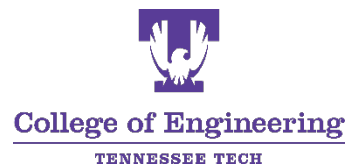
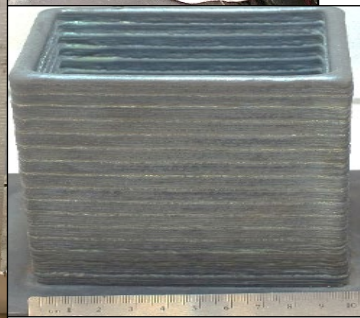
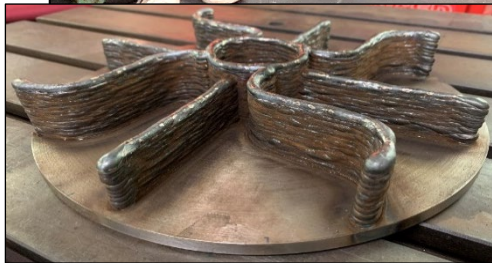


ANNUAL REPORT FY 2020—2021

Center for Manufacturing Research

College of Engineering



About the Cover

Investigations into the Design Rules for the Control of Wire Arc Additive Manufacturing

Sponsor: National Science Foundation (NSF)

Principal Investigator: Duckbong Kim, Ph.D., CMR Faculty Associate

This project advances the understanding of defect formation in wire arc additive manufacturing, leading to improved processing and greater process control. This research addresses surface waviness and nonuniform wall thickness challenges in wire arc additive manufacturing, making it acceptable for many U.S. industries, including aerospace, defense, and automotive, and thereby benefiting the nation's economy and well-being. Wire arc additive manufacturing uses a welding arc as the energy source in making three-dimensional objects with high throughput. This process can be easily integrated with existing computer-numerical-control routers, or robot arms. Thus, the knowledge and methodology developed through this project can be directly transferred to small- and medium-sized enterprises interested in making or repairing metallic parts. Additionally, this project develops the professional skills of K-12, undergraduate, and graduate students, including women and underrepresented minorities, by training them through a unique set of integrated education and multidisciplinary research opportunities in the new area of wire arc additive manufacturing and data analytics. Accordingly, students are familiarized with emerging technology-intensive manufacturing and data science disciplines, thereby preparing a future workforce equipped with these new skills and knowledge.

Pictured (left to right): Yixing Wang (ME), Dr. Duckbong Kim (MET), Saiful Islam (ME), Dr. Gijeong Seo (visiting scholar), Juhong Lee (visiting scholar), Jadhav Sainand (ME), Rumman Ahsan (ME)

Alloys made via WAAM by Dr. Kim's group (left to right): mild steel, H13 tool steel, and nickel-based alloy Inconel 625.

Center for Manufacturing Research

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Table of Contents

Faculty, Staff , External Advisory Board and Faculty Associate List	1
Executive Summary	3
Center Research, Education and Outreach Areas	4
Selected Highlights from FY 2020 - 2021	4
Center Activities	12
Faculty, Staff and Student Accomplishments and Awards	16
Select 2020 – 21 CMR-Supported Alumni	18
Publications	20
External Activations	26
Schedule 7	30
FY 2022 – 2023 Budget Request and Justification	31
Supporting Materials	32
CMR Supported Graduate Student Degrees Awarded – Masters	33
CMR Supported Graduate Student Degrees Awarded – PhD	34
CMR Supported Graduate Students from State Appropriations	35
CMR Supported Graduate Students from External Funds	37
External Funding – Proposals Submitted	39

Tennessee Technological University Center for Manufacturing Research Annual Report – FY 2020 – 2021

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.”

The Center for Manufacturing Research (CMR) at TTU was established in 1984 and named a THEC Established Center of Excellence in 1990.

Director

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CMR External Advisory Board

Dr. Abhijeet Borole – Electro-Active Technologies, Knoxville, TN
Thomas Lawson – Nissan North America, Decherd, TN
Brad Long – Cummins Filtration, Cookeville, TN
Jonathan Miller – Aerojet Ordnance Tennessee, Jonesborough, TN
Dr. Richard Mu - TSU Interdisciplinary Graduate Engineering Research Institute, Tennessee State University, Nashville, TN
David Nesbitt – Applied Thermal Coatings, Chattanooga, TN
Robert Wiseman – Lochinvar LLC, Lebanon, TN

CMR Faculty and Staff

Dr. Cynthia Rice, Associate Prof., ChE
Dr. Kwun-Lon Ting, Professor, ME
Brian Bates, R&D Engineer
David Chesson, Research Associate (part-time, temporary)
Michelle Davis, Outreach Coordinator
Dr. Nan (Terry) Guo, R&D Engineer
E. Wayne Hawkins, Material Science Lab Manager
Suzanne Henry, Center Manager
Giovanni Mainardi Neto, R&D Engineer, (part-time, temporary)
Tammy Martin, Administrative Associate III (part-time, temporary)
Anysa Milum, Financial Associate VI
Mahdi Mohammedzadeh, Research Associate, (part-time, temporary)
Rob Reab, IT Systems Administrator (part-time, temporary)
Phyllis Stallion, Administrative Associate V
Darlene Wiegand, Financial Analyst (part-time, temporary)

CMR Faculty Associates*

Dr. Mohammad Albakri, ME
Dr. Ali Alouani, ECE
Dr. Steven Anton, ME
Dr. Pedro E. Arce, ChE
Dr. Andrea Arce-Trigatti, Curriculum & Instruction
Dr. Indranil Bhattacharya, ECE
Dr. Joseph J. Biernacki, ChE
Dr. J. W. Bruce, ECE
Dr. Stephen Canfield, ME
Dr. Pinggen Chen, ME
Dr. George Chitiyo, Curriculum & Instruction
Dr. Glenn Cunningham, ME
Dr. William Eberle, CS
Dr. Ismail Fidan, MET
Dr. Sheikh Ghafoor, CS
Dr. Manaak Gupta, CS
Dr. Syed Rafay Hasan, ECE
Dr. Ada Haynes, Sociology & Political Science
Dr. Stephen Idem, ME
Dr. Wayne Johnson, ECE
Dr. Stephanie Jorgensen, ChE
Dr. Duckbong Kim, MET
Dr. Ethan Languri, ME
Dr. Allen MacKenzie, ECE
Dr. Mohamed Mahmoud, ECE
Dr. Vahid Motevalli, College of Engineering, ME
Dr. Joseph Ojo, ECE
Dr. Andy Pardue, ME
Dr. Avinash Paruchuri, MET
Dr. Darek Potter, STEM
Dr. Mohan Rao, ME
Dr. Rory Roberts, ME
Dr. Jonathan (Robby) Sanders, ChE
Dr. Susmit Shannigrahi, CS
Dr. Ambareen Siraj, CS
Dr. Holly Stretz, ChE
Dr. Doug Talbert, CS
Dr. John Tester, GBE
Dr. Dennis Ulybyshev, CS
Dr. Ahmedreza Vaselbehagh, ME
Dr. L. (Fred) Vondra, MET
Dr. Chris Wilson, GBE, ME
Dr. Dale Wilson, ME
Dr. Jiahong (John) Zhu, ME

* CMR Faculty Associates are TTU faculty members who have been working with the CMR through serving as principal investigators, co-principal investigators or other senior personnel on externally-funded projects, or submitting proposals to seek external funding.

EXECUTIVE SUMMARY

2020 is the year marked by intense disruption due to the pandemic, and its ripple effect reminds us of the importance of resilience and reliability of U.S. manufacturing and critical supply chains. In the midst of a global crisis, we saw the increased collaboration among government, academia and industry to accelerate the development and deployment of new manufacturing technologies. As an example, additive manufacturing (AM) was used to help address shortages in medical supplies. Tennessee Tech faculty and students joined other campuses across the state to produce face shields for health care workers using 3D printing. The team led by Dr. Ismail Fidan fabricated over 3,000 headbands for assembly of face shields.

In FY20-21, research proposals submitted through CMR increased 130% over the previous year and reached the second highest level since the Center's inception in 1984. CMR Faculty Associates secured competitive grants with total activation of \$2,185,133 for externally-funded projects. In addition to 3D printing of polymers and composites, TTU faculty are actively working on 3D metal printing using robotic wire arc additive manufacturing (WAAM). Dr. Duckbong Kim received an NSF award to tackle the challenges in WAAM and make its use more justifiable for U.S. industries, including aerospace, defense and automotive. This project also helps develop the professional skills of K-12, undergraduate, and graduate students, including women and underrepresented minorities. A high-performance gas atomizer procured through a Defense University Research Instrumentation Program (DURIP) grant was installed at CMR. The first-of-a-kind atomizer among U.S. universities will give TTU the unique ability to cleanly melt and atomize a wide range of alloys and enhance the university's AM research capabilities.

To advance technologies and optimize efficiency, resiliency and sustainability across the full manufacturing life cycle, CMR Faculty Associates have focused their efforts in the following areas: research and demonstration of electric vehicles, development of more efficient power generation systems, and integration of renewable energy sources for next-generation onboard power of hypersonic vehicles and naval ships. In addition to the on-going project funded by Department of Energy (DOE), Dr. Pingen Chen received a second DOE grant (through the University of Texas at Austin) to demonstrate medium-duty electrified trucks in both Texas and Tennessee. Dr. Joseph Olorunfemi Ojo received a 3-year grant from the Office of Naval Research to develop an integrated ship-board power system for more efficient energy conversion, agile control and reduced weight and volume. Dr. Rory Roberts received several grants from different funding agencies to develop hypersonic on-board power and thermal management systems by integrating solid oxide fuel cells into the power supplies. Awarded by the DOE Advanced Research Projects Agency-Energy's (ARPA-E) program, Dr. Roberts and his students are working with Hyper Tech Research to develop and demonstrate a high-efficiency and high-power density integrated electric propulsion motor, drive, and thermal management system for future hybrid electric, single-aisle passenger aircraft. Due to the significant progress Dr. Ali Alouani's team has made in designing the intelligent robot for the Tennessee Valley Authority (TVA) substation inspection, TVA extended their three-year project to four years with additional funding.

As a state-funded research center, the CMR continues to support manufacturing industry in Tennessee. A new External Advisory Board (EAB) was formed and the first meeting was held in March 2021. The EAB, comprised of leaders and experts from industry and academia, will provide guidance, advice and direction for CMR's activities and help the Center develop strategic initiatives. The Industrial Assessment Center (IAC) led by Dr. Glenn Cunningham and Dr. Ethan Languri provided solutions and assistance in energy saving and waste reduction to small- and medium-sized manufacturers across the State. CMR Faculty Associates have also been dedicated to teaching and training next-generation manufacturing workforce. In FY20-21, the CMR supported a total of 41 graduate students, 27 Ph.D. and 14 M.S. students.

Center Research, Education and Outreach Areas

Digital Design and Manufacturing including (1) additive manufacturing, (2) advanced robotics and controls, and (3) cybersecurity in manufacturing.

Sustainable Materials and Manufacturing including (1) materials processing and modeling and (2) energy conversion / storage materials and devices.

Industry Support provides Tennessee manufacturers with technical expertise in problem-solving challenges faced in materials, design, testing, and processes.

Education and Outreach efforts enhance the Tennessee workforce development and outreach in the CMR's research areas in addition to such other activities as energy efficiency, waste reduction, and productivity improvements.

Selected Highlights from FY 2020 – 2021

External Funding Highlights

Twenty-three different research projects were funded for a total of \$2,185,133 from various funding agencies (i.e., National Science Foundation, Department of Energy, Tennessee Valley Authority).

CMR's new matching funds for the past FY were \$1,781,500. This amount excludes \$406,684 of indirect costs associated with this year's funded projects.

Thirty-six research proposals totaling \$16,384,473 were submitted by CMR faculty and faculty associates.

CMR supported 41 graduate students during the past FY. Fourteen M.S. students and 27 Ph.D. students were funded from both State appropriations and external funding received by faculty. Specifically, external grants funded nine of the M.S. students and 15 of the Ph.D. students. Thus, 59% of CMR graduate students supported was from external funding. Among the graduate students funded by CMR, three M.S. and three Ph.D. students were from underrepresented minorities.

Seven M.S. students and three Ph.D. students supported by CMR received their degrees during FY 2020-2021.

CMR supported a total of 50 undergraduate students during this past fiscal year from both State Appropriations and externally funded projects.

Table 1. Summary of CMR Accomplishments

	FY 15-16	FY 16-17	FY 17-18	FY 18-19	FY 19-20	FY 20-21
Total External Activations	\$2,127,390	\$2,628,183	\$2,242,209	\$2,090,724	\$2,411,429	\$2,185,133
Number of Graduate Students Supported by External Funding and State Appropriations	55	55	46	33	36	41
Percentage of Graduate Students Supported by External Funding	60%	49%	67%	55%	53%	59%
Number of Undergraduate Students Supported by External Funding and State Appropriations	67	69	53	46	35	50

Table 1 summarizes CMR accomplishments in the past six years. A brief description of some of these funded projects can be found in the “Research Highlights” on pages 7-11.

The Center’s annual external activations in the past 10 years are presented in Figure 1. The proposals submitted by the CMR Faculty Associates in the past 10 years are shown in Figure 2.

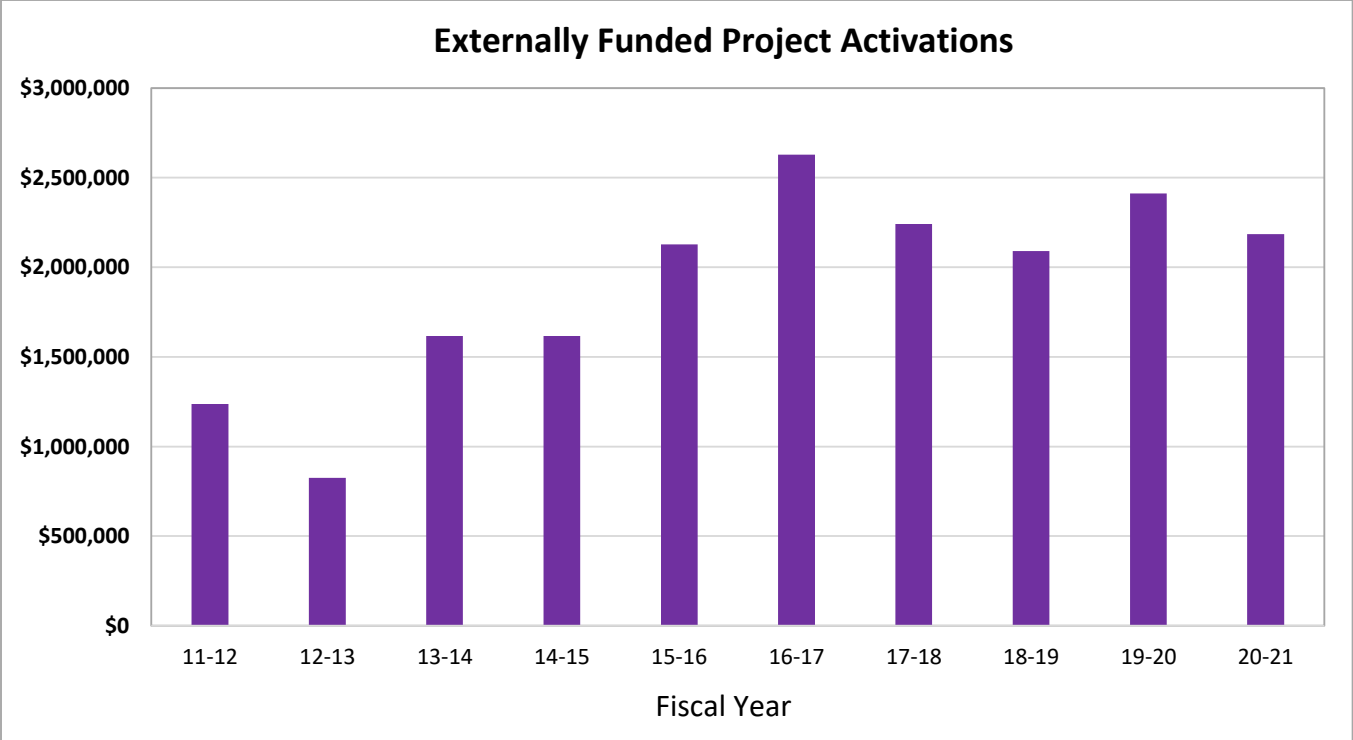


Figure 1 – Externally Funded Activations in Last 10 Years

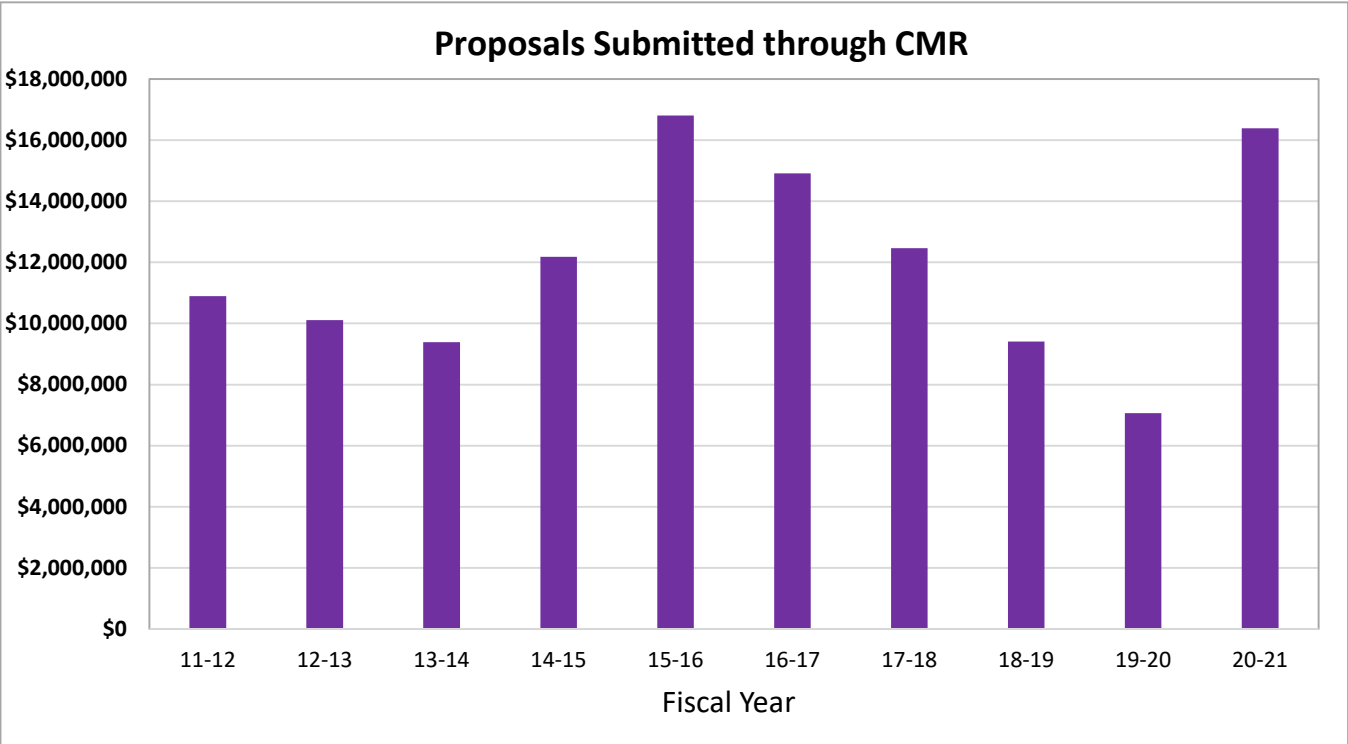


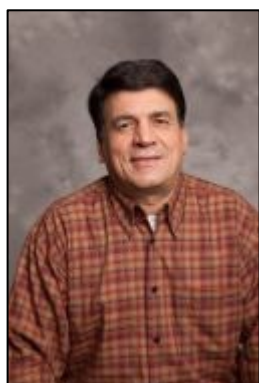
Figure 2 – Proposal Submitted through CMR in Last 10 Years

Table 2 shows various sources of external revenues for the past six years that were used to “release” or “free up” State appropriations for other strategic investment areas.

Table 2. Salary and Supplies Released by External Funding

Performance Metrics	FY 15-16	FY 16-17	FY 17-18	FY 18-19	FY 19-20	FY 20-21
CMR faculty and staff release time	\$128,231	\$142,801	\$101,464	\$86,717	\$129,844	\$155,410
Graduate student stipend and fees from external sponsors	\$282,994	\$481,254	\$428,579	\$287,144	\$157,179	\$294,022
Total of income resources (F&A return, testing income, GRA support, equipment usage, and release time)	\$552,393	\$796,950	\$614,388	\$412,454	\$304,220	\$472,841

Research Highlights



Dr. Ali Alouani, CMR Faculty Associate, was awarded \$173,000 from the Tennessee Valley Authority to design and build an Intelligent Robot for TVA Substation Inspection. The total four-year grant is \$647,265. The objective of the TTU group for this research is to design an intelligent robot to collect relevant data while autonomously traveling across a substation for the TVA. The robot automatically communicates pertinent data to a maintenance team/control center/operator via a dashboard. Furthermore, the robot has onboard intelligence and learning capabilities, utilizing sensors data fusion to detect abnormal patterns and alert the appropriate individual/group in real-time. It will also detect visible wear and tear of a piece of equipment in the substation by analyzing acquired images. The robot is to be utilized in different substations of different sizes and topologies.

Dr. Pinggen Chen, CMR Faculty Associate, received a three-year award totaling \$330,399 + \$498,447 cost-share (Year 1 funding: \$86,319) for the project: Medium-duty eTruck: Pilot Electrified Fleets in Urban and Regional Applications from DOE via the University of Texas at Austin. TTU will be leading a team for medium-duty electric truck (eTruck) demonstration in Tennessee. The objective of this project is to demonstrate an alternative fuel or advanced technology fleet of five or fewer vehicles and supporting infrastructure in communities, fleets, or areas that have no or little experience with these technologies. The testbed will be used to evaluate the

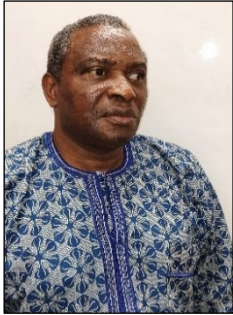


performance of medium-duty electric trucks in various applications by a diverse range of truck fleet owners. The project will help potential fleet owners gain necessary electric truck knowledge and experience to make informed decisions in medium-duty electric truck adoption. The project will collect detailed electric truck fleet operation and use data to analyze the challenges and needs associated with the use of EVs in medium-duty trucking fleets across broad range of geographical locations.

Dr. Pingen Chen was awarded \$155,133 for Year 2 of 3 (Total three-year funding: DOE share \$ 779,823 + cost share \$779,863) from the Department of Energy for “Developing an Electric Vehicle Demonstration Testbed in the Upper Cumberland Region of Tennessee, an Economy Distressed Rural Region”. This project will create a proof-of-concept demonstration testbed for electric vehicles (EVs) and charging infrastructures in the Upper Cumberland region. Comprehensive data will be collected and analyzed to report the operation cost, issues and performance of EV to help potential fleet owners and the public at large make informed decisions in EV adoption for rural areas before making significant financial investment.

CMR Faculty Associates Dr. Syed Hasan and Dr. Mohamed Mahmoud continued their three-year award from NSF to host the Research Experiences for Undergraduates (REU) Site – Secure and Privacy-Preserving Cyber Physical Systems at Tennessee Tech University during the summer of 2021. The 2020 REU program was not held due to the pandemic. This REU program is focused on research related to security and privacy preservation in smart cities infrastructures, including smart power grid and smart traffic management.





Dr. Joseph Olorunfemi Ojo, CMR Faculty Associate, received a three year award of \$503,954 (Year 1 funding: \$125,001) from the Office of Naval Research for Year 1 of the project “Control of Modular Multi-Dual Active Bridge Converters for Integrated Ship-Board Power System. Stand-alone power systems such as those found in Naval and cruise ships and electric aircrafts are being developed in large power range to meet increasing on-board power demands. With the need for greater availability and security, renewable energy and energy storages sources are increasing added to the fossil-based energy source. The research proposes and develops a promising integrated power system which nicely integrates diverse sources and delivers a significantly high efficient energy conversion process, agile control and reduced weight and volume using a high frequency switching technique and advanced control scheme.



Dr. Cynthia Rice, CMR Faculty Associate, was awarded a Summer Faculty Fellowship through the Office of Naval Research to build upon her previous experimental fuel cell work using an electrochemical microbalance to assess real-time mass changes in batteries under potentiostatic control. This insight into real-time changes in materials as a function of the state-of-charge can help attain the research goals of improving durability issues which affect lithium-ion batteries.



Dr. Rory Roberts, CMR Faculty Associate, was awarded \$500,000 (Year 1 funding \$150,000) from the Air Force Small Business Technology Transfer Program via Special Power Forces for the project: Hypersonic Onboard Power and Thermal Management System. Hypersonic vehicles offer promise as a platform to support traveling worldwide. However, hypersonic vehicles lack the ability to produce onboard power with traditional generators due to their use of supersonic combusting ramjets (scramjets), which do not have rotating shafts from which power can be extracted. Therefore, hypersonic vehicles lack significant electrical power production for supporting advanced electronics, electric actuators and weapons. Hypersonic vehicles require extensive thermal management systems as well. Electric power production by APUs can be derived from many different technologies, including internal combustion engines, gas turbines, fuel cells, batteries, thermoelectric, nuclear or magnetohydrodynamic generators. Hypersonic flight introduces challenges when it comes to producing power onboard. For example, access to air is not trivial. Air may be provided through engine bleeds, which is provided at extreme temperatures, $>700^{\circ}\text{C}$. This reduces the specific power of internal combustion and gas turbine engines. Therefore, an alternative technology which does not require air or can utilize high temperature air sources is beneficial. Thermal electric devices need cooling air for a heat sink and nuclear based technologies introduce technical and political challenges. Batteries provide a viable solution but are limited in energy density and the ability to perform in missions >30 minutes. As an alternative, a solid oxide fuel cell (SOFC) can operate within these conditions. SOFCs utilize high temperature air sources for their oxidants. Therefore, SOFC provide an opportunity for power production on hypersonic vehicles.

Dr. Rory Roberts was awarded \$334,036 (Year 1 funding \$68,080) from the Air Force Research Laboratory via DAGSI for the Atmosphere Independent Bipropellant Solid Oxide Fuel Cells for On-Orbit Space Power project. Sustained duration power output onboard modern spacecraft is primarily constrained by the rate of photovoltaic energy collection or the limited energy density of batteries. An alternative energy source is mandatory during eclipse, lunar night scenarios, or short manned missions such as the Apollo program where the long duration energy consumption made batteries infeasible. As a solution, the chemical energy of the propellants onboard a spacecraft can be utilized for electrochemical work in a fuel cell, thereby taking advantage of the much higher specific energy of liquid fuels. The hypergolic pair MMH/NTO represent a specific energy density approximately eight times that of modern space-worthy lithium-ion batteries. The option to use propellants for thrust and/or power greatly reduces the invested weight in the final plumbing and storage. Regenerative fuel cells have already been studied as a prospective power sources for satellites, as well as reusable fuel cells fed with hypergolic propellants for spacecraft. A similar solid oxide electrolyzer cell has already been successfully integrated into the Mars Perseverance rover. This project seeks to validate the concept of a solid oxide fuel cell integrated with a hypergolic bipropellant propulsion system.

Dr. Rory Roberts was awarded \$145,000 (Year 1 funding: \$45,420) from the Advanced Research Projects Agency (ARPA-E) for the project “Cryo Thermal Management of High Power Density Motors and Drives”. This project aims to design and demonstrate a multi-MW, high-efficiency, and high-power density integrated electric propulsion motor, drive, and thermal management system that meets the performance requirements of future hybrid electric, single-aisle passenger aircraft. The proposed technology incorporates an advanced and high-performance induction electric machine with a novel advanced thermal management techniques for synergistic cooling that safely uses cryogenic bio-LNG as the energy source for power generation and a large thermal-battery cooling system to provide a highly compact, light, and efficient thermal management system capability throughout all the different flight phases of a commercial narrow-body aircraft. If successful, the system will allow for a cost-effective motor capable of operating at a higher current density compared with existing conventional non-cryogenic motors without using superconductors.

CMR Faculty Associate Dr. Ambareen Siraj continues to serve as PI for the Tennessee CyberCorps: A Hybrid Program supported by NSF in Cybersecurity with Dr. Douglas Talbert serving as Co-PI. NSF provided the fifth year of funding of this Cybersecurity Program and CMR activated \$376,896. NSF also awarded a separate supplemental component for community college inclusion for \$26,495. This funding for Cybersecurity research continues to make Tennessee Tech one of the highly visible cyber defense education programs in the country as well as designation by both NSA and the Department of Homeland Security (DHS) as a National Center of Academic Excellence in Cyber Defense Education (CAE-CD) through AY 2021. The total award is \$5,058,651.



CMR Director Dr. Ying Zhang and CMR Faculty Associate Dr. Jiahong Zhu were awarded a grant of \$199,178 from the Department of Energy for Year 2 of 2 of the project “Development of Corrosion- and Erosion-Resistant Coatings for Advanced Ultra-Supercritical Materials”. The total award is \$1,250,755 (DOE share \$999,999 + cost share \$250,756). This work focuses on balancing the corrosion and erosion properties of the electro-codeposited coatings to protect steam turbine blades in advanced ultra-supercritical power plants.



CMR Faculty Associates and R&D engineers have published 38 journal papers, 29 conference papers, and four book chapters during the past year. They have received one patent.

Center Activities

External Advisory Board

The new CMR External Advisory Board (EAB) was formed in November 2020 and the first meeting was held in March 2021. The EAB is a dynamic group with members from industry and academia, such as Nissan North America, Cummins Filtration, and Aerojet Ordnance Tennessee. In the board meeting, members were introduced to the CMR and its mission, vision, goals and focus areas. Current research projects and research education infrastructure were reviewed. The EAB will provide guidance, advice, and direction for the CMR's activities and assist the Center with its strategic initiatives.

Tennessee Three-Star Industrial Assessment Center

The Tennessee Three-Star Industrial Assessment Center (IAC) received an award of \$109,585 from the Department of Energy to continue the IAC that was established in the CMR in 2006. The mission of the IAC is two-fold: 1) Assist small to medium sized manufacturers to become more energy efficient, and 2) Instruct engineering students in best practices of industrial energy efficiency to prepare them for the workforce.

As the IAC approaches its 15-year anniversary, its founder, Dr. Glenn Cunningham, is retiring and Dr. Ethan Languri will become the principal investigator. Dr. Cunningham has taught mechanical engineering courses at Tennessee Tech since 1986 in the areas of energy conversion and conservation, steam power plants, and HVAC design and applied thermodynamics. He has led virtually all of the 250 IAC assessments conducted for industry in Tennessee and the surrounding states.



Dr. Glenn Cunningham on assessment

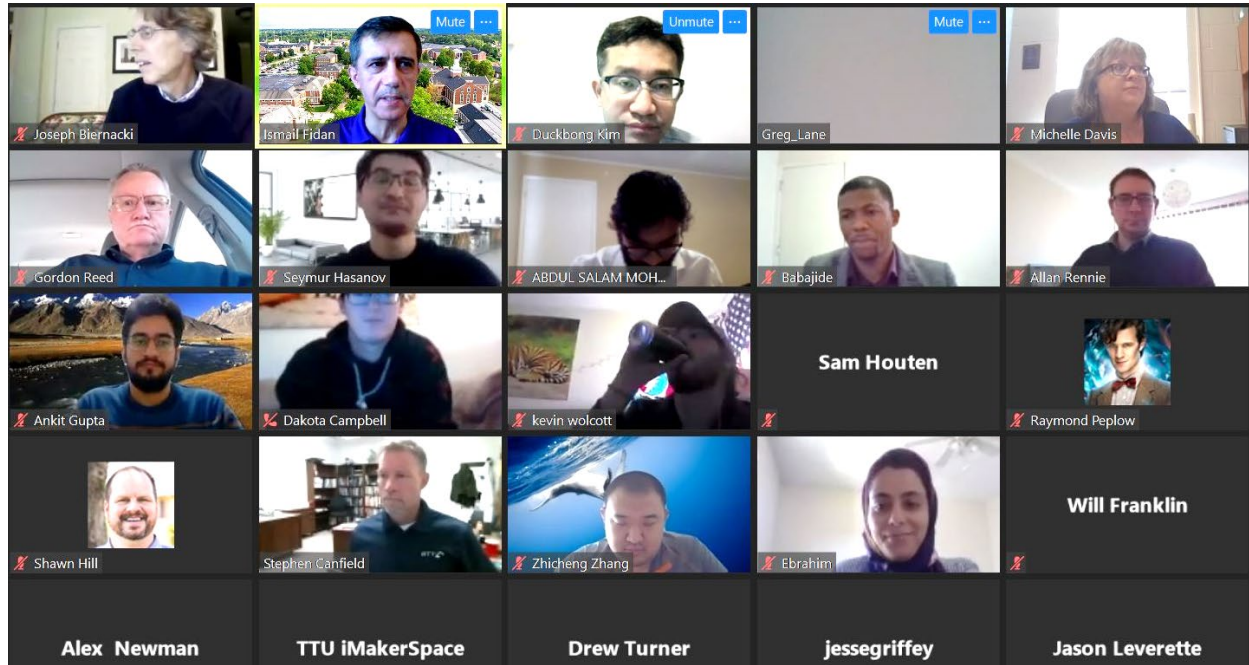


Dr. Ethan Languri and Dr. Glenn Cunningham

“Every assessment is a unique experience. You learn something or see something you have not encountered before in every different plant you visit,” said Dr. Cunningham, “The Waupaca Foundry in Etowah, TN with a cupola steel making furnace and support systems was the location of our first \$1,000,000 savings recommendation, which I think will be implemented.” When asked what he enjoyed most about the IAC, he answered, “It’s always a lot of fun to work with students on these projects. The opportunity to see them dig in and apply their engineering education on real industrial systems and equipment is a real blessing.”

National Manufacturing Day

The CMR participated in the National Manufacturing Day with a virtual series of talks with a focus on additive manufacturing and a quiz bowl. Manufacturing Day was created to show the reality of modern manufacturing careers by encouraging thousands of companies and educational institutions around the nation to open their doors to students, parents, teachers and community leaders.



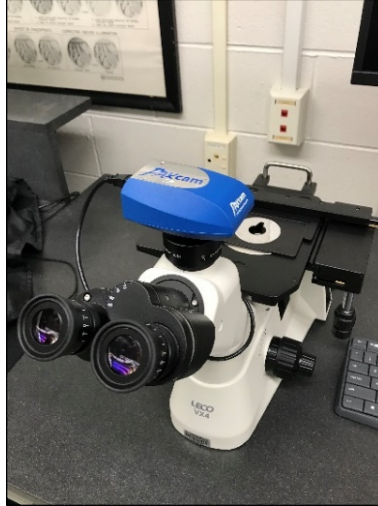
Pandemic Contributions

During the initial days of the Covid-19 pandemic in 2020, CMR Faculty Associate Dr. Ismail Fidan and students used Tennessee Tech's 3D printing equipment to fabricate headbands for assembly of protective face shields. Over 3,000 headbands for the shields were produced and donated to state and regional healthcare providers.



Materials Science Laboratory

The CMR's Materials Science Laboratory (MSL) added several new pieces of equipment that enhanced the Center's research capabilities as well as student instruction. The Buehler IsoMet High Speed Pro is a table top precision saw that provides precise cuts quicker without impacting cut quality. The Wilson VH1202 Micro Hardness Tester and the Leco VX4 Inverted Microscope advance the Center's capabilities for metallurgical research applications.



High Performance Laboratory-Scale Gas Atomizer

The DURIP grant (\$315,000) Dr. Zhang received from the Office of Naval Research enabled her to procure a high performance laboratory-scale gas atomizer for TTU's materials and coatings research. Gas atomization is the leading manufacturing process for production of high-grade metal powders that can meet specific quality criteria such as spherical shape, closely controlled chemical composition, high purity, and homogeneous microstructure.

The gas atomizer was installed in a newly renovated laboratory in the College of Engineering. The American-made VersaMelt inert gas atomizer (Arcast, Oxford, Maine) is substantially different from some laboratory atomization

systems currently available in the U.S. universities. The refractory lined induction furnace offers melting temperatures up to 1700°C, while the cold crucible or non-contact furnace via plasma/arc



allows melting and atomizing of reactive materials like titanium alloys and refractory metals with extremely high melting temperatures (such as tungsten, >3400°C).

The gas atomizer will allow the researchers at TTU to cleanly melt and atomize titanium, iron, nickel, tungsten and many other metal alloys and further increase the university's research capabilities in the areas of interest to the DoD, e.g., additive manufacturing, high-temperature protective coatings, and solid oxide fuel cells (SOFCs). The plan to establish a new atomization user facility at TTU will promote collaboration between TTU, industry and other universities. The new research equipment will also help establish TTU as a regional frontrunner in advanced materials and manufacturing research with broader impacts extending from undergraduate/graduate education to regional K-12 STEM communities.

Faculty, Staff and Student Accomplishments and Awards

Wayne Hawkins was awarded the College of Engineering's Outstanding Staff Award. Wayne manages the Materials Science Lab for the CMR. His nomination for the award was endorsed by students, professors, and an industry partner, all who value the commitment to excellence Wayne has displayed in his work.



Dr. Ismail Fidan, CMR Faculty Associate in Manufacturing and Engineering Technology, was awarded the 2020 - 2021 Kinslow Engineering Research Award which is given for the best paper written by a TTU engineering faculty member and published in a refereed professional journal. The paper's topic was three-scale asymptotic homogenization of short fiber reinforced additively manufactured polymer composites.

CMR Faculty Associate in Computer Science, **Dr. Sheikh Ghafoor**, was awarded the 2020 - 2021 Brown-Henderson Outstanding Engineering Faculty Award for significant accomplishments in the preparation of students for their professions through education, research and service.





Dr. Stephanie Jorgensen, CMR Faculty Associate in Chemical Engineering, was selected to receive the 2020 – 2021 Leighton E. Sissom Innovation and Creativity Award from the College of Engineering. She was selected for her innovative redesign of a Chemical Engineering Process, Products, Ethics course, which students have described as “changing the way we think”. This award was established to recognize innovation and creativity in scholarship, methodology, invention, technique, processes, or other unique contributions demonstrating innovation and creativity.

CMR-supported Mechanical Engineering (ME) students **Ankit Gupta** and **Seymur Hasanov** won the Precision Metalforming Association Scholarship award.

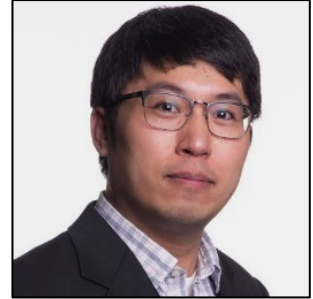
CMR-supported Electrical & Computer Engineering (ECE) graduate student **Mahmoud Badr** won the ECE Graduate (PhD) section of the Tennessee Tech Research and Creative Inquiry Day. Mr. Badr’s paper was titled “Efficient and Privacy-Preserving Contact Tracing System for Covid-19 Using Blockchain”.

In the Manufacturing and Engineering Technology (MET) section of the Tennessee Tech Research and Creative Inquiry Day, CMR-supported students **Tyler Edwards** won the Graduate (Masters) Award with his paper “Efficiency and Print Quality Benchmarking Between Fused Filament Fabrication and Stereolithography Processes” and **Seymur Hasanov** won the Graduate (PhD) Award with his paper “Experimental and Numerical Characterization of Functionally Graded Materials Fabricated by the Fused Filament Fabrication Process”.

CMR-supported student **Peter Oyekola** won the Mechanical Engineering Graduate (PhD) section of the Tennessee Tech Research and Creative Inquiry Day with his paper “Impedance-based NDE through Instrumented Fixtures; Effects of Clamping Force on Defect-Detection Capabilities”.

Select 2020-21 CMR Supported Alumni

Tingke Fang, M.S., Mechanical Engineering, 2020
Advanced Industrial Engineer
GE Appliances
Louisville, KY



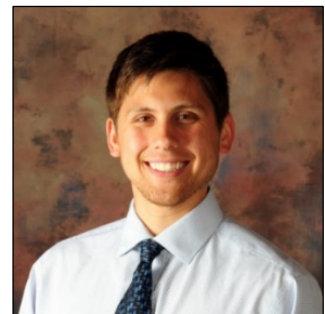
Benjamin Hargis, M.S., Mechanical Engineering, 2020
Research Engineer Intern
NASA
Yorktown, VA



Joshua Hooper, M.S., Mechanical Engineering, 2021
Mechanical Engineer
I.C. Thomasson
Nashville, TN



Joshua Lambert, M.S., Electrical & Computer Engineering, 2021
Control Engineer
JR Automation
Nashville, TN



Ogheneuriri Oderhohwo, M.S., Electrical & Computer Engineering,
2020
Applications Engineer
Intel Corporation



Tolulope Odetola, M.S., Electrical & Computer Engineering, 2020
Machine Learning Ph.D. Intern
Boston Scientific
Marlborough, MA



Publications of CMR Faculty Associates & Staff (January 2020 – December 2020)

Journal Publications

1. Ahmad, Waqar, Osman Hasan, Falah Awwad, Nabil Bastaki, and **Syed Rafay Hasan**. "Formal Reliability Analysis of an Integrated Power Generation System Using Theorem Proving." *IEEE Systems Journal* 14, no. 4 (2020): 4820-4831.
2. Ahsan, Md RU, A. N. M. Tanvir, Gi-Jeong Seo, **Brian Bates**, **Wayne Hawkins**, Chanho Lee, P. K. Liaw, Mark Noakes, Andrzej Nycz, and **Duck Bong Kim**. "Heat-treatment effects on a bimetallic additively-manufactured structure (BAMS) of the low-carbon steel and austenitic-stainless steel." *Additive Manufacturing* 32 (2020): 101036.
3. Alifui-Segbaya, Frank, Jasper Bowman, Alan R. White, Roy George, **Ismail Fidan**, and Robert M. Love. "Chemical characterization of additively manufactured methacrylates for dental devices." *Additive Manufacturing* 31 (2020): 100944.
4. Awaysheh, Feras M., Mamoun Alazab, **Maanak Gupta**, Tomás F. Pena, and José C. Cabaleiro. "Next-generation big data federation access control: A reference model." *Future Generation Computer Systems* 108 (2020): 726-741.
5. Badr, Mahmoud M., Wesam Al Amiri, Mostafa M. Fouda, **Mohamed MEA Mahmoud**, Abdulah Jeza Aljohani, and Waleed Alasmay. "Smart Parking System With Privacy Preservation and Reputation Management Using Blockchain." *IEEE Access* 8 (2020): 150823-150843.
6. Chan, Cody Leeheng, and **Kwun-Lon Ting**. "Curvature Theory on Contact and Transfer Characteristics of Enveloping Curves." *Journal of Mechanisms and Robotics* 12, no. 1 (2020).
7. Chan, Cody Leeheng, and **Kwun-Lon Ting**. "Rotatability of the Floating Link on Multi-Loop Planar Linkages." *Journal of Mechanisms and Robotics* 12, no. 6 (2020).
8. Chen, Yolnan, Cesar Ortiz Rios, Astrit Imeri, Nicholas A. Russell, and **Ismail Fidan**. "Investigation of the tensile properties in fibre-reinforced additive manufacturing and fused filament fabrication." *International Journal of Rapid Manufacturing* 9, no. 2-3 (2020): 251-267.
9. Chesson, D. A., and **J. H. Zhu**. "Effect of Off-Stoichiometry on Electrical Conductivity in Ni-Fe and Mn-Co Spinel Systems." *Journal of The Electrochemical Society* 167, no. 12 (2020): 124515.
10. Chukkapalli, Sai Sree Laya, Sudip Mittal, **Maanak Gupta**, Mahmoud Abdelsalam, Anupam Joshi, Ravi Sandhu, and Karuna Joshi. "Ontologies and artificial intelligence systems for the cooperative smart farming ecosystem." *IEEE Access* 8 (2020): 164045-164064.
11. **Gupta, Manak**, Mahmoud Abdelsalam, Sajad Khorsandroo, and Sudip Mittal. "Security and privacy in smart farming: Challenges and opportunities." *IEEE Access* 8 (2020): 34564-34584.
12. **Gupta, Manak**, Feras M. Awaysheh, James Benson, Mamoun Al Azab, Farhan Patwa, and Ravi Sandhu. "An attribute-based access control for cloud-enabled industrial smart vehicles." *IEEE Transactions on Industrial Informatics* (2020).
13. **Gupta, Manak**, James Benson, Farhan Patwa, and Ravi Sandhu. "Secure V2V and V2I communication in intelligent transportation using cloudlets." *IEEE Transactions on Services Computing* (2020).
14. Gupta, Ankit, **Ismail Fidan**, Seymur Hasanov, and Aslan Nasirov. "Processing, mechanical characterization, and micrography of 3D-printed short carbon fiber reinforced polycarbonate polymer matrix composite material." *The International Journal of Advanced Manufacturing Technology* 107, no. 7 (2020): 3185-3205.

15. Haris, Anfal, **Jonathan R. Sanders**, and **Pedro E. Arce**. "Influence of pre-electrophoresis on protein separations in polyacrylamide gels." *Journal of Applied Polymer Science* 137, no. 34 (2020): 48994.
16. Hasanov, Seymour, Ankit Gupta, Aslan Nasirov, and **Ismail Fidan**. "Mechanical characterization of functionally graded materials produced by the fused filament fabrication process." *Journal of Manufacturing Processes* 58 (2020): 923-935.
17. Hinshaw, Hunter James, Shane Terry, and **Ismail Fidan**. "Power consumption investigation for fused filament fabricated specimen." *International Journal of Rapid Manufacturing* 9, no. 2-3 (2020): 268-279.
18. Ibrahim, Mohamed I., Mahmoud Nabil, Mostafa M. Fouda, **Mohamed MEA Mahmoud**, Waleed Alasmay, and Fawaz Alsolami. "Efficient Privacy-Preserving Electricity Theft Detection with Dynamic Billing and Load Monitoring for AMI Networks." *IEEE Internet of Things Journal* 8, no. 2 (2020): 1243-1258.
19. **Jorgensen, S., J.R. Sanders, P. E. Arce, and A. Arce-Trigatti**, "An Innovation-Driven Approach to Virtual Learning: Using the Foundry Model to Transition Online," *Science Education & Civic Engagement, An International Journal, Special Section: Teaching through COVID-19*, 12(2), 38-39, (2020).
20. Khalid, Faiq, **Syed Rafay Hasan**, Osman Hasan, and Muhammad Shafique. "SIMCom: Statistical sniffing of inter-module communications for runtime hardware trojan detection." *Microprocessors and Microsystems* 77 (2020): 103122.
21. Khalid, Faiq, **Syed Rafay Hasan**, Sara Zia, Osman Hasan, Falah Awwad, and Muhammad Shafique. "MacLeR: Machine Learning-Based Runtime Hardware Trojan Detection in Resource-Constrained IoT Edge Devices." *IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems* 39, no. 11 (2020): 3748-3761.
22. Mohammadizadeh, Mahdi, Hao Lu, **Ismail Fidan**, Khalid Tantawi, Ankit Gupta, Seymour Hasanov, Zhicheng Zhang, Frank Alifui-Segbaya, and Allan Rennie. "Mechanical and Thermal Analyses of Metal-PLA Components Fabricated by Metal Material Extrusion." *Inventions* 5, no. 3 (2020): 44.
23. Mohammed, Hawzhin, **Syed Rafay Hasan**, and Falah Awwad. "Fusion-On-Field Security and Privacy Preservation for IoT Edge Devices: Concurrent Defense Against Multiple Types of Hardware Trojan Attacks." *IEEE Access* 8 (2020): 36847-36862.
24. Nasirov, Aslan, Ankit Gupta, Seymour Hasanov, and **Ismail Fidan**. "Three-scale asymptotic homogenization of short fiber reinforced additively manufactured polymer composites." *Composites Part B: Engineering* 202 (2020): 108269.
25. Nasirov, Aslan, and **Ismail Fidan**. "Prediction of mechanical properties of fused filament fabricated structures via asymptotic homogenization." *Mechanics of Materials* 145 (2020): 103372.
26. Pistono, Antonio O., and **Cynthia A. Rice**. "Automotive Subzero Cold-Start Quasi-Adiabatic Proton Exchange Membrane Fuel Cell Fixture: Design and Validation." *Molecules* 25, no. 6 (2020): 1410.
27. Safaei, Mohsen, R. Michael Meneghini, and **Steven R. Anton**. "Compartmental force and contact location sensing in instrumented total knee replacements." *Medical Engineering & Physics* 83 (2020): 64-72.
28. **Sanders, J. R., A. Arce-Trigatti, and P. E. Arce**. "Promoting student problem-identification skills via a Jeopardy-inspired game within the Renaissance Foundry." *Education for Chemical Engineers* 30 (2020): 49-59.
29. Shafee, Ahmed A., Mostafa M. Fouda, **Mohamed MEA Mahmoud**, Abdulah Jeza Aljohani, Waleed Alasmay, and Fathi Amsaad. "Detection of Lying Electrical Vehicles in Charging Coordination Using Deep Learning." *IEEE Access* 8 (2020): 179400-179414.
30. Su, Jin-Yang, Wen Yang, **Jia-Hong Zhu**, Wei-Hua Wang, Kun Li, Shu-Ping Liu, and Yong-Tang Li. "Tritium diffusion in a Li₂TiO₃ crystal terminated with the (001) surface from first-

principles calculations." *Physical Chemistry Chemical Physics* 22, no. 46 (2020): 27206-27213.

31. Takiddin, Abdulrahman, Muhammad Ismail, Mahmoud Nabil, **Mohamed MEA Mahmoud**, and Erchin Serpedin. "Detecting Electricity Theft Cyber-Attacks in AMI Networks Using Deep Vector Embeddings." *IEEE Systems Journal* (2020).
32. Tanvir, A. N. M., Md RU Ahsan, Changwook Ji, **Wayne Hawkins**, **Brian Bates**, and **Duck Bong Kim**. "Heat treatment effects on Inconel 625 components fabricated by wire+ arc additive manufacturing (WAAM)—part 1: microstructural characterization." *The International Journal of Advanced Manufacturing Technology* 103, no. 9 (2019): 3785-3798.
33. Tanvir, A. N. M., Md RU Ahsan, Gijeong Seo, **Brian Bates**, Chanho Lee, Peter K. Liaw, Mark Noakes, Andrzej Nycz, Changwook Ji, and **Duck Bong Kim**, "Microstructural stability and mechanical properties of wire + arc additively manufactured H13 tool steel at elevated temperatures, *Journal of Material Science and Technology* 67:80-94 (2020).
34. Terry, Shane, Hao Lu, **Ismail Fidan**, Yunbo Zhang, Khalid Tantawi, **Terry Guo**, and Bahram Asiabanpour. "The Influence of Smart Manufacturing towards Energy Conservation: A Review." *Technologies* 8, no. 2 (2020): 31.
35. Wang, Li-Peng, Wen Yang, Zhang-Bo Ma, **Jia-Hong Zhu**, and Yong-Tang Li. "First-principles study of chromium diffusion in the ferritic Fe-Cr alloy." *Computational Materials Science* 181 (2020): 109733.
36. Witman, J.C. and **Y. Zhang**. "Effect of Electro-codeposition Parameters on Particle Incorporation in Ni-CrAlY(Ta) Coatings", *Materials and Manufacturing Processes*, 36, (2021): 209-214.
37. Yu, Y. T., **J. H. Zhu**, and **B. L. Bates**. "Conductive spinels derived from Co–Mn based alloy precursor for SOFC cathode-side contact application." *International Journal of Hydrogen Energy* 45, no. 51 (2020): 27745-27753.
38. Zhang, Zhicheng, **Ismail Fidan**, and Michael Allen. "Detection of Material Extrusion In-Process Failures via Deep Learning." *Inventions* 5, no. 3 (2020): 25.

Conference Publications

1. Adams, B., **Arce-Trigatti, A.**, & **Arce, P. E.**, "Developing an Inquiry-guided laboratory manual with abet-centered student learning objectives for chemical engineering transfer science courses." Proceedings from the American Society for Engineering Education Southeastern Conference. March 8-10, 2020. Auburn, Alabama.
2. Adams, B., **Arce-Trigatti, A.**, **Arce, P.**, & **Sanders, J. R.**, "Understanding learning environments at the graduate level: A qualitative analysis of doctoral engineering education programs within the United States". Proceedings from the American Society for Engineering Education Southeastern Conference. March 8-10, 2020. Auburn, Alabama.
3. Adams, B., **Jorgensen, S.**, **Arce-Trigatti, A.**, & **Arce, P.E.** "Innovative Curriculum Design for Enhancing Learning in Engineering Education: Strategies, Principles and Challenges of An Inquiry-Guided Laboratory". Proceedings from the 14th annual International Technology, Education and Development (INTED)Conference. Valencia, 2nd, 3rd and 4th of March 2020. March 2-4, 2020. Valencia, Spain.
4. Al Amiri, Wesam, Mohamed Baza, Karim Banawan, **Mohamed Mahmoud**, Waleed Alasmay, and Kemal Akkaya. "Towards secure smart parking system using blockchain technology." In *2020 IEEE 17th Annual Consumer Communications & Networking Conference (CCNC)*, pp. 1-2. IEEE, 2020.
5. Alshaikh Ali, Mohammad, Eric C. Nolan, **Steven R. Anton**, and Mohsen Safaei. "An Impact-Based Experimental Setup for Evaluation of Rapid Electromechanical Impedance-Based Structural Health Monitoring." In *Smart Materials, Adaptive Structures and Intelligent Systems*, vol. 84027, p. V001T05A012. American Society of Mechanical Engineers, 2020.

6. Amsaad, F., A. Sherif, D. Halder, and **M. Mahmoud**. "Efficient and privacy aware hardware-based authentication scheme for AMI network," Proc. of IEEE SoutheastCon'20, Raleigh, NC, USA, March 2020.
7. **Arce-Trigatti, A., Jorgensen, S., Sanders, J. R., & Arce, P.E.**, "Constraining the landscape: Unpacking the inquiry learning aspects of the foundry model for the purpose of curriculum design". Proceedings from the American Society for Engineering Education Southeastern Conference. March 8-10, 2020. Auburn, Alabama.
8. Baza, Mohamed, **Mohamed Mahmoud**, Gautam Srivastava, Waleed Alasmay, and Mohamed Younis. "A light blockchain-powered privacy-preserving organization scheme for ride sharing services." In *2020 IEEE 91st Vehicular Technology Conference (VTC2020-Spring)*, pp. 1-6. IEEE, 2020.
9. Baza, M., A. Salazar, **M. Mahmoud**, M. Abdallah, K. Akkaya. "Privacy-preserving sharing of EHRs' models using mimic learning," Proc. of IEEE International Conference on Informatics, IoT, and Enabling Technologies (ICIoT'20), Doha, Qatar, 2020.
10. Choudhary, Nitu Kedarmal, Sai Sree Laya Chukkapalli, Sudip Mittal, **Maanak Gupta**, Mahmoud Abdelsalam, and Anupam Joshi. "YieldPredict: A Crop Yield Prediction Framework for Smart Farms." (2020).
11. Chukkapalli, Sai Sree Laya, Aritran Piplai, Sudip Mittal, **Maanak Gupta**, and Anupam Joshi. "A smart-farming ontology for attribute based access control." In *2020 IEEE 6th Intl Conference on Big Data Security on Cloud (BigDataSecurity), IEEE Intl Conference on High Performance and Smart Computing, (HPSC) and IEEE Intl Conference on Intelligent Data and Security (IDS)*, pp. 29-34. IEEE, 2020.
12. Fidan, Perihan, Stephanie L. Wendt, Jeremy Wendt, and **Ismail Fidan**. "Enhancing STEM Education: Learning About Biomedical Engineering with 3-D Pens (Resource Exchange)." In *2020 ASEE Virtual Annual Conference Content Access*. 2020.
13. Gupta, Deepti, Olumide Kayode, Smriti Bhatt, **Maanak Gupta**, and Ali Saman Tosun. "Learner's Dilemma: IoT Devices Training Strategies in Collaborative Deep Learning." In *2020 IEEE 6th World Forum on Internet of Things (WF-IoT)*, pp. 1-6. IEEE, 2020.
14. Haddad, Zaher, Mostafa M. Fouda, **Mohamed Mahmoud**, and Mohamed Abdallah. "Blockchain-based Authentication for 5G Networks." In *2020 IEEE International Conference on Informatics, IoT, and Enabling Technologies (ICIoT)*, pp. 189-194. IEEE, 2020.
15. Ibrahim, Mohamed I., Mahmoud M. Badr, Mostafa M. Fouda, **Mohamed Mahmoud**, Waleed Alasmay, and Zubair Md Fadlullah. "PMBFE: Efficient and Privacy-Preserving Monitoring and Billing Using Functional Encryption for AMI Networks." In *2020 International Symposium on Networks, Computers and Communications (ISNCC)*, pp. 1-7. IEEE, 2020.
16. **Jorgensen, S., Arce-Trigatti, A., Sanders, J. R., & Arce, P. E.**, "A Focus on Functional-Based Teams in the Development of Prototypes of Innovative Technology: Observations from a QEP Grant Implementation at Tennessee Tech." Proceedings from the American Society for Engineering Education Southeastern Conference. March 8-10, 2020. Auburn, Alabama.
17. Lam, Steven, Meghan Marie Bixby, and **Cynthia A. Rice**. "Optimization of Mass Transport within Direct Formic Acid Fuel Cell Catalyst Layer via Pore Formers." *ECS Transactions* 98, no. 9 (2020): 355.
18. Littrell, Michael, **George Chitiyo**, **Ismail Fidan**, Mel Cossette, Thomas Singer, and Ed Tackett. "Multi Institutional Collaboration in Additive Manufacturing: Lessons Learned." In *Proceedings of the 2020 ASEE Annual Conference*. 2020.
19. Littrell, M. N., **Chitiyo, G.**, Michel, L. A., and **Anton, S. R.**, Board Game Development as a Pedagogical Approach to Teaching Undergraduate Students in an Interdisciplinary Course that Addresses Contemporary Societal Issues, Proc. ASEE Annual Conference, 2020, Paper ID #30005 (9 pp)

20. McDole, Andrew, Mahmoud Abdelsalam, **Maanak Gupta**, and Sudip Mittal. "Analyzing cnn based behavioural malware detection techniques on cloud iaas." In *International Conference on Cloud Computing*, pp. 64-79. Springer, Cham, 2020.
21. Mithu, M. Rayhan Ahmed, Vadim Kholodilo, Rajesh Manicavasagam, **Denis Ulybyshev**, and Mike Rogers. "Secure industrial control system with intrusion detection." In *The Thirty-Third International Flairs Conference*. 2020.
22. Mohammadizadeh, M., and **I. Fidan**. "Experimental Evaluation of Additively Manufactured Continuous Fiber Reinforced Nylon Composites." In *TMS 2020 149th Annual Meeting & Exhibition Supplemental Proceedings*, pp. 321-328. Springer, Cham, 2020.
23. Oderhohwo, Ogheneuriri, Hawzhin Mohammed, Tolulope Odetola, **Terry N. Guo**, **Syed Hasan**, and Felix Dogbe. "An Edge Intelligence Framework for Resource Constrained Community Area Network." In *2020 IEEE 63rd International Midwest Symposium on Circuits and Systems (MWSCAS)*, pp. 97-100. IEEE, 2020.
24. Oderhohwo, Ogheneuriri, Tolulope A. Odetola, Hawzhin Mohammed, and **Syed Rafay Hasan**. "Deployment of Object Detection Enhanced with Multi-label Multi-classification on Edge Device." In *2020 IEEE 63rd International Midwest Symposium on Circuits and Systems (MWSCAS)*, pp. 986-989. IEEE, 2020.
25. Piplai, Aritran, Sudip Mittal, Mahmoud Abdelsalam, **Maanak Gupta**, Anupam Joshi, and Tim Finin. "Knowledge enrichment by fusing representations for malware threat intelligence and behavior." In *2020 IEEE International Conference on Intelligence and Security Informatics (ISI)*, pp. 1-6. IEEE, 2020.
26. Shafee, Ahmed, Mohamed Baza, **Douglas A. Talbert**, Mostafa M. Fouda, Mahmoud Nabil, and **Mohamed Mahmoud**. "Mimic learning to generate a shareable network intrusion detection model." In *2020 IEEE 17th Annual Consumer Communications & Networking Conference (CCNC)*, pp. 1-6. IEEE, 2020.
27. Sontowski, Sina, **Maanak Gupta**, Sai Sree Laya Chukkapalli, Mahmoud Abdelsalam, Sudip Mittal, Anupam Joshi, and Ravi Sandhu. "Cyber attacks on smart farming infrastructure." *UMBC Student Collection* (2020).
28. **Ulybyshev, Denis**, Christian Bare, Kristen Bellisario, Vadim Kholodilo, Bradley Northern, Abhijeet Solanki, and Timothy O'Donnell. "Protecting electronic health records in transit and at rest." In *2020 IEEE 33rd International Symposium on Computer-Based Medical Systems (CBMS)*, pp. 449-452. IEEE, 2020.
29. Yilmaz, Ibrahim, **Ambareen Siraj**, and **Denis Ulybyshev**. "Improving DGA-Based Malicious Domain Classifiers for Malware Defense with Adversarial Machine Learning." In *2020 IEEE 4th Conference on Information & Communication Technology (CICT)*, pp. 1-6. IEEE, 2020.

Book Chapters

1. Baza, Mohamed, Joe Baxter, Nouredine Lasla, **Mohamed Mahmoud**, Mohamed Abdallah, and Mohamed Younis. "Incentivized and secure blockchain-based firmware update and dissemination for autonomous vehicles." In *Connected and Autonomous Vehicles in Smart Cities*, pp. 475-493. CRC press, 2020.
2. Baza, Mohamed, Mostafa M. Fouda, Mahmoud Nabil, Adly Tag Eldien, Hala Mansour, and **Mohamed Mahmoud**. "Blockchain-based distributed key management approach tailored for smart grid." In *Combating Security Challenges in the Age of Big Data*, pp. 237-263. Springer, Cham, 2020.
3. **Fidan, Ismail**. "Section: Research and Development, Academic Activities and Capabilities in Additive Manufacturing," pp. 261-277, Wohlers Report 2020, (Book Chapter), ISBN: 978-0-9913332-6-4.

4. McDole, Andrew, **Maanak Gupta**, Mahmoud Abdelsalam, Sudip Mittal, and Mamoun Alazab. "Deep learning techniques for behavioral malware analysis in cloud iaas." In *Malware Analysis using Artificial Intelligence and Deep Learning*, pp. 269-285. Springer, Cham, 2021.

Patents

1. Witman, J.C., **Y. Zhang**, and **B.L. Bates**, "Apparatus Used for Producing Coatings," Patent Application #62349778 (2020).

External Activations

	Project Description	P.I.	Department	Total Funds
1	Cyber-Physical System Integrity and Security with Impedance Signatures Virginia Tech (via NSF funds) - Subaward 480322-19C95 - Year 1 of 2.5 Account #: 5-31321 843MC-Y1	Mohammad Albakri	ECE	\$31,929
2	Cyber-Physical System Integrity and Security with Impedance Signatures Virginia Tech (via NSF funds) - Subaward 480322-19C95 - Year 2 of 2.5 Account #: 5-31321 843MC-Y2	Mohammad Albakri	ME	\$26,714
3	Intelligent Robot for TVA Substation Inspection Tennessee Valley Authority (TVA) Account #: 5-32605 836MC-Y2	Ali Alouani	ECE	\$173,000
4	BioFoundry Design: Leveraging Biomimicry to Advance Environmental and Social Sustainability Innovation in Prototypes Developed in Foundry-Guided Undergraduate Chemical Engineering Courses Venturewell Account #: 5-35278 860MC	Pedro Arce Robby Sanders	ChE ChE	\$30,000
5	Developing an EV Demonstration Testbed in the Upper Cumberland Region of Tennessee, an Economy Distressed Rural U.S. Department of Energy - Year 2 of 3 - Award DE-EE0008888 Account #: 5-32601 821MC-Y2	Pingen Chen Stephen Canfield Joseph Ojo Vahid Motevalli Indranil Bhattacharya	ME ME ECE COE ECE	\$155,133
6	Medium-duty eTruck: Pilot Electrified Fleets in Urban and Regional Applications Department of Energy via University of Texas at Austin Account #: 5-39221 852MC-1	Pingen Chen Stephen Canfield	ME ME	\$86,319
7	Education Program for Connected and Automated Electric Vehicles (CAEVs) Denso North American Foundation Account #: 5-35918 855MC-R	Pingen Chen	ME Multi	\$157,964
8	Public-Private Partnership to Promote Efficient Manufacturing and Workforce Development Department of Energy, Office of Energy Efficiency and Renewable Energy - Award DE-EE0007702 Account #: 5-32278 658-M13	Glenn Cunningham Ethan Languri	ME ME	\$25,000

	Project Description	P.I.	Department	Total Funds
9	Public-Private Partnership to Promote Efficient Manufacturing and Workforce Development Department of Energy, Office of Energy Efficiency and Renewable Energy - Award DE-EE0007702 Account #: 5-32278 658-M15	Glenn Cunningham Ethan Languri	ME ME	\$84,585
10	SMART2 Smart Manufacturing for America's Revolutionizing Technological Transformation National Science Foundation via Motlow State Community College Account #: 531297 745MC-Y3	Ismail Fidan	MET	\$72,982
11	Mobile Additive Manufacturing Platform for the 21st Century STEM Workforce Enhancement Somerset Kentucky (via NSF funds) - Memorandum of Agreement - Year 2 of 3 Account #: 5-31314 786MC-Y2	Ismail Fidan	MET	\$91,751
12	Towards Efficient Deployment of Large CNNs for Real-time Object Detection in Full High Definition (FHD) Video Streams using Xilinx Vitis-AI Phelps2020, Inc. Account #: 5-35281 883MC	Syed Hasan	ECE	\$49,466
13	Project Title: Fundamental Study on Surface Integrity of Wire + Arc Additively-Manufactured High-Performance Alloy Structures National Science Foundation - Award 2015693 - Year 1 of 3 Account #: 5-31315 840MC-Y1	Duckbong Kim	MET	\$76,009
14	Development of Hybrid Learning-Driven Predictive Inspection-Methods and Control Methods for Quality Assurance on Additive Manufacturing Managing Institute and Joint Research Institute-Hanyang Account #: 5-35277 851 Sup	Duckbong Kim	MET	\$20,227
15	Development of Hybrid Learning-Driven Predictive Inspection-Methods and Control Methods for Quality Assurance on Additive Manufacturing Managing Institute and Joint Research Institute-Hanyang Account #: 5-35277 851MC-R	Duckbong Kim	MET	\$100,000

	Project Description	P.I.	Department	Total Funds
16	Southeast Combined Heat and Power Technical Assistance Partnership (CHP) North Carolina State University via DOE funds - Award DE-EE0008273 Year 3 of 5 Account #: 5-32817 723MC-Y3	Ethan Languri Glenn Cunningham	ME ME	\$39,285
17	Control of Modular Multi-Dual Active Bridge Converters for Integrated Ship-Board Power System Office of Naval Research - Award N00014-21-1-2114 - Allocation #1 Account #: 5-32618 877MC-A1	Joseph Ojo	ECE	\$125,001
18	AFRL Senior Design Technology Dzyne Technologies via US Air Force Research Laboratory Account #: 5-23401 878MC	Byron Pardue	ME	\$25,000
19	Atmosphere Independent Bipropellant Consuming Additively Manufactured Solid Oxide Fuel Cells for Assured On-Orbit Space Power Southwestern Ohio Council for Higher Education (SoCHE) - (via DoD funds) Account #: 5-39238 868MC-1	Rory Roberts	ME	\$34,040
20	Cryo Thermal Management of High Power Density Motors and Drives ARPA-E via Hyper Tech Account #: 5-32619 872MC-Y1	Rory Roberts	ME	\$22,710
21	Hypersonic On-Board Power and Thermal Management System Air Force STTR via Special Power Forces - Subcontract SPS-TTU-11012020 Account #: 5-39299 RR-PC	Rory Roberts	ME	\$75,000
22	TENNESSEE CYBERCORPS: A HYBRID PROGRAM IN CYBERSECURITY National Science Foundation - Award 156562 - Year 5 of 5 Account #: 5-31279 620MC-Y5	Ambareen Siraj Doug Talbert	CSC CSC	\$376,896
23	Supplement to Tennessee Cybercorps: A Hybrid Program in Cybersecurity - Community College Inclusion - 2018-2021 National Science Foundation - Award 156562 - CC Supplement #3 Year 3 of 3 Account #: 5-31279 782C-CC3	Ambareen Siraj Doug Talbert	CSC CSC	\$26,495
24	TNTech Printed Tool Project FlowServe US, Inc. Account #: 5-35285 869MC	Fred Vondra Ismail Fidan	MET MET	\$47,096

	Project Description	P.I.	Department	Total Funds
25	Manufacturing Testing and Design - 2020-2021 Various Industries Account #: 5-38585 100MC-18	Ying Zhang	CMR	\$12,354
26	Development of Corrosion- and Erosion-Resistant Coatings for Advanced Ultra-Supercritical Materials US Department of Energy - Award DE-FE0031820 - Year 2 of 2 Account #: 5-32600 816MC-Y2	Ying Zhang Jiahong Zhu	CMR ME	\$199,178
27	Pack Aluminide Coatings on Steel Coupons Oak Ridge National Laboratory - Award 4000185237 Account #: 5-32614 889MC	Ying Zhang	CMR	\$20,999

External Activations in FY 2020-2021 \$2,185,133

Schedule 7

CENTERS OF EXCELLENCE ACTUAL, PROPOSED, AND REQUESTED BUDGET

Institution Tennessee Technological University Center Center for Manufacturing Research

	FY 2020-21 Actual			FY 2021-22 Proposed			FY 2022-23 Requested		
	Matching	Appopr.	Total	Matching	Appopr.	Total	Matching	Appopr.	Total
Expenditures									
Salaries									
Faculty	237,049	248,057	485,106	350,000	393,761	743,761	375,000	350,000	725,000
Other Professional	132,793	339,135	471,928	75,000	478,735	553,735	75,000	420,000	495,000
Clerical/ Supporting	18,576	47,151	65,727	20,000	46,605	66,605	25,000	45,000	70,000
Assistantships	182,232	189,330	371,562	250,000	371,158	621,158	250,000	325,000	575,000
Hourly Students	58,375	48,734	107,109	50,000	50,358	100,358	50,000	30,000	80,000
Total Salaries	629,025	872,407	1,501,432	745,000	1,340,617	2,085,617	775,000	1,170,000	1,945,000
Fringe Benefits	214,675	351,438	566,113	275,000	437,471	712,471	300,000	375,000	675,000
Total Personnel	843,700	1,223,845	2,067,545	1,020,000	1,778,088	2,798,088	1,075,000	1,545,000	2,620,000
Non-Personnel	NOTE: Appropriation Expenditures in Fringe Benefits include \$110,194 for Graduate Student Fees in FY 2020-21.								
Travel	71,080	0	71,080	75,000	31,866	106,866	75,000	20,000	95,000
Computer Maint./Software	0	18,840	18,840	0	5,000	5,000	0	5,000	5,000
Books & Journals	0	0	0	0	0	0	0	0	0
Other Supplies	143,164	103,273	246,437	300,841	171,281	472,122	350,000	73,200	423,200
Equipment	130,350	40,090	170,440	300,000	156,347	456,347	450,000	75,000	525,000
Lab. Upgrades/Mainten.	0	17,454	17,454	0	80,500	80,500	0	0	0
Scholarships for Service	202,655	0	202,655	250,000	0	250,000	125,000	0	125,000
Consultants/Subcontracts	263,663	0	263,663	500,000	0	500,000	300,000	0	300,000
Renovation	0	3,402	3,402	0	0	0	0	0	0
Seminars/Workshops/Con	33,990	0	33,990	100,000	5,000	105,000	125,000	0	125,000
Total Non-Personnel	844,902	183,059	1,027,961	1,525,841	449,994	1,975,835	1,425,000	173,200	1,598,200
GRAND TOTAL	1,688,602	1,406,904	3,095,506	2,545,841	2,228,082	4,773,923	2,500,000	1,718,200	4,218,200
Revenue	NOTE: Actual Matching Funds do not include Indirect Costs of \$406,684 for FY 2020-21.								
New State Appropriation	0	1,592,700	1,592,700	0	1,636,400	1,636,400	0	1,718,200	1,718,200
Carryover State Appropriation	0	405,886	405,886	0	591,682	591,682	0	0	0
New Matching Funds	1,781,500	0	1,781,500	2,250,000	0	2,250,000	2,500,000	0	2,500,000
Carryover from Previous Matching Funds	202,943	0	202,943	295,841	0	295,841	0	0	0
Total Revenue	1,984,443	1,998,586	3,983,029	2,545,841	2,228,082	4,773,923	2,500,000	1,718,200	4,218,200
NOTE: Carryover funds of \$591,682 are committed to the following areas: 1) beginning investigators and early-career faculty (to build a foundation of leadership in manufacturing-related research); 2) graduate student support; 3) cost-sharing for external grants, and 4) laboratory upgrades.									

FY 2022 – 2023 Budget Request and Justification

The CMR is requesting a 5.0% increase in the FY 2022-23 State appropriations to account for increasing salaries, benefits, student support, tuition and fees, supplies, and other costs as well as annual inflationary increases in these budget areas.

Even though the CMR has been successful in securing substantially increased external funding over the past few years, additional State appropriations are being requested to support the research/operational plans listed below.

- While we anticipate continued growth in FY22, there are functions within the Center in support of the research infrastructure and the State manufacturing industry that cannot be paid for with external grants and cost recovery. It is critical for the CMR to allocate partial funding annually to upgrade/replace capital equipment to maintain the state-of-the-art research capabilities.
- The requested budget increase will allow the CMR to continue in an effort to increase the number of graduate students supported by the Center and offer graduate student assistantships at levels consistent with the College of Engineering to remain competitive and compensate students equitably. One of CMR's missions is to prepare the future advanced manufacturing workforce. Attracting and retaining quality graduate students is of high importance for the CMR to fill this mission.
- The increased core funding will also enable the CMR to meet cost sharing obligations for external grants, promote new research initiatives, and incentivize faculty associates for research activities and industry engagement in the areas related to advanced manufacturing.

SUPPORTING MATERIALS

CMR Supported Graduate Students Degrees Awarded in 2020-2021 Fiscal Year

Masters

Fang, Tingke

“Synthesis and Evaluation of Manganese Cobalt Spinel Coating on Metallic Interconnect for Solid Oxide Fuel Cell Application”

Summer 2020

Advisor: Dr. Jiahong Zhu

Mechanical Engineering

Hargis, Benjamin E.

Summer 2020

Advisor: Dr. Steve Canfield

Mechanical Engineering

Hooper, Joshua

“A Modeling Tool to Analyze the Performance of Industrial Cooling Towers”

Spring 2021

Advisor: Dr. Glenn Cunningham and Dr. Ethan Languri

Mechanical Engineering

Lambert, Joshua

“System Design for Extreme Low Temperature Range Thermal Cycling Experiments”

Spring 2021

Advisor: Dr. Robert Wayne Johnson

Electrical and Computer Engineering

Lu, Hao

“Preliminary Mechanical Characterization of the Low-Cost Metal 3D Printing”

Summer 2020

Advisor: Dr. Ismail Fidan

Mechanical Engineering

Oderhohwo, Ogheneuriri Dorothy

“Multi-Label Multi-Classification Implementation with Object Detection for Edge Intelligence”

Summer 2020

Advisor: Dr. Syed R. Hasan

Electrical and Computer Engineering

Odetola, Tolulope Adedapo

Spring 2021

Advisor: Dr. Syed R. Hasan

Electrical and Computer Engineering

CMR Supported Graduate Student Degrees Awarded in 2020-2021 Fiscal Year

Ph.D.

Baza, Mohamed Ismail Mahmoud

“Blockchain-Based Secure and Privacy-Preserving Schemes for Connected Vehicles”

Fall 2020

Advisor: Dr. Mohamed Mahmoud

Bonning, Bo

“Mechanical Analysis and Predictions of Properties for Polymer Materials at
Cryogenic Temperatures”

Summer 2020

Advisor: Dr. Holly A. Stretz

Chesson, David A.

“Effect of Off-Stoichiometry on Electrical Conductivity in NI-FE and MN-CO Spinel
Systems for Solid Oxide Fuel Cell Interconnect Coating and Contact Layer
Applications”

Spring 2021

Advisor: Dr. Jiahong Zhu

CMR Graduate Students Supported from State Appropriations

Masters

Alshaikh Ali, Mohammad

Advisor: Dr. Steve Anton
Mechanical Engineering

Buida, Will

Advisor: Dr. Ying Zhang
Mechanical Engineering

Collier, Abigail *

Advisor: Dr. Chris Wilson
Mechanical Engineering

Edwards, Tyler *

Advisor: Dr. Ismail Fidan
Mechanical Engineering

Kramer, Trevor *

Advisor: Dr. Rory Roberts
Mechanical Engineering

Lawson, Nicholas

Advisor: Dr. Craig Henderson
Civil and Environmental Engineering

Miller, Brandon

Advisor: Dr. Steve Anton
Mechanical Engineering

Sadler, Hollee

Advisor: Dr. Glenn Cunningham
Mechanical Engineering

Ph.D.

Ahsan, Rumman *

Advisor: Dr. Duck Bong Kim
Mechanical Engineering

Dunham, Kurt

Advisor: Dr. Pedro Arce
Chemical Engineering

Gupta, Ankit

Advisor: Dr. Ismail Fidan
Mechanical Engineering

Haris, Anfal

Advisor: Dr. Robby Sanders
Chemical Engineering

Imeri, Astrit

Advisor: Dr. Chris Wilson
Mechanical Engineering

Innis, Cody

Advisor: Dr. Pinggen Chen
Mechanical Engineering

Jaladi, Divya *

Advisor: Dr. Ethan Languri
Mechanical Engineering

Lamantia, Maxavier *

Advisor: Dr. Pinggen Chen
Mechanical Engineering

Li, X.

Advisor: Dr. Allen MacKenzie
Electrical and Computer Engineering

Oyekola, Peter

Advisor: Dr. Mohammad Albakri
Mechanical Engineering

*- Jointly supported by State Appropriations and External Funds

CMR Graduate Students Supported from State Appropriations (continued)

Ph.D.

Paul, Sumit

Advisor: Dr. Duck Bong Kim
Mechanical Engineering

Shuaibu, Musayyibi

Advisor: Dr. Joseph Ojo
Electrical and Computer Engineering

Su, Zifei

Advisor: Dr. Pinggen Chen
Mechanical Engineering

Taheri Afarani, Hajar

Advisor: Dr. Joseph Biernacki
Chemical Engineering

Yang, Kuo

Advisor: Dr. Pinggen Chen
Mechanical Engineering

CMR Graduate Students Supported from External Funds

Masters

Collier, Abigail *

Advisor: Dr. Chris Wilson
Mechanical Engineering

Edwards, Tyler *

Advisor: Dr. Rory Roberts
Mechanical Engineering

Femi-Oyetero, James

Advisor: Dr. Ismail Fidan
Mechanical Engineering

Hayes, Jacob Ryan

Advisor: Dr. Jiahong Zhu
Mechanical Engineering

Hooper, Joshua

Advisor: Dr. Glenn Cunningham
Mechanical Engineering

Kramer, Trevor *

Advisor: Dr. Rory Roberts
Mechanical Engineering

Leach, Dalton

Advisor: Dr. Chris Wilson
Mechanical Engineering

Messerschmidt, Laurie

Advisor: Dr. Glenn Cunningham
Mechanical Engineering

Nevills, Miles

Advisor: Dr. Glenn Cunningham
Mechanical Engineering

Ph.D.

Abdelfattah, Sherif

Advisor: Dr. Mohamed Mahmoud
Electrical and Computer Engineering

Adeyemo, Adewale

Advisor: Dr. Syed Hasan
Electrical and Computer Engineering

Ahsan, Rumman *

Advisor: Dr. Duck Bong Kim
Mechanical Engineering

Badr, Mahmoud Mohamed

Advisor: Dr. Mohamed Mahmoud
Electrical and Computer Engineering

Bain, Aaron

Advisor: Dr. Rory Roberts
Mechanical Engineering

Baza, Mohammed

Advisor: Dr. Mohamed Mahmoud
Electrical and Computer Engineering

Boateng, Emmanuel

Advisor: Dr. J. Bruce
Electrical and Computer Engineering

Chesson, David

Dr. Jiahong Zhu
Mechanical Engineering

Hasanov, Seymour

Advisor: Dr. Ismail Fidan
Mechanical Engineering

*- Jointly supported by State Appropriations and External Funds

CMR Graduate Students Supported from External Funds

Ph.D.

Ibrahem, Mohamed

Advisor: Dr. Mohamed Mahmoud
Electrical and Computer Engineering

Islam, Saiful

Advisor: Dr. Duck Bong Kim
Mechanical Engineering

Jaladi, Divya *

Advisor: Dr. Ethan Languri
Mechanical Engineering

Lamantia, Maxavier *

Advisor: Dr. Pingen Chen
Mechanical Engineering

Mehedi, Al-Barkat

Advisor: Dr. Mohammad Albakri
Mechanical Engineering

Odetola, Tolulope

Advisor: Dr. Syed Hasan
Electrical and Computer Engineering

*- Jointly supported by State Appropriations and External Funds

External Funding – Proposals Submitted

	Status	Title	P.I.	Dept.	Total Funds
1	912MC 203202021	Intelligent Robot for TVA Substation Inspection Tennessee Valley Authority (TVA) - Supplement to 532605 (836MC)	Ali Alouani	ECE	\$223,007
2	894MC 2/17/2021 130(20-21)	A Computational Framework to Predict Patient Risk of Instability and Aseptic Loosening in Arthroplasty National Institute of Health (NIH)	Steven Anton	ME	\$556,203
3	863MC 7/2/2020 320(20-21)	FAI: An Explainable, Knowledge-Infused Framework for Advancing Fairness in AI University of Hartford via National Science Foundation	William Eberle	CSC	\$434,997
4	866MC Unfunded	One-Stop Youth Center for the 21st Century Workforce Upper Cumberland Workforce Development	Ismail Fidan Darek Potter	MET STEM	\$1,757,426
5	870MC 58(20-21)	Manufacturing for the Future (M4F) National Center University of Louisville Research Foundation (via National Science Foundation)	Ismail Fidan	MET	\$1,018,527
6	871MC 10/2/2020 59(20-21)	The Development and Implementation of Low- Cost Virtual Reality Framework for Making Manufacturing Accessible to All Somerset (via National Science Foundation)	Ismail Fidan	MET	\$158,331
7	906MC	Creating a Sustainable Innovation and Entrepreneurship Framework for the Community College (I&E4CC) Education National Science Foundation	Ismail Fidan Stephen Canfield	MET ME	\$355,158
8	903MC 5/20/2021	Collaborative Research: Sensing by Leveraging Cellular Communication Networks: A Framework of Medium Distance Baseline Interferometry National Science Foundation	Nan Guo Allen Mackenzie	CMR ECE	\$200,000
9	861MC 7/6/2020 520(20-21)	Collaborative Research: SaTC: EDU: Collaborative: College Curriculum Development with Multi-University Remote Lab for Teaching Secure Edge Intelligence National Science Foundation	Syed Hasan Nan Guo	ECE CMR	\$236,312
10	883MC 102(20-21) 5-35281	Towards Efficient Deployment of Large CNNs for Real-time Object Detection in Full High Definition (FHD) Video Streams using Xilinx Vitis-AI Phelps2020, Inc.	Syed Hasan	ECE	\$49,466
11	890MC 4/7/2021	Developing Golden Eagle Scholars to Enhance STEM Education in Rural Under-Developed Communities of Tennessee (TN) (DESTini-TN) National Science Foundation	Syed Hasan Denis/Fidan Vaselbehaugh/Bruce	ECE CSC ME/ECE	\$1,500,000
12	905MC	Defense Against Hardware Intrinsic Attacks in COTS base Internet of Things and Futuristic Artificial Intelligence of Things Qatar National Research Foundation	Syed Hasan Terry Guo	ECE CMR	\$108,000

Status	Title	P.I.	Dept.	Total Funds
13 882MC 1/7/2021 112(20-21)	Collaborative Research: Digital Twin-Driven Qualification in Metal Additive Manufacturing National Science Foundation	Duckbong Kim	MET	\$299,921
14 886MC	MRI: Acquisition of an Electron Backscatter Diffraction (EBSD) System for the Newly Installed Field Emission Scanning Electron Microscope National Science Foundation	Duckbong Kim Ismail Fidan	MET MET	\$143,261
15 888MC 111(20-21)	Reinforcement Learning for the In-Situ, Real-time, Closed-loop WAAM Quality Control Baldaur (via NASA funds)	Duckbong Kim	MET	\$24,999
16 898MC	Development of Artificial Intelligence-based Generative Process Planning Mechanism in Additive Manufacturing Institute for Information and Communications Technology Promotion, South Korea	Duckbong Kim	MET	\$122,810
17 899MC 3/30/2021	Investigations into the Design Rules for the Control of Wire Arc Additive Manufacturing National Science Foundation	Duckbong Kim	MET	\$24,735
18 901MC 4/22/2021 Awarded	Public-Private Partnership to Promote Efficient, Resilient and Secure Manufacturing and Workforce Development US Department of Energy (DOE)	Ethan Languri Stephen Idem	ME ME	\$1,750,000
19 877MC 11/16/2020 94(20-21) 5-32618	Control of Modular Multi-Dual Active Bridge Converters for Integrated Ship-Board Power System Office of Naval Research	Joseph Ojo	ECE	\$503,954
20 902MC	A High-Power Density Symmetric Two-Phase Induction Motor Drive with Switching Device Stress and Unbalance Alleviation for Domestic Application IEEE Industry Applications Society	Joseph Ojo	ECE	\$25,000
21 878MC 10/6/2020 119201920 5-23401	AFRL Senior Design Technology Dzyne Technologies via US Air Force Research Laboratory	Byron Pardue	ME	\$25,000
22 873MC 10/1/2020 55(20-21)	Rane Bathtub Model Drafting Rane Bathing and Accessibility Products	Avinash Paruchuri	MET	\$6,489
23 881MC 11/2/2020 89(20-21)	3D Modeling of Rane Bathing and Accessibility Products Rane Bathing and Accessibility Products	Avinash Paruchuri	MET	\$14,041
24 909MC	Piston Pump Reverse Engineering Eastman Chemical Company	Avinash Paruchuri	MET	\$18,346

Status	Title	P.I.	Dept.	Total Funds
23 881MC 11/2/2020 89(20-21)	3D Modeling of Rane Bathing and Accessibility Products Rane Bathing and Accessibility Products	Avinash Paruchuri	MET	\$14,041
24 909MC	Piston Pump Reverse Engineering Eastman Chemical Company	Avinash Paruchuri	MET	\$18,346
25 895MC	Engineering the Evolution of Advanced Materials for Robust Automotive Fuel Cell Subzero Cold-Starts National Science Foundation	Cynthia Rice	ChE	\$399,997
26 868MC	Atmosphere Independent Bipropellant Consuming Additively Manufactured Solid Oxide Fuel Cells (SOFCs) for Assured On-Orbit Space Power AFRL via DAGSI	Rory Roberts	ME	\$334,036
27 872MC 47202021 5-32619	Cryo Thermal Management of High-Power Density Motors and Drives ARPA-E via Hyper Tech	Rory Roberts	ME	\$145,000
28 879MC 10/27/2020 76(20-21)	Nano Layer, Low Temperature, Low Cost, High Power Solid Oxide Fuel Cells on Tubular Supports Global Research and Development Inc. (via AFWERX funds)	Rory Roberts	ME	\$16,544
29 880MC 10/27/2020 75(20-21)	Development of Nano Layer Solid Oxide Fuel Cell Technology that Operate on Various Fuels Global Research and Development Inc (via AFWERX funds)	Rory Roberts	ME	\$16,544
30 884MC 95202021	Cryo Cooled High Power Density Cables for Electric Aircraft ARPA-E via Hyper Tech	Rory Roberts	ME	\$150,000
31 862MC 10/28/2020 77(20-21)	Making Computerized Trauma Triage Decision Support Accurate and Understandable National Institute of Health (NIH)	Doug Talbert	CSC	\$390,232
32 892MC	STAMPEDE - Science & Technology Additive Manufacturing Product Engineering & Design Education National Science Foundation	John Tester	GBE	\$274,046
33 869MC 10/2/2020 16(20-21) 5-35285	TNTech Printed Tool Project FlowServe US, Inc.	Fred Vondra Ismail Fidan	MET MET	\$47,096
34 867MC 1/25/2021 120(20-21)	Phase 2: Development of Corrosion- and Erosion-Resistant Coatings for Advanced Ultra-Supercritical Materials US Department of Energy	Ying Zhang Jiahong Zhu	CMR ME	\$5,000,000
35 887MC 12/17/2020 106(20-21)	Sintering and Oxidation Behaviors of Novel EPD Coatings for Enhanced Hypersonic Hot Structures Durability Faraday Technology, Inc. (via NASA funds)	Ying Zhang	CMR	\$33,996

Status	Title	P.I.	Dept.	Total Funds
36 889MC 12/22/2020 107(20-21) 5-32614	Pack Aluminide Coatings on Steel Coupons Oak Ridge National Laboratory - Award 4000185237	Ying Zhang	CMR	\$20,999

Proposals Submitted in FY 2020-2021

\$16,384,473