



**Center for Manufacturing Research**

**Tennessee Technological University**

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



ANNUAL REPORT FY 2010 - 2011



**ABOUT THE COVER:** Shown on the cover are two, 9 – 12<sup>th</sup> Grade student participants in the President’s Academy on Science & Technology investigating fuel cell membranes in Dr. Cynthia Rice-York’s laboratory. Students not only gain a fundamental understanding of how fuel cells work but also how they will play a key role in powering the automobile and factory of the future. Generating electricity from one of the cleanest and most abundant elements in the universe – **Hydrogen** – the students catch a glimpse into some of the manufacturing challenges of fuel cells. Dr. Rice-York also makes this complicated and challenging research field interesting and fun for students as they conclude their participation by racing fuel cell driven model cars for the honors of “Fuel Cell Scientist of the Future.”

## Center for Manufacturing Research

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# Tennessee Technological University Center for Manufacturing Research Annual Report – FY 2010 – 2011

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**The Center for Manufacturing Research (CMR) at Tennessee Tech University is a THEC Established Center 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-York, 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 II E. Wayne Hawkins, Mat. Science Lab Mgr. Suzanne Henry, Contract Compliance Asst.	Dr. Zhen Hu, Postdoctoral Research Assoc. Sue Richardson, Secretary II / Receptionist Dr. Raghu Ranganathan, Postdoctoral Research Assoc.  Rob Reab, Network Mgr. Mike Renfro, R&D Engineer II Joel Seber, Engr. Computer Support Mgr. Phyllis Stallion, Technical Clerk Darlene Wiegand, Financial Analyst
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## CMR Faculty Associates

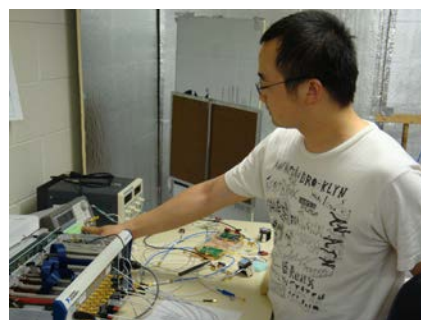
Dr. Ali Alouani, Prof, ECE Dr. Holly Anthony, Asst. Prof., Curriculum & Instruction Dr. Pedro E. Arce, Chairperson, Prof, ChE Dr. Joe J. Biernacki, Professor, ChE	Dr. Peter Li, Professor, Earth Science Dr. Wayne Liemer, Prof., Earth Science Kevin R. Liska, Director, Bus. Media Ctr. Dr. Y. (Jane) Liu,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

## Top 5 Highlights from FY 2010 – 2011

Despite the closing out of two large, multi-year projects (Army funded “Advanced Portable Power Institute – Phase 4” and DOE funded “In-Situ, Real Time Monitoring and Control of Metal Casting”), there have been a significant number of new projects worth mentioning. The top five highlights of the CMR are listed below:

- 1. Dr. Rice-York Receives Sigma Xi Award for best paper published at TTU -** Dr. Cynthia Rice-York was awarded the 2011 Sigma Xi award at Tennessee Tech University for the best paper published in the previous fiscal year. The paper entitled, “Electrochemical Impedance Spectroscopy Detection of Saturation Level in a Frozen Polymer Electrolyte Membrane,” was published in the December 2010 issue of the Journal of the Electrochemical Society. Dr. Rice-York along with co-authors Antonio Pistono (graduate student) and Vijayyasekaran Boovaragavan (Postdoctoral Research Associate) developed a modified electrochemical impedance spectroscopy (EIS) method to probe fundamental hydration properties in polymer electrolyte membrane fuel cells (PEMFCs) related to subzero cold-start phenomena. Subzero cold-starts are vital to widespread automotive PEMFC commercialization in the automotive market.
- 2. Cognitive Radio Research Receives Over \$1.2 million in Last 2 Years –** 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. While continuing to purchase equipment from a \$396,000 grant from the Office of Naval Research (ONR) as part of



*Graduate student, Yu Song adjusts equipment associated with an Ultrawideband (UWB) Multiple Input, Multiple Output (MIMO) radar system in the WNSL.*

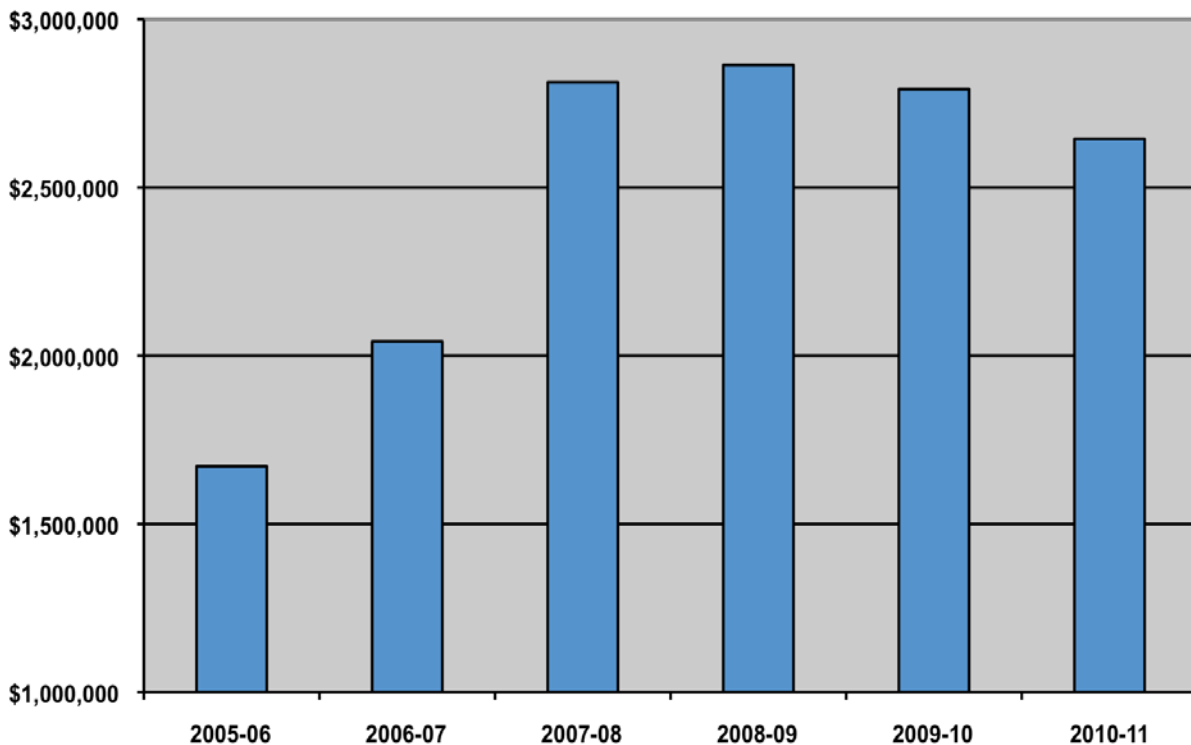
the Defense University Research Instrumentation Program (DURIP), the WNSL is developing a robust cognitive radio network and test facility for continuing research into machine learning algorithms for dynamic spectrum sensing, imbedded security for smart-grid, and cognitive radar and sensing applications. Dr. Qiu also received 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.

3. **Tennessee EPSCoR issues Sub-Award to CMR and Drs. Rice-York, Stretz, and Currie to Research Solar, Energy Conversion, and Energy Efficiency –** 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. Rice-York 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). The total value of the five-year grant is expected to total more than \$1 million.
4. **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 will receive 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 each state to conduct these new assessments. During year two and three, each of these states and their industrial clients will also participate in a pilot program to implement an ANSI-accredited Plant Certification program. As a result, industrial clients will implement an energy management program that will help to sustain and continually improve their energy efficiency efforts. At the same time, state energy specialists will be trained to deliver implementation assistance for future plant certification programs. Year two and three of the project will also include implementation assistance to those companies receiving energy assessments to increase opportunity adoption.
5. **Industrial Assessment Center (IAC) Receives ARRA Funding -** Through the American Recovery and Reinvestment Act of 2009 (ARRA), TTU's Industrial Assessment Center (IAC) has provided enhanced energy efficiency assessments to manufacturers. In addition to regular IAC-type assessments, these enhanced assessments included activities such as partnership with state government and utilities to assist the client in cost savings, including rebates; pre-assessment surveys targeted at small to medium sized industrial facilities; and/or multiple-day

assessments for larger facilities with additional pre-assessment information to target projects where the clients would require additional assistance in implementing energy efficiency strategies. Under this program, the IAC performed a number of Technical Assistance events for selected previous IAC clients. These events provided additional support to increase adoption of recommended savings opportunities over and above the past assessment implementation results.

## External Funding Highlights

Although the Center's external funding was depressed from previous years, the Center's overall productivity in releasing salaries and supplies through funded activities was at an all-time high. Figure 1 represents the 3-year moving average of external funding with the value of activations processed through the CMR for FY 2010-11 at approximately **\$1.8 million**. This represents nearly 53% of last year's external funding and is attributable to a record number of faculty retirements and resignations with several active grants moved to other universities. On a positive note, Center faculty and staff recorded a record amount of release time from external projects. 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**

<b>Performance Metric</b>	<b>FY 2008-09</b>	<b>FY 2009-10</b>	<b>FY 2010-11</b>
Faculty & Staff Release Time*	\$193,758	\$214,681	\$353,026
Graduate Student Stipend & Fees from External Sponsors	\$179,207	\$409,340	\$312,645
Percentage of GRA Support from External Sponsors	42%	53%	53%
Total “Soft Money” (F&A return, Testing income, GRA support, Equipment usage, and Release Time)	\$489,651	\$678,705	\$781,814

**CENTER FOR MANUFACTURING RESEARCH  
Tennessee Technological University  
Strategic Plan Update  
Goals and Benchmarks – FY 2010-11**

**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 strategies<sup>1</sup> for the 21<sup>st</sup> 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 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 the intelligent oversight and processing. The resultant

<sup>1</sup> \_ “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 21<sup>st</sup> 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.



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. Energy Materials and Devices for Energy Conversion and Storage
2. Energy Efficiency
3. Wireless Communications, Sensing, and Machine Learning
4. Digital Representation and Modeling for Intelligent Manufacturing

## 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%)

2010 – 11 projected progress - Increase of 10 basis points over baseline or 2 basis points increase over prior year. **Actual Progress = 17.3% GOAL EXCEEDED – last year = 13.3%**

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)

2010 – 11 projected progress - Increase of 25% over baseline on average monthly stipends of both Masters and Ph.D. students. **Actual Progress = \$1,194/mo for Masters and \$1,438 for Ph.D. – GOAL NOT MET; ~ 3.6% improvement year-over-year**

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)

2010 – 11 projected progress - Increase of 25% over baseline. **Actual Progress = \$781,814 – 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%)

2010 – 11 projected progress - Increase of 25 basis points over baseline. **Actual Progress = 53% – 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.

2010 – 11 projected progress - \$1,000,000 total investment by the end of cycle. **Actual Progress = \$213,656 for the year and a cumulative of \$2,013,707 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.

2010 – 11 projected progress - One (1) MRI proposal submitted. **Actual Progress = 1 MRI proposal to the National Science Foundation, Major Research Instrumentation – GOAL 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.

2010 – 11 projected progress - \$5,000 invested. **Actual Progress = \$40,348 – 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)

2010 – 11 projected progress - Increase of 25% over baseline **Actual Progress = \$1,831,872 – 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)

2010 – 11 projected progress - Increase of 25% over baseline **Actual Progress = \$8,062,641 – GOAL NOT MET**

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)

2010 – 11 projected progress - Increase of 25% over baseline **Actual Progress = \$48,349 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)

2010 – 11 projected progress - Increase of 25% over baseline **Actual Progress = \$118,526 – 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)

2010 – 11 projected progress - Increase of 25% over baseline **Actual Progress = Not Available at time of press**

**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)

2010 – 11 projected progress - Increase of 25% over baseline **Actual Progress = Not Available at time of press**

**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 2012.**

## Faculty, Staff and Student Accomplishments/Awards

### FY 2010 – 11

**Cynthia Rice-York**, Assistant Professor, Chemical Engineering (ChE), was awarded the 2011 Sigma Xi award at Tennessee Tech University for the best paper published in the previous fiscal year. The paper entitled, "Electrochemical Impedance Spectroscopy Detection of Saturation Level in a Frozen Polymer Electrolyte Membrane," was published in the December 2010 issue of the Journal of the Electrochemical Society. Dr. Rice-York along with co-authors Antonio Pistono (graduate student) and Vijayyasekaran Boovaragavan (Postdoctoral Research Associate) developed a modified electrochemical impedance spectroscopy (EIS) method to probe fundamental hydration properties in polymer electrolyte membrane fuel cells (PEMFCs) related to subzero cold-start phenomena.

## Scholarly Publications and Presentations

### FY 2010 – 11

CMR faculty and staff published six (6) journal publications, and thirty-two (32) national and international conference or invited presentations.

### **Kenneth R. Currie**

#### *Refereed Journals*

Ting, K. L., C. Xue, J. Wang, **K. Currie**, "Full Rotatability and Singularity of Six-Bar and Geared Five-Bar Linkages," *Journal of Mechanisms and Robotics* **2**, no. 1 (2010) pp. 011011-1~9.

#### *Reports*

Abdelrahman, M. A. and **Currie, K.R.**, "In-Situ, Real-Time Monitoring and Control of Mold Filling and Casting Processes – FINAL REPORT", December 2010.

**Currie, K.R.**, "APPI – Phase 4 Final Report," April 2011.

### **Robert Qiu**

#### *Refereed Journals*

Z. Chen, N. Guo, and **R. C. Qiu**, "Demonstration of real-time spectrum sensing for cognitive radio" (short paper), *IEEE Communications Letters*, vol. 14, no. 10, pp 915-917, October 2010.

### **Conference Presentations**

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

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

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

Z. Chen, N. Guo, and **R. C. Qiu**, "Demonstration of real-time spectrum sensing for cognitive radio," *Proceedings of IEEE Military Communications Conference (MILCOM 2010)*, San Jose, CA, November, 2010.

Zhen Hu, Nan Guo, **R.C. Qiu**, Jason Bonior, Lihyeh Liou, David Lin, Matthew Longbrake, Peter Buxa, Thomas Dalrymple, Seng Hong, Stephen Hary, James Tsui, "Design of Look-up Table Based Architecture for Wideband Beamforming," *2010 International Waveform Diversity and Design Conference*, Niagara Falls, Canada, August 08-13, 2010.

Zhen Hu, Nan Guo, **R. C. Qiu**, Jason Bonior, Lihyeh Liou, David Lin, Matthew Longbrake, Peter Buxa, Thomas Dalrymple, Stephen Hary, James Tsui, "Robust Wideband Beamforming," *IEEE National Aerospace and Electronics Conference*, Dayton, OH, July 14-16, 2010.

N. Guo, Y. Song, Z. Hu, P. Zhang, J. Q. Zhang and **R. C. Qiu**, "UWB Time Reversal: From Theory to Practice," *IEEE ICUWB 2010*, Nanjing, China, September 20-23, 2010.

Y. Song, N. Guo, Z. Hu, and **R. C. Qiu**, "FPGA Based UWB MISO Time-Reversal System Design and Implementation," *IEEE ICUWB 2010*, Nanjing, China, September 20-23, 2010.

P. Zhang and **R. C. Qiu**, "Wireless Tomography, Part III: Compressed Sensing for Ultra-wideband Signals," *IEEE 5th International Waveform Diversity & Design Conference*, Niagara Falls, Canada, August 8-13, 2010.

**R. C. Qiu**, Z. Hu, M. C. Wicks, S. Hou, L. Li, and J. L. Garry, "Wireless Tomography, Part II: A System Engineering Approach," *IEEE 5th International Waveform Diversity & Design Conference*, Niagara Falls, Canada, August 8-13, 2010.

**R. C. Qiu**, M. C. Wicks, L. Li, Z. Hu, S. Hou, P. Chen, and J. P. Browning, "Wireless Tomography, Part I: A Novel Approach to Remote Sensing," *IEEE 5th International Waveform Diversity & Design Conference*, Niagara Falls, Canada, August 8-13, 2010.

H. Li, R. Mao, L. Lai and **R. C. Qiu**, "Compressed Meter Reading for Delay-sensitive and Secure Load Report in Smart Grid," *IEEE SmartGridComm 2010*, Gaithersburg, MD, October 4-6, 2010.

H. Li, L. Lai and **R. C. Qiu**, "Communication Capacity Requirement for Reliable and Secure Meter Reading in Smart Grid," *IEEE SmartGridComm 2010*, Gaithersburg, MD, October 4-6, 2010.

H. Li and **R. C. Qiu**, "A Graphical Framework for Spectrum Modeling and Decision Making in Cognitive Radio Networks," *IEEE GLOBECOM 2010*, Miami, FL, December 6-10, 2010.

**R. C. Qiu**, Z. Chen, N. Guo, Y. Song, P. Zhang, H. Li and L. Lai, "Towards A Real-time Cognitive Radio Network Testbed: Architecture, Hardware Platform, and Application to Smart Grid," invited paper, *Fifth IEEE Workshop on Networking Technologies for Software-Defined Radio and White Space*, Boston, MA, June 21, 2010.

## **Kwun-Lon Ting**

### ***Refereed Journals***

**Ting, K. L.**, C. Xue, J. Wang, K. Currie, "Full Rotatability and Singularity of Six-Bar and Geared Five-Bar Linkages," *Journal of Mechanisms and Robotics* **2**, no. 1 (2010) pp. 011011-1~9.

J. Wang, **Ting, K. L.**, C. Xue, "Discriminant method for the mobility identification of Single Degree-of-freedom double-loop Linkages," *Mechanism and Machine Theory*, Volume 45, Issue 5, May 2010, Pages 740-755

Ma, W., D. Wang and **Ting, K. L.**, "Characteristic Matrices and Conceptual Design of Hydraulic Systems" *Journal of Mechanical Design*, Vol. 132, 031005 (2010) (13 pages)



## Cynthia Rice-York

### *Refereed Journals & Conference Papers*

Pistono, A., **C.A. Rice-York**, and V. Boovaragavan, "Electrochemical Impedance Spectroscopy Detection of Saturation Level in a Frozen Polymer Electrolyte Membrane Fuel Cell" *Journal of The Electrochemical Society*, **2011**, 158, B233-B238.

Abdelrahman, M.; **Rice-York, C.A.**; York, J.D.; Sircy, R.; Stowers, C. ASEE, "Two Legacy Cycle modules in Math and Chemistry for High School Students based on Fuel Cell Technology," ASEE Annual Conference & Exposition, Louisville, KY, June 20 – 23, 2010, AC 2010-778.

### *Conference Presentations*

A.S. Bauskar, **C. Rice- York**, 'Influence of a Pore-former in the performance of a Direct Formic Acid Fuel Cell', AICHE Annual Meeting, Salt lake City, UT, Nov. 8th, 2010.

S. Beravelli, **C. Rice-York**, J.D.A. S. Bauskar, 'Influence of Sulfated Zirconia-Doped Nafion<sup>TM</sup> Composite Membranes and Catalyst Layers on Direct Methanol Fuel Cell Performance', AICHE Annual Meeting, Salt lake City, UT, Nov. 11th, 2010.

J. D. York, S. Beravelli, **C. A. Rice-York**, S. A. Gold, 'Direct Methanol Fuel Cell Performance Enhancement with Segregated Sulfated Zirconia-Nafion<sup>TM</sup> Composite Membranes', AICHE Annual Meeting, Salt lake City, UT, Nov. 9th, 2010

**C.A. Rice-York**, A. Pistono, 'Water Mobility in Polymer Electrolyte Membrane Fuel Cells During Sub-zero Isothermal Cold-Starts' 218th ECS Meeting, Las Vegas, NV, Oct. 13th, 2010.

S. Beravelli, **C. Rice-York**, J.D. York, A. S.Bauskar, E. Hannah, 'Sulfated Zirconia/Nafion Composite Membranes for improved performance of DMFCs', 218th ECS Meeting, Las Vegas, NV, Oct. 13th, 2010.

A.S. Bauskar, **C. Rice-York**, 'Influence of a Pore-former in the performance of a DFAFC', 218th ECS Meeting, Las Vegas, NV, Oct. 13th, 2010.

A.S. Bauskar, **C. Rice-York**, 'Influence of a Pore-former in the performance of a DFAFC', Gordon Research Conference, Bryant University, Smithfield, RI, Aug. 4th, 2010

S. Beravelli, **C. Rice-York**, J.D. York, A. S.Bauskar, E. Hannah, 'Influence of Sulfated Zirconia-doped Nafion composite membrane on Direct Methanol Fuel Cell performance', Gordon Research Conference, Bryant University, Smithfield, RI, Aug. 3rd, 2010.

D. Betancourt, **C. Rice-York**, 'Degradation of PEM Fuel Cell Catalyst Due to automotive Potential Cycling,' Northeast Regional Meeting of the American Chemical Society, Potsdam, NY, Jun 5-9, 2010.

D. Betancourt, **C. Rice-York**, 'Degradation of PEM Fuel Cell Catalyst Due to Start/Stop Automotive Voltage Cycling,' TTU Student Research Day, Cookeville, TN, Apr. 15<sup>th</sup>, 2010.

D. Betancourt, **C. Rice-York**, 'EQCM Study of PEM Fuel Cell Catalyst Degradation Due to Voltage Cycling,' TTU Student Research Day, Cookeville, TN, Apr. 15<sup>th</sup>, 2010.

S. Beravelli, **C. Rice-York**, 'Effect of Sulfated-Zirconia Doped Nafion Composite Membrane in a DMFC' TTU Student Research Day, Cookeville, TN, Apr. 15<sup>th</sup>, 2010.

A. Bauskar, **C. Rice-York**, 'Formic Acid Oxidation on Pure and Bismuth-Modified Platinum,' TTU Student Research Day, Cookeville, TN, Apr. 15<sup>th</sup>, 2010.

E. Hannah, H. Orr, **C. Rice-York**, 'AIChE Regional ChemE Car Team—Direct Formic Acid Fuel Cell Car,' TTU Student Research Day, Cookeville, TN, Apr. 15<sup>th</sup>, 2010.

E. Hannah, D. Martin, P. Moody, **C. Rice-York**, 'Catalyst for Direct Formic Acid Fuel Cells' TTU Student Research Day, Cookeville, TN, Apr. 15<sup>th</sup>, 2010.

### ***Invited Presentations***

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

**C. Rice-York**, "PEM Fuel Cell for Automotive Subzero Cold-Starts-Supercooled Water Mobility and Ice Formation," American Chemical Society North East Region Meeting, June 2-5, 2010.

### ***Patents***

Kameswaran, S.; Zaffou, R.; Suzuki, T.; Hagans, P.L.; Cipollini, N.E.; Perry, M.L.; **York, C.A.** "Proton exchange membrane fuel cell catalyst and diffusion layer structure for increased water storage capacity and improved cold start performance" WO 2010132050, Nov 18th, 2010.

Patterson, T.W.; Resnick, G.; Balliet, R.J.; Gupta, N.; **York, C.A.**; Reiser, C.A.; Darling, R.M.; Marzullo, J.M.; Meyers, J.P.; "Tailoring liquid water permeability of diffusion layers in fuel cell stacks." WO 2009075861, Dec 9th, 2010.

## Nan “Terry” Guo

### *Journal Publications*

Z. Chen, **N. Guo**, and R. C. Qiu, "Demonstration of real-time spectrum sensing for cognitive radio" (short paper), *IEEE Communications Letters*, vol. 14, no. 10, pp 915-917, October 2010.

### *Conference Presentations*

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

Z. Chen, **N. Guo**, and R. C. Qiu, "Demonstration of real-time spectrum sensing for cognitive radio," *Proceedings of IEEE Military Communications Conference (MILCOM 2010)*, San Jose, CA, November, 2010.

Zhen Hu, **Nan Guo**, R.C. Qiu, Jason Bonior, Lihyeh Liou, David Lin, Matthew Longbrake, Peter Buxa, Thomas Dalrymple, Seng Hong, Stephen Hary, James Tsui, "Design of Look-up Table Based Architecture for Wideband Beamforming," *2010 International Waveform Diversity and Design Conference*, Niagara Falls, Canada, August 08-13, 2010.

Zhen Hu, **Nan Guo**, R. C. Qiu, Jason Bonior, Lihyeh Liou, David Lin, Matthew Longbrake, Peter Buxa, Thomas Dalrymple, Stephen Hary, James Tsui, "Robust Wideband Beamforming," *IEEE National Aerospace and Electronics Conference*, Dayton, OH, July 14-16, 2010.

**N. Guo**, Y. Song, Z. Hu, P. Zhang, J. Q. Zhang and R. C. Qiu, "UWB Time Reversal: From Theory to Practice," *IEEE ICUWB 2010*, Nanjing, China, September 20-23, 2010.

Y. Song, **N. Guo**, Z. Hu, and R. C. Qiu, "FPGA Based UWB MISO Time-Reversal System Design and Implementation," *IEEE ICUWB 2010*, Nanjing, China, September 20-23, 2010.

R. C. Qiu, Z. Chen, **N. Guo**, Y. Song, P. Zhang, H. Li and L. Lai, "Towards A Real-time Cognitive Radio Network Testbed: Architecture, Hardware Platform, and Application to Smart Grid," invited paper, *Fifth IEEE Workshop on Networking Technologies for Software-Defined Radio and White Space*, Boston, MA, June 21, 2010.

# Faculty Research Grants

**FY 2010 – 11**

<b>Center for Manufacturing Research Project Summary</b>					
<b>Project Description/ Source/ Acct. No.</b>		<b>Principal Investigators</b>	<b>Activated Amount</b>	<b>Project Duration</b>	<b>Estimated 12-month Expenses</b>
1.	Manufacturing Center Testing & Design - FY 2010-11 Various Industries Account #: 5-38585	Kenneth Currie	\$48,349	7/1/2010 – 6/30/2011	\$61,658
2.	University of Tennessee Center for Industrial Services (UT-CIS) – FY 2010-11 UT-CIS Account #: 5-33526	Kenneth Currie	\$80,000	7/1/2010 – 6/30/2011	\$66,975
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	1/01/2011 – 08/31/2011	\$40,000
4.	Tennessee 3-Star Industrial Assessment Center - Amendment 13 – Award DE-FC36-06GO16079 U.S. Department of Energy Account #: 5-32285	Glenn Cunningham Kenneth Currie	\$40,000	4/1/2011 – 08/31/2011	\$13,491
5.	From Art to STEM: A Creative Journey of Discovery and Transformational Project for Nashville School Students Alignment Nashville Account #: 5-39361	Ismail Fidan	\$66,706	3/1/2011 – 2/28/2012	\$66,706
6.	Collaborative Research: Wideband Cognitive Radio Communication Systems Modeling, Algorithms and Testbed – Award ECCS-0901420 Year 2 of 3 National Science Foundation Account #: 5-31265	Robert Qiu	\$55,359	8/01/2010 – 7/31/2011	\$32,930
7.	RUI: Controlling the Properties and Performance of Concrete Using Computer-Aided Molecular Design Award CMMI-0928539; Year 2 of 3 National Science Foundation Account #: 5-31267	Joseph Biernacki Donald Visco	\$103,430	8/1/2010 – 7/31/2011	\$64,300

<b>Center for Manufacturing Research Project Summary</b>					
<b>Project Description/ Source/ Acct. No.</b>		<b>Principal Investigators</b>	<b>Activated Amount</b>	<b>Project Duration</b>	<b>Estimated 12-month Expenses</b>
8.	Detecting Anomalies in Shipping Data Using a Graph-Based Approach – Contract HSHQDC-10-C-0212  Department of Homeland Security Account #: 5-32391	William Eberle	\$170,000	9/21/2010– 9/20/2011	\$170,000
9.	Effect of Thin Al-rich Coatings on Mechanical Integrity of Coated Austenitic and Ni-base Alloys Modification #3 Subcontract 4000071336  Oak Ridge National Laboratory Account #: 5-39342	Ying Zhang	\$10,000	8/1/2010 – 7/31/2011	\$10,000
10.	Aluminide Coatings to Protect High-Temperature Cast Stainless Steel CF8C-Plus – Year 2 of 2 Subcontract 4000087522  Oak Ridge National Laboratory Account #: 5-31655	Ying Zhang	\$19,198	11/1/2010 – 9/30/2011	\$19,198
11.	Cognitive Radio Institute – Award No. N00014-11-1-0006  Office of Naval Research Account #: 5-32346	Robert Qiu  Kenneth Currie	\$760,000	11/02/2010 – 11/01/2011	\$760,000
12.	Components and Devices for Energy Storage and Conversion  University of Tennessee (via NSF Award EPS-10040830) Account #: 5-31228	Cynthia Rice- York	\$165,331	10/07/2010 – 10/07/2011	\$165,331
13.	Polymer Microcapsule Pesticide Product Imaging and UV Degradation  Syngenta Corporation Account #: 5-35218	Holly Stretz	\$19,974	8/1/2010 – 7/31/2011	\$19,974

<b>Center for Manufacturing Research Project Summary</b>					
<b>Project Description/ Source/ Acct. No.</b>		<b>Principal Investigators</b>	<b>Activated Amount</b>	<b>Project Duration</b>	<b>Estimated 12-month Expenses</b>
14.	Alumina Forming Coatings for Power Generation Applications – Modification #4 – Subcontract 4000071336 Oak Ridge National Laboratory Account #: 5-39342	Ying Zhang	\$10,000	8/01/2010 – 07/31/2011	\$10,000
15.	Southeast Industrial Energy Alliance – Year 1 of 3 – CEFA Contract # SIEA 2010-102 Georgia Environmental Facilities Authority Account #: 5-39337	Kenneth Currie	\$84,234	7/1/2010 – 6/30/2011	\$72,234
16.	Automatic Dynamic Resource-Aware Runtime System Sandia National Laboratories, California Account #: 5-32271	Stephen Scott	\$75,000	2/25/2011 – 9/30/2011	\$75,000
17.	Development of a Regional Assessment/Implementation SEN Delivery Partnership System II West Virginia University Account #: 5-31691	Stephen Idem	\$27,790	12/01/2010 – 10/31/2011	\$27,790
18.	REU Supplement to NSF Award CMMI-0928539 – Controlling the Properties and Performance of Concrete Using Computer-Aided Molecular Design for 2011-2012 National Science Foundation Account #: 5-31267	Joseph Biernacki	\$6,000	5/15/2011 – 5/14/2012	\$6,000
19.	Evaluation and Design of Advanced 3-dof Gimbal for In-Space Applications – Allotment #1 – Contract TUI-10-DA-001 (PRIME W9113M-10-C-0075) Tethers Unlimited, Inc. Account #: 5-35256	Stephen Canfield	\$50,501	10/15/2010– 8/31/2011	\$50,501
<b>TOTALS</b>			<b>\$1,831,872</b>		<b>\$1,732,088</b>

## Professional and Community Service

The CMR is completing its fifth year as a Department of Energy (DOE) funded Industrial Assessment Center (IAC). The DOE has identified 26 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**.

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 (more than \$48,000) with 36 separate testing projects. This increase in testing is reflective of the high quality of service and the expanded range of available testing laboratories through recent equipment acquisitions.

**Table 2. IAC Savings by \$ and Energy Metrics**

	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%

**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 2010-11 Actual			FY 2011-12 Proposed			FY 2012-13 Requested		
	Matching	Appropriations	Total	Matching	Appropriations	Total	Matching	Appropriations	Total
Expenditures									
<b>Salaries</b>									
Faculty	287,624	231,046	518,670	250,000	288,705	538,705	250,000	295,320	545,320
Other Professional	166,990	348,372	515,362	175,000	592,480	767,480	190,000	560,010	750,010
Clerical/ Supporting	0	56,814	56,814	10,000	59,750	69,750	10,000	61,670	71,670
Assistantships	204,000	186,761	390,761	175,000	176,052	351,052	225,000	150,000	375,000
Hourly Students	63,338	82,827	146,165	57,200	71,085	128,285	65,000	65,000	130,000
<b>Total Salaries</b>	<b>721,952</b>	<b>905,820</b>	<b>1,627,772</b>	<b>667,200</b>	<b>1,188,072</b>	<b>1,855,272</b>	<b>740,000</b>	<b>1,132,000</b>	<b>1,872,000</b>
Fringe Benefits	123,406	240,944	364,350	120,000	240,384	360,384	140,000	194,200	334,200
<b>Total Personnel</b>	<b>845,358</b>	<b>1,146,764</b>	<b>1,992,122</b>	<b>787,200</b>	<b>1,428,456</b>	<b>2,215,656</b>	<b>880,000</b>	<b>1,326,200</b>	<b>2,206,200</b>
<b>Non-Personnel</b>									
Travel	53,826	24,603	78,429	65,000	26,861	91,861	50,000	20,000	70,000
Software	7,955	4,422	12,377	5,000	500	5,500	5,000	500	5,500
Books & Journals	5,586	0	5,586	8,000	0	8,000	1,000	0	1,000
Other Supplies	221,472	81,650	303,122	200,000	72,113	272,113	250,000	65,000	315,000
Equipment	145,578	37,925	183,503	368,742	36,000	404,742	584,000	0	584,000
Maintenance	0	0	0	5,000	500	5,500	25,000	500	25,500
Scholarships	104,411	97,945	202,356	95,000	97,314	192,314	105,000	90,000	195,000
Consultants/Subcontracts	130,395	0	130,395	125,000	500	125,500	100,000	0	100,000
Renovation	0	0	0	0	0	0	0	0	0
Other (Seminars/Conf.)	0	0	0	0	500	500	0	500	500
<b>Total Non-Personnel</b>	<b>669,223</b>	<b>246,545</b>	<b>915,768</b>	<b>871,742</b>	<b>234,288</b>	<b>1,106,030</b>	<b>1,120,000</b>	<b>176,500</b>	<b>1,296,500</b>
<b>GRAND TOTAL</b>	<b>1,514,581</b>	<b>1,393,309</b>	<b>2,907,890</b>	<b>1,658,942</b>	<b>1,662,744</b>	<b>3,321,686</b>	<b>2,000,000</b>	<b>1,502,700</b>	<b>3,502,700</b>
<b>Revenue</b>									
New State Appropriation	0	1,512,400	1,512,400	0	1,458,900	1,458,900	0	1,502,700	1,502,700
Plus MOE Stimulus Funds	0	44,000	44,000	0	0	0	0	0	0
Adjusted Appropriations	0	1,556,400	1,556,400	0	1,458,900	1,458,900	0	1,502,700	1,502,700
Carryover State Appropriation	0	40,753	40,753	0	203,844	203,844	0	0	0
New Matching Funds	1,615,089	0	1,615,089	1,557,020	0	1,557,020	2,000,000	0	2,000,000
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	1,414	0	1,414	101,922	0	101,922	0	0	0
<b>Total Revenue</b>	<b>1,616,503</b>	<b>1,597,153</b>	<b>3,213,656</b>	<b>1,658,942</b>	<b>1,662,744</b>	<b>3,321,686</b>	<b>2,000,000</b>	<b>1,502,700</b>	<b>3,502,700</b>

## **FY 2012-13 Budget Request and Justification**

The CMR is requesting a 3% increase in the FY 2012-13 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.