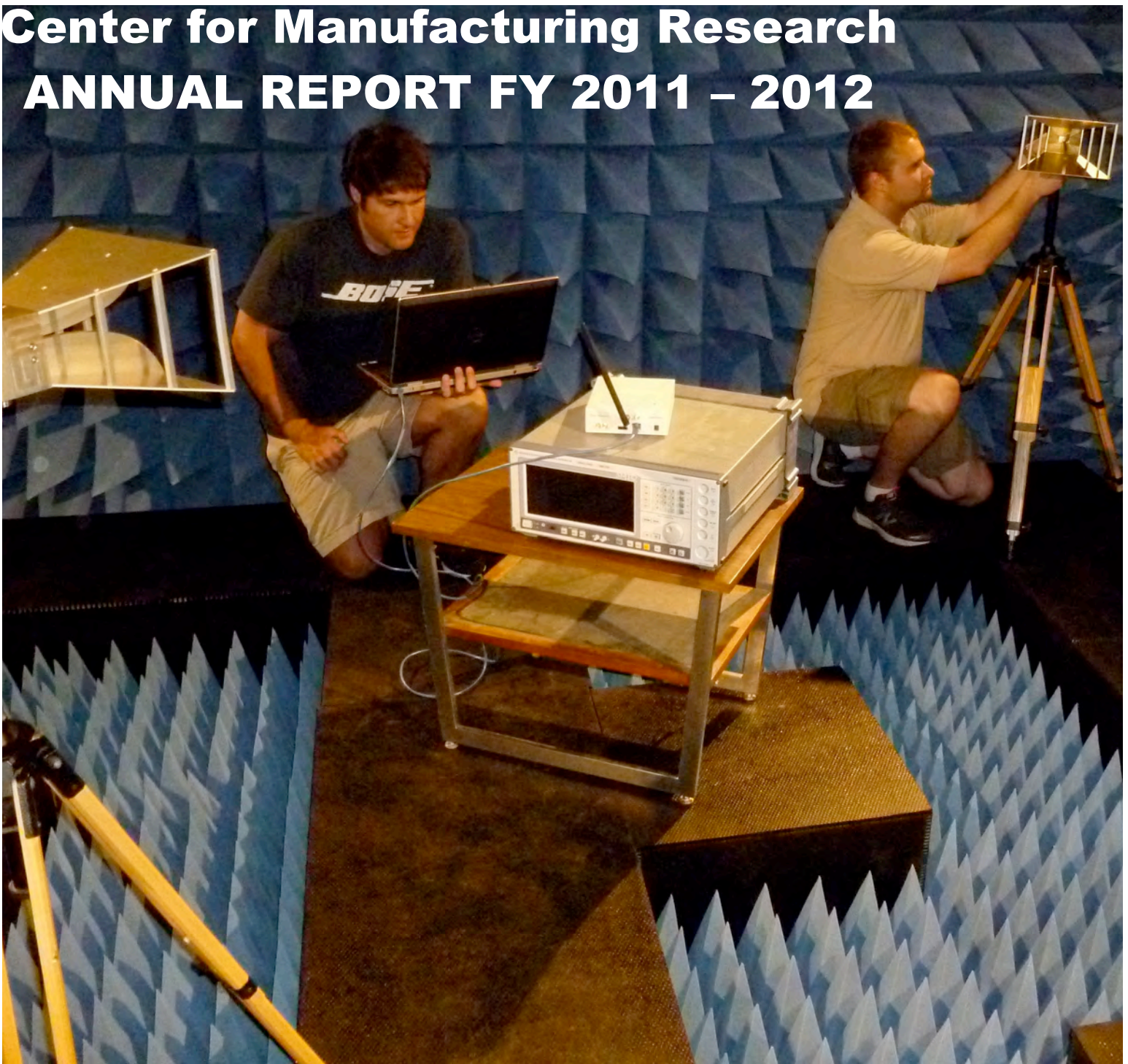


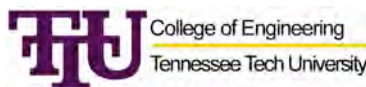
Center for Manufacturing Research ANNUAL REPORT FY 2011 – 2012



Center for Manufacturing Research

Tennessee Technological University

*Leading a manufacturing transformation in the areas of
energy, communications, sensors, and design.*



ABOUT THE COVER: Shown on the cover are undergraduate Brett Witherspoon (left) and PhD candidate Jason Bonoir (right), Electrical and Computer Engineering students, working in Dr. Robert Qiu's Wireless Networking Systems Laboratory. Brett & Jason are standing in a new Radio Frequency (RF) Anechoic Chamber for conducting experiments for the \$760,000 Office of Naval Research (ONR) Cognitive Radio Institute (CRI) grant. Costing approximately \$90,000, the RF Anechoic Chamber along with \$200,000 in cognitive radio platforms are part of another ONR Defense University Research Initiation Program equipment grant of \$400,000 to support these same activities.

Under President Obama's Manufacturing Roadmap ("A Framework for Revitalizing American Manufacturing", December 2009), one of the items under revitalizing information technologies for improving our infrastructure was "Cognitive Radio."

"Support research for next-generation information and communications technology. The Administration is committed to supporting research that will foster the next wave of innovation in information and communications technologies, such as "cognitive radio" that allow for the efficient sharing of spectrum, . . ."

The grants listed above utilize the CMR's Cognitive Radio experimental models and system test-beds that utilize multi-GHz spectrum sensing, which are impervious to conventional jamming techniques, a mission critical objective of the Armed Forces. Cognitive radio is a new paradigm in wireless communications that can opportunistically take advantage of unused radio frequency spectrum. Cognitive Radio provides a completely new paradigm to 3G and 4G wireless devices and comparable systems. With the Department of Defense focusing on the Joint Tactical Radio System, the US has a clear incentive to develop technical and commercial leadership in cognitive radio. The Cognitive Radio research conducted as part of the Center for Manufacturing Research will be at the leading edge of technology to integrate cognitive radio with unparalleled anti-jamming capabilities critical for the military, homeland security, and the next generation of communications for manufacturing competitiveness.

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Tennessee Technological University Center for Manufacturing Research Annual Report – FY 2011 – 2012

Director

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***The Center for Manufacturing Research (CMR)
at TTU is a THEC Established Center of
Excellence and has been since 1990.***

Mission Statement (Unchanged since 2001)

“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.”

CMR Faculty and Staff

Dr. Kenneth R. Currie, Director, Prof., ME
Dr. Robert Qiu, Professor, ECE
Dr. Cynthia Rice, Asst. Prof., ChE
Dr. Kwun-Lon Ting, Professor, ME

Brian Bates, R&D Engineer I
Michelle Davis, Outreach Coordinator
Dr. Nan (Terry) Guo, R&D Engineer III
E. Wayne Hawkins, Mat. Science Lab Mgr.
Suzanne Henry, Contract Compliance Asst.
Dr. Zhen Hu, Postdoctoral Researcher
Sue Richardson, Secretary II / Receptionist
Rob Reab, Network Mgr.
Mike Renfro, R&D Engineer II
Joel Seber, Engr. Computer Support Mgr.
Phyllis Stallion, Technical Clerk
Dr. Patrick Urchaga, Postdoctoral Researcher
Darlene Wiegand, Financial Analyst
Dr. Yanbin Zhang, Visiting Scholar

CMR Faculty Associates

Dr. Ali Alouani, Professor, ECE
Dr. Adam Anderson, Asst. Professor, ECE
Dr. Holly Anthony, Asst. Professor, Curriculum & Instruction
Dr. Pedro E. Arce, Chairperson, Professor, ChE
Dr. Joe J. Biernacki, Professor, ChE
Dr. Stephen Canfield, Professor, ME
Dr. Glenn Cunningham, Assoc. Professor, ME
Dr. Corinne Darvennes, Professor, ME
Dr. S. Deivanayagam, Assoc. Dean of Research, College of Engineering
Dr. William Eberle, Asst. Professor, CS
Dr. Omar ElKeelany, Assoc. Professor, ECE
Dr. Ahmed ElSawy, Chair, Professor, MIT
Dr. Ismail Fidan, Professor, MIT
Dr. Melissa Geist, Asst. Professor, Nursing
Dr. Sheikh Ghafoor, Asst. Professor, CS
Dr. Syed Rafay Hasan, Asst. Professor, ECE
Dr. Stephen Idem, Professor, ME
Dr. Glen Johnson, Professor, ME
Dr. Larry W. Knox, Professor, Earth Science
Dr. Peter Li, Professor, Earth Science
Dr. Wayne Liemer, Professor, Earth Science
Kevin R. Liska, Director, Bus. Media Ctr.
Dr. Y. (Jane) Liu, Professor, CEE
Dr. Satish Mahajan, Professor, ECE
Dr. Ben Mohr, Assoc. Professor, CEE
Dr. Joseph Ojo, Professor, ECE
Dr. Sally Pardue, Assoc. Professor, ME/ Director, Millard Oakley STEM Center
Dr. P. K. Rajan, Professor, ECE
Dr. Stephen Scott, Professor, CSC/ECE / Stonecipher & Boeing Distinguished Professor of Computing
Dr. Ambareen Siraj, Asst. Professor, CS
Dr. Holly Stretz, Assoc. Professor, ChE
Dr. Meenakshi Sundaram, Professor, ME
Dr. Doug Talbert, Professor, CS
Dr. Fred Vondra, Professor, MIT
Dr. Chris Wilson, Assoc. Professor, ME
Dr. Dale Wilson, Professor, ME
Dr. Hwan-Sik Yoon, Asst. Professor, ME
Dr. Ying Zhang, Professor, ME
Dr. John Zhu, Professor, ME

Top 5 Highlights from FY 2011 – 2012

The Center for Manufacturing Research (CMR) has a growing portfolio of research projects that reinforce our vision, ***“Leading a manufacturing transformation in the areas of energy, communications, sensors, and design.”*** The top five highlights of FY 2011 - 2012 are listed below:

Dr. Qiu receives recognition for outstanding research – Dr. Robert Qiu was recognized twice in early 2012 for outstanding research results in wireless communication and networking, machine learning and Smart Grid technologies. He was invited to deliver one of the keynote addresses at the IEEE 2012 International Conference on Computing, Networking, and Communications (ICNC). Dr. Qiu’s invited talk discussed the application of cognitive systems at the intersection of wireless communications, sensing, and radar. Dr. Qiu also received the 2012 Kinslow Award for best paper published in TTU’s College of Engineering. The paper recognized with the Kinslow Award systematically investigated the novel idea of applying the next generation wireless technology, cognitive radio networks, for the smart grid. In particular, system architecture, algorithms, and hardware testbeds were examined. The concept of independent component analysis (ICA) in combination with the robust principal component analysis (PCA) technique was employed to recover data from the simultaneous smart meter wireless transmissions in the presence of strong wideband interference. The performance illustrates the significant benefit of bringing the state of the art mathematics/optimization to smart grid robustness. Both of these prestigious honors are a result of the ground-breaking research that is being conducted in the Cognitive Research Institute, funded by the Office of Naval Research.

Cognitive Radio Institute completes first full year of operation – Dr. Robert Qiu and his team of faculty researchers, staff, and students in the Wireless Networking Systems Lab (WNSL) have successfully garnered more than \$1.2 million of external funding to promote a Cognitive Radio testbed for researching the next generation of wireless communications, radar, and anti-jamming. Networks of 20-40 “cognitive” radios have been purchased and are in the process of being tested as a testbed around the campus. An RF anechoic chamber is also in the process of being installed as part of a \$396,000 grant from

the Office of Naval Research (ONR) and a Defense University Research Instrumentation Program (DURIP) grant. The WNSL is developing a robust cognitive radio network and test facility for continuing research into machine learning algorithms for dynamic spectrum sensing, imbedded security for smart-grid, and cognitive radar and sensing applications. Dr. Qiu is also finishing up research on a \$760,000 legislative directed spending grant from ONR to establish the Cognitive Radio Institute to further enhance research in the next generation of wireless communications.

Tennessee EPSCoR (TN-SCORE) issues Sub-Award to CMR and Drs. Rice, Stretz, and Currie to Perform Research on Solar, Energy Conversion, and Energy Efficiency Topics – In September 2010 the State of Tennessee EPSCoR committee was awarded a \$20 million Research Infrastructure Improvement grant from the National Science Foundation to research materials and devices focused on renewable energy and efficient energy conversions. Dr. Cynthia Rice is serving as a statewide co-thrust leader for Thrust #2 (Components & Devices for Energy Storage & Conversion) and is leading the TTU effort. Dr. Holly Stretz is supporting Thrust #1 (Advanced Solar Conversion & Innovation) and Dr. Ken Currie is supporting Thrust #3 (Nanostructures for Enhancing Energy Efficiency). In 2011-12 Dr. Rice also received a supplemental award from TN-SCORE of \$66,302 to purchase a Residual Mass Gas Analyzer. TN-SCORE co-sponsored the 2012 Electrochemical Energy Storage and Conversion Forum held in Knoxville on April 19-20. The event



Graduate student, Akshay Bauskar receives an award from John Hopkins, Director of TN-SCORE, for best poster at the Statewide Collaboration Meeting in Nashville in June 2012.

drew over 115 attendees and brought area researchers from both academe and industry together with students. The forum-featured top speakers from industry and academia covering state-of-the-art advances in lithium batteries, low temperature fuel cells, and flow batteries. A student poster competition was held, and graduate student Sai Monhar Goli in Dr. Rice's lab placed third with his research poster entitled, "Impact of Potential Cycling on Catalyst Durability of Automotive Fuel Cell." In addition, at the statewide TN-SCORE meeting, Dr. Rice's graduate student, Akshay Bauskar was awarded first place in Thrust #2 for his poster presentation entitled, "Carbon supported PtPd catalyst for formic acid electro-oxidation."

Southeast Industrial Energy Alliance Promotes Superior Energy Performance at Demonstration Sites – The Energy Resources Division of the Georgia Environmental Facilities Authority (GEFA) is leading a coordinated, multi-state effort in response to the DOE/ITP solicitation, *Save Energy Now: State, Regional and Local Delivery*. The grant, entitled *Southeast Industrial Energy Alliance*, is a collaboration of three states; Georgia, North Carolina, and Tennessee with the CMR serving as the TN delivery organization to provide a wide array of energy efficiency activities that will transform the market for industrial energy efficiency in the Southeast. Recruited industry clients in each state received energy assessments that are based on the new ASME Energy System Assessment Standards. This effort will lead to significant industrial energy savings, and will also build expert capacity in the State of TN to conduct these new assessments.

In a separate task of the project, CMR Director, Ken Currie, and Outreach Coordinator, Michelle Davis, provided coaching and mentoring to the Energy Management Team at Schneider Electric in Smyrna, TN as they became one of only a handful of organizations in the U.S. to be certified in compliance with the new ISO Energy Management Standard – ISO 50001. TTU's Center for Manufacturing Research boasts three staff members who are among the nation's first certified practitioners in energy management systems, meeting a demand for firms seeking assistance in meeting a new quality standard known as ISO 50001. Through involvement in this novel collaboration between states, DOE, and private industry, Currie and Dr. Glenn Cunningham, have passed core and industrial sector exams to become two of only about 30

certified practitioners of energy management systems in the U.S. With this certification, they can assist industrial facilities in establishing and maintaining an energy management system that meets the requirements of ISO 50001. In addition to passing the core exam, Michelle Davis, the Center's outreach coordinator, achieved certification as a lead auditor for the ISO 50001 standard.

Industrial Assessment Center (IAC) Receives Reauthorization for the next 5 years totaling \$1.5 million - The Tennessee 3-Star Industrial Assessment Center (TN 3-Star IAC) has been in existence since 2006 and has conducted over 70 **free** energy assessments in that time period with approximately \$2.8 million of implemented energy-related savings. Anchored by faculty and students at Tennessee Tech University's Center for Manufacturing Research, the TN 3-Star IAC is also supported by satellite centers at the University of Memphis and East Tennessee State University. During that time the total number of students impacted has exceeded sixty-five (65), with thirteen (13) of those students receiving DOE certification of participation in the IAC program. The CMR submitted a winning proposal in August 2011 entitled, "*Public-Private Partnership for a Comprehensive Workforce Development Plan to Stimulate Industrial Energy Efficiency and Demand Reduction*," striving to form a broad coalition of industry, non-profit, and government entities to create a systemic transformation of workforce development for industrial energy efficiency professionals. It is systemic in the sense that the plan is to develop the professional at the root (student engineer) such that the entire system (industrial energy efficiency) is affected including outreach to every tissue of the system through end-user training of efficient energy system practices.

External Funding Highlights

The Center's external funding continued a downward trend as congressionally directed spending has been eliminated at the federal level and the number of faculty actively submitting competitive proposals has begun to level off after several key faculty departures in the last two years. The Center's overall productivity in releasing salaries and supplies through funded activities, although at a high level, was far below last year's record level. Figure 1 represents the 3-year moving average of external funding with the

value of activations processed through the CMR for FY 2011-12 at approximately **\$1.24 million** or 67% of last year's level. Table 1 gives a historical perspective of various sources of external

revenues that were used to “release” or free up State appropriations for other strategic investment areas.

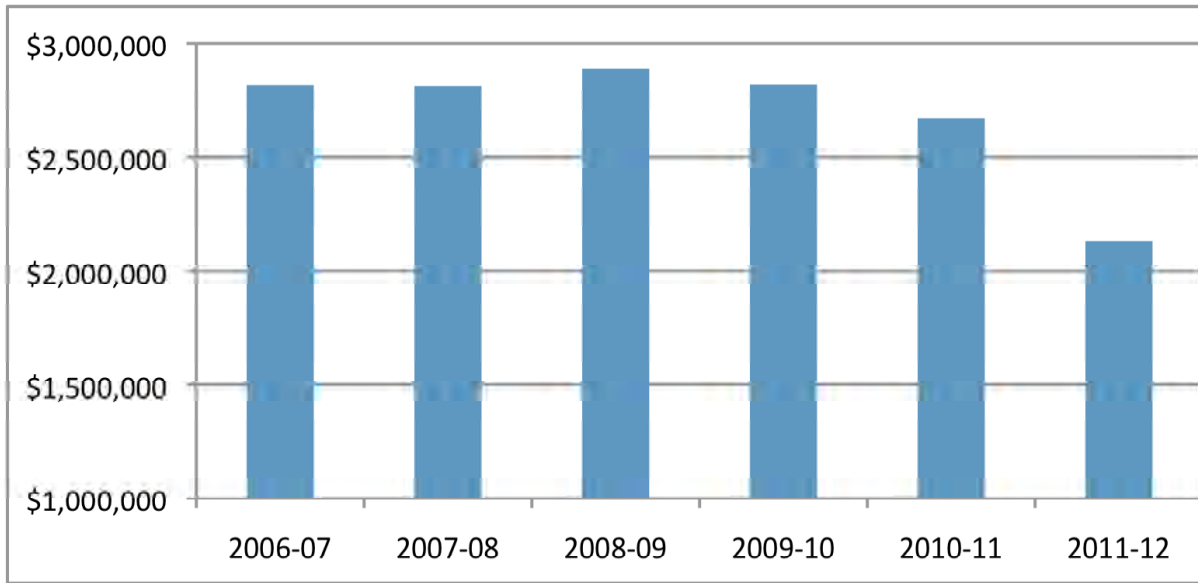


Figure 1 – Last 6 Years of External Funding (3-Year Moving Average)

Table 1. Salary and Supplies Released by External Funding

Performance Metric	FY 2009-10	FY 2010-11	FY 2011-12
Faculty & Staff Release Time*	\$214,681	\$353,026	\$220,338
Graduate Student Stipend & Fees from External Sponsors	\$409,340	\$312,645	\$160,122
Percentage of GRA Support from External Sponsors	53%	53%	32%
Total “Soft Money” (F&A return, Testing income, GRA support, Equip. usage, and Release Time)	\$735,545	\$781,814	\$499,477

CENTER FOR MANUFACTURING RESEARCH

Tennessee Technological University

Strategic Plan Update

Goals and Benchmarks – FY 2011-12

Strategic Plan

In an effort to strengthen alignment of the Center's strategic plan with the recommendations from the College Reengineering Study, the CMR conducted an intensive strategic planning exercise that utilized manufacturing roadmap strategies¹ for the 21st Century along with feedback from existing faculty and a survey of university technical capabilities and laboratory infrastructure. The resulting vision centered along the concept of a **"Dark Factory."** The original term "Dark Factory" was coined to refer to a discrete manufacturing facility with digitally driven process plans and automated workstation instructions for assembly/processing without human intervention. We have expanded this term to apply it to any manufacturing facility, which can literally be "Dark" in the sense that it is a net energy neutral facility with wireless sensors and communications to facilitate intelligent oversight and processing. The resultant manufacturing facility would be digitally modeled, controlled, and operated independent of personnel or grid requirements for oversight, power and communications. This has led us to identify four key focus areas of expertise and investment:

1. **Materials and devices for cost effective energy storage/conversion/efficiency**
2. **Wireless Communications, Sensing, and Machine Learning**

¹ "A Framework for Revitalizing American Manufacturing," Executive Office of the President of the United States, December 2009.

"Smart Process Manufacturing: Executive Summary and Framework for an Operations and Technology Roadmap," Smart Process Manufacturing Engineering Virtual Organization Steering Committee, November 2009.

"Innovation and Product Development in the 21st Century," Hollings Manufacturing Extension Partnership Advisory Board, February 2010.

"Intelligent, Integrated Manufacturing Systems," Integrated Manufacturing Technology Initiative, Inc., March 2009.

"Grand Challenges for Engineering," National Academy of Engineering, 2008.

3. **In-situ and Non-Invasive Sensing, Modeling, and Control of Systems and Processes (Fuel Cells, Manufacturing Processes, Biological Processes, etc.)**

Goals and Benchmarks

1. Personnel:

- 1.1. Increase the diversity of the graduate student population by expanding female and minority student participation.

Measurable Benchmark 1.1 – Increase the percentage of female and minority students receiving some level of support through the CMR. (2004-05 Baseline = 9%)

2011 – 12 projected progress - Increase of 10 basis points over baseline or 2 basis points increase over prior year. **Actual Progress = 20.5% GOAL EXCEEDED – last year = 17.3%**

- 1.2. Increase the exposure and attractiveness of the CMR to potential graduate students through effective advertising and increased scholarship/stipend incentives.

Measurable Benchmark 1.2 – Increase the average monthly stipend for both Masters and Ph.D. students. The CMR will increase the average monthly stipends by 25% over the baseline by the end of cycle. (2004-05 Baseline = Average monthly stipends of \$985 for Masters and \$1,320 for Ph.D. students)

2011 – 12 projected progress - Increase of 25% over baseline on average monthly stipends of both Masters and Ph.D. students. **Actual Progress = \$1,160/mo for Masters and \$1,470 for Ph.D. – GOAL NOT MET; ~ 2.8% decrease year-over-year in average M.S. stipends, 2.2% increase year-over-year in average Ph.D. stipends**

1.3. Improve the productivity of existing faculty and staff as measured by external funding of direct activities.

Measurable Benchmark 1.3a – Increase the total amount of “soft money” available to the CMR through return of Facilities and Administrative (F&A) fees, Testing income, Equipment Usage fees, and salary release of faculty and staff. The CMR will increase these funds by 25% over the baseline by the end of cycle. (2004-05 Baseline = \$231,301)

2011 – 12 projected progress - Increase of 25% over baseline. **Actual Progress = \$499,477 – GOAL EXCEEDED**

Measurable Benchmark 1.3b – Increase the percentage of total graduate student support (stipends + fees) provided by external projects. The CMR will increase this percentage by 25 basis points over the baseline (resulting in 56.4% of total graduate student support provided from external projects) by the end of cycle. (2004-05 Baseline = 31.4%)

2011 – 12 projected progress - Increase of 25 basis points over baseline. **Actual Progress = 37.8% – GOAL NOT MET**

2. Facilities

2.1. Enhance Laboratory Development by investing in equipment and major supplies.

Measurable Benchmark 2.1a – Total laboratory investment of \$1,000,000 by the end of cycle.

2011 – 12 projected progress - \$1,000,000 total investment by the end of cycle. **Actual Progress = \$435,495 for the year and a cumulative of \$2,449,202 since the Base Year – GOAL EXCEEDED BY 100%**

Measurable Benchmark 2.1b – Submit one (1) credible, Major Research Instrumentation (MRI) proposal every year during the planning cycle.

2011 – 12 projected progress - One (1) MRI proposal submitted. **Actual Progress = 0 MRI**

proposal to the National Science Foundation, Major Research Instrumentation – GOAL NOT MET

2.2. Renovate CMR laboratory and administrative environments for improved morale and utilization of existing spaces.

Measurable Benchmark 2.2 – Invest an average of \$5,000/yr on renovation of laboratory and administrative environments. A total of \$25,000 invested during the planning cycle.

2011 – 12 projected progress - \$5,000 invested. **Actual Progress = \$41,932 – GOAL EXCEEDED**

3. Activities

3.1. Increase the level of externally funded research and service activities in alignment with the CMR’s strategic foci and mission.

Measurable Benchmark 3.1a – Increase the three-year moving average (3YrMA) of external funding by 5% per year. The CMR will increase these funds by 25% over the baseline by the end of cycle. (2004-05 Baseline = \$2,042,000)

2011 – 12 projected progress - Increase of 25% over baseline **Actual Progress = \$2,129,390 – GOAL NOT MET**

Measurable Benchmark 3.1b – Increase the valuation of proposals processed through the CMR by 5% per year. The CMR will increase annual proposal valuations by 25% over the baseline by the end of cycle. (2004-05 Baseline = \$14,200,000)

2011 – 12 projected progress - Increase of 25% over baseline **Actual Progress = \$10,895,277 – GOAL EXCEEDED ~ 35.1% increase year-over-year in proposal valuation**

3.2. Cultivate new and existing sources of direct income to the CMR while simultaneously fulfilling outreach and service to Tennessee/National manufacturing needs.

Measurable Benchmark 3.2a – Increase the income resulting from testing services by 5% per year. The CMR will increase these funds by 25% over the baseline by the end of cycle. (2004-05 Baseline = \$46,661)

2011 – 12 projected progress - Increase of 25% over baseline **Actual Progress = \$40,940 GOAL NOT MET**

Measurable Benchmark 3.2c – Increase the valuation of donated equipment and cash donations to the CMR by 5% per year. The CMR will increase annual donations by 25% over the baseline by the end of cycle. (2004-05 Baseline = \$10,200)

2011 – 12 projected progress - Increase of 25% over baseline **Actual Progress = \$38,000 – GOAL EXCEEDED**

3.3. Promote and effectively communicate the positive impact of the CMR on National, State, and Local Manufacturing communities.

Measurable Benchmark 3.3a – Increase the number of scholarly works as book chapters and articles published in archival journals that demonstrate scholarly integrity as a result of CMR research activities. The CMR will increase these communication activities by 25% over the baseline by the end of cycle. (2004 -05 Baseline = 19)

2011 – 12 projected progress - Increase of 25% over baseline **Actual Progress = 4 GOAL NOT MET**

Measurable Benchmark 3.3b – Increase the number of national/international conference publications that demonstrate dissemination of CMR research pursuits. The CMR will increase these communication activities by 25% over the baseline by the end of cycle. (2004-05 Baseline = 18)

2011 – 12 projected progress - Increase of 25% over baseline **Actual Progress = 28 GOAL EXCEEDED**

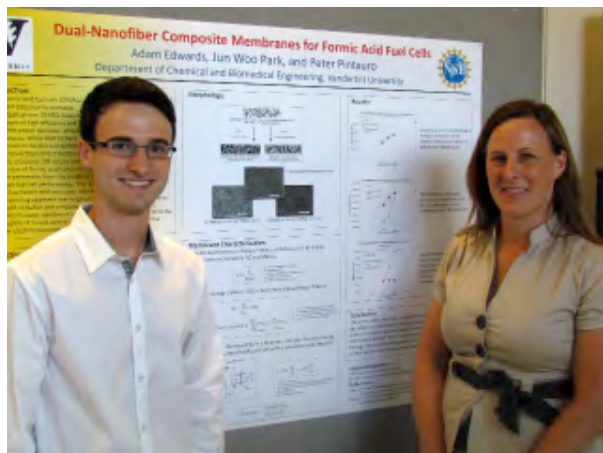
The Center has not undergone an external review since 2005. Plans are underway to revise the Center strategic plan and goals and will conduct an external review in Spring 2013.

Faculty, Staff and Student Accomplishments/Awards

FY 2011 – 12

Robert Qiu, Professor of Electrical & Computer Engineering (ECE), was awarded the 2012 Kinslow award at Tennessee Tech University for the best paper published in the College of Engineering. The paper entitled, "Cognitive Radio Network for the Smart Grid: Experimental System Architecture, Control Algorithms, Security, and Microgrid Testbed," was published in the December 2011 issue of the IEEE Transactions on Smart Grid. Dr. Qiu was also invited to deliver a keynote address at the 2012 International Computers, Networking & Communications Conference entitled, "Towards A Large-Scale Cognitive Radio Network: Testbed, Intensive Computing, Frequency Agility and Security."

Cynthia Rice, and her research group were recognized at several of the TN-SCORE meetings. TN-SCORE co-sponsored the 2012 Electrochemical Energy Storage and Conversion Forum held in Knoxville on April 19-20, 2012. The event drew over 115 attendees and brought area researchers from both academe and industry together with students. Graduate student Sai Monhar Goli was recognized with a third place award in a student poster contest. In addition, at the statewide TN-SCORE meeting, Dr. Rice's graduate student, Akshay Bauskar was awarded first place in Thrust #2 poster competition. Finally,



Undergraduate REU student Adam Edwards is recognized at the STEM REU Symposium alongside faculty advisor Dr. Cynthia Rice.

undergraduate student Adam Edwards was recognized for his poster entitled, "Dual-nanofiber Composite Membranes for Formic Acid Fuel Cells," at the 2012 TN-SCORE Research Experiences for Undergraduates symposium.

Scholarly Publications and Presentations

FY 2011 – 12

CMR faculty and staff published four (4) journal publications, and twenty-eight (28) national and international conference or invited presentations.

Robert Qiu

Journal Publications

R. C. Qiu, Z. Hu, G. Zheng, Z. Chen and N. Guo, "Cognitive Radio Network for the Smart Grid: Experimental System Architecture, Control Algorithms, Security, and Microgrid Testbed," to appear in *IEEE Transactions on Smart Grid*, No. 2, Vol. 4, December 2011.

Conference Presentations

R. Ranganathan, **R. C. Qiu**, S. Hou, and H. Li, "Blind Recovery of Smart Meter Wireless Transmissions Employing Independent Component Analysis in the Presence of Strong Wideband Interference," *IEEE SmartGridComm 2011*, Brussels, Belgium, October 17 - 20, 2011.

J. Yu, C. Zhang, Z. Hu, F. Lin, N. Guo, M. Wicks, **R. C. Qiu**, K. Currie, and L. Li, "Cognitive Radio Network as Wireless Sensor Network (I): Architecture, Testbed, and Experiment," *IEEE National Aerospace & Electronics Conference 2011*, Fairborn, OH, July 20 - 22, 2011.

F. Lin, Z. Hu, S. Hou, J. Yu, C. Zhang, N. Guo, M. Wicks, **R. C. Qiu**, and K. Currie, "Cognitive Radio Network as Wireless Sensor Network (II): Security Consideration," *IEEE National Aerospace & Electronics Conference 2011*, Fairborn, OH, July 20 - 22, 2011.

N. Guo, Z. Hu, J. Bonior, **R. C. Qiu**, L. Liou, and D. Lin, "Wideband Beamforming with Heavily

Imbalanced Channels," *IEEE National Aerospace & Electronics Conference 2011*, Fairborn, OH, July 20 - 22, 2011.

J. Pogge, Y. Song, N. Guo, and **R. C. Qiu**, "Ultra-wideband Multichannel Receiver Test Bed," *IEEE National Aerospace & Electronics Conference 2011*, Fairborn, OH, July 20 - 22, 2011.

J. Bonior, M. Renfro, N. Guo, Z. Hu, and **R. C. Qiu**, "Calculation of Weight Vectors for Wideband Beamforming Using Graphics Processing Units," *IEEE SoutheastCon*, Nashville, TN, March, 2011.

Y. Song, N. Guo, and **R. C. Qiu**, "Towards a real-time UWB MIMO testbed for Sensing and Communications," *IEEE SoutheastCon*, Nashville, TN, March, 2011.

Z. Chen and **R. C. Qiu**, "Cooperative spectrum sensing using Q-learning with experimental validation," accepted by *IEEE SoutheastCon*, Nashville, TN, March, 2011.

Z. Chen, N. Guo and **R. C. Qiu**, "Building a cognitive radio network testbed," accepted by *IEEE SoutheastCon*, Nashville, TN, March, 2011.

Z. Chen and **R. C. Qiu**, "Q-Learning Based Bidding Algorithm for Spectrum Auction in Cognitive Radio," accepted by *IEEE SoutheastCon*, Nashville, TN, March, 2011.

Z. Chen, N. Guo, Z. Hu and **R. C. Qiu**, "Channel state prediction in cognitive radio, part I: Response delays in practical hardware platforms," accepted by *IEEE SoutheastCon*, Nashville, TN, March, 2011.

Z. Chen, N. Guo, Z. Hu and **R. C. Qiu**, "Channel state prediction in cognitive radio, part II: Single-user prediction," accepted by *IEEE SoutheastCon*, Nashville, TN, March, 2011.

S. J. Hou, Z. Hu, M. C. Wicks† and **R. C. Qiu**, "Phase Reconstruction Using Machine Learning For Wireless Tomography," *2011 IEEE radar conference*.

N. Guo, S. J. Hou, Z. Hu, **R. C. Qiu**, "Robust PCA Based Extended Target Estimation with Interference Mitigation," *2011 IEEE radar conference*.

H. Li, L. Lai and **R. C. Qiu**, "A Denial-of-Service Jamming Game for Remote State Monitoring in Smart Grid," *CISS 2011*.

S. Gong, H. Li, L. Lai and **R. C. Qiu**, "Decoding the nature encoded messages for distributed energy generation in microgrid," *ICC 2011. BEST PAPER AWARD*

Kwun-Lon Ting

Journal Publications

Ting, K. L., C. Xue, J. Wang, "Mobility Criteria Of Planar Single-Loop N-Bar Chains With Prismatic Joints," *Journal of Mechanisms and Robotics*, 2011, vol. 3, no. 1.

Dong, H., **K. L. Ting**, D. Wang, "Kinematic Fundamentals of Planar Harmonic Drives," *Journal of Mechanical Design*, **133**, No. 1, January 2011.

Dong, H., **K. L. Ting**, D. Wang, "Kinematic Effect of the Compliant Cup in Harmonic Drives," *Journal of Mechanical Design*, Vol. 133, No. 1, January 2011.

Conference Presentations

Bowen Yu, **Kwun-lon Ting**, "Conjugate Curve Design with Spline Contact Path", CAD'2011, Taipei, Taiwan.

Bowen Yu, **Kwun-lon Ting**, "Free-form Conjugation Theory", ASME 2011 IDETC/CIE Conference DETC2011/MECH-48337

Invited Presentations

Invited seminar speaker, National Science Council International Prominent Scholar Seminar Program:

"Mobility Laws of Linkages and Manipulators," National Taiwan University, Taipei, Taiwan, June 2011.

"Harmonic Drives," Industrial Technology Research Institute, Taichung, Taiwan, June 2011.

"Mobility Laws of Linkages and Manipulators," National Sun Yat-Sen University, Kaohsiung, Taiwan, June 2011.

"Free-Form Conjugation Design," National Cheng Kung University, Tainan, Taiwan, June 2011.

"Harmonic Drives," National Sun Yat-Sen University, Kaohsiung, Taiwan, June 2011.

"Higher Education and Exchange Program" United University, Miaoli, Taiwan, June 2011.

Cynthia Rice

Conference Presentations

C. Rice-York, Shilpa Beravelli, A.S. Bauskar, 'Anode Catalyst Layers for Direct Liquid Fuel Cells,' American Institute of Chemical Engineering, Minneapolis, MN, Oct. 2011.

A. Pistono, **C. Rice-York**, 'Membrane Electrode Assembly Fabrication Effects in PEMFC Subzero Characteristics', **Poster**, Electrochemical Society, Boston, MA, Oct. 2011.

S. Beravelli, **C. Rice-York**, 'Electrodes enhanced with sulfated zirconia for direct methanol fuel cells', **Oral**, Electrochemical Society, Boston, MA, Oct. 2011.

A.S. Bauskar, **C. Rice-York**, 'Highly active and stable carbon supported PtBi catalyst for formic acid electrooxidation', **Oral**, Electrochemical Society, Boston, MA, Oct. 2011.

A.S. Bauskar, **C. Rice-York**, 'Highly Active Pt@Pd@Bi Catalyst for Formic Acid Electrooxidation', **Poster**, Electrochemical Society, Boston, MA, Oct. 2011.

S. Beravelli, **C. Rice-York**, 'Impact of S-ZrO₂ modified anode catalyst layers on DMFCs performance', **Poster**, TN-Score Annual Conference, Nashville, TN, Aug. 2011.

A.S. Bauskar, **C. Rice-York**, 'Highly Active Pt@Pd@Bi Catalyst for Formic Acid Electrooxidation', **Poster**, TN-Score Annual Conference, Nashville, TN, Aug. 2011.

S.M. Goli, A. Bauskar, **C. Rice-York**, "Impact of Potential Cycling on Catalyst Durability of Automotive Fuel Cell", **Poster**, TN-Score Annual Conference, Nashville, TN, Aug. 2011.

Invited Presentations

C. Rice-York, "Anode Catalysts for Complex Liquid Fuel Cells," TTU Sigma Xi, October 26th, 2011.

C. Rice-York, Prepared fuel cell video targeting high school students for TBR/TTU STEM Unconference, October 17th, 2011.

C. Rice-York, "PEM fuel cells for automotive subzero cold-starts," University of Tennessee Knoxville, September 22nd, 2011.

C. Rice-York, "PEM fuel cells for automotive subzero cold-starts," Illinois Institute of Technology, February 16th, 2011.

Nan "Terry" Guo

Journal Publications

Y. Song, **T. N. Guo**, R. C. Qiu, "Implementation of UWB MIMO Time-reversal Radio Testbed," *IEEE Antennas and Wireless Propagation Letters*, no. 99, pp. 1-1, 2011.

Conference Presentations

T. N. Guo, "Distributed Radio Relay for Communication and Control with Physical-Layer Security in Smart Grid," *CSII/RW '11*, October 12-14, 2011, Oak Ridge, TN.

T. N. Guo, X. Li, J. Pogge, Y. Song, R. C. Qiu, et al, "Unique Measurement and Modeling of Total Phase Noise in Wideband Receive," accepted by *IEEE Waveform Diversity and Design Conference 2012*, Kauai, Hawaii, January 22 - 27, 2012.

Faculty Research Grants

Center for Manufacturing Research FY 2011 – 2012 Project Summary					
Project Description/ Source/ Acct. No.		Principal Investigators	Activated Amount	Project Duration	Estimated 12-month Expenses
1.	Manufacturing Center Testing & Design - FY 2011-12 Various Industries Account #: 5-38585	Kenneth Currie	\$40,940	7/1/2011 – 6/30/2012	\$84,617
2.	University of Tennessee Center for Industrial Services (UT-CIS) UT-CIS Account #: 5-33518	Kenneth Currie	\$80,000	7/1/2011 – 6/30/2012	\$42,183
3.	Tennessee 3-Star Industrial Assessment Center – Amendment 12 – Award DE-FC36-06GO16079 U.S. Department of Energy Account #: 5-32285	Glenn Cunningham Kenneth Currie	\$40,000	7/15/2011 – 08/31/2011	\$40,000
4.	IAC – 2011 – Public Private Partnership for a Comprehensive Workforce Development Plan to Stimulate Industrial Energy Efficiency and Demand Reduction Award DE-EE0005533 U.S. Department of Energy Account #: 5-32290	Glenn Cunningham Kenneth Currie	\$120,000	9/30/2011 – 09/29/2012	\$120,000
5.	IAC – 2011 – Public Private Partnership . . . Amendment #1 U.S. Department of Energy Account #: 5-32290	Glenn Cunningham Kenneth Currie	\$180,000	9/30/2011 – 9/29/2012	\$129,500
6.	Collaborative Research: Wideband Cognitive Radio Communication Systems: Modeling, Algorithms and Testbed – Award ECCS-0901420 Year 3 of 3 National Science Foundation Account #: 5-31265	Robert Qiu	\$59,300	8/01/2011 – 7/31/2013	\$59,300

**Center for Manufacturing Research
FY 2011 – 2012 Project Summary**

	Project Description/ Source/ Acct. No.	Principal Investigators	Activated Amount	Project Duration	Estimated 12-month Expenses
7.	RUI: Controlling the Properties and Performance of Concrete Using Computer Aided Molecular Design (Funded under GOALI) Award CMMI-0928539 Year 3 of 3 National Science Foundation Account #: 5-31267	Joseph Biernacki	\$105,243	8/1/2012–7/31/2013	\$50,243
8.	An Alternative Low-Cost Process for Deposition of MCrAlY Bond Coats for Advance Syngas and Hydrogen Turbine Applications Modification #3 Subcontract – Award DE-FE0007332 Year 1 of 3 U.S. Department of Energy Account #: 5-32275	Ying Zhang	\$119,930	9/12/2011 – 9/11/2012	\$87,430
9.	Alumina Forming Coatings for Power Generation Applications Modification #5 Subcontract 4000071336 Oak Ridge National Laboratory Account #: 5-39342	Ying Zhang	\$20,000	8/1/2011 – 7/31/2012	\$20,000
10.	Components and Devices for Energy Storage and Conversion Amendment #1 Subgrant # A11-0171-001.04 (A11-0171-S006-A01) University of Tennessee (via NSF Award EPS-1004083) Account #: 5-31228	Cynthia Rice	\$20,856	10/7/2010–10/7/2011	\$20,856
11.	Components and Devices for Energy Storage and Conversions, Advanced Solar Conversion and Innovation & Nanostructures for Enhancing Energy Efficiency Subcontract A11-0171-001.04 Amendment #2 University of Tennessee (via NSF Award EPS-1004083) Account #: 5-31228	Cynthia Rice	\$245,705	10/7/2011 – 10/7/2012	\$235,000

**Center for Manufacturing Research
FY 2011 – 2012 Project Summary**

Project Description/ Source/ Acct. No.		Principal Investigators	Activated Amount	Project Duration	Estimated 12-month Expenses
12.	Southeast Industrial Energy Alliance – Year 2 of 3 – GEFA Contract # SIEA2010-102 Georgia Environmental Facilities Authority Account #: 5-39337	Kenneth Currie	\$77,166	7/01/2011 – 06/30/2012	\$61,606
13.	Program Income for Southeast Industrial Energy Alliance Grant #5-39337 Various Industries Account #: 5-39338	Kenneth Currie Glenn Cunningham	\$800	7/1/2011 – 10/29/2012	\$800
14.	Resiliency Techniques for Large-Scale and Heterogeneous Environments Oak Ridge National Laboratory Account #: 5-39362	Stephen Scott	\$88,105	3/1/2012 – 2/28/2013	\$88,105
15.	Subcontract from University of South Florida – Virtually Transparent Epidermal Imagery University of South Florida (via NSF funds) Account #: 5-32398	Adam Anderson	\$24,645	9/1/2011– 8/31/2012	\$20,000
16.	Subcontract from University of South Florida - Impedance Changes as an Indicator of Successful Skin Electroporative DNA Delivery University of South Florida (via NIH funds) Account #: 5-32397	Adam Anderson	\$14,136	10/1/2011– 12/31/2011	\$14,136
TOTALS			\$1,236,826		\$1,073,776

Professional and Community Service

The CMR is completing its sixth year as a Department of Energy (DOE) funded Industrial Assessment Center (IAC). The DOE has identified 23 Industrial Assessment Centers (IAC) across the nation to assist small to medium-sized companies save energy and decrease their manufacturing waste streams. Directed by Dr. Glenn Cunningham (ME) with help from Dr. Ken

Currie as Assistant Director, The Tennessee 3-Star IAC is a virtual organization with TTU/CMR as the lead institution and the University of Memphis and ETSU as satellite centers. This collaboration allows for a broad coverage including all of Tennessee and parts of KY, AR, VA, and NC. Since completing the first assessment in December 2006, the TN 3-Star IAC has compiled 70 assessment reports with a total of 443 recommendations representing potential energy savings in excess of \$8.7 million (See Table 2 below). Each participating company in the IAC program is also contacted after 6-9 months after the report is submitted to determine which of the recommendations were implemented. Thus far, 50 follow-up contacts have been recorded with actualized energy savings of **\$2.1 million**.

	ASSESSMENTS 70 Completed	FOLLOW-UPS AT 6 – 9 MONTHS 50 Completed (Of those, 1 plant had closed)		
	Recommendations Made	Recommendations Made	Recommendations Implemented	Percent
# of Recommendations	443	335	134	40%
Energy Dollar Savings	\$8,730,665	\$7,022,291	\$2,084,081	30%
Electric Usage Savings (kWh)	74,146,120 kWh	59,041,051 kWh	17,754,813 kWh	30%
Electric Demand Savings (kW)	680,189 kW	72,832 kW	40,041 kW	55%
Natural Gas / Liquid Propane Savings (MMBtu)	529,499 MMBtu	450,752 MMBtu	193,742 MMBtu	43%

Table 2. IAC Savings by \$ and Energy Metrics

The CMR also impacted more than 25 different Tennessee manufacturing concerns through testing services and personalized research/consulting projects involving graduate students and faculty expertise. The CMR had another significant year in terms of testing services (\$40,940) with 36 separate testing projects. This level of testing is reflective of the high quality of service and the expanded range of available testing laboratories through recent equipment acquisitions.

The CMR is currently *not* accredited nor has it received any special recognition by any disciplinary association or other national or international source since July 2008.

Schedule 7

CENTERS OF EXCELLENCE/CENTERS OF EMPHASIS ACTUAL, PROPOSED, AND REQUESTED BUDGET

Institution Tennessee Technological University Center Center for Manufacturing Research

	FY 2011-12 Actual			FY 2012-13 Proposed			FY 2013-14 Requested		
	Matching	Appopr.	Total	Matching	Appopr.	Total	Matching	Appopr.	Total
Expenditures									
Salaries									
Faculty	170,727	295,809	466,536	238,678	288,295	526,973	180,000	295,320	475,320
Other Professional	75,473	448,051	523,524	175,000	583,488	758,488	100,000	560,010	660,010
Clerical/ Supporting	0	61,304	61,304	10,000	68,716	78,716	10,000	70,000	80,000
Assistantships	104,800	174,043	278,843	175,000	151,898	326,898	125,000	150,000	275,000
Hourly Students	86,803	67,331	154,134	57,200	63,754	120,954	65,000	65,000	130,000
Total Salaries	437,803	1,046,538	1,484,341	655,878	1,156,151	1,812,029	480,000	1,140,330	1,620,330
Fringe Benefits	61,961	309,441	371,402	120,000	225,000	345,000	140,000	210,570	350,570
Total Personnel	499,764	1,355,979	1,855,743	775,878	1,381,151	2,157,029	620,000	1,350,900	1,970,900
Non-Personnel									
Travel	50,712	23,824	74,536	65,000	24,205	89,205	50,000	20,000	70,000
Software	1,700	535	2,235	5,000	0	5,000	5,000	500	5,500
Books & Journals	9,998	0	9,998	8,000	0	8,000	1,000	0	1,000
Other Supplies	175,460	57,578	233,038	200,000	64,158	264,158	200,000	65,000	265,000
Equipment	173,770	29,186	202,956	368,101	6,814	374,915	494,000	0	494,000
Maintenance	10,440	0	10,440	5,000	0	5,000	25,000	500	25,500
Scholarships	55,322	103,665	158,987	95,000	99,649	194,649	105,000	90,000	195,000
Consultants/Subcontracts	188,795	0	188,795	125,000	0	125,000	100,000	0	100,000
Renovation	0	0	0	0	0	0	0	0	0
Other (Seminars/Conf.)	0	0	0	0	0	0	0	500	500
Total Non-Personnel	666,197	214,788	880,985	871,101	194,826	1,065,927	980,000	176,500	1,156,500
GRAND TOTAL	1,165,961	1,570,767	2,736,728	1,646,979	1,575,977	3,222,956	1,600,000	1,527,400	3,127,400
Revenue									
New State Appropriation	0	1,460,000	1,460,000	0	1,482,900	1,482,900	0	1,527,400	1,527,400
Plus MOE Stimulus Funds	0	0	0	0	0	0	0	0	0
Adjusted Appropriations	0	1,460,000	1,460,000	0	1,482,900	1,482,900	0	1,527,400	1,527,400
Carryover State Appropriation	0	203,844	203,844	0	93,077	93,077	0	0	0
New Matching Funds	1,110,578	0	1,110,578	1,600,440	0	1,600,440	1,600,000	0	1,600,000
ARRA Stimulus Funds	0	0	0	0	0	0	0	0	0
Carryover from Previous Stimulus Funds	0	0	0	0	0	0	0	0	0
Carryover from Previous Matching Funds	101,922	0	101,922	46,539	0	46,539	0	0	0
Total Revenue	1,212,500	1,663,844	2,876,344	1,646,979	1,575,977	3,222,956	1,600,000	1,527,400	3,127,400

FY 2013-14 Budget Request and Justification

The CMR is requesting a 3% increase in the FY 2013-14 State appropriations to account for increasing salaries, supplies, and travel costs. Despite the state of the economy, prices for supplies, benefits, and travel continue to increase on a yearly basis and inflation is threatening to erode the CMR's ability to continue a high-level of research and service to Tennessee manufacturing industries.

