Mechanical Engineering
Research and Graduate Program

THE UNIVERSITY OF TENNESSEE
CHATTANOOGA
College of Engineering and
Computer Science

Mechanical Engineering at The University of Tennessee Chattanooga

We are a premier program in applied research, teaching, and experiential learning. Our undergraduate and graduate programs incorporate a synergistic blend of the traditional mechanical engineering areas, mechanics and thermal fluid sciences, with modern innovations in the fields of Computational Fluid Dynamics (CFD), advanced energy systems, material science, and advanced manufacturing techniques.

Our programs offer significant opportunities for practicing engineers to grow their fundamental understanding of the engineering sciences as well as prepare them to be leaders in both research and industrial settings. We strive to ensure that our graduates are equipped with the needed capabilities to address the current problems facing the world today and are prepared to be innovators in facing the problems of the future. We are proud to have a highly dynamic graduate program that opens the possibilities of research and innovation for each student.

Our research captures emerging areas of innovation in mechanical engineering including: CFD and Fluid-Thermal-Structural Analyses of Hypersonic Vehicles, application of artificial intelligence/ machine learning to advanced energy systems, design of various biomedical devices, computational design of durable additively manufactured materials.

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Dr. Charles Margraves
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UTC RESEARCH

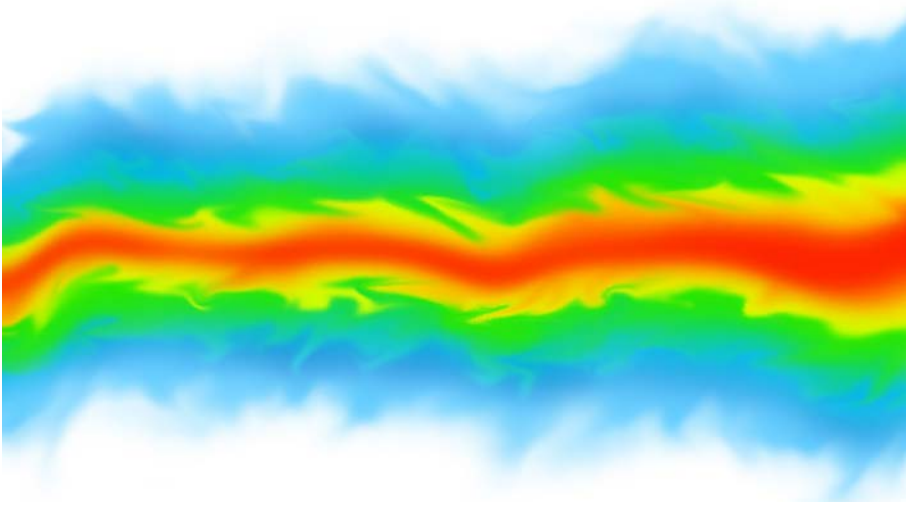
"The department of mechanical engineering is focused on preparing our graduate students to be leaders in solving the world's current and future technological challenges."

— Dr. James Newman
Department Head of Mechanical Engineering

AREAS OF RESEARCH

Computational Fluid Dynamics (CFD)

Faculty: *James Newman, Kidambi Sreenivas, Reetesh Ranjan*



The faculty members of the ME department focus on the development and application of novel numerical methods and models for the investigation of problems in the areas of aerodynamics, turbulent flows, fluid-structure-interaction, combustion, thermal sciences, and biomedical flows. The local and national level High Performance Computing (HPC) resources are utilized to solve challenging problems, where higher-order numerical algorithms are used along with techniques such as uncertainty quantification, reduced-order modeling, and machine learning.

- Development of multi-fidelity computational tools
- Physics-based modeling of multi-physics turbulent flows: algebraic, transport-equation and multi-scale models
- Reduced order modeling for design evaluation
- Uncertainty quantification for improved predictive capabilities
- Hybrid programming paradigm for efficient solution on current HPC platforms
- Data driven modeling using artificial neural networks
- Application of high-fidelity tools to solve complex geometry/complex physics problems
- Development of high-order accurate unstructured flow solvers

Energy Systems

Faculty: *Prakash Dhamshala, Yunye Shi, Chuck Margraves, Trevor Elliott*

Research is focused on the design and modeling of energy systems, with an emphasis on advancing gasification-based systems for efficient and cost-effective conversion. Process simulation, data-driven modeling techniques, and economic analysis tools are used to determine thermal system feasibility and performances.

- Developing numerical models for solar thermal, PV, PV/T panels and desiccant wheels
- Various techniques for air-to-air energy recovery
- Transient models for the estimation of buildings loads
- Designing Zero+ Energy Buildings
- System analysis and process modeling of bioenergy conversion systems
- Gasification output prediction using machine learning techniques

Aerospace

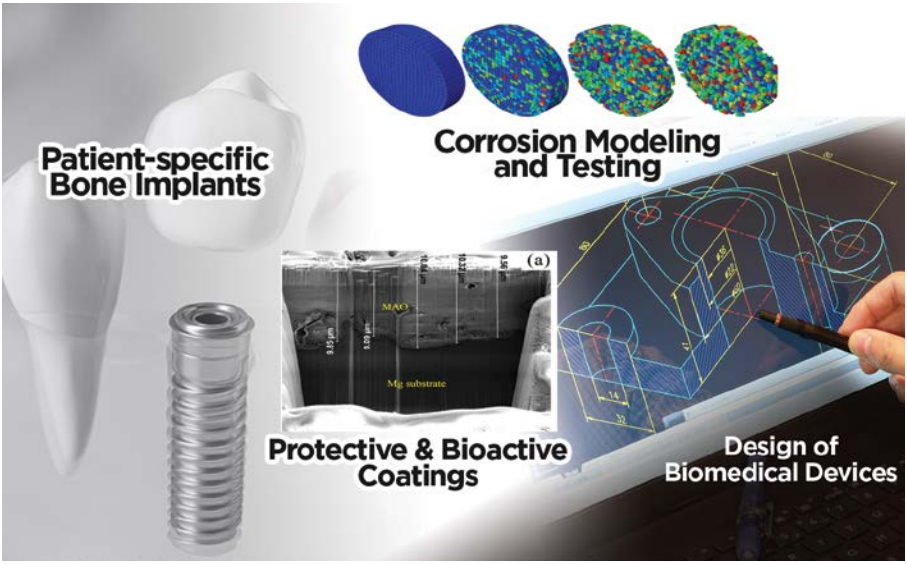
Faculty: *James Newman, Kidambi Sreenivas, Reetesh Ranjan, Trevor Elliott*

The research interests in aerospace applications include transonic (transport aircraft, turbomachinery), hypersonic flows, combustion in turbulent flows, rocket propulsion (additive manufacturing of hybrid rocket fuels), material science, and rocketry.

- Aerodynamics: fundamental turbulence physics and its modeling, separating/reattaching flows, laminar-to-turbulent transition, non-equilibrium turbulent boundary layers
- Propulsion: high-speed flows without chemical reactions
- Energetic materials: improved modeling of thermodynamics and chemistry
- Rocket combustion: stable and unstable flame dynamics
- Hypersonic Flows: Aerothermodynamics, Fluid-Structure-Thermal interactions
- Rotating Machinery: Wind turbines (vertical and horizontal axis), turbomachinery (axial and centrifugal)

Biomedical

Faculty: *Hamdy Ibrahim, Ron Goulet, Kidambi Sreenivas, James Newman, Mohammad Mahtabi*



The biomedical research projects in the ME department aim at improving health care and patient quality of life. A major focus in this research area is on developing novel designs and hybrid manufacturing techniques to create the next generation of medical devices. The projects involve the use of both computational and experimental tools in different fields such as biomechanics, hemodynamics, biomaterials, and biocorrosion. Ongoing primary research projects include:

- Pulmonary flows: computational modeling of airflow and aerosol dynamics in human airways
- Additive manufacturing of biomaterials towards patient-specific bone fixation devices
- Corrosion modeling and testing of biodegradable metals for bone implant applications
- Surface treatments and bioactive coatings on NiTi and magnesium-based alloys
- Development of novel biomedical devices based on shape memory alloys
- Design optimization of additively manufactured lattice structures for biomedical implants

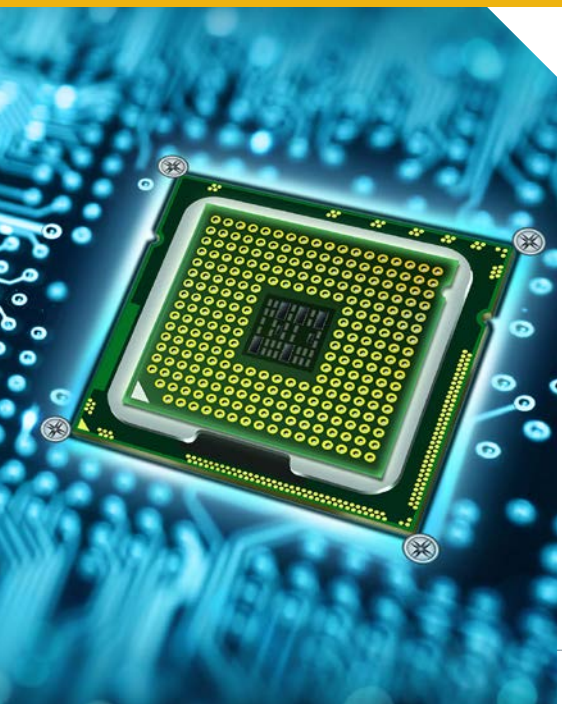
Solid Mechanics, Materials, and Advanced Manufacturing

Faculty: *Mohammad Mahtabi, Hamdy Ibrahim, Ron Goulet, Gary McDonald, Trevor Elliott*

The solid mechanics, materials, and advanced manufacturing research projects are highly interdisciplinary in nature, offering a wide range of opportunities for graduate and undergraduate students. Our faculty work on transformative research that involves both computational and experimental efforts in the fields of biomechanics, manufacturing, mechanical design, and materials science. The focus in this area is on investigating and developing novel hybrid manufacturing techniques to enable the design and fabrication of innovative high-efficiency products. Ongoing research projects include experimental and computational studies of biomaterials, additive manufacturing, shape memory alloys (SMAs), and bioactive coatings and surface treatments.

- Fatigue and fracture modeling of new materials and SMAs
- Additive manufacturing of metallic materials
- Integrated Computational Materials Engineering (ICME)
- Understanding and developing smart materials
- Multiscale modeling of materials
- Computer simulation of manufacturing processes
- Using systems thinking for process improvement
- Manufacturing of porous metallic scaffolds
- Advanced manufacturing strategies for durable materials
- Computer simulations of additive manufacturing process
- Additive Manufacturing of Energetic Materials

GRADUATE RESEARCH



"Access to world-class computing resources through the SimCenter at UTC provides our graduate students a significant leg-up over students in programs of comparable size."

— Dr. Kidambi Sreenivas
Graduate Coordinator; Computational Science PhD Program Coordinator

GRADUATE PROGRAM

Our M.S. program promotes excellence in research, innovation and real-life problem solving. Graduate students are involved in cutting edge fundamental and applied research projects with our faculty and actively participate in collaborative projects with the community and local industry partners. Our graduate students regularly present their work at various national and regional conferences and publish in peer-reviewed journals.

Course Guidelines for the M.S. Program

AREA	DESCRIPTION	HOURS
Area I	Mathematics Component	3-6
Area II	Approved Electives in Mathematics, Science or Engineering	3-6
Area III	Engineering Concentration	12-16
Area IV	Thesis or Special Project and/or Internship	12

Area I: Mathematics Component* (3-6 hours)

MATH 5470 - Applied Mathematics for Science and Engineering I
MATH 5480 - Applied Mathematics for Science and Engineering II
MATH 5600 - Numerical Analysis I
MATH 5610 - Numerical Analysis II

Additional Information and Notes: **With approval of the graduate adviser, students can take an equivalent course in this area.*

Area II: Approved Electives (6-9 hours)

Area III: Specialty (12-16 hours)

ENME 5320 - Advanced Thermodynamics
ENME 5340 - Transport Phenomena
5000-level approved elective 3-4 hours
ENME 5360 - Mass Transfer Operations or
ENME 5380 - Heat Conduction and Radiation

Area IV: Thesis (6 hours) or Project + Additional Coursework (9 hours)

Thesis option:
Two or more semesters of ENCE 5999r - Thesis (6 hours total)
OR
Project + Coursework option:
Two additional approved graduate courses (6 hours)
ENGR 5900 - Project (3 hours)

Program Total:

30 hours (Thesis), 33 hours (Project + Coursework)

Research Equipment

The Mechanical Engineering research facilities are housed on the first and second floors of the Engineering, Math and Computer Science building. The department also has access to two High Performance Computing (HPC) clusters located at the Multi-Disciplinary Research Building. Some of our major research equipment is listed below.

- 924 cores shared cluster with 1 NVidia 16GB P100 GPU with 1792 double precision cores.
- 160 cores/640 threads shared cluster with 4 NVidia Volta GPUs with 16 GB GPU
- Electrochemical Corrosion Testing Potentiostat
- Inert Gas Tube Furnace/Vacuum
- Ceramic 3-D Printer
- Instron 8521S axial-torsion mechanical testing machine
- Delta WASP 2040 Clay 3D Printer
- Gamry Interface 1010E Potentiostat/Galvanostat/ZRA (Zero Resistance Ammeter)
- Pinnacle Plus+, Pulsed DC Power System
- 2048 cores shared cluster (AMD EPYC 7762)

Projects Funded

- **Reusable Hypersonic Vehicle Structures,** University of Dayton Research Institute (Air Force Research Laboratory), ($893,239). PIs – Dr. Newman and Dr. Sreenivas
- **Aerostructural Analysis Supporting the Development of Hypersonic Vehicle Flight Test Structures,** University of Dayton Research Institute (Air Force Research Laboratory), ($737,077). PIs – Dr. Newman and Dr. Sreenivas
- **RET Site: Providing Research Experiences and Practicum on Cyber-Physical Systems for Regional Community College Faculty (PREP-CPS).** National Science Foundation (NSF), Division of Engineering Education and Centers (EEC) ($591,489). PIs – Dr. Harris (ChemE) & Dr. Philipp (Education). Senior Personnel – Dr. Clark (Psychology), Dr. Danquah (ChemE), Dr. T. Elliott (MechE), Dr. Margraves (MechE), & Dr. Yang (ChemE).
- **Hypersonic Vehicle Structure Critical Technology Gaps,** University of Dayton Research Institute (Air Force Research Laboratory), ($535,125). PIs – Dr. Newman and Dr. Sreenivas
- **CC* Compute: A Cost-Effective, 2,048 Core InfiniBand Cluster at UTC for Campus Research and Education** (NSF), ($392,235). PIs – Dr. Skjellum, Dr. Kandah, Dr. Tanis (Computer Science), Dr. Sreenivas (Mechanical Engineering), Dr. Panagiotou (Math) $392,235
- **Degradation Modeling of Coated Magnesium Towards Patient-Specific Biomedical Implants,** CEACSE funding award, submitted to the Center of Excellence in Applied Computational Science and Engineering (CEACSE), 2020. Requested amount: $95,111. PIs – Dr. Ibrahim & Dr. Mahtabi
- **Enhanced Eulerian-Lagrianan Formulation for Investigation of Turbulent Dispersed Multiphase flows,** Center of Excellence in Applied Computational Science & Engineering, UTC, ($92,911). Co-PI - Dr. Ranjan
- **Modeling of Transition to Turbulence in Large Eddy Simulation Using the Two-Level Simulation Approach,** Center of Excellence in Applied Computational Science & Engineering, UTC, ($89,675). PI - Dr. Ranjan
- **An Efficient Framework for Numerical Investigation of Turbulent Combustion using Detailed Finite-Rate Chemistry,** Center of Excellence in Applied Computational Science & Engineering, UTC, ($76,099). PI - Dr. Ranjan
- **Treating Bone Trauma Using ResorbFix,** I-Corps Teams, submitted to the National Science Foundation (NSF), 2020. Requested amount: $50,000. PI – Dr. Mahtabi
- **Investigation and Implementation of Industrial Internet of Things (IIoT) Equipment and Software for Baja SAE Capstone Project.** DENSO North American Foundation, ($50,000). PI – Dr. T. Elliott
- **Advanced Fabrication Technologies and Nondestructive Testing for Baja SAE Capstone Project.** DENSO North American Foundation, ($45,000). PI – Dr. T. Elliott
- **Computational Investigation of Regional Aerosol Deposition in Realistic Human Airways:** Biomedical Research Initiation Collaborative Grant, UTC-UTCOM, ($24,920). PI - Dr. Ranjan
- **Non-Intrusive Method to Detect Valve Disc Location and Stem-to-Disc Integrity.** Tennessee Valley Authority, ($9,757). PI – Dr. T. Elliott
- **Modelling and Experimentation of a Variable Mass Rocket's Dynamics.** UTC, Undergraduate Research and Creative Endeavor (URaCE), SEARCH Grant, ($1,000). Student – Ashwyn Sam, Faculty – Dr. T. Elliott

OUR PEOPLE

Dr. James C. Newman III
Department Head; Professor
EMAIL: James-Newman@utc.edu

Research Areas:
- Computational fluid dynamics
- Hypersonic vechicles
- Fluid structure interaction

Dr. Prakash Dhamshala
Professor
EMAIL: Prakash-Dhamshala@utc.edu

Research Areas:
- Advanced conventional and alternative energy systems
- Sustainable resources
- Engineering education

Dr. Louie Elliott
Assistant Professor
EMAIL: Louie-Elliott@utc.edu

Research Areas:
- Additive manufacturing

Dr. Trevor S. Elliott
UC Foundation Assistant Professor
EMAIL: Trevor-Elliott@utc.edu

Research Areas:
- Additive manufacturing
- Alternative energy and building efficiency design
- Automotive engineering
- Battery characterization
- Engineering design
- Injection driven flows
- Propulsion systems and two-phase combustion stability modeling and simulation

Dr. Ronald Goulet
Associate Professor
EMAIL: Ron-Goulet@utc.edu

Research Areas:
- Bio materials

Dr. Hamdy Ibrahim
Assistant Professor
EMAIL: Hamdy-Ibrahim@utc.edu

Research Areas:
- Biodegradable metals
- Additive manufacturing
- Corrosion behavior of biomaterials
- Surface treatments and coatings
- Biocomposites
- Shape memory alloys

Dr. Mohammad Mahtabi
Assistant Professor
EMAIL: Mohammad-Mahtabi@utc.edu

Research Areas:
- Additive manufacturing
- Fatigue and fracture mechanics
- Shape memory alloys
- Computational mechanics
- Multiscale modeling of materials
- Mechanical behavior of materials

Dr. Charles Margraves
UC Foundation Associate Professor;
ME Graduate Coordinator
EMAIL: Charles-Margraves@utc.edu

Research Areas:
- Conventional and alternative energy systems
- Zero+ energy buildings
- Air quality sensors
- Engineering education

Dr. Gary McDonald
UC Foundation Associate Professor
EMAIL: Gary-McDonald@utc.edu

Research Areas:
- Engineering education

Dr. Reetesh Ranjan
Assistant Professor
EMAIL: Reetesh-Ranjan@utc.edu

Research Areas:
- Computational fluid dynamics and combustion
- Turbulence modeling
- Reduced order modeling
- Uncertainty quantification
- High-performance computing

Dr. Yunye Shi
Assistant Professor
EMAIL: Yunye-Shi@utc.edu

Research Areas:
- Biomass thermochemical conversion
- Biorenewable energy utilization
- Techno-economic analysis of energy systems

Dr. Kidambi Sreenivas
Professor; Computational Science PhD Program Coordinator
EMAIL: Kidambi-Sreenivas@utc.edu

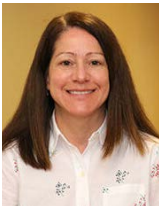
Research Areas:

- Computational fluid dynamics (CFD) applied to complex geometry / complex physics problems
- High performance computing
- High-order methods
- Rotating machinery

Dr. Cecelia Wigal
UC Foundation Professor
EMAIL: Cecelia-Wigal@utc.edu

Research Areas:

- Engineering education



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Key Publications

- Behzadi, F., and Newman III, J.C., "An Exact Source-Term Balancing Scheme for Finite Element Solution of Shallow Water Equations," Computer Methods in Applied Mechanics and Engineering, Vol. 359, Feb. 2020, https://doi.org/10.1016/j.cma.2019.112662.

- Wu, Z., Newman III, J.C., and Taylor III, A.C., "Higher Order Accurate K-Eigenvalue Sensitivity Estimation Using the Complex-Step Derivative Method," Proceedings of the International Conference on Mathematics and Computational Methods for Nuclear Science and Engineering, August 2019, Portland, OR.

- Azarnoosh, J., Sreenivas, K., and Arabshahi, A, "Numerical Simulation of Tidal Breathing Through the Human Respiratory Tract." ASME. J Biomech Eng. January 2020, doi: https://doi.org/10.1115/1.4046005.

- Ibrahim, H., Dehghanghadikolaei, A., Advincula, R., Dean, D., Luo, A., & Elahinia, M., "Ceramic coating for delayed degradation of Mg-1.2 Zn-0.5 Ca-0.5 Mn bone fixation and instrumentation," Thin Solid Films, 687, October 2019, 137456.

- Ibrahim, H., Luo, A., Dean, D., & Elahinia, M. (2019). Effect of Zn content and aging temperature on the in-vitro properties of heat-treated and Ca/P ceramic-coated Mg-0.5% Ca-x% Zn alloys. Materials Science and Engineering: C, 103, 109700.

- Bayati, P., Jahadakbar, A., Barati, M., Nematollahi, M., Saint-Sulpice, L., Haghshenas, M., Arbab Chirani, S., Mahtabi, M.J., & Elahinia, M. (2020). Toward low and high cycle fatigue behavior of SLM-fabricated NiTi: considering the effect of build orientation and employing a self-heating approach. International Journal of Mechanical Sciences, 105878.

- Aboutaleb, A. M., Mahtabi, M. J., Tschopp, M. A., & Bian, L. (2019). Multi-objective accelerated process optimization of mechanical properties in laser-based additive manufacturing: Case study on Selective Laser Melting (SLM) Ti-6Al-4V. Journal of Manufacturing Processes, 38, 432-444.

- Elliott, Louie and Wigal, Cecelia, " Design, Build, Install: An Experiential Implementation of Freshman Engineering Design," Proceedings of the ASEE Southeast Section Meeting and Conference, March 8 - 10, 2020, Auburn, Alabama.

- Chuck Margraves, Gary McDonald, "Creation of a Small Scale Geothermal Heat Sink Experiment", Proceedings from the 2019 ASEE Southeast Section Meeting and Conference , March 10-12, 2019, Raleigh, North Carolina.

- Ashley Thompson, Wes Gibson, Chuck Margraves "Creation of a Small Scale Zero Energy Building", 2018 ASEE Southeast Section Conference, Daytona Beach, FL, 2018

- R. Ranjan, S. Karpe, P. Patel, S. Menon, "Assessment of Surrogate Models for Inverse Uncertainty Quantification of Simulant Combustion", AIAA-2020-2137, 2020.

- S. Karpe, R. Ranjan, S. Menon," Large Eddy Simulation of Sooting Turbulent Non-Premixed Mixing Layers", AIAA-2020-2138, 2020.

- Ranjan, S. Menon, "Nonlinear Reduced Order Modeling for Large Eddy Simulation of Turbulent Reacting Flows", AIAA-2020-2140, 2020.

- R. Ranjan, M.K. Venkataswamy, and S. Menon, "Dynamic one-equation-based subgrid model for large-eddy simulation of stratified turbulent flows," Phys. Rev. Fluids, 5, June 2020. doi.org/10.1103/PhysRevFluids.5.064601.

- Elliott, T., Sam, A., Grider, T., Majdalani, J., "Evaluation of Discretization Schemes in Biglobal Stability Analysis of Cylindrically-Shaped Solid and Hybrid Rockets," Proceedings of the AIAA Propulsion and Energy Forum, August 19-22, 2019, Indianapolis, Indiana. (Nominated for Best Professional Paper in Hybrid Rockets.)

- Roberts, B., Sam, A., Brand, J., and Elliott, T., "Comparative Analysis and Justification of Optimal Rocket Motor Selection in NASA USLI By Applying Newton's Second Law to a Variable Mass Body." Proceedings of the AIAA Propulsion and Energy Forum, August 19-22, 2019, Indianapolis, Indiana. doi.org/10.2514/6.2019-4138. (Awarded Best Student Paper in Solid Rockets.)

- Elliott, T., and Gibson, W.A., "Stability Analysis of the Swirling Majdalani-Fist Mean Flowfield in Solid Rocket Motors," AIAA Journal, Vol. 57, No. 12, Sept. 2019. doi.org/10.2514/1.J058568

- Crawford, A., and DeBardelaben, C. (Faculty Advisor Sreenivas, K.), "ANSYS Shape Optimization for the UTC Flying Mocs Design/Build/Fly Nose Cone," AIAA Region II Student Conference (cancelled), April 6-7, 2020, Tuscaloosa, AL. (Placed 3rd overall in the Master's student category.)

- Crawford, A., and Sreenivas, K., "Helios and Tenasi Results for the Workshop for Integrated Propeller Prediction," AIAA Paper 2020-2675, Aviation 2020, June 15-19, 2020 (Virtual Conference)

- Dhamshala, P., "Zero-Energy Buildings by Use of PV/T Panels, M-Cycle, Desiccant and Heat Wheels," Proceedings of the International Mechanical Engineering Congress & Exposition, November 10-14, 2019, Salt Lake City, Utah. 13663, Poster # V453.

- Dhamshala, P., "Update of Chapter 26: Air-to-Air Energy Recovery Equipment", ASHRAE Handbook of HVAC Systems and Equipment, June 2020.

- Warrington, Don, "Basic Configuration of Sheet Pile Design Analysis," Pile Buck Magazine, May 11, 2020.

- Zang, G., Jia, J., Shi, Y., Sharma, T., Ratner, A., 2019. Modeling and economic analysis of waste tire gasification in fluidized and fix bed gasifiers. Waste Management.

- Shi, Y., Maya, D., Nascimento, R., Sharma, T., Ratner, A., Lora, E., 2018. Experimental and simulation studies of corn kernel gasification in a double air stage downdraft reactor. ASME 2018 International Mechanical Engineering Congress and Exposition Conference Proceedings.

- Abdalla, M., Joplin, A., Elahinia, M., & Ibrahim, H. (2020). Corrosion Modeling of Magnesium and Its Alloys for Biomedical Applications. Corrosion and Materials Degradation, 1(2), 219-248.

- Chmielewska, A., MacDonald, T., Ibrahim, H., McManus, T., Lindemann, J. L., Smith, P., ... & Elahinia, M. (2020). Biocompatibility of a novel heat-treated and ceramic-coated magnesium alloy (Mg–1.2 Zn–0.5 Ca–0.5 Mn) for resorbable skeletal fixation devices. MRS Communications, 10(3), 467-474.

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