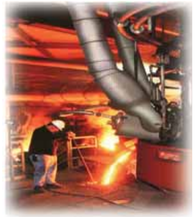
Casting a Vision for the Future



High efficiency Cupola capable of 60 tons per hour

The Center for Manufacturing Research (CMR) started the 2000-2001 fiscal year establishing a strategic plan for the future. The strategic planning process included establishment of a long-term vision of success, defining our set of core values, and re-examination of our mission:

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.

In addition to overarching statements of direction, the strategic plan addressed laboratory development plans and operating guidelines to better utilize graduate students, faculty associates, Center faculty, and Center staff. Finally, the CMR narrowed its research focus to align itself more closely with national manufacturing roadmap strategies.

The results are quite remarkable with records set in both total external funding ($1,497,787) and total matching funds ($2,577,682). To put this in perspective, the external funding increased by almost 38 percent over last year's level. These record-breaking results came despite a reduction in administrative costs of 11 percent and a reduction of 11 percent in faculty costs. The average funding amount per project rose by more than 40 percent over last year as the Center placed a greater emphasis on federally funded research. Student support remained high with 11 Ph.Ds, 56 Master's students, and 72 undergraduates receiving some type of Center or project funding. We also had an amazing 40 faculty associates participating in Center activities.

Research Highlights

There were several major research initiatives that contributed to the Center's success this year, but none as important as our efforts to nurture a stronger relationship with NASA. After years of close interaction with Marshall Space Flight Center (MSFC), faculty associates Sam Han and Steve Canfield have succeeded in attracting NASA funding for four projects totaling $164,813 for the first year. Han's two projects with NASA focus on advancements in space propulsion systems and Canfield's two projects will affect the way space structures are designed for flexibility and utility. A fifth NASA funded project ($22,000) supports Ph.D. student Phillip Allen under the guidance of faculty associate Chris Wilson. Together, Wilson and Allen are researching failure mechanisms, such as fatigue, on critical space system components.

In a separate NASA collaboration, TTU and the CMR were invited to participate in a university/NASA partnership with four other universities to research the affordability and reliability of manufacturing large space structures, specifically focusing on composite materials. In December 2000, the University of New Orleans (UNO) was funded by MSFC to establish a national center to "…develop innovative advanced composite manufacturing technologies utilizing the National Center for Advanced Manufacturing - Louisiana Partnership." The partnership includes MSFC, UNO, Mississippi State University, TTU, Texas A&M, and Virginia Tech. The focus of the partnership is to create a world-class center devoted to education and research in advanced manufacturing with the initial concentration on composite technologies. In response to the first call for proposals, the CMR submitted four proposals and three were selected for first-year funding totaling $363,000. Faculty associate Chris Wilson is leading the first project entitled "Understanding Service Life of Composites" ($127,300). Wilson is planning to compare differences in the "as-manufactured" and the "as-analyzed" composite structure to better understand service life predictions especially when considering initial material quality. The second project, led by Ken Currie, is entitled "Minimizing Life Cycle Costs of Composites Through Design" ($145,700). Currie plans to link design parameters to manufacturing and life cycle costs to build parametric cost models and cost drivers for improving composite design. To better balance staff support for these projects, the third NCAM project dealing with simulation and modeling of friction stir welding by faculty associates George Buchanan and John Peddieson ($90,000) is being managed by the Center for Electric Power.

National Center for Advanced Manufacturing - Louisiana Partnership (NCAM-LP) Logo

Research Highlights (continued)

Expanding Innovation Opportunities in Tennessee

A three-year grant for $579,000 was awarded from the National Science Foundation to Glen Johnson and Ken Currie to work with partner organizations across the state to systematically connect the knowledge-discovery process that occurs 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 new wealth. Partner organizations include several TBR universities, Oak Ridge National Laboratory, Tennessee Biotechnology Association, Tennessee Technology Development Corporation, Scytech Inc., and Cumberland Emerging Technologies. The goal will be to enable gifted students to study and experience all aspects of starting a technology business through becoming an actual owner/operator. The one-year study program will act as a catalyst for forming management teams to operate businesses for converting intellectual property into commercial companies.

Extension Services

CMR fulfilled its mission to both in-state and out-of-state industries by advancing technology transfer activities in specific areas such as ergonomics, materials testing and manufacturing design/processing. The programs discussed below enabled faculty and students, at both graduate and undergraduate levels, to interact with numerous industries and assist those industries with solutions to real manufacturing problems.

- A work-study program with a local industry provided 38 undergraduate students the opportunity to obtain hands-on experience while being employed part-time in a manufacturing environment. This program has secured $323,078 in external funding during this fiscal year, primarily in the form of student hourly payroll.
- Funding of the Tennessee Small Business Development Center (TSBDC), which serves a ten-county region, comes from the U.S. Small Business Administration, the Tennessee Board of Regents, the Tennessee Department of Economic and Community Development, the College of Business Administration, and the Center for Manufacturing Research. This program was funded at a total of $69,136 for the 2001 calendar year. During the TSBDC's third year of operation in 2000, the Director and staff worked diligently to assist 154 entrepreneurs in 17 counties to achieve their goals.
- The Center continues to provide assistance to industries through its Testing Services Program, using a combination of CMR facilities and access to personnel from both the Center and other departments/colleges. The following is an example of a completed testing project.

  ➡ Stress analysis of the APPLE Monitor Stand and G4 Cube Case was performed for the Apple Computer Company at the request of Exponent Consultants, Menlo Park, California. This testing performed by Dr. Darrell Hoy revealed unforeseen residual tensile stresses in the cracking region of the stand's front rib. This led to redesign of the rib and injection molding process.

Apple Monitor Stand and G4 Cube

- The Tennessee Manufacturing Extension Program (TMEP) led by Dr. S. "Deivy" Deivanayagam provided ergonomic studies for
  - Marvin Windows (Ripley)
  - Hutchinson (Byrdstown)
  - B&P Lamps (McMinnville)
  - Frito-Lay (Pulaski)
  - Federal-Mogul (Gordonsville)
  - Cebal America (Shelbyville).

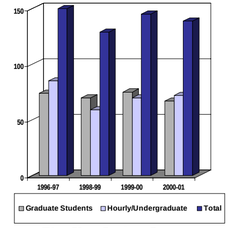
  These studies were used to identify ergonomic hazards, needs for workstation redesign, and injury-related causative factors that resulted in recommendations for workplace safety and management personnel seminars.

Extension Activities (continued)

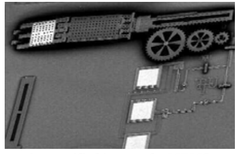
- The University of Tennessee Center for Industrial Services Program (UT-CIS) continues to be an avenue by which the CMR serves industrial clients across the State of Tennessee. Faculty investigators are identified based on each company's request and the expertise necessary to provide consulting in the manufacturing arena. Brown Manufacturing Company of Old Hickory, Industrial Design Fabrication of McEwen and Perfection Moulders of Goodlettsville are three Tennessee industries who called upon CMR services in 2000-2001.

Student Focus

In FY 2000-01, CMR worked closely with a number of students through financial assistance, faculty advisors, and mentoring support. In fact, 139 total undergraduate and graduate students benefited from Center financial support. Of these, 56 were MS students, 11 were Ph.D. candidates, and the remainder were pursuing undergraduate degrees. Additionally, 29 MS degrees and 2 Ph.D. degrees were earned by Center-funded students bringing the total over the past 16 years to 300 MS and 54 Ph.D. students. These levels of graduate student support represent 39 percent of the College's total MS students and 34 percent of all Ph.D. students surpassing both benchmarks in this goal.



Five-Year Student Support

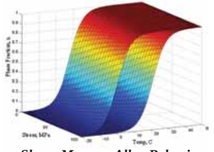


A magnified image of a MEMS pop-up, micromachined mirror

Dr. Glenn Cunningham, Dr. Jeff Frolik, Dr. Satish Mahajan, and Dr. Joe Biernacki taught an interdisciplinary graduate course focused on the design, fabrication, and performance of Micro-Electro-Mechanical Systems (MEMS). Enhanced in its second offering by the lessons learned from an initial class, MEMS devices were designed and built at a semiconductor foundry and are currently in the process of characterization and testing. This course taught a very complex subject matter and emphasized the formation of student teams to produce objectives unattainable by individuals. These devices include steerable mirrors, ultrasound devices, and pressure transducers among others.

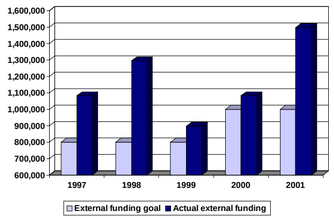
Several graduate students have received their support from NASA-funded research projects or the NASA Graduate Student Research Program (GSRP). Mr. Phillip Allen, a Ph.D. student in Mechanical Engineering, is working with engineers from the George C. Marshall Space Flight Center and Dr. Chris Wilson (Mechanical Engineering) to better understand hydrostatic pressure effects on static yielding and very low cycle fatigue. Phillip has received two years of support on the GSRP and is preparing to start his third year. Under the direction of Dr. Stephen Canfield (Mechanical Engineering), Mr. David Johnson has been involved in NASA-funded research to create a dynamic model and analysis of momentum exchange tethers for the Marshall Space Flight Center. David will continue his research next year as a participant in the GSRP. Dr. Canfield has also been supervising Mr. Patrick Hull on the development of a novel prototype actuator for NASA that uses concentrated radiant heat to actuate a Shape Memory Alloy (SMA) element. This work is based on an innovative active control system proposed for the NASA Space Solar Power ISC concept structure. Patrick spent the summers of 2000 and 2001 performing his research on site at Marshall Space Flight Center, and continues to correspond with NASA personnel as part of this continuing research project.

Dr. Canfield is also involved in supporting students in projects that have potential commercial applications. Mr. Robert Parsons performed research in miniature and micro-compliant manipulators. His work, sponsored by DSM of Franklin, Tennessee, and BDMO, resulted in a series of inexpensive manipulators with output resolution on a micro or even nanoscale. This research was initially funded as part of a Small Business Innovation Research grant, and has potential applications in high precision manufacturing, fiber optic cable alignment, or disposable surgical tools. Ms. Somer Walls is investigating the design of new topologies for compliant manipulators synthesized using genetic algorithm optimization techniques. One application Somer is currently investigating is the design of disposable surgical tools or miniature manipulators.



Shape Memory Alloy Behavior under Varying Temperature and Stress

CMR Success Measures



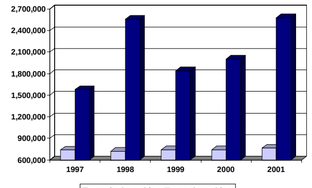
Five-Year External Funding

External Funding

CMR not only bettered its goal of $1 million in external funding but set all-time records for both external and matching funding. The total for external funding in FY 2000-01 was $1,497,787. This represented a significant increase (38%) over last year's level and approached a 1:1 match with State-appropriated funds. This increase in external funding is primarily due to an increased emphasis on federal funding resulting in an average project funding increase of more than 40% over last year.

Matching Funding

The Tennessee Board of Regents also requires that matching funds (external funding plus equipment and supplies gifts) brought in by the CMR total more than half of the State-appropriated funds. This past year the Center was required to show matching funds of $763,630. The CMR has never had difficulty in meeting this level, and this year was no exception. The Center posted a record matching amount exceeding $2,577,000 or a little over $1.69 for every dollar appropriated from the State.



Five-Year Matching Funding

Publications and Presentations

CMR faculty, faculty associates and staff members submitted more that 69 regional, national, and international publications and presentations during the 2000-2001 fiscal year. CMR-produced materials appeared and were published in countries including Mexico, Australia, France, Canada and Italy as well as the states of Georgia, Texas, Florida, North Carolina, Illinois, Maryland, California, Washington, D.C. and, of course, Tennessee in the United States.

CMR initiated the first in a seminar series entitled "Manufacturing 2020." The focus of each seminar will be to address current state-of-the-art manufacturing issues and forecast future research hurdles. Dr. Lynne Parker was the first speaker and delivered a discussion of "Multi-Robot Teams." Dr. Parker is the Group Leader for the Computational Intelligence Group, which is in the Intelligent and Emerging Computational Systems Section of the Computer Science and Mathematics Division at Oak Ridge National Laboratory. The Center plans to continue the "Manufacturing 2020" seminar series hosting a different speaker each semester. The CMR also assisted the Water Center in hosting the 2001 Stonecipher Symposium on Technology, Communication and Culture with "Driving America" as the theme of the two-day event.

Dr. Parker, a TTU graduate of Computer Science gets reacquainted with faculty (above left) before delivering her presentation (above right) .

Strategic Research Foci

The CMR has restructured its research into four strategic foci based in part on national manufacturing strategies and faculty expertise. Listed below are the four areas and representative projects:

1. Control of Processes and Equipment, Year 3 of a DOE-funded project entitled "Integrated Industrial Process Sensing and Control System Applied to and Demonstrated on Cupola Furnaces," Mohamed Abdelrahman ($158,036).

2. Next Generation Materials and Manufacturing Processes, "Interconnect Material for Fuel Cell Powered Vehicles: Innovative Fabrication of Conductive Coatings," John Zhu ($30,000).

3. Integrated Product/Process Realization, "Minimizing Life Cycle Costs of Composites through Design," Ken Currie ($144,700).

4. Pervasive Simulation and Modeling, "Thermodynamic Modeling of Polymeric Foam Systems," Don Visco (internally funded).

External Advisory Board (2000-01)

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Mr. Max H. Sharpe, *Retired, NASA*
Mr. Guy Wilson, *Nissan Motor Manufacturing Corporation*

Cover graphics: A cupola furnace burns coke with an air blast to melt scrap steel, cast iron, and alloying materials into a consistent grade of iron for casting purposes. Intelligent Integrated Industrial Process Sensing and Control (I^3PSC) is the title of the DOE project lead by Principal Investigator Mohamed A. Abdelrahman, faculty associate of CMR. This research is in its third and final year. Research goals were established to test the developed intelligent, integrated, industrial process sensing and control system on a research cupola furnace for regulation melt rate, temperature, and iron composition.

Front cover: Close-up photo of the cupola tap-hole during melting operation (temperature ~1565°C) Insets: Overview of Albany Research Cupola Facility (Albany, Oregon) during a test run. Workman manually taking a sample to check quality of molten iron.

Center for Manufacturing Research
at Tennessee Technological University
115 W. 10th Street • Brown Hall 222
Box 5077 • Cookeville, TN 38505-0001
Phone: (931) 372-3362 • FAX: (931) 372-6345
E-mail: mfgctr@tntech.edu
www2.tntech.edu/cmr www.tntech.edu

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