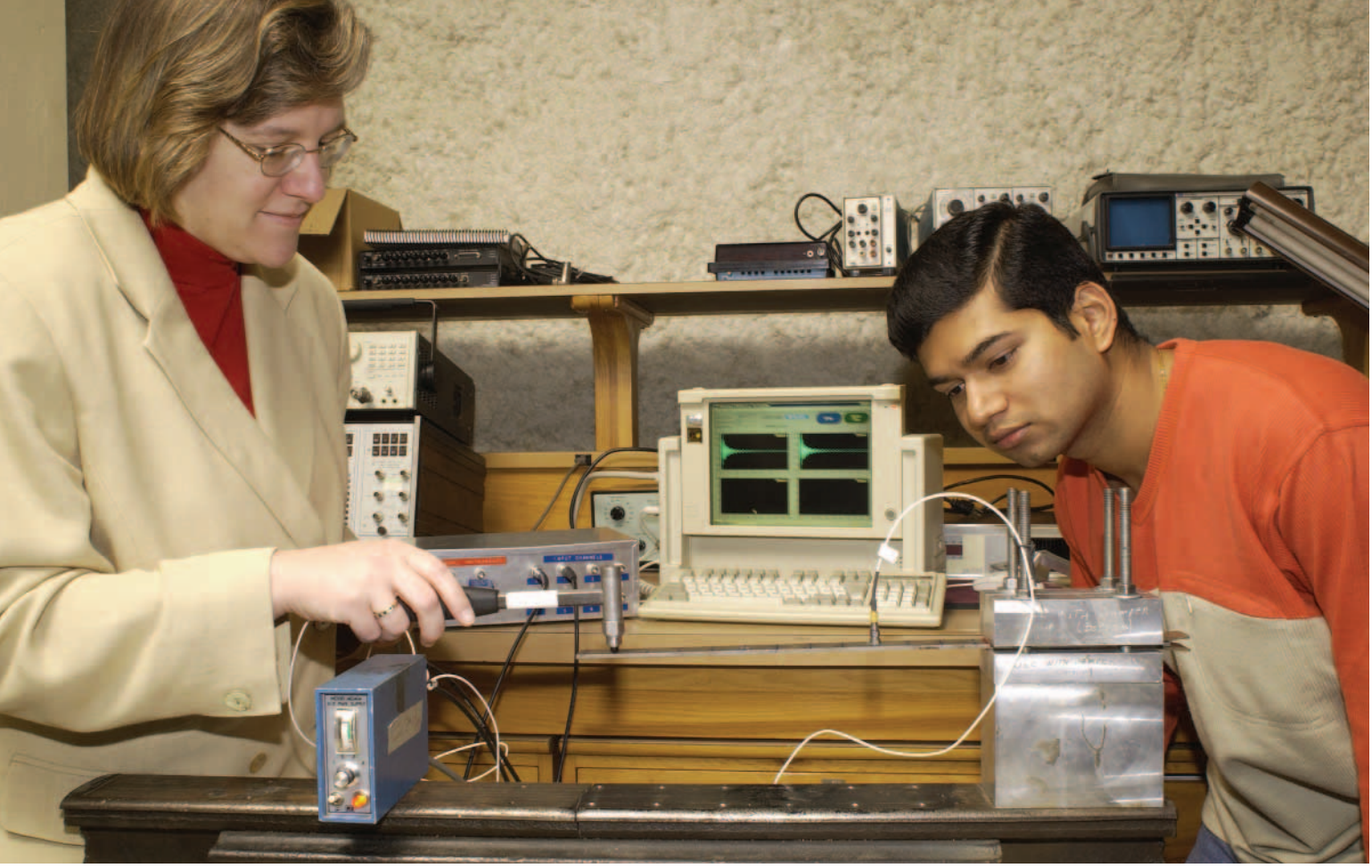
Dr. J. Zhu prepares the electric conductivity measurement system used



Photos courtesy Center for Manufacturing Research

to determine the electrical conductivity of developmental alloys or coatings for solid oxide fuel cell interconnect application.



Dr. S. Pardue and mechanical engineering graduate student S. Sridharala examine a cantilever beam with vibration instrumentation for the National Center for Advanced Manufacturing (NCAM) project entitled "Understanding the Service Life of Composites."

The CMR has returned more than $2.45 in additional revenue to the state economy for every state-appropriated dollar.

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Advancement of Manufacturing Knowledge

The CMR has concentrated on four strategic research areas. Listed below are just a few of the successes that demonstrate nationally recognized research:

- *Intelligent Control of Processes and Equipment*—A recent three-year, $964,000 Department of Energy (DOE) funded study developed an intelligent control process for efficient operation of a steel cupola. Preliminary results indicate significant cost and energy savings while at the same time reducing harmful emissions by integrating theoretical models with "fused" sensory feedback. This integrated, intelligent process-control methodology has applications in many other complex process dependent industries, and initial research is beginning to extend it to composite curing and lost foam casting. The CMR has also worked extensively with the Naval Surface Warfare Center and other agencies to study intelligent data fusion techniques for improved pattern recognition of unknown radar signatures.
- *Integrated Product and Process Realization*—What started out as a small National Science Foundation (NSF) industry-university partnership grant between Saturn and the CMR led to a significant opportunity to research product development processes. With minimal funding from NSF, supplemented by support from Saturn, CMR faculty and students performed an exhaustive evaluation of the 1996 model year change-over at Saturn with a final report that detailed recommendations for improvement. These recommendations became the impetus to propose a much broader study. In cooperation with Saturn Corp., The Aerostructures Corp., and Northrop Grumman Electronic Sensor Systems Division, the CMR was awarded a $364,000 NSF grant to study the cost affordability of new product development. Exhaustive case studies and questionnaires were developed to determine factors that affect performance with regard to budget and schedule. The results indicated that there is an incredible savings available to most companies by exercising key disciplines to enable "Lean Product Development."

NSF has also granted more than $800,000

in five different projects for research of machinery/mechanisms design, motion, and control. The results of these projects led to important discoveries in machine theory and offered methods for intelligent and robust design methods. The center faculty member responsible for this research, Dr. Kwun-Lon Ting, has distinguished himself by publishing numerous journal articles, winning the Kinslow research award given by the TTU College of Engineering, and winning the coveted South-Pointing Chariot Award, one of the most prestigious awards in mechanism theory, given by the Applied Mechanisms and Robotics Division of ASME. This distinguished award recognizes lifetime achievement through service and research in the field. As a result, TTU is recognized as one of the leading research institutes in the nation in the area of mechanisms and machine theory.

- *Next Generation Materials and Manufacturing Processes*—Materials are a key component to virtually all manufacturing processes, and in many cases the proper selection of materials, coatings, and heat treatments can alter product performance dramatically. Dr. John Zhu has received two prestigious research grants to explore a novel materials coating approach to improve the efficiency of solid oxide fuel cells. Initially Dr. Zhu received a Honda initiation grant whereby he discovered novel processing methodologies for coating ferritic fuel cell interconnect materials with thermal and corrosive resistant alloys. Dr. Zhu has also been honored by the National Science Foundation with a CAREER award in recognition of his outstanding research and teaching potential, particularly in the area of thin film coatings and material science. The CAREER award is highly competitive, and it is a testament to the excellent young faculty working with the CMR as well as recognition of a strong materials research program at TTU.

The CMR is also involved in a DOE funded grant sponsored by the Tennessee Economic Community Development's energy division to explore unique material and manufacturability issues of Proton Exchange Membrane (PEM) fuel cells. Oak Ridge National Laboratory (ORNL) is funding multiyear projects related to materials that operate within high-temperature or corrosive environments. The first project is exploring the growth of nanomaterials to mitigate defect mechanisms in novel materials designed for use in automated actuator applications. Another project funded by ORNL for $156,000 over the past two years is researching high-temperature protective aluminide coatings for thermal barrier coating applications and corrosion resistance in boiler tubes for power plants.

The National Center for Advanced Manufacturing (NCAM) through the National Aeronautics and Space Administration (NASA) has established a special partnership with five universities, of which TTU is one, to improve manufacturing processes of composites for advanced space structures. Typically these composite structures are quite large, and manufacturing them in a cost-effective manner poses special challenges. The CMR has received more than $400,000 from NCAM contracts to research issues related to modeling of service life and life-cycle costs relative to initial design specifications. The CMR is also establishing groundbreaking research into the micro machining of engineered materials using technologies that will realize spindle speeds approaching millions of revolutions per minute.

- *Pervasive Modeling and Simulation*—Much of the modeling and simulation conducted by the CMR has to do with determining the mechanical limitations of manufactured systems. Over the last three years, NASA has funded five different projects with funding exceeding $400,000 to model and/or simulate a variety of space systems. These projects include (1) development of new, complex mathematical models to determine the hydrostatic stress effects on yielding and fatigue life in high-stress environments such as turbine housings; (2) analysis of nearly steady photospheric flows, such as those exhibited on the surface of the sun, so that better simulations can be conducted to harness solar winds for space travel; (3) concept development and evaluation of capture devices for rendezvous with tether-driven transfer vehicles for transporting vehicles from low-space orbit to a higher orbit; (4) active control of large, flexible space structures using shape memory alloys that are activated by heat from the sun; and (5) enhancement of rocket ejector efficiency in advanced, reusable propulsion engines. Each of these projects involves complex models and simulations to verify that future generations of space vehicles can meet mission-specific requirements.

These projects are just a sample of the CMR's ability to win nationally competitive research contracts, thus achieving national recognition

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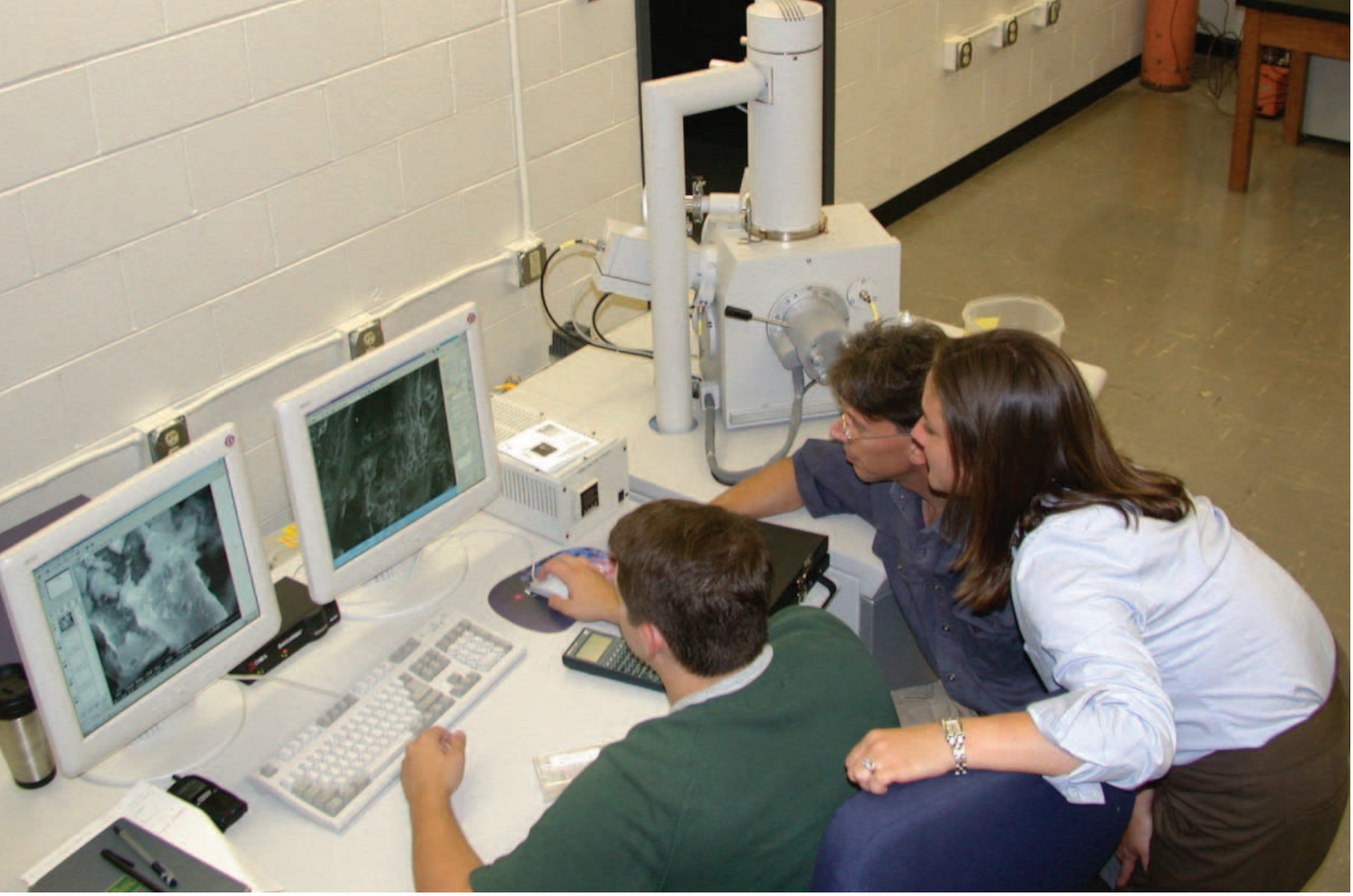
CMR Mission Statement:

To advance and support scientific and engineering knowledge in areas related to manufacturing through fundamental research and technology transfer activities, and to impact the instructional program in those areas.



Dr. K. Kurtis from the Georgia Institute of Technology visits with faculty associate Dr. J. Biernacki, chemical engineering, and graduate student J. Richardson to discuss joint proposal ideas and investigate the Environmental Scanning Electron Microscope.

CMR has achieved national recognition in terms of funding sources for projects and center faculty recognition through scholarly works and grants.

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both in terms of funding sources for projects and center faculty recognition through scholarly works and awards. The CMR uses this intellectual capital not only to solve national problems but also to meet the needs of small businesses through technology transfer activities.

Technology Transfer

In an August 1995 article of *Entrepreneur Magazine,* the owner of startup company Flexial credited the CMR's testing facility for helping him secure his initial Small Business Innovation Research grant to commercialize his leakless seal. Today, Flexial is a thriving and growing small business in Cookeville with more than 40 employees and plans to expand. We have continued our relationship with Flexial, providing additional testing services and training opportunities including participation in two CMR cosponsored Regional Manufacturing Excellence Conferences in 2001-02. These conferences highlighted the successes of local companies that have remained profitable in the midst of an economic downturn and provided valuable lessons to local industries seeking new business and cost-reduction ideas. Approximately 35 employers, representing more than 5,000 manufacturing jobs in middle Tennessee, attended both conferences. The list of activities performed by the CMR to transfer manufacturing research and technology is quite lengthy and is custom-tailored to fit the demand from industry. Outreach services include testing, training, student development, and partnerships on federal research grants involving existing industries as well as small businesses and new startup ventures. The following items are snapshots of how the CMR provides technology transfer to Tennessee industries.

- The Aerostructures Corporation (TAC) in Nashville has contracted with the CMR to conduct multiple testing programs to determine mechanical properties of materials and manufactured structures. Fatigue profiles, impact tests, tensile tests, stress analyses, and composite microstructural characteristics are all examples of work performed for TAC. In some instances the CMR will perform benchmarking studies of products to determine the performance of clients' products against their competitors'. Both Sunbeam-Oster and Trac

Outdoor Products have come to the CMR to conduct specialized tests on their products as well as their competitors'.

- Local Cookeville industries Fleetguard-Nelson and TRW-VSSI (Vehicle Safety Systems, Inc.) have used a CMR-sponsored work-study program allowing undergraduate students the opportunity to work in industry while pursuing full-time studies. Over the past six years, more than 150 undergraduate students have been employed by these two industries, helping fill critical shortages in engineering support functions while providing much-needed financial help to the students, enabling some to stay in school.
- The CMR, along with the College of Business Administration, leverages funds to support the Tennessee Small Business Development Center (TSBDC) at Tennessee Technological University. The TSBDC's primary goal is to assist small business owners across the state, helping them grow and develop by providing one-on-one counseling for management and technical issues. Over the TSBDC's three-year operation, its staff members have assisted more than 450 entrepreneurs in 17 counties achieve their goals. Center faculty associates have also participated in four Small Business Innovation Research Phase I grants and a recent Phase II grant as research experts.
- A three-year, $579,000 NSF grant entitled "Expanding Innovation Opportunities in Tennessee" was awarded in fiscal year 2000-01 to allow the CMR to work with partner organizations across the state (including most TBR universities) to systematically connect the knowledge-discovery process occurring at universities and federally managed laboratories with the development and license of new products and services that will enhance economic development, provide jobs, and create wealth. Currently new businesses are either in the development stage or beginning incubation.
- Safety for Tennessee citizens has also been a key part of the CMR, whether it is providing ergonomic assistance to more than 25 industries across the state, research that aids the Tennessee Department of Transportation to determine the safety of woodpile bridges, or prototype rollover trucks to assist the highway patrol in teaching children the importance of buckling their seat belts.

Institutional Benefits

In the last two years, the CMR has leveraged approximately $200,000 of state appropriations to purchase equipment valued at more than $800,000. That equates to receiving $3 for every dollar invested, a feat that requires creativity, ingenuity, and teamwork on the part of faculty as they wrote detailed equipment proposals to federal funding agencies. The most significant improvements have been in the material science laboratory, which has benefited from a $250,000 NSF equipment grant for a new Environmental Scanning Electron Microscope. The project was initiated by faculty from four different disciplines and equally matched between the Center for Water Resources and the CMR. The total project cost, including matching from other sources, exceeded $380,000, with the CMR contributing approximately $30,000. Other laboratories with major improvements include those for computer-aided engineering, mechanical properties, and material coating/ thin films. The CMR provides technician and engineering support as well as equipment repair/replacement in each of these laboratories, serving not only the needs of TTU researchers but also those of the manufacturing community for testing products and materials.

CMR support of graduate students has consistently been a major component of its strategic mission, approaching half a million dollars from state appropriations in 2001-02. The number of graduate students receiving some level of center funding since it was chartered exceeds 300 M.S. and 55 Ph.D. students. Statistics from the center's five-year Self-Study Report for 1995-2000 show that more than 50 percent of Ph.D. and 40 percent of M.S. students wih degrees conferred from the College of Engineering received financial assistance from the CMR. This level of support demonstrates the critical role that the CMR plays in assisting the university as it strives to change its Carnegie classification from a Master's Colleges and Universities Level I to a Doctoral/Research University-Intensive institution. Without the CMR, the College of Engineering graduate program at TTU would be adversely affected. The CMR is also an equal-opportunity research partner, having worked with three colleges and 11 departments.

The CMR is constantly exploring ways to improve its "value proposition," but there is one fact that cannot be ignored—there will always be a need in Tennessee to invest in future technologies and research that will attract new businesses and expand new knowledge. The CMR's positive impact on the economy and TTU is helping to develop a nationally recognized manufacturing research program that serves as a catalyst for wealth creation in Tennessee. ■

Kenneth Currie is a professor of industrial and manufacturing engineering and director of the Tennessee Technological University Center for Manufacturing Research.

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